17th WORLD CONGRESS OF SOIL SCIENCE
14-21 August 2002, BANGKOK, THAILAND

Soil Science: Confronting New Realities in the 21st Century

ABSTRACTS

Volume IV

Symposia 37-52
Preface

The Abstracts consist of six volumes. They contain the abstracts submitted and accepted for the 65 Symposia of the 17th World Congress of Soil Science, the theme of which is:

Soil Science: Confronting New Realities in the 21st Century

Most of the 65 Symposia were proposed and accepted during the IUSS Council Meeting in April 2000 in Bangkok under the present structure of Commissions, Subcommissions and Working Groups. A few Symposia were added into the structure of the Scientific Programme of the Congress at later dates on specific requests by Chairpersons, International Agencies and National Soil Science Society, approved by Council Members through correspondence. Over 2300 abstracts were received but their actual number in these Abstracts is less than 1800. These six volumes of Abstracts have been structured as follows:

Volume I Symposia 01-12
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The voluminous publication of diverse scientific studies and reviews in soil science and related fields included in the Abstracts, Programme and Transactions of the Congress is considered a product of collective effort among soil scientists and scientists in related fields. It can serve as a basic tool to help confront new realities in soil science and mark the beginning of a new phase of soil science to advance into the twenty-first century. We have tried very hard to minimize our mistakes in editing and formatting each individual abstract in these books. However, due to very diverse styles of authors, it has been very difficult. We accept this with no excuses. Nevertheless we hope you will find the 17th World Congress of Soil Science fruitful and enjoyable.

Irb Kheoruenromne

15 July 2002
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01 Effect of soil structure and properties on preferential flow dynamics and pollutant transport in soils
02 Landscape scale research: methodology, concepts and consequences for soil and water quality
03 Influence of biological activity on soil physical properties
04 Use of soil data in predicting soil physical properties: importance, limitations and conditions of validation

Commission II: Soil Chemistry
05 Properties, functions, and dynamics of organic matter in tropical soils
06 Frontiers in the chemistry and biochemistry of the soil rhizosphere
07 Effects of soil chemical and biochemical processes on soil global climate change
08 Use of molecular scale techniques in determining contaminant speciation and soil remediation

Commission III: Soil Biology
09 Composition of soil microbial and fauna communities: new insight from new technologies
10 Research to enhance carbon sequestration in soils
11 Microbial processes and populations in sub-merged soils
12 Manipulating soil microbial and enzymic activities

Commission IV: Soil Fertility and Plant Nutrition
13 Management of organic matter for soil fertility improvement in humid tropical environments
14 Soil fertility as an ecosystem concept
15 Perceptions of soil management: matching indigenous and scientific knowledge systems
16 Mechanisms and indicators for efficient nutrient use through integrated soil management
17 Use of natural nutrient sources and amendments: which, where, when and how?

Commission V: Soil Genesis, Classification and Cartography
18 Anthropogenic factor of soil formation
19 Soil system and land use
20 Arid and semi-arid soils: records of past climates, carbon sequestration, genesis and management
21 Soil classification, accomplishments and future

Commission VI: Soil Technology
22 Technologies to overcome rootzone soil constraints
23 Models and parametric methods for predicting soil degradation
24 Use and abuse of industrial and urban wastes in agricultural soils

Commission VII: Soil Mineralogy
25 Mineralogy and geochemistry of regolith
26 Reaction of soil minerals on changes of climate and land management
27 Mineralogy and micromorphology of pedogenesis including isotope methods and dating of soil processes
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35 Soil micromorphology to quantify soil structure qualities
36 Soil micromorphology and submicroscopy for interpretation of soil qualities

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GC: Soils and Global Change
45 Soil carbon dynamics and the greenhouse effect

LD: Land Degradation and Desertification
46 Land degradation and desertification: confronting the realities of the 21st Century

MO: Interactions of Soil Minerals with Organic Components and Microorganisms
47 Soil mineral - organic component - microorganism interactions and the impact on the ecosystem and human welfare

PM: Pedometrics
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Symposium 37

Identification and determination of soil quality parameters to evaluate the sustainability and socioeconomic impacts

Convenor: DECHEN Sonia Carmela Falci
Co-Convenor: BOONCHEE Sawadee

Oral Session
Thursday 15 August 2002
8:30 - 11:50
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Demand-driven land evaluation: a case study in Santa Catarina, Brazil

BACIC Ivan L.Z. (1), ROSSITER David G. (1) and BREGT Arnold K. (2)

(1) Soil Science Division, International Institute for Geo-Information Science & Earth Observation (ITC), P.O. Box 6, 7500 AA Enschede, The Netherlands
(2) Wageningen UR, Centre for Geoinformation, P.O. Box 47, 6700 AA Wageningen, The Netherlands

Land evaluation is the prediction of land performance over time under specific uses. These predictions are then used to guide strategic land-use decisions. Modern land evaluation has a 30-year history, yet the results are generally accepted to be disappointing. Land users and planners are inclined to ignore land evaluators, reflecting the poor quality and low relevance of many actual land evaluations, as well as poor communication with users. This research searched out the opinions and expectations of the clients of the land evaluation reports, by means of questionnaires and interviews, in order to propose improvements to the current land evaluation method in use in Santa Catarina State, Southern Brazil. We found that soil and land evaluation surveys are still considered useful, but they need some improvements to fulfill the clients' expectations. We suggest the adoption of a demand-driven approach, evaluating according to the real needs and possibilities of the decision-makers. The following main aspects should be included: environmental degradation risks assessment, socio-economic analysis, uncertainties and risk assessment, all referring to a set of realistic land use alternatives from which the decision-makers can choose.

Keywords: land evaluation, demand-driven, Brazil
Black soil on hard limestone at the habitats of naturally-occurring pyrethrum in Montenegro

CUPAC Svjetlana (1), STOJANOVIC Stojan (2), STOJANOVIC Dimitrije (1), JOVANOVIC Ljubinko (1) and JANJIC Vaskrsija (1)

(1) Institute SERBIA, Pesticide and Environmental Research Centre, 11080 Belgrade, Banatska 31b, Yugoslavia
(2) Faculty of Agriculture, 11080 Belgrade, Nemanjina 6, Yugoslavia

Pyrethrum (*Tanacetum cinerariaefolium* Trev.), a herbaceous perennial plant and member of the *Asteraceae* family, grows as an endemic species in the coastal region of Eastern Adriatic. It has long been an object of scientific scrutiny and used in practice for its insecticidal components contained in the flower (pyrethrines I and II) which constitute a natural and environmentally safe product more acceptable than similar synthetic products. Wild pyrethrum flourishes on degraded soils and we have attempted to study more closely its ecological and micro soil requirements.

The following methods were employed: a combined sieving and pipett method with Na-pyrophosphate preparation for soil texture; the Savinov method for soil structure and stability of structural aggregates in water; the 100 cm$^3$ Kopecky cylinder for soil volume mass and water capacity of soil; computation for porosity and air capacity of soil; a modified Darcy device with changeable pressure for hydraulic permeability of soil; the potentiometric method for soil reaction (pH in H$_2$O and KCl); soil hydrolitic acidity was determined according to Kappen; cation exchange by the Kappen method; total carbon according to Tjurin's method modified by Simakov; total soil nitrogen by the Kjeldahl method; available phosphorus by an Al method according to Egner-Riehm; available potassium by the Schachtshabel method; available microelement content (Zn, Mn, Cu and Fe) by the atomic absorption spectrophotometry method. The data was statistically processed using a correlation analysis.

Pyrethrum grows on black soils on hard limestone at 120-1200 m altitude in the sub-Mediterranean part of Montenegro. Black soils generally have favourable chemical properties, with pH reaction ranging from neutral to slightly alkaline (pH 7.03-8.07) and the adsorption complex highly saturated with basic cations. The contents of organic carbon and total nitrogen are high (1.90-16.28% and 0.22-0.75%, respectively). Available phosphorus can be found in traces, while available potassium varies considerably (4.29-27.23 mg 100 g$^{-1}$). The content of available microelements is satisfactory: 6.3-18.0 mg kg$^{-1}$ of Zn, 24.8-330.0 mg kg$^{-1}$ of Mg, 2.5-6.5 mg kg$^{-1}$ of Cu, and 18.5-237.0 mg kg$^{-1}$ of Fe. Despite favourable chemical properties, the overall soil quality is determined by the local unfavourable relief and physical soil properties. As the black soil has developed on hard limestone parent material and in typically karst relief, the habitats are characterized by pronouncedly rocky surface (50-90%), and mostly shallow (10-30 cm) and skeletal solum (up to 79%), all of which makes the soil water permeable and rather dry even at locations with moisture index exceeding 1 over the vegetation period. Drought conditions help provide the soil with organic matter but hamper nitrogen mineralization, which creates poor micro-conditions for pyrethrum at its natural habitats in Montenegro.

**Keywords:** pyrethrum, black soil, limestone, Montenegro
Riverbank erosion control and soil fertility improvement by vetiver hedgerow under Bangladesh condition

FARID A.T.M.

Soil Science Division, BARI, Gazipur, Bangladesh

Bangladesh is a riverine country. The rivers, including three major ones, their tributaries and distributaries number about 250. Fifty-four of these rivers have their origins outside the country. The sediment carrying capacity of three major rivers is very high. Roughly they carry a solid load of two billion tons a year which is comparable only to Hwang Ho (Miah, 1990). Topographically major portion of the country is a low flood plane. Every year nearly 50% of the country’s area goes under floodwater. In 1988 and 1989 nearly two-thirds of the country’s area went under floodwater. Flood with erosion at some place and siltation at others is a regular yearly phenomenon. Flood alone is the cause of sorrow and happiness as well. Fisheries, navigation and agriculture depend fully on river flow and flood. But untime, speedy and flush flood always become hazardous. Riverbank erosion and subsequent sedimentation are two main functions of river course. 4.3 million hectares of land are effected by these functions. However development of vetiver hedgerow to reduce the aggressiveness of flood has been tried and reported. Hedgerow was developed across the slope on the riverbanks and the crop fields nearby. Plantation was made in lines 3-4 meters apart. Soil samples collected after 4 years of growth, processed and were analyzed for particle size distribution, major plant nutrients. From the results it is evident that percent silt and clay content has increased relatively in the samples near the vetiver root zone area. Crop fields having vetiver hedgerow as fence and on boundaries improved in respect of fertility and yield (Farid et al., 1999).

Keywords: riverbank erosion, fertility, vetiver
Controlling soil erosion in farmers' fields using legume cover crops, Gatanga, Kenya

KHISA Protus W. (1), GACHENE Charles K.K. (1), KARANJA Nancy K. (1) and MUREITHI Joseph G. (2)

(1) Department of Soil Science, University of Nairobi, P.O. Box 29053, Nairobi, Kenya
(2) Kenya Agricultural Research Institute, National Agricultural Research Laboratories, P.O. Box 14733, Nairobi, Kenya

The study was conducted on farmers' fields in Gatanga Division, Thika District of central Kenya with the aim of assessing the effect of selected legume cover crops on soil erosion especially at the onset of the rain season when the soil is bare and prone to severe soil erosion. Workshops involving farmers and researchers were held to select legumes and train the farmers on monitoring erosion and data collection. The four systems tested consisted of the following: pure stand of maize (Zea mays) (T1), maize intercropped with Mucuna pruriens (T2), maize plus Vicia benghalensis (T3), and maize plus Lablab purpureus (T4). Measurements taken included runoff, soil loss, percent crop cover and analysis of nutrients in the original soil and eroded sediments. Cumulative soil loss recorded during 1999 long rain season ranged from 58.64 to 61.7 t ha\(^{-1}\). At the onset of the 1999 short rain season, soil loss was significantly different between treatments (P≤0.05). This was attributed to post-harvest crop cover provided by the legume cover crops grown from the previous season. The highest (3.3 t ha\(^{-1}\)) and the lowest (0.35 t ha\(^{-1}\)) soil losses were recorded from T1 and T2 respectively. There were significant differences (P≤0.05) in percent cover between treatments. The average percent cover taken at the onset of the 1999 short rain was 0, 43.2, 9.0 and 11.4% for T1, T2, T3 and T4 respectively. Nutrients in sediments were compared with the original soil and the enrichment ratio (ratio of nutrients in eroded sediment to that of the original soil) for major nutrients (i.e. organic C, total N, available P, Ca and K) was greater than 1. The soil material lost from the plots was on average 262% richer in P than the original soil. The pH of the eroded sediments was slightly higher than that of the original soil. All the farmers who were involved in the trials agreed that mucuna was superior in controlling soil erosion when compared with the other green manure cover crops. This was evident from field observations where soils eroded from the plots were accumulated in gunny bags with respect to the different treatments.

Keywords: cover crops, soil loss, enrichment ratio, on-farm
Gully erosion monitoring in Sao Luis City, Maranhao State, Brazil

GUERRA Antonio Jose Teixeira (1), MENDONÇA Jane K.S. (2), RÊGO Marcelo (2) and ALVES Ileana S. (2)

This paper regards urban gully monitoring in Sao Luis City, taking into account environmental and social characteristics. Soil properties, rain regime, slope characteristics, land use and vegetation clearance are the main factors which cause runoff and throughflow, leading to gully erosion. All those factors occur in Sao Luis City and, therefore, gullies can be found throughout the municipality.

Sao Luis is located in Maranhao Island (2° 19' 9" - 2° 51' S and 44° 1' 16" - 44° 19' 37" W). The municipality covers a total area of 831 km² with 867,690 inhabitants. The dry season runs from August to November and has a deficit in precipitation, with mean monthly rain around 30 mm. The rainy season runs from December to July, with mean monthly rain around 250 mm.

The geology is mainly from the Tertiary, with a domain of sandstones, and with shales, argillites and siltstones, belonging to the Barreiras Formation. The rocks have high porosity and are friable, presenting a high level of laterization.

The soil is very susceptible to erosion, especially where landforms are hilly. This soil is also sandy and silty, due to the sandstones and siltstones weathering. The main soil types are Podzolics and Lithosols, with high sand and silt contents.

The field work consists of locating and mapping the gullies, through aerial photographs and field control, using GPS. Soil samples were collected for laboratory analysis. An infiltrometer has been used to determine infiltration rates.

A file was created for each gully, to take note of: geology, geomorphology, soil type, vegetation cover and land use. The gullies selected for monitoring involve different situations: proximity to the coast, to illegal settlements, to a clay quarry and to residential areas. The monitoring outlines the following steps: 1) location of the gully; 2) a diagram of the gully made on site; 3) stakes placed into the soil, 10 metres from the border, around the gully; 4) use of a Brunton compass and a metre to obtain three measurements taken from each stake and the gully border.

Starting December, 2000, seventeen gullies have been identified, and seven are being monitored. Although the monitoring period is short (five months, so far), it includes the rainy season, and some gullies have already shown a rapid retreat.

Some of them have retreated more than one metre within this period, especially on the gully head. Most of the gullies take place where the vegetation has been cleared, on slopes between 5° and 15°, where there are illegal settlements without urban infra-structure.

Gully erosion also occurs in areas where irregular quarries have been established to explore sand or clay, and these erosion features spread on the slopes. Authorities usually turn a blind eye to this kind of economic activity.

The next step in this research work is to set up rain-gauges in the gullies, in order to monitor the daily rainfall amount, so that it is possible to associate different rainfall patterns and input with gully retreat, besides the soil properties and land use and management.

Keywords: soil erosion, gully monitoring, land use, soil properties
Soil resistance under different tillage methods

KISIC Ivica, BASIC Ferdo, MESIC Milan and BUTORAC Andjelko

Department of Agronomy, Faculty of Agriculture, Svetosimunska 25, Zagreb, Croatia

Aimed at determining the optimal tillage method for the region, penetration resistance measurements were carried out on a Stagnic Luvisol in Central Croatia. Measurements of soil resistance to penetration to the depth of 50 cm in four repetition, as the principal parameter of soil compaction, were carried out continuously parallel to the plant cover growth and application of appropriate agricultural practices using The Bush Soil Recording Penetrometer. The investigations point to the conclusion that the soil resistance to penetration is predominantly influenced by the effective state of the plant cover development, actual soil moisture and the tillage method applied. The lowest penetration resistance results in all trial treatments were recorded in first measurements, immediately after the application of tilling practices. In treatments involving deep practices (very deep ploughing and subsoiling till 50 cm) penetration resistance values were constant to the measurement depth whereas an increase was recorded in penetration resistance below the ploughing depth in treatments with conventional ploughing to the depth of 30 cm. Soil resistance to penetration recorded in the winter period was expressly low, one might say it was practically non-existent. The overall lowest values of soil resistance to penetration throughout the investigation period were recorded in treatments with very deep ploughing and subsoiling or ploughing across the slope, while the highest penetration resistance was determined in the no-tillage treatment, as a consequence of the tillage method applied in this treatment.

Keywords: soil resistance, tillage methods, stagnic Luvisols, Central Croatia
Amelioration of compacted subsoil layer by tillage rotation and its effect on productivity

MALINDA David and DARLING Rick

South Australian Research and Development Institute, PMB 2, Glen Osmond, South Australia 5064, Australia

"Tillage rotation" is being compared with no-till and conventional cultivation. Tillage rotation treatment uses "super seeder" points to direct drill allowing depth of cut of up to 150 mm. The depth is varied from year to year to avoid a consistent uniform depth of working (in 1997 was 120 mm, 1998 was 150 mm, 1999 was 120 mm and 2000 was 150 mm). The points are designed for deep tillage, but with normal seed depth placement in a one-pass operation. The three tillage regimes are being tested in three rotations; continuous wheat, wheat-pasture-pasture-wheat, and wheat-grain legume-canola-wheat. Base measurements taken before the trial was established in 1997 showed a compacted zone with a bulk density of up to 2 t m\(^{-3}\) between 80 and 150 mm. Penetration resistance at a 15% water content was 7 MPa in this layer. Organic carbon of the 0-200 mm depth was 0.82%.

Results show that, at shallower depths, conventional cultivation resistance to penetration exceeded the critical value of 2.5 MPa even though the water content was above the lower limit of availability. In comparison with no-till and conventional cultivation, tillage rotation reduced penetration resistance at all moisture contents in all the four years of experimentation. Due to the soil physical change, tillage rotation has increased root numbers, water and nitrogen uptake on average by 144%, and 53% and 59% respectively compared with conventional cultivation. In continuous wheat, grain yield in tillage rotation outyielded conventional cultivation by 11% in 1997 to 17% in 1999 and to 19% in 2000. In 2000 wheat yields in rotations that included grain legumes, canola or legume pasture were consistently higher than continuous wheat. Comparing the three tillage rotation systems with the lowest yielding conventional cultivation system shows that tillage rotation with wheat-pasture-pasture-wheat, tillage rotation with wheat-grain legume-canola-wheat and tillage rotation with continuous wheat outyielded conventional cultivation with continuous wheat by 98%, 92%, and 19% respectively. The highest yield in 2000 was 113% of the potential yield calculated from the model of French and Schultz and the next highest was 110%. These compare with 57% of potential on the lowest yielding treatment. A yield of 70% of potential was regarded as satisfactory at the time the model was developed, confirming that the compact layer was restricting water entry and root penetration and so limiting crop productivity and water use efficiency. In four years, organic carbon in the 0-200 mm soil layer in the tillage rotation with wheat-pasture-pasture-wheat has increased from 0.82 to 1.2% (46% increase). The greatly increased carbon sequestration in this system indicates better soil health and is an important environmental parameter.

Keywords: tillage rotation, no-till, conventional cultivation, crop rotation, organic carbon, compaction, yield
Soil quality parameters for assessing the impact of water erosion on the productivity of agricultural lands

MBAGWU Joe S.C., NNABUDE Peter C. and IGWE Charles A.

Department of Soil Science, University of Nigeria, Nsukka, Nigeria

Soil erosion by water has devastated many agricultural lands in the humid tropics. In sub-Saharan Africa estimated and measured soil losses far exceed 600 t ha\(^{-1}\) y\(^{-1}\). Our knowledge of the actual mechanics of soil erosion and methods of characterising and quantifying the various causative factors far outweighs our understanding of the actual decline in the productivity of the residual soils. One of the reasons for this gap in knowledge is that soil erosion occurs gradually and its impact on the soil can be obliterated by high technology inputs like fertilisers and pesticides. Another reason is that the traditional farmers in the humid tropics do not have the economic base to attempt to restore the productivity of eroded soils. The situation is now very alarming and serious calls have been made for the formation of working groups to tackle the problem. It is our belief that for such working groups to succeed they have to be guided in the types of soil measurements to take to reflect productivity decline on soils. Such indicators of consequences of soil erosion can be grouped into physical, chemical and biological properties as well as crop yield decline.

The soil physical properties which reflect losses due to erosion are dynamic and include texture, bulk density (\(P_b\)), saturated hydraulic conductivity (\(K_s\)), instantaneous infiltration rate (\(i\)), quasi steady-state infiltration rate (\(i_c\)), cumulative infiltration (\(I\)), time to reach quasi steady-state infiltration rate (\(t\)) and soil moisture content (\(\theta\)). As a consequence of soil erosion the finer (silt + clay) particles are removed leaving a coarser soil surface. However, where the entire Ap horizon is lost the underlying Bt horizon may contain more clay than the lost soil. Loss of soil by erosion increases \(P_b\) and reduces \(K_s\), \(i\), \(i_c\), \(I\) and \(t\). Also loss of the colloidal fraction (OM + clay) reduces water retention properties of the residual soil.

The soil chemical properties which are reduced by erosion are OM, total exchangeable bases, CEC, total N and available P. These exchangeable properties, total N and available P reside in the OM and clay fractions. Hence their loss reflect losses in these nutrients.

The changes in biological properties of the soil are reflected in reductions in the number and activity of micro- and macro- organisms, microbial biomass C and N and in the evolution of CO\(_2\) as a result of reduced microbial respiration. These changes are rarely measured directly because they can be inferred from OM contents.

The overall effect of these reductions in soil properties is lowered structural stability of the residual soils and a decline in the performance and yield of crops grown on them. Organic matter has a direct or inverse relationship with these properties. Hence, measurement of OM content, particle size distribution and CEC of these soils will always give an indication of the extent of productivity decline expected and the mitigating management practices to adopt.

**Keywords:** water erosion, soil quality, soil productivity, impact assessment, agricultural lands
Chemical and micromorphological characterization of soils of the Murge area, Apulia, Italy

LOPEZ Raffaele (1), MIANO Teodoro M. (1), COCOZZA Claudio (1), D’ORAZIO Valeria (1) and TERRIBILE Fabio (2)

(1) Dip. di Biologia e Chimica Agro-Forestale ed Ambientale, Università di Bari, Via Amendola 165/A, 70126 Bari, Italy
(2) Dip. di Scienze Chimiche Agrarie, Università di Napoli Federico II, Via dell’Università 100, 80055 Portici (NA), Italy

The Murge area, located in the Apulia region, Southern Italy, represents a wide calcareous high plain characterized by moderate relief, scarcely developed river network, limestone rock outcrops, deep soils in the lowest areas, shallow in the highest ones. The former often show even superficial rockiness, and therefore are designated as to natural pastures and grasslands, but can be cultivated crushing deep and surface stones and rocks and homogenizing them with soil to obtain a softer substrate for growing crops. Such practices result in immediate and evident changes in the landscape morphology as well as in dramatic increases of soil erosion, loss of soil structure and organic matter (OM). In order to investigate these consequences on soils quality, authors compared micromorphological, chemical, physical and spectroscopic features of natural deep and shallow soils and crushed ones. Natural deep soils were characterized by several horizons designated in the field as Apl-Ap2-Ab1-Ab2-Bt1-Bt2-Bt/2B1-2B2, according to the Soil Taxonomy (Soil Survey Staff). In these soils carbonate, pH, OM, sand and silt contents decrease systematically along the profiles. In particular, soil particle size decreases markedly through the first portion of the profile towards Ab1-Ab2 horizons; then, it increases in the intermediate portion (to Bt1) and finally decreases again dramatically till the lowest horizon. On the other hand, shallow soils were classified as Ap-horizon laying on the consolidated limestone bedrock, whereas crushed soils obviously did not show any stratigraphy. Soil samples were collected from each crushed soil and from each horizons of natural soils. The most important differences between all samples are due to the quantity and quality of the OM. In fact, natural soils show always highest OM content, such as soils crushed most recently, while soils crushed far in the past have the lowest OM content. Fluorescence and Fourier transform infrared spectroscopic data show different quality and complexity of the OM in general and HA in particular. Briefly, natural and recently crushed soils show very complex HA molecules with aliphatic, aromatic and polysaccharidic residues, while soils crushed in the past were characterized by HA with simpler chemical structure and prevalently aromatic features. In conclusion, the agronomical practice of crushing soils seems to reduce chemical soil quality as a consequence of losses in amounts and complexity of OM, possibly due to new environmental conditions such as more aeration, ploughing and major exposure to erosion.

Keywords: soil quality, limestone rocks, organic matter, micromorphology
Soil conservation and crop productivity in Yunnan Province, P.R. China

MILNE Eleanor (1), FULLEN Michael A. (1), HOCKING Trevor J. (1), MITCHELL David J. (1), WU Bozhi (2), LIU Liguang (2) and ZHAO Yan (2)

(1) School of Applied Sciences, The University of Wolverhampton, Wolverhampton WV1 1SB, UK
(2) Faculty of Agricultural Science and Technology, Yunnan Agricultural University, Kunming 650201, Yunnan Province, P.R. China

In Yunnan Province, China, 95% of land is mountainous, which necessitates cultivation of steep slopes. This study considered the effectiveness of two soil conservation measures in relation to crop productivity. Thirty runoff plots were constructed on three slope angles (Slope I 3°, Slope II 10° and Slope III 27°) with 10 plots on each slope. Maize was cultivated on the slopes over two cropping seasons running from May to October, 1998 and 1999. Treatments investigated were traditional downslope cultivation (D) (the control), contour cultivation (CC) and contour cultivation plus straw mulch (CC+SM). Measurements of runoff and soil loss were made after every storm. Crop growth parameters were measured every two weeks. Measurements of soil temperature and moisture were made on Slope II during both years. Soil water potential was measured using Delta-T Equitensiometers. Soil nutrient status was measured at the beginning and end of each cropping season. Yield and yield components were measured at the end of each cropping season.

In 1998 seasonal rainfall was 1,024 mm, over 28% greater than the 30-year mean. Soil loss was significantly reduced by CC on Slopes I and II, with D and CC producing 3.07 and 0.57 t ha⁻¹, respectively, on Slope I and 19.11 and 8.01 t ha⁻¹ on Slope II. However, the addition of straw mulch gave no extra reduction. On Slope III, D, CC and CC+SM produced 6.92, 6.29 and 0.04 t ha⁻¹ respectively. CC did not significantly reduce soil loss, but CC+SM did. In 1999, a much drier year, no significant treatment effects were found on Slope I. CC significantly reduced soil loss on Slopes II and III, with D and CC producing 11.52 and 1.64 t ha⁻¹ respectively on Slope II and 8.62 and 0.23 t ha⁻¹ on Slope III. The addition of straw mulch gave no extra reduction. In 1999, on Slope II, CC+SM significantly increased in Green Leaf Area Duration and yield (P <0.05). In both years significant treatment effects were found on soil temperature, with CC+SM causing a reduction. However, any adverse effect this may have had on crop growth was offset by an increase in soil moisture content during drought periods under CC+SM. In 1999, during a 24-day drought, CC (unmulched) plots reached permanent wilting point (PWP) after 14 days, whereas CC+SM (mulched) plots had not reached PWP after 24 days. At the end of the 1998 season, significantly higher soil available N was found under CC+SM on all three slopes (Slopes I and II P <0.001, Slope III P <0.05). At the end of the 1999 season, soil available K was significantly higher under CC+SM on the steepest slope (P <0.001). In conclusion, contour cultivation plus straw mulch can both reduce soil erosion and increase maize productivity in the prevailing agro-environmental conditions in Yunnan.

Keywords: soil erosion, China, crop productivity
Soil and water management options for seasonal wetlands (*vleis*) in semi-arid areas of Masvingo Province, Zimbabwe


(1) Institute of Agricultural Engineering, Makoholi Research Station, Masvingo, Zimbabwe
(2) Silsoe Research Institute, Silsoe, Bedfordshire, MK45 4HS, UK
(3) Crop Science Department, University of Zimbabwe, Harare, Zimbabwe
(4) Natural Resources Institute, University of Greenwich, Chatham, Kent, ME4 4TB, UK
(5) ICRISAT, Bulawayo, Zimbabwe

*Vleis* are low-lying, usually gently sloping, seasonally waterlogged areas. Two major problems facing farmers in this environment are weed control and water management. On-farm tillage trials tested in four locations were broad beds, pre-plant ridges, post-plant ridges, drainage furrows and flat-planting. PVC pipes were installed to 1m depth and height of water table was recorded monthly. Maize and rice yields were recorded from each plot. Mean water level below the soil surface under broad beds was 63 cm compared to 56 and 57 cm under post-plant ridges and furrows, respectively. The effect of the broad-beds on water levels was consistent across the season. Broad-beds gave significantly higher maize yields compared to the worst performing treatment, flat planting, where areas of inundation and waterlogging were recorded. However, rice yields were favourable under flat planting. Post-plant ridges and furrows produced no rice yield due to inappropriate timing of their construction. Economic analyses indicate that despite the increased labour and draft animal requirement, beds give better returns than other treatments. Flat planting, being the one most commonly used by farmers, is the second most productive treatment and for those without access to DAP, this is likely to be the one they continue to use.

**Keywords:** beds, ridges, tillage, water management, water table, *vleis* (wetlands)
The study of the irrigation levels on the cultivation of tomato

NOURJOU Amir, ZOMORODI Shahin and ALIEH EMAMI

Agricultural Research Center, West Azarbaijan, Iran

Considering the existing limited water resources and increasing cultivatable land areas (as the condition of Iran), increasing the production rate per unit of water and optimization of water resource usage have special importance. One of the principal ways to increase the cultivatable area and optimize the water use efficiency in the irrigable lands is the application of deficit irrigation, the efficiency of which has been proven all over the world. Considering that about 21,000 hectares of tomatoes are cultivated in west Azarbaijan, a project was designed to investigate the possibility of economic use of water and the effect of deficit irrigation on the cultivation of tomatoes. The project was carried out using complete random blocks with 4 treatments in 4 replications at Kahrize Research Station, Urmia. Irrigation treatments were 125%, 100%, 75%, 50% of the water needs of the plant. The real need for water was estimated on the basis of evaporative pan and evapotranspiration potential (on the basis of the Laicimetric statistic of the station in the past years). The analysis of results showed that there was significant effect between the amount of water used for irrigation and product yield and water soluble solids at the levels of 1% and 5% respectively. Increasing the irrigation water caused reduction in the water soluble solids. The effect of amount of irrigation water on the acidity and pH values of the product was not significant.

Keywords: tomato, deficit irrigation, yield, quality
Alternative measures for coping with soil erosion and poverty in Udi communities, South Eastern Nigeria

OGBOZOR E.N.

Agribusiness Advisor, Enterprise for Development International (EfDI), 40 Oladipo Bateye Street, Ikeja GRA, Lagos, Nigeria

Prior to the oil boom and coal mining era, agriculture was the mainstay of the Nigerian economy. Nigeria grew to be the only coal producing and exporting country in West Africa, as well as a consumer of this commodity. Coal of the sub-bituminous type was discovered on the scarp face of the Udi Escarpment in 1909.

However, when the Nigeria Railway decided to dieselise their rolling stock in the 1960’s, the demand for coal fell and many mines were closed down. Production fell from the peak of 914,000 tonnes in 1959 to 1,000 tonnes in 1990. The coal mining labour force dropped from 9,000 in 1959 to 3,000 in 1965. Today, less than 1,000 are directly employed in the industry. Udi division, in addition to providing virtually the entire labour force for the coal exploration and mining, also sacrificed its entire agricultural land for this activity. The vast agricultural lands of the communities have been left as an enclave exposing a bare land for soil erosion and other agents of denudation. The resultant effect on the communities is poverty and the need for alternative sources of livelihood. The coal era brought joy and sorrow to the communities.

Udi lies advantageously at the intersection of north-south and east-west highways. Its central accessibility from all parts of the country enhanced its position as a growth centre for the location of a variety of small and medium scale enterprises, principally breweries, soft drink factories, metal workshops, feed mill factories and other small businesses. Hawking along the highways is a popular trade in the communities. Various markets and motor parks have also developed and constitute potential sources of income for the communities.

Although, the development of micro-enterprises has proved to be an effective instrument in addressing poverty problems in Udi southeast Nigeria, occasioned by the coal era and subsequent soil erosion menace, the sustainability of these businesses has been hampered by many factors. In the case of eastern Nigeria, Onyeiwu (1992) argued that graduation problems among small businesses from small to larger categories constitute a threat to micro-business development in eastern Nigeria. Kilby, 1988; Schatz, 1977 argued that of all the constraints on entrepreneurship in Africa, managerial bottleneck is often isolated as pernicious problem. More specifically, it is often contended that small business are unable to graduate because the entrepreneurs, having started ‘one-person business’ do not have the capacities to manage large firms (Harris, 1971). This seems plausible because most of them acquired only apprenticeship training without a management component.

However, Enterprise for Development International (EfDI), has demonstrated that with managerial and technical assistance training to micro-entrepreneurs, the managerial bottlenecks of micro-entrepreneurs can be overcome. The experience of EfDI with Community Based Enterprises (CBEs) in some parts of Nigeria will be ideal in this regard.

Keywords: agriculture, coal mining, soil erosion, poverty, micro-enterprises
Improvement of water use efficiency under contour cultural practices on highland slopes in Thailand

PANOMTARANICHAGUL Mattiga (1) and FULLEN Mitchael (2)

(1) Department of Soil Science, Faculty of Agriculture, Chiang Mai University, Thailand
(2) School of Applied Science, University of Wolverhampton, Wolverhampton, UK

The effects of selected contour cultural practices on soil and water conservation and crop water use efficiency were compared under a rainfed highland agricultural system. The field trial was conducted during 2000 and 2001 on a 35% hill slope (latitude 19°33’47” N, longitude 98°12’9” E, altitude 780 m) in Maehongson Province, Northern Thailand. A completely randomized design, with four treatments and three replicates, used a cropping sequence of maize, followed by lablab bean, was conducted from May 2000 to April 2002. The treatments were (i) conventional contour planting, CC, (ii) contour ridge cultivation without mulching, CR, (iii) contour ridge cultivation with polythene sheet + straw mulch, INCOPLAST or CRP and (iv) alley cropping with mango-hedgerow tree and ground surface cover with Graham Stylo, AL. Soil water stored within 1700 mm was monitored every 2-3 weeks by neutron moisture meter. Runoff and erosion were measured after every rain storm. Soil sampling and analysis were conducted one month after sowing and one month before harvesting maize. Crop development was measured as total dry biomass at different growth stages and maize and lablab bean yields were harvested as total dry-matter and yields.

Results obtained during the two experimental years (2000-2001) showed that alley cropping (AL) was the most effective treatment in decreasing runoff and erosion, while CRP was the second best at erosion control. However, CRP had the highest rate of runoff and erosion under high intensity rainfall during the early growing season. Generally, CRP protected the soil surface from the splash erosion and had better soil physical properties, leading to the highest crop water use efficiency, and had the highest growth rate of Lablab bean. Crop yields under CRP and AL were relatively high and comparable compared with either CC or CR during the dry seasons of both years.

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Keywords: alley cropping, INCOPLAST, soil loss, runoff, water use efficiency, soil water evaporation
Crop residues and vegetative barriers: promising technologies for soil erosion control in Oaxaca, Mexico

RUIZ V.J. (1), BRAVO E.M. (2) and LOAEZA R.G. (3)

(1) Becario COFAA, Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR), Calle Hornos No. 1003, Sta. Cruz Xoxocotlán, Oax. CP 71 230, Mexico
(2) Centro Nacional de Investigación para Producción Sostenible, INIFAP, Apartado Postal No. 7-116, Morelia, Mich, Mexico
(3) Ex Investigador del CAE Valles Centrales de Oaxaca, INIFAP, Sagar, Mexico

Due to steep topographical conditions, soil erosion in fields planted with maize affects most of the Oaxaca state, where some 300,000 farmers plant the crop for self consumption. Decreasing productivity and less available land per capita are indicating the need for a more sustainable land use. Thus, evaluation and promotion of soil conserving technologies are required. Covering the soil and reducing the slope length have proven to be efficient approaches to reduce soil erosion elsewhere. Therefore, plant residues and several plant species with potential to be used as alive barriers were evaluated for soil water conservation and erosion control at different altitudes. In sloping soils, the addition of a 5 cm layer of chopped maize residues at first weeding gave higher soil water contents, which resulted in larger seed yields in both maize and peanuts. In mountain soils, where the slash and burn system is practiced, avoiding to burn resulted in considerable reduction in soil erosion rates, but these were still higher than the tolerable rates for sustainable soil use, indicating that land with slope above 50% should be left under natural vegetation. Also, not burning the slashed vegetation resulted in higher maize yields due to more availability of soil water. Some of the promising species for alive barriers at different altitudes were castor bean and prickle pear (1,500-1,700 m), agave (1,600-1,800 m), vetiver grass (1,700-2,000 m) and Creole peach (2,000-2,200 m). Creole peach and agave, the last one used to produce, an alcoholic beverage ("Mezcal"), had the largest acceptance among the farmers.

Keywords: water erosion, vegetative control practices, maize
The phosphorus enrichment ratio of overfertilized soils

SCALENGHE Riccardo (1), BARBERIS Elisabetta (2) and EDWARDS Anthony C. (3)

(1) Università di Palermo ACEP - Viale delle Scienze, Palermo I-90128, Italy
(2) Università di Torino, DIVAPRA - 44, via Leonardo da Vinci, I-10095 Grugliasco, Italy
(3) Macaulay Land Use Research Institute, Craigiebuckler AB15 8QH, Aberdeen, UK

Phosphorus (P) associated with inorganic and organic soil material eroded during high flow storm events can constitute a large proportion (>60 percent) of the P transported in surface runoff from cultivated land. The size selective nature of erosive transport results in the preferential loss of the finer clay sized particles which also tend to show the highest accumulations of P. In situations where clay particles are predominantly composed of phyllosilicates and iron and aluminium oxides a large specific surface area of the finer fraction is common. The associated surface charge depends greatly upon the surrounding environmental conditions such as the soil solution’s ionic strength and pH. These conditions can be strongly modified by sorption of anions such as P which has important consequences for the extent of particle dispersion/flocculation degree.

Recently it has been demonstrated that adsorption of P onto iron oxides, phyllosilicates and calcite can lead to an increase of the net negative charge and a consequent dispersion of particles, organic P was observed to cause dispersion more than the inorganic form because of the higher charge density and steric stabilisation effects. Thus, while on the one hand high rates of P sorption can decrease P concentrations in soil solution reducing the potential leaching to surface waters, while perhaps enhancing nutrient transfer by increasing the mobilisation of colloidal particles that can act as carriers. To test this hypothesis clay (<2 µm), silt (2-20 µm) and sand (20-200µm) fractions of twelve overfertilized soils belonging to six World Reference Base groups were separated using progressively stronger dispersion methods. In all cases total P content was highest in the clay fraction ranging from 1,020 to 11,430 mg P kg⁻¹. The highest contents of Fe₉₀, Fe₆₄ and OC were also found in the clay fraction. Phosphorus enrichment ratio (PER), defined as the ratio of total P content of separates to that of soil, is always >1 in clay (indicating a concentration). PER shows an inverse trend with clay content and this is probably due to the high P sorption saturation occurred on the clay fraction.

Keywords: P losses, adsorption, desorption, P forms, dispersibility, clay
Soil biochemical and structural characteristics in native and tilled Brazilian Cerrado soils

STOTT Diane E. (1) and GREEN V. Steven (2)

(1) USDA-ARS National Soil Erosion Research Laboratory, 1196 Soil Bldg., West Lafayette, Indiana 47907-1196, USA
(2) Purdue University, West Lafayette, Indiana, USA

The Brazilian Cerrado is one of the last remaining agricultural frontiers and is undergoing a rapid increase in capital-intensive agricultural development. Soil quality in the Cerrado region is a pressing issue due to the inherent low fertility of these soils. There is limited knowledge on the baseline soil quality of these soils under native vegetation, especially with regards to the biochemical properties, and how the parameters shift under agricultural management. Soil enzymes are involved in nutrient cycling processes and are indicative of the general biological activity of the soil. Enzyme activities are sensitive to soil management and often show signs of soil degradation well before other physical and chemical indicators. Our objective was to survey the baseline soil biochemical indicators of several Cerrado soils. For comparison, we studied the impact of different tillage practices on a dark red Latosol, an important agricultural soil in the region. We hypothesized that soils managed with tillage systems would have lower biological activity than soils under native vegetation, and that among the managed soils, no-till soils would have the highest biological activity and organic C content, but it would be concentrated in the surface layer.

Soil samples from tilled plots along with an area under native vegetation located at the EMBRAPA research facility located at Sete Lagoas, Minas Gerais. Samples were collected in April 1998. Soil was sampled at 3 different depths: 0-5, 5-20, and 20-30 cm, as these were natural horizon breaks in the profile under native vegetation and under no-till management; no visible distinction could be made between the 0-5 and 5-20 cm depths in the tilled systems. The 0-5 cm depth is rich in organic matter; the 5-20 cm depth is the layer where the majority of root growth is taking place; the 20-30 cm depth is just below the primary root zone. Soil samples were gently sieved to pass a 2.0 mm sieve and air-dried. Additionally, soil bulk density was measured at the top of each sampling layer. Five soil enzyme analyses were performed: β-glucosidase, acid phosphatase, and arylsulfatase, arylamidase, and fluorescein diacetate hydrolysis. Physical measurements included antecedent moisture, aggregate stability and surface sealing potential.

Initial analyses indicated that as organic C decreased under tillage, biochemical activity also decreased. Benchmark soil quality levels were established for these sites. When managed, the no-till soils maintained the highest activities, followed by the disk harrow system, with the disk plow system having generally lower activities. These results indicate that tillage regimes that are less aggressive maintain higher biological activity than aggressive tillage operations in these tropical Cerrado soils. Soil organic carbon levels followed the same general pattern as the enzymatic activities. At most sites, the increase in biological activity and organic C translated into an increased aggregate stability and a lower tendency to develop a surface seal. In these tropical soils, a no-till management system is likely to be more sustainable due to the influence of soil biological activity in nutrient cycling and aggregate stabilization.

Keywords: aggregation, surface sealing, enzyme activities
Soil conservation as a strategy for sustainable development

TALEGHANI Gholamreza

Tehran University, Tehran, I.R. Iran

In the present article, reference is made to different techniques and methods of protecting water and soil resources. This is done with regards to the strategic importance of protecting vegetation in an established ecosystem and the necessity to expand the greenery of different regions as well as applying correct management of implementing this vitality.

The study covers the following aspects, explained in detail under separate issues:
- Study of management on soil, water and natural resources.
- Management of methods and techniques;
- Obstacles;
- Greenary and vegetation as essential factors of preventing soil erosion;
- Proper implementation of recommendation on management issues in order to discover suitable strategies to achieve sustainable development.
- Conclusion and results
- Reference and resources

Keywords: soil conservation, management, water protecting, natural resources, vitality, sustainable development
Marl soils and different types of erosion in Iran

ZADEH Hamid Smaeil
Faculty of Natural Resources, University of Tehran, PO Box 31585-4314, Karaj, Iran

Marls in arid lands are highly erodable regions where sediment originates. These type of soils are found in many parts of Iran and come in several colors like gray, red and green.

The erosion process in marls with a lack of plant cover and decreasing permeability is very active, especially in marl dunes. Different types of erosion, especially in badlands characterise marl regions and there are many complex factors involed in marls erosion.

Also, erosion in marls depends on environmental factors like rain distribution and soil properties. The importance of marls is in the type and amount of sediment that is produced as well as the variety of erosion forms. Today, the fact that the effective longevity of huge dams in Iran such as Sefidroud, Save and Panozahe khordad has decreased is a subject of great interest for most specialists and researchers of earth science.

The study of erosion forms in marls demonstrated that there is a direct relationship between erosion forms and some soil chemical properties with regard to different sorts of erosion, such as sheet erosion, rill erosion and badland erosion. The highly density of rill and galley occurs on marls that have high solution sodium and sodium absorption ratio (SAR).

The comparing of mean physico-chemical factors of marls with different erosion forms demonstrated that the amount of Na, Mg, SAR, pH and organic carbon have differ significantly in sheet, rill and badland erosion. This problem accounts for the role of the above factors in stable and unstable marl regions and among these factors, SAR value is the most important one which controls erosion index for marls.

The occurence of many causes of slope instability in marls formation in these regions of Iran on the one hand and lack of comprehensive research on this topic on the other hand, formed the main incentive to carry out the present paper.

Keywords: marl soils, badland, sheet and rill erosion, SAR
Quantifying tillage translocation and tillage erosion rates in hilly areas of SW-China

ZHANG Jianhui (1), LI Yong (1) and LOBB David A. (2)

(1) Institute of Mountain Hazards and Environment, Chinese Academy of Sciences & Ministry of Water Conservancy, Chengdu 610041, P.R. China
(2) Department of Soil Science, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

Tillage translocation and tillage erosion were assessed in the hilly areas of Sichuan Basin, southwestern China (30°24' N and 104°35' E) using tracer technique. The tillage experiment was conducted on three field sites with different slope gradients ranging from 4-37 %. A plot of soil was labelled with a tracer, which was made of rock fragments with 3-4×3-4×1.5-2.0 m$^3$ in size. The plots were established perpendicular to the direction of tillage in 1.00 m wide, 0.20 m long, and 0.20-0.23 m depending on soil layer thickness. The objectives of this study were (1) to quantify the rate of tillage erosion by manual hoeing, and (2) to examine the influence of slope gradients on soil loss rate by tillage in the humid sub-tropics.

The effects of tillage translocation due to hoeing tillage on hillslopes are quite evident. A direct evidence of tillage erosion demonstrates that soil tillage is partly responsible for soil loss. Tillage translocation rates ranged from 43.70 to 64.47 kg m$^{-1}$, and average tillage erosion rates reached 65.05-97.05 t ha$^{-1}$ y$^{-1}$. Soil translocation was related closely to slope gradients, with a significant linear correlation between mean displacement distance and slope gradient ($P<0.01$). Tillage erosion rates depend mainly on downslope parcel length due to small patches of the fields and shortly linear slope segment.

Keywords: hillslope, hoeing tillage, tillage erosion, tillage translocation
Symposium 38

Advanced integral modeling to make decision in soil conservation

Convenor: DELGADO Fernando
Co-Convenor: TANGTHAM Nipon

Oral Session
Saturday 17 August 2002
14:00-17:20
Room: Meeting Room 2

Poster Session
Saturday 17 August 2002
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Towards soil detachability determination under Divergent Rain Induced Flow Transportation (DRIFT)

ALEXANDRE Carlos (1) and FERREIRA Alfredo G. (2)

(1) Dep. Geociências, Univ. de Évora, Apartado 94, 7002-554 Évora, Portugal
(2) Dep. Eng. Rural, Univ. de Évora, Apartado 94, 7002-554 Évora, Portugal

Interrill erosion increases significantly with runoff occurrence. Soil detachment by raindrop impact is usually determined by splash measurements. Although splash transport decreases steeply when a water layer above soil surface occurs, becoming null for water depths above 2 mm, rain detachment can still be active at water depths one order of magnitude greater. For these conditions it is necessary to model sediment transport in order to determine soil detachment and soil detachability. Usually those models describe sediment transport with runoff, and its experimental application requires simulations of rain and runoff on small flumes or plots. However, it is not necessary to have a large area of soil to simulate the mechanism of soil detachment by rain impact. It is also easier to control the depth of a water layer if the reference plane of the surface is levelled, as can be done with cylindrical splash-cups. Using this technique we simulated Divergent Rain Induced Flow Transportation (DRIFT), the rain being the only detachment agent and the main transport agent, also for particles that remain in the water layer. Multiple drop impacts induce transport actions in all directions that, like splash, give a null net transport of sediments if there is a uniform soil surface and a uniform spatial distribution of drop impacts.

It is proposed a sediment transport model for DRIFT considering the following mechanisms: detachment; primary submerged transport, associated to the formation of clouds of particles lifted by raindrop impacts; secondary submerged transport, which is mainly a dispersion flux of suspended particles induced by near subsequent drop impacts; and deposition. This model gives an adequate description of the transport process, with fine particles representing most of the total concentration, and coarse ones representing the main proportion of the detachment rate, which emphasizes the importance of the transport by clouds of detached particles for estimation of the detachment rate.

Keywords: soil erosion, interrill erosion, rain detachment, divergent rain induced flow transportation (DRIFT)
Soil erodibility control by short-term tree fallow under simulated conditions in Western Kenya

BOYE Anja (1,2) and ALBRECHT Alainb (1)

(1) International Centre for Research in Agroforestry (ICRAF), P.O. Box 2389, Kisumu, Kenya
(2) International Centre for Research in Agroforestry (ICRAF), ICRAF/IRD, P.O. Box 30677, Nairobi, Kenya

Agroforestry has the potential to improve soil fertility and productivity in the tropics. Planting improved fallow species such as Tephrosia vogelii and Crotalaria grahamina may increase maize yields from 2 t ha\(^{-1}\) to 2.7 t ha\(^{-1}\) and 3.6 t ha\(^{-1}\), respectively. The objective of this study was to examine soil erodibility on soils previously cropped with the improved fallow species Tephrosia vogelii and Crotalaria grahamina and to assess soil and water loss during high intensity rain storms by the use of a field rainfall simulator.

The study was conducted for the long cropping season in 1999 as an on-farm experiment at Ochinga farm, Vihiga District, Western Kenya (O°06'N, 34°34'E, altitude=1432 m). The soil classified as an Oxisols (FAO) consists of 48 % clay, 25 % silt, and 29 % sand, is moderately to highly leached and has low organic matter 1.7 %. The climate is tropical with two rainy seasons, long rains last from March to June and short rains from October to December. Annual rainfall is 1800 mm. Rainfall simulations were performed on three land use types: (i) continuous maize and two improved fallow species (ii) Crotalaria grahamiana and (iii) Tephrosia vogelii. The rainfall simulations had a rainfall intensity of approx. 50 mm h\(^{-1}\) and lasted for 30 minutes. Runoff and soil loss were measured for three surface treatments (i) full cover (C), (ii) bare soil (NT), and (iii) tilled soil (T). Each treatment had three replicates. Measurements were carried out with the field Orstom rainfall simulator, which simulates over 4 m\(^2\) and measures runoff from 1 m\(^2\) (Asseline & Valentin, 1978). Soil strength was determined by three different methods; water stable aggregates, soil shear strength, and soil cohesion, where the latter two were measured on-site with a penetrometer CL 700A (kg cm\(^{-2}\)) and a torvane CL 600 (kg cm\(^{-2}\)), respectively. Water stable aggregates were determined by wet sieving after shaking.

The results showed that soil loss and runoff were considerably lower for the two improved fallow species due to lower soil erodibility. Of the improved fallow species Crotalaria grahamiana showed lower runoff and soil loss compared to Tephrosia vogelii. Soil shear strength and cohesion are used as an index for soil erodibility and are correlated with soil carbon content and water stable aggregates. For Crotalaria grahamiana soil erodibility was mainly explained by soil carbon content and soil cohesion and shear strength, whereas for Tephrosia vogelii soil erodibility was mainly explained by percentage water stable aggregates. Thus percentage water stable aggregates and soil strength can be increased without a significant increase in soil carbon content. Furthermore, the good correlation between percentage water stable aggregates and soil shear strength and cohesion showed that soil strength can easily be determined on-site in the field by the use of simple instruments.

Keywords: soil erodibility, improved fallow, rainfall simulator, Western Kenya
Watershed-scale terrain analysis for determining nutrient loss potential

BRYANT Ray B. (1), GIASSON Elvio (2) and DEGLORIA Stephen D. (2)

(1) USDA/ARS Pasture Systems and Watershed Management Research Unit, University Park, PA, USA
(2) Department of Crop and Soil Sciences at Cornell University, Ithaca, NY, USA

As in other regions, individual states in the Northeast Region of the USA have developed indices to assess the risk of diffuse loss of phosphorus (P) and nitrogen (N) to surface waters at the field scale. Many of these indices have identified the soil and management conditions that are of state-specific importance for characterizing the potential for nutrient movement in landscapes. Some indices distinguish between the various modes of transport (erosion, runoff and leachate), assigning risk values for the various transport pathways. This study combines geographical information, nutrient indices and nutrient application data for identifying and ranking watersheds and larger geographical areas in the Northeast Region of the USA with respect to potential for nutrient export to streams. Concepts such as the delivery ratio (DR) developed by Draper et al. (1979) and the availability factor, an estimate of the proportion of nutrients that move into runoff from surface-applied manure (Heatwole and Shanholtz, 1991), are used in combination with soil drainage class and other soil parameters that influence risk of nutrient loss. This index approach to terrain analysis for assessing the environmental status of watersheds is a much simpler alternative to complex hydrologic modeling. Where water-monitoring data and modeling results are available, such as in the intensely studied Cannonsville Reservoir Basin, in Delaware County, NY, this index approach to terrain analysis may be calibrated and tested. Terrain analysis results show the potential for application of the index approach for selecting priority areas for implementing best management practices or enrollment in programs like the Conservation Reserve Program (Giasson, et al., 2002). Comparisons across different physiographic regions illustrate where livestock production operations are well suited or poorly suited to the physical environment in which they are located.

Keywords: water quality, terrain analysis, GIS
Changes in soil and nutrient rich salts losses due to deforestation in sloping area

CHEN Yan and MIHARA Machito

Tokyo University of Agriculture 1-1-1 Sakuragaoka Setagaya-ku, Tokyo 156-8502, Japan

A large number of studies have been made on changes in water quality of surface runoff from upland field, however little is known about changes in water quality of surface runoff from reclaimed agricultural land. This study dealt with changes in soil and nutrient rich salt losses due to deforestation in a sloping area. In addition, the cover and plant management factor (C factor) in USLE was calculated on the basis of experimental results from both bared and forested plots. Then the effects of the Ao layer and plant cover on reducing soil loss in forest were investigated using the artificial rainfall simulator.

The bared and forested plots were set up in Tama hilly area of Tokyo. Surface water was sampled using water tanks. Surface discharge, soil loss, total nitrogen and phosphorus in suspension and supernatant, and inorganic nitrogen in supernatant of surface runoff were observed monthly. The physical properties of soils were measured in December 1998. The chemical properties of soils were measured in July and December from 1998 to 2000. There was a tendency for nitrogen and phosphorus loads of forested plot to be higher than bared plot in the range of soil loss in forested plot. However, soil loss in forested plot was obviously lower than in bared plot, then total loads of nitrogen and phosphorus in forested plot became lower than in bared plot. It became clear that soil conservation measures have an important role for reducing nitrogen and phosphorus losses in deforested area.

Bared plots and covered with fallen leaves plots were set up under the artificial rainfall simulator. The intensity of artificial rainfall was controlled in the range from 58 to 62 mm h$^{-1}$ for two hours. Surface runoff was sampled using water tanks. Additionally, surface discharge and soil losses were measured in each plot. The coefficient of the cover and plant management factor (C factor) in USLE (Universal Soil Loss Equation) of the forested plot was 6.43$\times$10$^{-2}$. It was greatly lower than the coefficient of the bared plot. It follows that this factor contributed for reducing the amount of soil losses in forested plot. In the forested plot, the effects of C factor can be divided into the effect of plant cover and the effect of Ao layer. Experimental results using the artificial rainfall simulator indicated that the effect of plant cover was 2.2 times higher than Ao layer effect.

It was concluded that cover and plant management factor (C factor) is important for reducing soil losses and chemical transfer.

**Keywords:** C factor, deforestation, soil loss, nutrient rich salts
A framework to make decisions in soil conservation for tropical mountains

DELGADO Fernando

Interamerican Center for Environmental and Territorial Research and Development (CIDiat)
University of Los Andes, Mérida, Venezuela

Soil conservation on tropical mountains, especially in developing countries, is of unpostponable priority. This is not only for reasons having to do with agricultural production in countries with little readiness of good quality lands, but also for the environmental challenges related to the biodiversity conservation and high-watersheds protection. In this paper we present a framework to facilitate the selection of soil technologies for sustainable agriculture on tropical mountainous hillsides, being based on the evaluation of two basic land qualities: soil productivity and soil erosion risks. The proposed methodological approach consists of the quantification of these two land qualities. Both are quantified through the main characteristics that determine them, applying multifactorial methods. Soil productivity can be estimated from soil characteristics such as soil air-water relationships, soil impedance and soil fertility. On the other hand, erosion risks depends basically on soil hydrologic properties, rainfall patterns and terrain slope. Two indexes are obtained from soil and land characteristics: soil productivity index (PI) and erosion risk index (ERI), each one evaluates the respective land quality. Subsequently, a matrix is generated, showing different land classes as well as soil conservation priorities, conservation requirements and proposed land uses. This is a systematic way to the selection of soil conservation practices for hillside agriculture, included in the following soil conservation categories: (I) Practices to improve soil productivity and soil erosion resistance, as well as to reduce rainfall erosivity impacts; (II) Practices to reduce runoff impacts; (III) Complementary practices. The framework has been applied in some areas of Latin American countries as Colombia, Costa Rica, Dominican Republic and Venezuela.

Keywords: soil productivity, soil erosion risks, soil conservation, tropical mountains
Predicting soil loss based on soil and vegetation properties

ESKANDARI Z. (1) and MOHAMMADI J. (2)

(1) Dept. of Natural Res. Center, Isfahan, Iran
(2) Dept. of Soil Sci., Agri. College, Shahare Kord Univ., Shahre Kord, Iran

There is a need in many emerging nations to develop simple and empirical models for predicting the amount of soil loss due to the erosion process. Pedotransfer functions (PTFs) were developed in order to model soil erosion. Variable selection through the stepwise technique indicate that the soil properties are more significantly contributed to soil loss prediction than plant properties. Since to aid policy formulation, maps showing the location and distribution of soil erosion are useful in providing regional and/or national perspectives, the resulting PTFs can be easily incorporated into the newly developed technology of geographical information systems (GIS).

Keywords: erosion, modelling, pedotransfer function, GIS
Modeling the effects of direct sowing with a mulch of residues on soil water management

FINDELING Antoine (1), MARLET Serge (1), MARAUX Florent (1), LAFOLIE François (2), CHANZY André (2), RUY Stéphane (2), BRUCKLER Laurent (2), HAVERKAMP Randel (3), SCOPEL Eric (4) and ARREOLA TOSTADO Manuel (5)

CIRAD-AMIS, TA 40/01, Avenue Agropolis, 34398 Montpellier Cedex 5, France
INRA Unité Climat Sol et Environnement, Domaine St Paul, 84914 Avignon Cédex 9, France
LTHE - campus - 1025, rue de la piscine - BP 95 - 38402 St Martin d’Hères Cedex, France
EMBRAPA-CPAC, Km 18, BR 020, Rodovia Brasilia/Fortaleza, BP 08223, CEP 73301-970, Planaltina DF, Brazil
Inifap - Serapio Rendon 83 - Colonia San Rafamel - Delegacion Cuauhtemoc, 06470 Mexico DF, Mexico.

Soil water management is a critical issue for farmers and agronomists in places where water resources happen to be scarce. It’s thus necessary to propose and study alternative soil management that can improve water use efficiency and lead to sustainable agriculture. This presented work was carried out in Mexico in a semi-arid tropical climate. It addresses the main effects of direct sowing with corn residues (DSR) on the water balance of a corn-planted soil. Experiments and modeling were carried out at the plot scale. The adopted methodology consisted of identifying the physical phenomena that were induced by DSR: i) limitation of evaporation, ii) modification of surface soil structure and infiltration, and iii) reduction of runoff. Experimental data about each effect of DSR were collected on la Tinaja’s experimental plots (Mexico). Laboratory work provided with some parameters which were impossible to measure in real conditions. All those data put together enabled us to build up a rich experimental data base. The theoretical approach was driven in two parts. First we split the general issue into three elemental and specific points dealing with DSR effects i), ii) and iii), in controlled conditions. The first point aims at modeling heat and water fluxes in the soil-mulch-atmosphere system, in order to model quantitatively the effect of a mulch, on soil evaporation and thermal amplitude. The second point treats cumulative effects of DSR on soil hydraulic properties and the capacity of soil to infiltrate water. The third point deals with modeling of runoff on either bare soil, mulch-covered soil, or cultivated and mulch-covered soil (rain interception, surface retention, infiltration, channeling of runoff in rills, and flowing out). Then we put together the results of these three points to integrate and study simultaneously all the effects of DSR. This work was carried out thanks to a numerical model that simulates water, temperature and nitrogen dynamics, and that was coupled with the main effects of DSR on the soil-mulch-plant-atmosphere system. The latter model proves to be a powerful tool that gives strategic and valuable information on soil water management, and can be useful for decision making concerning sustainable agriculture.

Keywords: experiment, model, water balance, conservation tillage, mulch of residues, corn
Simulation of runoff reduction and nutrient retention in riparian buffer strips

FREDE Hans Georg, ZILLGENS Birgit and FOHRER Nicola

Institute of Natural Resources Management, Justus-Liebig-University Giessen, Heinrich-Buff-Ring 26-32, D-35392 Giessen, Germany

The scientific aim of this project was the optimisation of the design of riparian buffer strips in terms of runoff reduction and nutrient and sediment retention. The efficiency of buffer strips of different densities and vegetation cover was quantified by employing simulation models. The main focus was given to the retention of adsorbed and dissolved Phosphorus. The simulation of surface runoff and the infiltration into micro- and macro-pores was performed with the model HILLFLOW 2D, the sedimentation process was described with the GRASSF model. The proportion of adsorbed and dissolved phosphorus during a runoff event was calculated basing on the Langmuir adsorption isotherm. The calibration and validation of the two models was carried out using experimental field data for riparian buffer strips with 5 m and 10 m effective filter width in different landscapes.

The efficiency of filter strips in terms of phosphorus retention was mainly determined by infiltration and storage of surface runoff in the soil matrix. The reduction of surface runoff and thus infiltration could be modelled rather well with HILLFLOW 2D. Inaccuracies in the model prediction were observed when the initial soil moisture was very low and when the field experiments were dominated by pass flow. The potential storage volume of a location was determined crucially by the depth of the macro porous soil layer. Thus the potential storage volume of buffer strip can be influenced by vegetation type or by a modification of the effective filter width.

Keywords: riparian buffer strips, runoff reduction, sediment retention, modelling, HILLFLOW 2D, GRASSF
Soil indicator systems: 
the basis for soil conservation decisions

FRIELINGHAUS Monika, PIORR Hans-Peter and MÜLLER Lothar

Center for Agricultural Landscape and Landuse Research (ZALF), Institute of Soil Landscape Research, Eberswalder D-15374 Müncheberg, Germany

The efficiency and acceptance for soil conservation management is not very high and therefore not a guarantee for sustainable land use and soil functionality or quality. The best method for increasing acceptance is a regional soil indicator system evaluating the state of soil quality and the pressure due to land use. The results form the basis to estimate the potential and actual risk for sustainable soil functionality. Like the concept of “critical load inputs” for chemical pollutants, this system would make it possible to quantify the soil state and soil condition for decisions concerning the soil carrying or load capacity. Most important is the assessment of the land use pressure on soil in terms of the soil load capacity and the driving forces for land use.

For the most important problems soil erosion (water erosion and wind erosion) and soil compaction indicators have been developed. Five risk classes for potential soil erosion risk and potential soil compaction risk allow getting by working for risk maps. Soil surface cover as a result of soil tillage and land use management is the indicator for the actual erosion risk. The comparison of the contact pressure with the maximum bearing capacity for soil tillage and management technical systems forms the indicator for the actual soil compaction risk.

These results may determine the response level required: in a balanced situation, Best Management Practices may help ensure sustainability is maintained, slightly disproportionate results suggest additional special agricultural management techniques may be needed, while significant differences may indicate the need for additional land use adjustments or changes in technical management. The indicator system is ideal for application in northeastern Germany for all moraine areas and the areas at risk to water and wind erosion and soil compaction.

Keywords: soil indicator system, soil erosion, soil compaction, and soil conservation
Sustainable land management in Vietnam: assessment of hedgerow farming systems on sloping lands

PHIEN Thai (1), HIEN Bui Huy (1) and ACTON Donald (2)

(1) National Institute for Soils and Fertilizers, Hanoi, Vietnam
(2) University of Saskatchewan, Canada

Food production on sloping lands is vitally important for food security in Vietnam. Traditional 'slash and burn' agriculture has resulted in severe soil erosion and loss of productivity on sloping lands. The use of hedgerows as biological measure for erosion control was evaluated at sites extending from the High Plateau in central Vietnam to the northern mountainous zone. Tephrosia candida was the most popular hedgerow used alone or in combination with tea, Leucaena glauca or several Crotalaria species for annual crops and coffee, tea and fruit trees. Where shading is necessary, Cassia siamea, Leucaena glauca, Alueris montana and several Acacia species are preferred.

Incorporating these shrubby green manure cover crops, as hedgerows, into annual and perennial cropping systems has resulted in many benefits, including:

1. Hedgerows contribute 3.5 to 6.8 t ha\(^{-1}\) y\(^{-1}\) of above-ground biomass, containing about 21-50 kg N, 3-5 kg P\(_2\)O\(_5\), and 20-40 kg K\(_2\)O ha\(^{-1}\) every year.
2. Hedgerows reduce soil and nutrient losses by 50-60% annually.
3. Hedgerows maintain or increase yield of alley crops even though they reduce the planted area about 5-10%.
4. Maize and cassava were more responsive to alley cropping than leguminous crops such as peanut and mungbean.
5. The positive effects of hedgerows increase with time.
6. The benefits of hedgerows and alley cropping can be enhanced by applying inorganic fertilizers.
7. Hedgerows contribute to the formation of natural terraces that further reduce runoff and erosion.

**Keywords:** sustainable land management, hedgerow farming, erosion control, alley cropping, biomass returning
Changes in soil and eutrophic components losses from rotary and shaft tillage

SANG-ARUN Janya (2), MIHARA Machito (1), TAJIMA Kiyoshi (1) and HORAGUCHI Yasukuni (1),

(1) Mae Fah Luang University, 333 Moo. 1, Tasud sub-district, Muang district, Chiang Rai 57100, Thailand
(2) Tokyo University of Agriculture, 1-1-1 Sakuragaoka Setagaya-ku, Tokyo 156-8502, Japan

In this study, the amount of soil and eutrophic component losses from shaft tillage were compared with rotary tillage. Slope plots under a rainfall simulator were employed for these experiments. In the case of bared condition, soil and eutrophic component losses from shaft tillage was higher than rotary tillage. It follows that shaft tillage under bared soil conditions was not effective for reducing soil and eutrophic component losses. However, the loads of soil loss, total phosphorus and total nitrogen from shaft tillage under weed and a residue covered conditions were much lower than those from rotary tillage. It was concluded that shaft tillage under weed and residue covered conditions was effective for soil and water environment conservation.

Keywords: tillage, soil loss, eutrophic components, soil conservation
Soil erosion: an approach to the assimilation of remote sensing data into runoff and erosion prediction models: examples of the European project FLOODGEN

KING Christine (1), LECOMTE-MOREL Véronique (1), BAGHDADI Nicolas (1) and BISSONNAIS Yves (2)

(1) BRGM (ARN/MSO), 3, Av. Claude Guillemin – 45 060 Orléans Cedex, France
(2) INRA (Science du Sol) BP20619 45210 Olivet Cedex, France

Erosion progressively reduces the potential of sustainable agriculture and has been identified as the major type of human-induced land degradation from a global perspective. A significant effort by the scientific community is expected concerning the proposal of new methods for selecting priority areas to be protected and monitoring the efficiency of protection measurement.

Remote sensing data were investigated from various angles for the location of areas suffering from erosion, the identification of fragile terrain degradable in the near future, and locally the quantitative assessment of erosion phenomena, such as degraded areas, soil loss, spatial distribution, and land use changes. This paper presents a brief synthesis of the parameters required to understand and model erosion processes and examines which of these parameters can be supplied by data retrieved from various remote sensing sensors (SPOT or Landsat TM, Radarsat or ERS, new sensors with high spatial or spectral resolution). Empirical, probabilistic and deterministic models are examined. Examples from Normandy (F) and Lombardia (I) illustrate the work.

Particular attention is given to a deterministic model of runoff (STREAM). This distribution runoff model working at the time step of the rainfall event and at the catchment scale has been developed to simulate the influence of land use modifications. The main characteristics of the model are that it takes into account the surface state degradation processes when calculating the infiltration rates and the agricultural features when computing the runoff circulation network. STREAM is based on an expert system approach which focuses on the dominant processes with few input parameters usually provided by ground surveys. Satellite data cover large areas with consistent precision and can be considered as alternative inputs in such a model. An adaptation of the STREAM model make it able to work with satellite data input (STREAM-TED) and to compare the results obtained with this approach with field data.

This study uses Radarsat data acquired in winter 98, Spot, and Landsat TM data gathered during both winter and springtime 97 and 98. The extraction of roughness indices from Radarsat data have already been undertaken and validated (Baghdadi et al., 2001).

To evaluate STREAM-TED we compared the predictions of the both STREAM versions together with measured values on a gauged catchment: Bourville (Haute-Normandie, France). A very good correlation is obtained between the runoff predictions of the STREAM and the STREAM-TED models, regardless of the type of precipitation event considered.

These highly convincing results prove that it is possible to extend the application of a deterministic a model well beyond the catchment basin where it has been calibrated without being dependent on field data. Optical and radar satellite data can be substituted with success thus opening up new possibilities for quantifying runoff at a regional scale. Results of regional extension will be given.

Keywords: loamy soils, model of runoff, remote sensing, synthetic aperture radar, optic satellite images, assimilation, Normandie, France, Lombardie, Italie
Application of USLE to the prediction of eutrophic components losses in soil erosion processes

MIHARA Machito (1), UENO Takashi (2) and YAMAUCHI Yuichiro (1)

(1) Tokyo University of Agriculture, Faculty of Regional Environment Science, 1-1-1 Sakuragaoka Setagaya-ku, Tokyo 156-8502, Japan
(2) Tokyo University of Agriculture and Technology, United Graduate School of Agricultural Science, 3-5-8 Saiwai-cho, Fuchu-shi, Tokyo 183-8509, Japan

The objective of this study was to apply USLE to the prediction of nitrogen and phosphorus losses in soil erosion processes. In order to predict total nitrogen and phosphorus losses, the coefficients of total nitrogen and phosphorus transfer were discussed on the basis of the experiments results. There was a tendency that the coefficients of total nitrogen and phosphorus transfer increased with increasing average concentration of total nitrogen and phosphorus in soils. It follows that the more granular the fertilizer applied causes higher coefficients of total nitrogen and phosphorus transfer in the calculations. Also, the coefficients of heavily fertilized plots were higher than 1.0.

Keywords: soil loss, eutrophic components, USLE, predicting equation
Degradation of soil and water resources, which is increasing throughout the World, is affecting directly and indirectly all the vital processes on the Earth's surface. This is partially due to non-appropriate land use planning, where soil and water conservation must be the most important components. Global climate changes may contribute to accelerate some soil and water degradation processes and their effects in some regions of the world. For an adequate planning of soil and water conservation, a better understanding and prediction of the interactions between climate characteristics and soil properties is required. Under different scenarios of changing climate and changing land use and management practices and systems which are often tied to social economic and political issues. The planning framework for effective soil and water conservation must be considered and awareness of the increased complexity of environmental processes and problems derived of soil and water degradation, from local to regional and to global dimensions must be developed. These interactions must be integrated over time using simulation modelling. The generated information may be used in planning strategies for land use, and in the selection of soil and water conservation practices, based on probabilities of success, levels of risk, and long term sustainability. Natural disasters like flooding and landslides, linked to extraordinary climatic events need to be considered in modelling soil and water conservation, in order to identify appropriate interventions which could eliminate or reduce the impact of specific kinds of disasters. Models must be based on well established cause-effect relationships for prediction, and be flexible enough to be able to include the variety of possible soil-climate-cropping-socio-economic situation, and to be constantly improved as knowledge increases. Empirical regression-based models combining climate, topography, soils and management as components have been the ones more used in erosion prediction. They are frequently misused, derived from the site specificity of the values assigned to it's factors, and extrapolations beyond the validity limits of its original data base. The consequences have been in many cases arbitrary prescriptions of ineffective soil and water conservation practices frequently leading to failure and even disastrous consequences. Process-based prediction models, based on equations that represent fundamental hydrological and erosion processes may solve the limitations of the empirical soil loss prediction models, like site specificity, limited transferability and others. Many of the so called process-based models developed up to date still keep critical empirical components like the ones related to the soil hydrological processes, to the use of pedotransfer functions, etc., and/or require input information seldom available or difficult to get in many cases, which limit their practical use. These are presented examples of those limitations and of the potential application of simplified hydrological approaches for evaluating the causes and effects of soil and water degradation as a basis for planning soil and water conservation practices.

**Keywords:** modelling, hydrology, degradation, conservation, empirical, process-based
Mapping of waterlogged and saline areas of Tibbi and Rawatsar Tehsils and it's remedial approaches

RATHORE Santosh

Soil Science Indo-Dutch Project Agricultural Research Sub Station [R.A.U. Bikaner], Hanumangarh, Rajasthan 335513, India

Tibbi and Rawatsar tehsils are situated in the southeast of Hanumangarh District, which lies in desert lb zone of northwest Rajasthan. Here, the main source of irrigation is the Indira Gandhi Main Canal, its main branches and tributaries. Rawatsar is a severely waterlogged area locally called Gaddhasar due to the topography, especially at Jeevan Nagar and Khedasari. A few locations are also suffering with waterlogging and salinity problems. Most severely affected areas are Seelwala, Masitanwali Luna Ki Dhani, Meharwala and Dabli. At Tibbi and Rawatsar detailed bench-mark surveying has been done with the help of Remote Sensing Technology.

These tehsils consist of aeoline, flood plain and desert plain soils with widespread sandy, barren or well cultivated fields, sand dunes of varying heights and well levelled plains for cultivation. Here, waterlogging and salinity are directly related with low uneven topography, seepage from the water bodies and light salt texture. Aeoline soils were formed by the deposition of fine loamy sand by wind and water erosion in the past. These soils are deep with sand to loamy fine sandy soil texture. These are calcareous draughty, rapid sub soil permeability, high infiltration rates, porosity, and a poor drainage system due to an underground impervious layer at shallow depths. Gypisiferous material is often found in amorphous or crystalline forms. Here the salinity problem is more dominant than the alkalinity problem. The rising water table and evaporation of water from the water table and profile characteristics have been interpolated and projected in Table 2&3 with the help of visual characteristics vis-à-vis image characteristics. These interpolated characters have been utilized for the preparation of a flow route map of waterlogged and saline areas. Final mapping of waterlogged and saline areas of Tibbi and Rawatsar has been completed to give a real picture of the sites with the help of GIS Technology using ARC/INFO(GLS-S/W) software.

Keywords: Indira Gandhi Main Nahar, geographical information system, waterlogging, salinity
Evaluation of water erosion risk and recommendation for sustainable land use in Northeastern Syria

SHINJO Hitoshi (1), HIRATA Masahiro (2), KOGA Naoki (3) and KOSAKI Takashi (1)

(1) Graduate School of Agriculture, Kyoto University, Kyoto 606-8502, Japan
(2) The Center for Southeast Asian Studies, Kyoto University, Kyoto 606-8501, Japan
(3) Graduate School of Agriculture, Kyushu University, Fukuoka 812-8581, Japan

The semiarid Mediterranean region is characterized by severe water erosion due to its climatic regime and the generally sparse vegetation cover. To meet food demand of increasing population, the countries of the Middle East have been subjected to socioeconomic changes that might enhance water erosion, such as the sedentarisation of previous nomadic peoples and the encroachment of cropland onto the traditional grazing areas. In northeastern Syria, afforestation and protection programs have been undertaken since the late 1970s to rehabilitate vegetation and yet their impact on water erosion remains to be clarified.

Under these circumstances, we are strongly urged to develop sustainable land management that can satisfy the growing demand of food and feed and, at the same time, alleviate water erosion. Thus, our objective was to evaluate the water erosion risk geographically and allocate several types of land use accordingly. For this purpose, we firstly evaluated the impact of grazing and cropping on water erosion through field experiment in three sites and clarified the relationship between soil loss and the factors relevant to water erosion. Then, we estimated these factors geographically using DEM and Landsat TM images and integrated for the assessment of the erosion risk in an area of 27 by 33 km. We discussed the recommendation for the sustainable land use with this risk map after considering the location of settlements and the current land use.

Based on the field experiment monitoring the magnitude of soil loss together with some soil properties and seasonal changes of vegetation coverage during the two rainy seasons, we found that the rangeland had a negligible amount of soil loss due to the high vegetation coverage throughout the experimental period, while the cropland experienced an accelerated soil loss through the disturbance of soil by tillage and the removal of shrub species. Among the sites in the rangeland, the amount of soil loss was comparable irrespective of the slope gradients due to the higher grade of aggregate stability in the steeper slope. This positive correlation between the aggregate stability and the slope gradient, implied that unstable aggregates on steeper slopes had already been translocated while stable aggregates remained, and was confirmed by the multivariate analysis of the measurements in 55 sites of the rangeland.

The erosion risk map indicated that 72% of the rangeland was classified as the low risk area. Overlaying the risk map with the land use map, we suggested that afforestation and protection programs were effective measures for alleviating water erosion in the afforested and protected rangeland and, at the same time, may accelerate water erosion in the grazed rangeland through the increase of grazing pressure. Thus, in conclusion, the low risk area in the afforested and protected rangeland was recommended to be grazed. Further encroachment of cropland should be avoided since the cropland has already extended to most of the gentle sloping area.

Keywords: afforestation, GIS, land evaluation, semiarid area, Syria, water erosion
Rainfall simulation experiments to develop an environmental soil P test

SISAK Istvan (1), STRAUSS Peter (2), AZAZOGLU Erol (3) and SZ CS Pter (1)

(1) University of Veszprem, Georgikon Faculty of Agriculture, Deak F. St.16, H-8360 Keszthely, Hungary
(2) Institut für Kulturtechnik und Bodenwasserhaushalt, Bundesamt für Wasserwirtschaft, Pollnbergstr. 1, A-3252 Petzenkirchen, Austria
(3) Institut für Bodenforschung, Universität für Bodenkultur, Gregor-Mendelstrasse 33, A-1180 Wien, Austria

The consortium of DESPRAL project is going to develop an easy applicable soil test in order to identify “hot spots” with high P loading potential within watersheds. The Austrian and Hungarian participants of the consortium carried out a set of rainfall simulation experiments in Hungary near Lake Balaton in the watershed of River Zala on a Haplic Luvisol (sandy loam, slope 7.5%) prepared to seedbed conditions five days before the experiment started. Simulated rainfall was applied (uniform intensity of 60 mm h\(^{-1}\)) on four plots (2\(\times\)5 m). After week one, two, three of the first rainfall application the simulations were repeated. Runoff (R) and total soil erosion (E) were measured and suspended sediment content in runoff (SR) calculated. Sub-samples were taken from the runoff samples and investigated further: they were shaken in the lab and let settling for 1000 and 10,000 seconds. Subsequently suspended sediment content of the surface layer (SS) was measured.

Tillage of soil decreases surface soil density consequently increases erosion on the one hand side and increases infiltration and decreases runoff and erosion on the other hand which result considerable variability in erosion from freshly tilled soils. The steady state runoff rate has been 0.52 mm min\(^{-1}\) and erosion rate has been 12.1 g m\(^{-2}\) min\(^{-1}\) on the average in the fourth simulation with variability of 1% and 12%, respectively. SR concentration in runoff from consolidated soil may decrease because relatively resistant aggregates protect the remainder soil from raindrops. This phenomenon might partly explain the lower suspended sediment content at receding hydrograph. The SS content of sub-samples after 1000 and 10,000 seconds deposition time did not depend on the SR content although the range of SR concentrations was from almost zero to 26000 mg.L\(^{-1}\) in runoff. In contrast SS after 1000 seconds was a function of sampling time while this effect was not more significant for a settling time of 10,000 seconds.

The results point out that soils might show rather constant hydrologic properties in “settled condition” and rainfall is able to disperse only a certain amount of eroded soil under the experimental conditions. Therefore it should be possible to find a test to characterise soil and particulate nutrient load from agricultural areas. The topic will be investigated further.

Keywords: erosion, phosphorus, rainfall simulation, plot study
Knowledge-based system for soil conservation and land resources management in agriculture

TA-OUN Mongkon (1), PRUANGKA Suttipong (2) and DAUD Mohamed (3)

(1) Department of Land Resources and Environment, Faculty of Agriculture, Khon Kaen University, Thailand
(2) Department of Fisheries, Faculty of Agriculture, Khon Kaen University, Thailand
(3) Faculty of Engineering, Universiti Putra, Malaysia

Soil plays an important role to human beings, as many activities will involve the use of land which includes cultivation, property development, grazing, plantation and others. Presently, information technology (IT) has been being increasingly developed and widely applied in agricultural developments. This technical paper aims at applying knowledge-based systems to guide users in preparing ways of conserving land resources under agricultural activities. The system prototype is being developed with wxCLIPS version 1.62, an object oriented expert system development shell, distributed by NASA. The domain knowledge base which was derived from expert opinions, field studies, and established literature is used for categorizing creating expert system rules in the form of IF (premise)....THEN (action). The system knowledge base is stored in the form of production rules that can be updated and/or revised at any time. Besides providing better information, this method equips farmers and agricultural technologists for better land management practices. This system also has significant potential for use in environmental training and education, particularly in circumstances where there is a shortage of expertise, as in the field of soil conservation and land resources management.

Keywords: knowledge-based system, soil conservation, land resources management
The potential of soil radioactive nuclides utilized as tracers in study of soil erosion process

TIAN Junliang, YANG Mingyi, LIU Puling and LI Yaqi

Institute of Soil and Water Conservation, Chinese Academy of Science and Ministry of Water Resources Northwestern Sci-Tech University of Agriculture and Forestry Yangling, Shaanxi 712100, China

The radioactive nuclides exited in soils may have a different origin. Most of them came from the decay of natural radioactive nuclear series such as U and Th series. Some of them i.e. $^{137}$Cs, $^{90}$Sr, from the fallout caused by a nuclear test mainly happened in the middle of the last century. There is another kind of "fallout", the radioactive nuclides, i.e. $^{7}$Be, are naturally produced in the upper atmosphere by a nuclear reaction dealing with cosmic ray, and then fell into soil with precipitation. Those nuclides have caught the attention of soil scientists in the fields of soil environment, soil geochemistry as well as soil erosion.

As important basic information, the distributions of the nuclides in soil profile are analyzed and discussed in this paper. $^{137}$Cs, known as tracer in the study of soil erosion in the past more than two decades, mainly distributed in the top 30 cm soil in the profile. However, $^{7}$Be was found mainly in 10 cm top soil. The different distribution patterns among the nuclides in soil profiles make them possible to be used to study the development of the soil erosion process. The primary results in our study of soil erosion by using a few soil radioactive nuclides as tracers are presented. For an example, $^{137}$Cs was used in a study of soil erosion spatial variation in a small watershed located in the loess plateau in China. The result provides an important base to optimize the planning of soil and water conservation. The $^{7}$Be has been successfully employed in a recent study of soil erosion process in slope land. The result shows that $^{7}$Be is an ideal tracer to distinguish the erosion amounts caused from sheet erosion and rill erosion during a rain storm. The erosion process described by the $^{7}$Be tracing method has a good agreement with the situation observed on site. The methodology of the tracing experiment, including the sampling, nuclide analyses and the calculation model are exhibited in the paper. And the potential of the nuclides used as tracers in soil erosion studies is also discussed. It is believed that the tracer method has a potential in a new way to make soil erosion study more quantitative with some special advantages compared to the traditional methods used in soil erosion study.

Keywords: radioactive nuclides, tracer, soil erosion
Effect of grass filter strips management on reduction of soil loss from upland field

UENO Takashi (1), MIHARA Machito (2), SANG-ARUN Janya (3) and DOKIYA Yukiko (1)

(1) Tokyo University of Agriculture and Technology, 3-5-8 Saiwai-cho Fuchu-shi Tokyo, Japan
(2) Tokyo University of Agriculture, 1-1-1 Sakuragaoka Setagaya-ku Tokyo 156-8502, Japan
(3) Mae Fah Luang University, 333 Moo. 1. Tasud sub-district, Muang district, Chiang Rai 57100 Thailand

This study dealt with the reduction of soil loss from variously managed grass filter strips. Slope plots under a rainfall simulator were employed in this study. In order to investigate the effect of grass filter strips on the reduction of soil loss, the amount of soil supplied was compared with soil loss in each plot. The reduction of soil loss from cut weeds was similar to that from naturally grown weeds. Therefore, it was considered that cutting weeds for pest control can be applied to the grass filter strip for reducing soil loss.

In the case of Tall Fescue plots under various stem density, there was no remarkable difference in reduction of soil loss between 800 stems m$^{-2}$ and 1,480 stems m$^{-2}$. However, the density of 2,330 stems m$^{-2}$ was effective for reducing soil loss compared with the density of 800 stems m$^{-2}$ and 1,480 stems m$^{-2}$. It follows that stem density for grass filter strips should be maintained around 2,330 stems m$^{-2}$ to reduce soil loss from upland fields.

Keywords: grass filter strips, soil loss, surface runoff, uplands
Surface roughness evolution of a Ferralsol

VIDAL VAZQUEZ E. (1), De MARIA I.C. (2) and PAZ GONZALEZ A. (1)

(1) Facultad de Ciencias, University of A Coruna. A Zapateira, 15071, A Coruna, Spain
(2) Instituto Agronomico, Centro de Solos e Recursos Agroambientais. Av. Barao de Itapura, 1481, Caixa Postal 28, 13001-970 Campinas (SP), Brazil

Surface roughness, the general term for variation in the surface elevation across a field has a great importance, as it may affect overland flow and soil losses. Soil surface roughness also may change considerably with rain. The predominant roughness measure in soil conservation and management studies is the random roughness (RR), defined as the standard error among heights after effects of oriented roughness such as tillage marks and land slope have been removed. In addition, surface configuration parameters based on geostatistics, i.e. the so-called limiting difference (LD) and limiting slope (LS) have also been currently used. A study was conducted during October and November 2000 in Campinas (Sao Paulo, Brazil) on a Rhodic Ferralsol, according to the FAO classification system. Forty-eight microrelief data sets were obtained on bare plots. Each data set consisted of 3025 point elevations on a 2.5 cm grid. Data were available for six different tillage practices as shown in Table 1. Measurements were performed on four different dates, the first one just after tillage and before rain and subsequently with increasing quantities of natural rain. On each study date two replicated plots were selected for each tillage practice.

Over the studied period, the largest variability in RR and LD existed for moldboard plowing system and the smallest for chisel plowing and harrow + diskling (Table 1).

Table 1 Tillage treatments and roughness indices range. (RR and LD in mm).

<table>
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<tr>
<th>Tillage practice</th>
<th>Moldboard plowed</th>
<th>Harrowed</th>
<th>Chisel plowed</th>
<th>Moldboard plowed + disked</th>
<th>Harrowed + disked</th>
<th>Chisel plowed + disked</th>
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<tr>
<td>RR range</td>
<td>14.2-23.4</td>
<td>9.0-17.6</td>
<td>8.4-11.8</td>
<td>7.3-15.6</td>
<td>6.6-12.4</td>
<td>3.7-14.5</td>
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<tr>
<td>LD range</td>
<td>15.1-25.9</td>
<td>9.7-20.6</td>
<td>8.9-12.8</td>
<td>7.3-16.0</td>
<td>7.7-13.8</td>
<td>3.6-15.2</td>
</tr>
<tr>
<td>LS range</td>
<td>0.034-0.17</td>
<td>0.031-0.14</td>
<td>0.032-0.21</td>
<td>0.022-0.30</td>
<td>0.027-0.15</td>
<td>0.023-0.12</td>
</tr>
</tbody>
</table>

RR and LD values decreased with increasing rainfall, so depending on tillage practices, the soil roughness was degraded between 80% and 50% of the initial value after rain amounts of about 250-300 mm. The rate of microrelief evolution is very significant, notwithstanding that the studied Rhodic Ferralsol is considered to exhibit a good soil structural quality and to be one of the less erodible soil types of the region. Chisel plowing was the system showing the smallest roughness degradation. The decay of roughness indices RR and LD could be described as a function of the cumulative amount of rainfall.

Keywords: surface roughness, microrelief, pinmeter, Ferralsol
Application of surface flow collecting drainage for soil and water environment conservation

MIHARA Machito (1), YAMAMOTO Naoyuki (1) and SANG-ARUN Janya (2)

(1) Tokyo University of Agriculture, Faculty of Regional Environment Science 1-1-1 Sakuragaoka Setagaya-ku, Tokyo 156-8502, Japan
(2) Mae Fah Luang University, School of Agricultural Technology 333 Moo.1, Tasud sub-district, Muang district, Chiang Rai 57100, Thailand

In upland fields of sloping area, severe rainfall causes soil and eutrophic components losses. A large number of investigations have been made on soil and water environment conservation measures. What seems to be lacking, however, is the evaluation of combined measures for soil and water environment conservation. Surface flow collecting drainage is one of effective measures for reducing surface runoff from upland fields. So, this study dealt with application of conservation measures using surface flow collecting drainage in upland fields for soil and water environment conservation.

Slope plots with a rainfall simulator were employed for erosion experiments. Three plots were set up as bared plot (plot I), no vegetation and buffer strip in slope toe (plot II), no vegetation and surface flow collecting drainage installed at upper point of buffer strip in slope toe (plot III). Simulated rainfall was supplied for 120 minutes under the intensity from 55 to 61 mm h$^{-1}$. During the experiments with a simulated rainfall, the discharge of surface runoff and percolating water, soil loss and water quality in plots I to III and surface flow collecting drainage in plot III were measured.

Total nitrogen and phosphorus concentration in suspension of surface runoff and surface flow collecting drainage were much higher than in supernatant. It was considered that soil particles in surface runoff and surface flow collecting drainage transported nitrogen and phosphorus components.

The loads of soil loss, total nitrogen and phosphorus in plot I were higher than in plots II and III. In case of plot III, cumulative discharge of surface flow collecting drainage was 73% of total discharge, also the loads of soil loss, total nitrogen phosphorus in surface flow collecting drainage were 91%, 88% and 88% of total loads, respectively. Thus, the loads of soil loss, total nitrogen and total phosphorus in surface runoff of plot III were 6%, 8% and 10% of plot I, and 14%, 17% and 19% of plot II, respectively. It was concluded the combined measures of surface flow collecting drainage and buffer strip are effective for separating soil and eutrophic components from surface runoff.

In further study, management system for soil and water environment conservation will be carried out.

Keywords: surface flow collecting drainage, buffer strip, soil loss, eutrophic components
Soil water erosion identification using remotely sensed data and DEM data

ZHANG Tiefu
Remote Sensing Center, Heilongjiang Academy of Agriculture Sciences Heilongjiang, P.R. China

Based on an on-going project covering an intensive farming area in Heilongjiang province in Northeast China, this paper presents a way of water erosion identification by using LandsatTM data and DEM data. The LandsatTM data were used for analysing vegetation density and human activities. The DEM data is mainly used for obtaining topographic information such as slopes. Combined with other available data such as soil and rainfall, the working area is classified into different groups in terms of water erosion intensities.

Keywords: erosion, intensive farming, remote sensing
Amelioration of degraded soils through afforestation

Convenor: HUETTL Reinhard F.
Co-Convenor: THAIUTSA Bunvong

Oral Session
Friday 16 August 2002
14:00-17:20
Room: Meeting Room 1

Poster Session
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Assessing soil factors affecting seedlings growth in rehabilitation of logged-over lowland forest

MOKHTARUDDIN A.M. (1), BAHAROM Maswar (2), MAJID N.M. (1), KAMIL YUSOF M.M. (1), FARIDAH HANUM I. (1), AZANI A.M. (1) and KOBAYASHI S. (3)

(1) Universiti Putra Malaysia, 43400 UPM SERDANG, Selangor, Malaysia
(2) Center for Soil and Agroclimatic Research, Jln. Ir. H. Juanda No. 98, Bogor, Indonesia
(3) Center of International Forest Research, Bogor, Indonesia

Forest harvesting has been known to have a drastic impact on soil physical properties. For example, it has been reported that the bulk density increased by 32% on the skid trail and 42% on the logging roads compared to that of undisturbed forest (Baharuddin, 1995). On the other hand, plants growth is generally influenced by soil and climatic factors. The important soil properties affecting growth of plants are texture, bulk density, compaction, moisture availability, penetration, thickness of A-horizon, saturated hydraulic conductivity organic matter and nutrients contents (Kramer and Kozlowski, 1979). While the effect of soil physical properties on crops is wider studied, their effects on forest seedlings establishment and growth is lacking. Furthermore it is possible that tree growth is not determined by a single soil factor but the interaction of several factors because changes in one factor may bring changes in other factors. Soil compaction for example increases bulk density or strength of the soil, commonly referred to as its mechanical impedance, and reduces its conductivity, permeability and diffusivity to water and air (Greenland, 1977). In addition, compaction reduces the infiltration rate and consequently encourages soil and nutrient losses. Thus it is necessary to identify factors that are more dominant so that corrective measures can be taken during rehabilitation in order to ensure a more efficient establishment of seedlings and to minimize the risk of planting failure. This in turn reduces the cost of rehabilitation.

An experiment was carried to evaluate the effect of soil properties on growth of young seedlings of tree species under enrichment planting at the over-logged tropical lowland forest ecosystem. The tree species used were Hopea odorata and Azadirachta excelsa. Planting techniques adopted were line and gap plantings (10x10 m and 20x20 m). Thirteen months after planting, seedlings were classified into "good" and "poor" growth and the height increment during that period was recorded. Topsoil samples were collected from vicinity of each tree for physico-chemical properties determination. Statistical analysis of the results was carried out to determine how soil properties significantly contribute to the difference in the growth of the seedlings.

Results showed that soil properties which significantly affect the seedling’s growth are organic matter content, penetration resistance, soil texture, thickness of A-horizon, Ca and Mg contents. Organic matter, thickness of A-horizon, Ca and Mg contents were found to be significantly higher in soils which supports "good" growth rather than "poor" ones, but penetration resistance is reversed. Surface soils under "good" growth has lower clay content and higher sand content compared to that under "poor" growth. It was found that the favorable soil conditions for good growth was also manifested in biomass and litter accumulation. This means dry biomass in the "good" and "poor" growth were 174 and 72 g m\(^{-2}\) respectively, and for dry litters, were 300 and 154 g m\(^{-2}\) respectively.

Stepwise multiple linear regression analysis between the growth parameters and soil properties revealed that properties most limiting to the growth performance of seedlings in the study area are the depth of A-horizon, bulk density (mechanical resistance) and the amount of clay in the surface soil. Amelioration on these factors is therefore an important consideration in ensuring the success of rehabilitation and reforestation of over-logged degraded forest.

Keywords: assessment, soil, growth, rehabilitation, logged-over, forest
Impacts of nitrogen fertilization on soil nitrogen and biological properties in a hoop pine plantation

CHEN Chengrong (1,2) and XU Zihong (1,3)

(1) Co-operative Research Centre for Sustainable Production Forestry, Griffith University, Nathan, Queensland 4111, Australia
(2) Faculty of Environmental Sciences, Griffith University, Nathan, Queensland 4111, Australia
(3) Queensland Forestry Research Institute, PO Box 631, Indooroopilly, Queensland 4068, Australia

A field experiment was conducted to investigate the impacts of nitrogen (N) fertilization soil N dynamics and associated biological properties in an 8-year-old hoop pine (Araucaria cunninghamii) plantation at the Imbil, Southeast Queensland, Australia. The treatments included: (1) control (without N application), (2) 300 kg N ha\(^{-1}\) and (3) 600 kg N ha\(^{-1}\). The experiment employed a randomised complete block design with 4 replications. Nitrogen fertilizer (ammonium nitrate) was broadcast through gross plots to simulate the aerial application. Soil samples were taken about 5 years after the N application. The results showed that application of 600 kg N ha\(^{-1}\) significantly increased concentrations of ammonium-N ((NH\(_{4}\))N) in 0-10 cm soil compared with the control and application of 300 kg N ha\(^{-1}\). Concentrations of nitrate-N (NO\(_{3}\))N) in soil (both 0-10 cm and 10-20 cm) with an application rate of 600 kg N ha\(^{-1}\) were significantly higher compared with the control. Concentrations of soil total mineral N (NH\(_{4}\)N + NO\(_{3}\))N) increased significantly with the N application rate. However, N application did not significantly affect the concentrations of soil organic C, total N and potential mineralizable N. In addition, N application did not significantly influence soil microbial biomass C and N, microbial C:N ratio, respiration and metabolic quotient (qCO\(_{2}\)), which might be associated with greater spatial variations in the experimental site.

Keywords: Araucaria cunninghamii, nitrogen fertilization, potential mineralizable N, microbial biomass C, microbial biomass N, respiration
Trace metals in the forest floor, litterfall patterns and topography

MANNA Sylvie (1), COURCHESNE François (1), ROY André (1), TURMEL Marie-Claude (1) and CÔTÉ, Benoît (2)

(1) Département de géographie, Université de Montréal, C.P. 6128, succursale Centre-Ville, Montréal (Québec), H3C 3 J7, Canada
(2) Department of Natural Resource Sciences, Macdonald Campus, McGill University, 21 111 Lakeshore road, Ste.-Anne de Bellevue, Québec, H9X 3V9, Canada

Soils materials were collected at every 10 m along four 200 m long transects in a 5.1 ha headwater catchment (Hermine, Canada) in order to test for the existence 1) of meter-scale spatial patterns in the distribution of trace metals (Cd, Cu, Ni, Pb and Zn) in the organic horizons and 2) of spatial relationships between metals and environmental factors such as litter composition and topographic attributes. The forest vegetation is dominated by sugar and red maples (Acer saccharum, Acer rubrum), American beech (Fagus grandifolia) and yellow birch (Betula alleghaniensis) and the soils are classified Podzols. The soil horizons L, F and H were collected separately in each of 63 evenly spaced (10 m apart) 0.1 m² plots. In the L horizon, the freshly fallen leaves from the fall season of 2000 were sorted by tree species, air-dried and weighed. Leaves were also collected from each tree species and analysed for total trace metals. The amounts of H₂O-soluble and acid (HCl-HNO₃)-extractable metals (Cd, Cu, Ni, Pb, Zn) were measured in F horizon samples by ICP-AES, or ICP-MS. The results indicate that the median thickness of F and H horizons is significantly higher (α = 0.01) in pits (median = 10.3 cm) as compared to mounds or flat surfaces (median = 5.0 cm). The statistical analyses further show, on the one hand, that the patterns of H₂O-soluble Cd, Cu, Ni and Zn in the F horizons are spatially correlated (r = 0.42 to 0.83). Moreover, the H₂O-soluble and acid-extractable metal patterns are, in general, well correlated for Cd and Zn (r = 0.44 to 0.91). On the other hand, the abundance of leaves from different species in the fresh litter also showed some level of organization with yellow birch, trembling aspen and large-toothed aspen leaves dominating on the north facing slope whereas leaves from American beeches were concentrated on the south slope; sugar and red maple leaves, although ubiquitous, presented an inverse spatial pattern (r = -0.52). Finally, patterns for H₂O-soluble and acid-extractable Cd and Zn in the F horizons are significantly correlated to the abundance of yellow birch leaves in the fresh litter horizon (r = 0.46 to 0.60). Chemical analyses of leaves from the canopy of each tree species reveal that yellow birch leaves are richer, by up to an order of magnitude, in Cd, Pb and Zn than leaves from other species. These results stress the critical role of elemental biocycling by trees on the spatial redistribution of metals at the surface of forest soils, notably in areas not severely contaminated by exogenous inputs of trace metals.

Keywords: forest soils, trace metals, spatial patterns, biocycling, litterfall, topography
Managing soil fertility in eucalypt plantations in China

XU Daping (1) and DELL Bernie (2)

(1) Research Institute of Tropical Forestry, Guangzhou, P.R. China
(2) Murdoch University, Perth, Australia

More than 1.5 M ha of eucalypt plantations have been established in Southern China, increasing by about 100,000 ha y⁻¹. Productivity is uneven and low, only about 25-50% of the world average for eucalypt plantations. Most land available for eucalypts are degraded Oxisols and Ultisols which also are acidic, highly leached and deeply weathered. Phosphorus deficiency is very severe and its availability is reduced because of limited compatible ectomycorrhizal fungi. Nitrogen supply is limited because of low organic matter content in the topsoil. This paper reviews a decade of field trials in the region concerning the use of fertilisers, harvest residue management and inoculation with ectomycorrhizal fungi. One of the key questions addressed is whether the productivity of plantation eucalypts in Southern China can be increased to the world average by nutrient management across a rotation. Some of the key findings are: Application of superphosphate at establishment substantially increased growth, tree survival and nutrient uptake. Coppice response to P was lower than the response to P in the first rotation. Inoculation with ectomycorrhizal fungi affected stand volume. Field effects were isolate-dependent, and poorly related to performance of isolates in the greenhouse. Reduction in the amount of residue removed during harvest increased tree growth by increasing available nutrient supply and reducing the loss of soil organic C. Intercropping with N-fixing trees enhanced tree growth. More than 80% of nutrient accumulation by trees was lost via harvesting practices. It is concluded that productivity of plantation eucalypts can be improved to 10-20 m³ ha⁻¹ y⁻¹, the average productivity in the world, by nutrient management. Harvest residue retention and coppice regeneration are recommended as operational practices in the second rotation. Research indicates that the productivity of well-managed plantations can be sustained whereas poor management practices result in dramatic yield declines across rotations.

Keywords: afforestation, sustainable forestry, nutrient management, mycorrhizal fungi
Effects of local soil chemical and hydraulic nonequilibria on element budgets of disturbed sites

GERKE Horst H. (2), SCHAAF Wolfgang (1) and HUETTL Reinhard F. (1)

(1) Department of Soil Protection and Recultivation, Brandenburg University of Technology, P. O. Box 101344, D-03013 Cottbus, Germany
(2) Department of Soil Landscape Research, Centre for Agricultural Landscape and Land Use Research (ZALF), Eberswalder Strasse 84, D-15374 Müncheberg, Germany

Open-cast lignite mining is causing large-scale and long-term disturbance, resulting in a destruction of existing ecosystems and the creation of landscapes formed by overburden spoil piles. Overburden sediments can largely differ from parent geological material of previously existing and undisturbed sites. It is expected that new soils and ecosystems will develop from overburden sediments with element budgets differing with respect to rates and directions of development from the undisturbed situation. Amelioration measures further alter the conditions. Typical of such mine soils is a small-distance spatial heterogeneity as a result of mixing of chemically and physically different sediments. Initially, highly different components, such as pyrite / alkaline ash, sand / clay / coal fragments, lignite / soil organic matter, or saline / nonsaline zones, can exist directly next to each other. For such small-distance spatial variability, predictions of long-term development of soils and sites are challenging. Despite disturbed soils show hardly any diagnostic horizons, soil profiles are characterized by distinct depth gradients of soil chemical conditions. Precipitation of secondary minerals, water repellency features of the lignite components, and preferential flow paths may depend on the small-distance spatial heterogeneity. Irregular flow patterns could be observed by dye-tracer studies. Element budgets of disturbed sites are characterized by extremely high soil solution concentrations of most elements. Although solute concentrations decrease with site age, they were still several orders of magnitude higher compared to undisturbed sites even 50 years after disturbance. Chemical conditions change more rapidly along preferential flow paths than in other soil regions, by enhanced dissolution and transport, thereby affecting plant root growth and soil development. Better understanding of the effects of local non-equilibrium conditions in geochemical and physical properties will help to improve the long-term prediction of the development of disturbed sites.

Keywords: disturbed sites, mine soils, element budgets, spatial variability, local nonequilibrium
Production of biomass in an alley cropping system

HÜTTL Reinhard F., GRÜNEWALD Holger and SCHNEIDER B. Uwe

Brandenburg University of Technology, Chair of Soil Protection and Recultivation, P.O. Box 10 13 44, D-03013 Cottbus, Germany

In the industrialised countries the demand for production and use of woody biomass for energy transformation purposes has significantly grown throughout the last decade (Hüttl et al. 2000). Especially in rural areas the production of solid biofuels may provide a stable source for a decentralised generation of heat and electric power (Bens and Hüttl, 2001). To reach this aim, it is claimed that the total area dedicated to bioenergy production has to be extended and that alternative land use systems are needed which are supposed to integrate social, economic and ecological requirements of the local population. In this context the expansion of fuelwood production at the landscape level may positively benefit the recovery and development of infrastructure in remote areas, the protection of natural resources, the increase of biodiversity, the maintenance of cultural landscapes, job creation and the regional real net product as costs for the external recruitment of energy are minimised.

Even in the industrialised countries there is still a large areal potential existing in remote areas which may serve for the production of woody biomass, e.g. agricultural set-aside areas, low productivity sites and reclaimed mine sites of post-mining landscapes (Bungart et al., 2000). The large scale production of biomass, however, has to integrate various other landscape functions, such as biodiversity, crop production, and groundwater formation and quality etc. A frequent alternation between forest and short rotation plantations and other traditional land use forms is supposed to comply with those requirements. More recently agroforestry systems have come into focus in the temperate zone since they integrate crop and bioenergy production already on a very small scale and benefit biodiversity, natural resource protection and groundwater formation at the same time and at very low management costs (Grünewald et al., 2001).

To test the suitability of agroforestry systems under central European conditions an alley-cropping system was established on quaternary mine spoils. Four different tree species and clones, respectively, were planted (Black Locust, Willow, and two poplar clones Androscoggin and Hybride 275) in a randomised block design. Three and six years after planting, pruning was carried out for each tree species on a selected number of plots. Different crops were tested on the intercroppings. The productivity and nutrient status of treatments were monitored on an annual basis. The root distribution at the hedgerow/intercropping interface was investigated to look for effects of either competition or synergism between root systems of crops and trees and possible impacts on the productivity of both. In addition, the soil chemical status and the formation of soil organic matter were studied periodically to investigate the influence of different (N-fixing) tree species and crops on the development of soil ecological functions in the initial state of soil formation.

Keywords: alley cropping, temperate zone, root competition, bioenergy production
Secondary development stages of soils formed on inland dunes under pine woodlands

JANKOWSKI Michal and BEDNAREK Renata

Department of Soil Science, Institute of Ecology and Environmental Protection, Nicholas Copernicus University, str. Sienkiewicza 30, 87-100 Torun, Poland

This paper presents results of studies carried out in the dune area of the Toruń Basin, Northern Poland. Combined chronosequence of soils representing early developmental stages of podzolization was investigated. The soils under study developed under particular stages of the plant succession: from the initial grassland community to man-planted pine forests of the various age ranges. Ploughing of the soils repeated before planting of each new pine generation makes the destruction and slow regeneration of these soils the cyclic process. As the evolution of soil proceeds, the solum increases in thickness and individual genetic horizons appear (A, O in initial soils and E and B in older soils). In the surface mineral horizons we observed an increase in organic carbon (from 0.2 to 2.0%) and total nitrogen (0.02 to 0.09%) contents, widening of the ratio C/N (12 to 24) and an increase in acidity (pH decrease 5.5 to 3.9). There were also accumulation and later vertical translocation of pedogenic forms of iron and aluminium. The direction of the soil material transformation makes podzolization the active typological process in the soils under study. It is determined by the specific parent rock and plant succession. The results of the studies make it possible to distinguish three developmental stages of soils, associated with respective stages of plant succession: initial (represented by aeolian Regosols), intermediate (Arenosols) and mature (Podzols at the early stage of podzolization). In the last of the examined profiles the Podzol eroded after deforestation. Deeper parts of the profile (B horizon) thus exposed became a parent material for a new generation of soils.

Keywords: soil genesis, development stages, dune soils, podzolization
Regeneration of a degraded Acrisol with multipurpose agroforestry trees in the forest zone of Ghana

KAHO Francois (1), YMEFACK Martin (1) and QUASHIE–SAM Simon James (2)

(1) Institute of Agricultural Research for Development (IRAD), PO Box 2067 Yaounde, Cameroon
(2) Department of Agroforestry, Institute of Renewable Natural Resource (IRNR), University of Science and Technology (UST), Kumasi, Ghana

A degraded Acrisol at Kumasi, Ghana was divided into three plots in 1988. The first plot was planted with *Leucaena leucocephala*, the second with *Senna siamea* while the third was left to natural revegetation. The main objective of the study was to compare the fertility regeneration of the improved fallow agroforestry systems with the naturally revegetated fallow. Nine years later (in April 1997) the trees were cut back and the natural fallow vegetation cleared. Maize (*Zea mays* L. var obatampa) was planted as a test crop in the three plots in the major rainy seasons of 1997 and 1998 at three rates of NPK fertiliser. The fertiliser treatments were allocated in each plot (woodlots and natural fallow) in a randomised complete block design with three replicates. Soil samples were collected in 1988 (at fallow establishment), 1997 (before land clearing), 1998 (after crop harvest) at a depth of (0-15 cm) and analysed for organic C, total N, pH, exchangeable Ca, K, Na, total acidity and available P.

Results of soil analysis indicated that, in *Leucaena* plots, organic C and ECEC increased by 90% and 86% respectively compared to 1988 values. In Senna plots, soil organic C and ECEC increased by 96% and 99% respectively. In natural fallow, the increase was 61% for org C and 110% for ECEC. Two seasons after cropping, soil organic C, exchangeable Mg, K, Na and available P were significantly different (*p* = 0.0082, *p* = 0.0438, *p* = 0.0494 *p* = 0.0494 and *p* = 0.0006 respectively) among fertiliser treatments after crop harvest in *Leucaena* plots; while in *Senna* plots, a significant difference was observed only for total N (*p* = 0.037). In natural fallow no significant difference was observed among fertiliser treatments for all the soil properties tested.

During the two years of cropping, maize grain yield increased significantly (*p* <0.05) in the three fallow systems with the application of inorganic fertilisers. However, in the second year of cropping, maize grain yield decreased significantly (*p* <0.05) in natural fallow plots; while in *Leucaena* and *Senna* plots, the decrease was not significant. The mean grain yield over two years (without fertiliser), were: 2.0, 1.6 and 1.5 t ha⁻¹ in *Senna*, *Leucaena* and Natural fallow plots respectively. At the full rate of fertiliser, the mean grain yields were 3.8, 3.7 and 3.1 t ha⁻¹ in *Senna*, *Leucaena* and natural fallow plots respectively.

Keywords: *Leucaena leucocephala*, *Senna siamea*, organic matter, soil fertility, chemical properties, improved fallow
Assessment of techniques of rehabilitation on a logged-over lowland tropical forest

MOKHTARUDDIN A.M. (1), MASWAR (2), MAJID N.M. (1), KAMIL YUSOF M.M. (1), FARIDAH HANUM I. (1), AZANI A.M. (1) and KOBAYASHI S. (3)

(1) Universiti Putra Malaysia, 43400 UPM SERDANG, Selangor, Malaysia
(2) Center for Soil and Agroclimatic Research, Jln. Ir. H. Juanda No. 98, Bogor, Indonesia
(3) Center of International Forest Research, Bogor, Indonesia

As in other parts of tropical areas, in Malaysia, there is an urgent need to search for techniques for the rehabilitation of degraded logged-over forest that are feasible, cost effective, conservative and socio-economically acceptable. To address some of these issues, an experiment was carried out in Pasoh Forest, Peninsular Malaysia. The area is a logged-over forest, clear cut using crawler tractors and left idle since 1984. Four rehabilitation techniques tested were line planting (T1), gap planting with gap 10 m x 10 m x 5 ha⁻¹ (T2), 20m x 20m x 5 ha⁻¹ (T3) and 10mx10m x 9 ha⁻¹ (T4). Line and gaps were cleared using chain saw and planted with tree species namely Hopea odorata, Azadirachta excelsa and Vitex pubescens. One year after planting, the seedling’s survival, undergrowth biomass and soil properties changes were measured.

In general the seedling’s survival rate was good. The average survival rate for the three species was 92% and there was no significant difference between treatments. The undergrowth biomass was highest in line planting (T1) with an increase of 4.6 folds within 6 months after planting, followed by T2 (2.9 folds), T3 (2.8 folds) and T4 (1.6 folds). The higher biomass production in T1 led to a more significant improvement in soil properties in terms of lower bulk density, and an increase in soil organic matter (SOM) and available water capacity.

The rehabilitation cost from land preparation until planting were in the order of USD741, 393, 177 and 98 for T1, T3, T4 and T2 respectively. This cost does not include the cost of weeding which can be very substantial especially during the early growth phase.

In conclusion, the line and gap planting techniques were found to be suitable for rehabilitating the logged-over forest in Malaysia. Although line planting was found to be superior in biomass production and in soil improvement but it appears to be costly. In order to assess the effect of the different rehabilitation techniques on the tree growth, longer monitoring time is needed which will be included in logged-over Phase II of the study.

Keywords: assessment, rehabilitation, logged-over, forest
Can tree-crops ensure the sustainability of degraded agricultural systems?

MURPHY Daniel (1), WEBB Bindi (1), HARPER Richard (2) and ABBOTT Lynette (1)

(1) Centre for Land Rehabilitation, Soil Science and Plant Nutrition, Faculty of Agriculture, University of Western Australia, Nedlands WA 6907, Australia
(2) Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, WA 6983, Australia

A major problem for sustainable use of the dryland agricultural areas of Southern Australia (rainfall 300-600 mm y⁻¹) is the rising water table and subsequent salinisation resulting from the lower water usage of agricultural crops compared to natural vegetation. Landholders are now considering the integration of deep-rooted perennials (e.g. lucerne) and trees into agricultural rotations, to maximise total productivity and enhance sustainability. Recent findings have highlighted the benefit of using short-term rotations (3-8 years) of tree-crops in Southern Australia to de-water agricultural land. However, the ability of tree-crops to combat other aspects of soil fertility such as organic matter buildup is still unclear. Since any large-scale revegetation in this region may be funded by investment in greenhouse sinks, detailed studies of the fate of soil organic matter under such dramatic changes in land management is essential. Landowners require this information before they can assess the merits of using tree-crops in sustainable and profitable management practices.

This study examined the effects of tree-crops on soil organic matter storage in coarse textured agricultural soils typical of Southern Australia. At six locations composite samples of soil (0-10, 10-20, 20-30 cm) were collected under either (i) seven-year old tree-crops of Eucalyptus globulus, (ii) seven-year old tree-crops of Pinus pinaster or (iii) adjoining agricultural fields (pasture or arable cropping). It was possible with E. globulus to also conduct measurements on 1994-archived soil (i.e. after 2-years of tree growth). Due to the slow rate of change of total organic matter we instead examined labile fractions of soil organic matter (i.e. light-fraction organic matter isolated by density separation and dissolved organic matter). Light fraction soil organic matter reflects recent (<10 year) inputs of plant debris and is therefore more sensitive than total organic matter to changes in management practice. Soluble (dissolved) organic matter was also considered as leaching of this pool is a major mechanism for the redistribution of soil organic matter in coarse textured soils.

This paper reports our preliminary findings based on soil analysed from the 0-10 cm soil layer. The full data set will be presented during the conference. There was no change in total soil organic matter levels under the tree-crops compared to surrounding agricultural areas. Light-fraction soil organic matter accumulated under E. globulus compared to P. pinaster and agricultural areas. Dissolved organic matter was also significantly higher under E. globulus compared to P. pinaster but not compared to agriculture. These findings suggest that whilst the inclusion of a short-term rotation of P. pinaster will not decline soil organic matter (during establishment and growth); rotations of E. globulus may increase labile fractions of soil organic matter and thus have the potential to improve soil organic matter storage and nutrient cycling within these coarse textured soils.

Keywords: tree-crops, greenhouse, Eucalyptus globulus, Pinus pinaster, labile soil organic matter, coarse textured soil, Southern Australia, sustainable farming systems
Effects of embankment on growth and mineral uptake of *Melaleuca cajuputi* in acid sulphate soil in Vietnam

NAKABAYASHI Kazuo (1), THOMPSON Julian (2), NGUYEN Nguyen Tran (3) and FUJITA Kounosuke (3)

(1) Institute for International Cooperation, Japan International Cooperation Agency (JICA), 10-5 Ichigaya Honmura-cho, Shinjuku-ku, Tokyo 162-8433, Japan
(2) Wetland Research Unit, Department of Geography, University College London, 26 Bedford Way, London, WC1H 0AP, UK.
(3) Faculty of Applied Biological Science, Hiroshima University, 4-4 Kagamiyama, 1-Chome Higashihiroshima, Hiroshima 739-8528, Japan

The embankments are commonly used in the Mekong Delta for the cultivation of crops such as yam and cassava as well as perennial crops. The method aims at avoiding wet season inundation of the plants and providing water in side-ditches for irrigation during the dry season. However, the effects of this practice upon biomass production and mineral nutrition status in tropical woody plants have not been well documented. Therefore, the significance of embankments on biomass production and its parameters was examined. In the field experiment, seedlings of *M. cajuputi* were planted on the embankments and on adjacent natural ground surface as a control. One year after planting, biomass production and mineral nutrition status in various plant parts of *M. cajuputi* were measured. Furthermore, a pot experiment was carried out using *M. cajuputi*, *M. leucadendra* and *Eucalyptus camaldulensis* in order to examine the growth enhancement by embankments. The seedlings were planted in plastic pots containing granite Regosols under controlled water level and Al concentration in the culture media.

Under the field conditions, planting on embankments enhanced plant growth. Whole plant biomass on the embankments increased by 236% relative to the control. Nitrogen uptake increased more significantly in the trees planted on the embankments than the other mineral elements. The Al concentrations decreased as a result of planting on embankments except for bark. The majority of N and Ca uptake by plants were accumulated in leaves but Al was stored in stumps and roots. The results of this pot experiment supported the field experiment. The embankment enhanced biomass production and N and P uptake by plants. In all the species, Po was reduced slightly by inundation, and notably by Al application. *M. cajuputi* accumulates Al in its roots preventing its movement to leaves. Based on the results, it is suggested that embankments are effective in enhancing tree growth. This is mainly as a result of accelerated N uptake as well as alleviation of deleterious effects of acid sulphate soils including Al toxicity.

**Keywords:** acid sulphate soils, biomass production, embankment, Mekong Delta, *Melaleuca cajuputi*, mineral nutrition
Recharge reduction on degraded agricultural soils with agroforestry systems


(1) Dept of Conservation & Land Management, Locked Bag 104, Bentley Delivery Centre, WA 6983, Australia
(2) Soil Science & Plant Nutrition, University of Western Australia, Nedlands WA 6907, Australia

Extensive clearing of native vegetation for agriculture has resulted in rising water tables and salinity in the lower rainfall areas (<600 mm y\(^{-1}\)) of Southern Australia. The re-introduction of deep-rooted perennials into farming systems is required to restore the water balance and remediate degraded agricultural soils. Alley farming (strips of trees and crop) and phase farming with trees have been proposed as options for reducing recharge while maintaining cereal cropping. For alley farming to succeed in reducing recharge, roots will have to laterally exploit adjacent cropped soils to several meters. Similarly, phase farming with trees depends on the depletion of soil water to several meters depth. To investigate the vertical and lateral extent of tree roots and patterns of soil water uptake, soil cores were taken to depths of up to 12 m, in transects perpendicular to 5-15 years old eucalypt belts at 5 sites across the 300-600 mm rainfall zone of South-western Australia. A range of soil properties, including matric suction, gravimetric water content, chloride concentration and bulk density were measured at 50 cm depth intervals. Lineal leaf area of belts and pre-dawn leaf water potentials were measured at the time of soil sampling. Results indicate that trees can exploit soil water to depths of at least 8-10 m within 7 years of planting. Results were similar in a range of other soils, with only silcrete pans and free water restricting root growth. This suggests that the premise of phase-farming with trees, which is the rapid depletion of soil water to depths of several meters to provide a buffer for water leaking from the subsequent crop phase is feasible. The lateral extent of the tree roots varied with site and soil type, however all were within 9-20 m. This has implications for the optimum spacing and width of alley belts necessary to control recharge across these farming systems.

Keywords: eucalyptus, rooting zone, soil water
Significance of symbiotic microorganisms in re-vegetation process in Lahar area of Mt. Pinatubo

SAITO Masanori (1), MINAMISAWA Kiwamu (2) and BARRAQUIO Wilfredo (3)

(1) National Institute of Livestock and Grassland Science, Nishi-nasuno, Tochigi, 329-2793, Japan
(2) Graduate School of Life Sciences, Tohoku University, Sendai, Miyagi, Japan
(3) Institute of Biology, University of the Philippines, Diliman, Quezon city, 1101, Philippines

In the violent eruption of Mt. Pinatubo, The Philippines, in 1991, very huge amounts of pyroclastic materials deposited on and around the mountain. The deposited materials have continued to erode as lahar during the rainy season and cover an extensive area. Because the lahar is comprised of newly erupted volcanic materials, it contains little organic matter and nutrients available for plants. We examined the re-vegetation process in the lahar area of Mt. Pinatubo in order to clarify how the plants establishes itself in the nutrient-deficient soil, with emphasis on symbiotic microorganisms associated with the pioneer plants.

In the experimental site, Pampanga, Philippines, more than 10 m of the volcanic deposit covered the original soil surface. Most of the area was sparsely vegetated with only a few gramineous plants, especially Saccharum spontaneum. However, some densely vegetated areas could be found in patches. These patches were characterized by the co-existence of the gramineous plants and leguminous plants such as Calopogonium mucunoides and Centrosema pubescens, which were well nodulated. Growth of the gramineous plants in these patches was greatly favored. In both less and densely vegetated areas, high density of arbuscular mycorrhizal (AM) fungal spores were found. S. spontaneum was slightly colonized with AM fungi while the leguminous plants were highly colonized. AM inoculation experiments carried out in the laboratory involving these gramineous plants showed that these plants were not highly mycorrhiza-dependent but were able to sustain the density of AM fungi. Diazotrophic endophytic bacteria were found with high frequency from the gramineous plant shoots in the less vegetated areas but with low frequency from those in the densely vegetated areas. The significance of the symbiotic microorganisms in the re-vegetation process was discussed.

Keywords: arbuscular mycorrhizal fungi, carbon sequestration, diazotrophic endophyte, pioneer plants, degraded soil, δ15N
Soil moisture influence on biomass production and nutrient concentration in *Eucalyptus grandis*

SANTANA Dalva L. de Q., BELLOTE Antonio F.J. and DEDECEK Renato A.

Embrapa-Florestas, Caixa Postal 319, 83.411-000 Colombo, PR, Brazil

Many research institutions have developed several technologies to grow *Eucalyptus sp.* in our conditions of soil and climate. These days, Brazil has obtained one of the best productivity rates of this species in the world. Eucalyptus is grown in a diversity of climate and soil, mostly on soils of low natural fertility and subjected which are to a long and acute dry period during the growing cycle. The objective of this study was to evaluate the effects of different soil moisture levels on growth, plant nutritional status and biomass production of *Eucalyptus grandis*, under greenhouse conditions.

*Eucalyptus grandis* seedlings were planted in 3-litre-vases filled with soil classified as Latossolo Vermelho (Rhodic Ferralsol, following FAO classification). Soil moisture during this study was kept on four different levels: near saturation, at field capacity, at 60% of field capacity, and at 30% of field capacity. At the end of this experiment the total height and diameter of plants were measured. The dry weight of different parts of plants and the mineral nutrient concentration in leaves, branches and stems were measured.

The results showed that total biomass produced was drastically reduced with soil moisture reductions. Soil moisture near saturation and at field capacity yielded 2.4 and 2 times more biomass than soil at 30% of field capacity, respectively. Independent of the soil moisture level, there was a similar proportion of biomass among different plant parts, branches, stems and leaves presented the following proportions respectively, 1:1.6:2.3.

Greater amounts of mineral macronutrients in the total biomass were found on the treatment where soil moisture was kept at field capacity. N, K and Ca were the mineral nutrients that varied the most among different treatments, considering the whole plant or in separate parts, stems and branches. In leaves, there was a direct correlation between N concentration and soil moisture level, decreasing the concentration of N with the decreasing of soil moisture level. Some nutrient content proportion was kept constant and independent of the soil moisture level, for leaves it happened between K/Ca and Ca + Mg/K, and for branches this happened between Ca/Mg.

**Keywords:** soil moisture deficit, Eucalyptus nutrition, *Eucalyptus grandis*
PCA on the soil degradation of successive Chinese fir plantation

SUN Qiwu and YANG Chengdong

Research Institute of Forestry, CAF Beijing 100091, P.R. China

Twenty three soil factors, those in different sites (site-index 12, 14, 16) and different growth periods (young, half-mature and mature) of the first and second generation Chinese Fir plantations in Dagang Mountain, Fenyi County of Jiangxi Province, are determined. Through the methods of PCA, six synthesize factors are selected as targets on evaluating soil fertility in Chinese Fir plantation. After this, quantified, scored and sequenced to the data-collected relevant to the soil fertility in the selected plots using PCA, results show that the score of all the 2nd generation Chinese Fir plantations are much lower than that of the 1st generation. It reveals the factor that soil degradation exists in successive Chinese Fir plantations. The results also show the tendency of soil productivity of different growth periods of 1st rotation is that soil productivity decreases from young to the half-matured period, but raises slightly from half-matured to the matured period. This result shows that the 1st rotation is the latent period of soil degradation of Chinese Fir plantation.

Keywords: Chinese Fir plantation, soil degradation, PCA
Soil nutrient status and root intensity in plantations of exotic tree species on highland soils in Northern Thailand

POOLSIRI Roongreang (1), GLATZEL Gerhard (1), SIEGHARDT Monika (1) and THAIUTSA Bunvong (2)

(1) Institute of Forest Ecology, University of Agricultural Sciences, Peter-Jordanstrasse, 82, A-1190 Vienna, Austria
(2) Department of Silviculture, Faculty of Forestry, Kasetsart University, Bangkok, Thailand

A study on nutrient status in soils of exotic tree species on highland soils of Northern Thailand was carried out at Doi Angkhang, Chiangmai province. Experimental plots (20x25 m²) were selected in 18 years old plantations of 4 exotic tree species, i.e. Acacia confusa, Cinnamomum camphora, Liquidambar formosana and Cunninghamia lanceolata for ecological studies. 15 soil cores were extracted at each plot and divided into geometric horizons of 0-10, 10-20, 20-35 and 35-50 cm depth. The soil samples were analyzed chemically for nitrogen (N), carbon (C), C/N ratio and the amount of roots.

The data shows that the nitrogen and carbon content decreased with soil depth. There are significant differences among the plots, most likely both due to pre-plantation soil heterogeneity and the effects of the planted species. The root study shows that there are pronounced, statistically significant differences between the species, Acacia confusa and Liquidambar formosana, having less than half the root mass of Cunninghamia lanceolata and Cinnamomum camphora in the top 50 cm of the soil. Data on nutrient cycling and exchangeable nutrients in the soil, which are currently being collected, will provide more information on the effect of the planted trees on the soil.

Keywords: forest plantation, nutrient cycling, exotic tree species, root study, nitrogen, carbon
Restoration of degraded outwash soils under red pine plantations

McPHERSON T.S. and TIMMER V.R.

Faculty of Forestry, University of Toronto, Toronto, Ontario, M5S 3B3, Canada

Soil degradation and subsequent amelioration were studied by examining changes in morphological, physical and chemical properties of soils along a chronosequence of old-growth forest, abandoned fields, and young and mature conifer plantations on the Oak Ridges Moraine, an environmentally vulnerable landform near Toronto, Canada that is threatened by encroaching urban development. The chronosequence reflected a history of pre-settlement deforestation, exploitive pioneer agriculture and ensuing land abandonment that led to soil fallowing and/or wind erosion in the 1920s followed by soil stabilization after extensive planting with red pine (Pinus resinosa Ait.). Soil degradation generally involved major regressive pedogenic processes characterized by profile haploidization and soil organic matter and nutrient losses, increased pH and base status, and higher surface bulk density on abandoned fields. Deflated areas experienced severe top soil loss exposing calcareous parent material with higher soil pH, infertility and compaction. After reforestation with red pine planting stock, progressive pedogenesis took place reversing soil degradation by reduced erosion because of tree development and litter accumulation. Profile differentiation and horizon development were accelerated on fallowed sites, and at faster rates on deflated sites. Top soil bulk density decreased due to humus build up and increased plant root and faunal activity. Soil fertility and acidification increased due to nutrient pumping and higher deposition and decomposition of organic material as the stands aged. Chronofunctions of soil properties revealed that reforestation led to substantial recovery in soil organic C, total N, available P, and exchangeable K, Ca and Mg status during plantation development on fallowed sites. Consequently remediation close to corresponding natural forest conditions was achieved within 75 years of initial reforestation. In comparison, estimated recovery was slow on deflated soils occurring well past plantation maturation. The susceptibility of deflated sites to severe degradation and the limited potential for recovery soon after reforestation exemplified the environmental sensitivity of forested soils on the Oak Ridges Moraine to uncontrolled development and disturbance.

Keywords: ecosystem degradation, soil remediation, pedogenesis, reforestation
Symposium 40

New developments in the evaluation and management of forest soils

Convenor: KHANNA Partap K.
Co-Convenor: WASUWANICH Pisan

Oral Session
Monday 19 August 2002
8:30 - 11:50
Room: Meeting Room 3

Poster Session
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Eucalyptus grandis growth on different soils of São Paulo State, Brazil

BELLOTE Antonio F.J. (1), QUADROS Ruth M.B. (2), SILVA Helton D. da (1) and BOGNOLA Itamar A. (1)

(1) Embrapa-Florestas, Caixa Postal 319, 83.411-000 Colombo, PR, Brazil
(2) Post Graduation - Program, Universidade Federal do Paraná, Caixa Postal, Curitiba, PR, Brazil

Eucalyptus grandis became economically very important in Brazil, because it is highly productive in a very short time period when compared to native species development. Its fast growing characteristics determine a high demand on soil resources, mainly water and nutrients, that question the site capacity on sustaining this high productivity. In São Paulo State, around 2 million hectares are cultivated with some Eucalyptus species, mostly for paper and cellulose purposes. Then it is possible to find eucalyptus growing in many different kinds of soil and climate that make possible this work with the objective of correlating eucalyptus growth and soil chemical and physical properties in São Paulo State.

It was measured the nutritional status of E. grandis, growing in 56 commercial plantations areas in different regions of São Paulo State. One hundred and fifty one plots, measuring 300 m² each plot, were set to evaluate total height, DBH, and diameter and crown height of plants. Nutritional status was performed based on plant leaves gathered from plant crowns. Soil samples for chemical and physical analyses were obtained on the following depths: 0-5, 5-10, 10-20 and 20-30 cm.

The results allowed us to distinguish two soil classes, based on their physical characteristics that affect E. grandis development. To the first group of soil, having average values of clay less than 180 g kg⁻¹, average growth in height varied from 16.5 to 18.2 m. In this group the following soil classes were found: Neossolos quartzarênicos (Entisol), Latossolo Amarelo loam texture (Oxisol) and Latossolo Vermelho loam texture (Oxisol). To the second group, that had average values of clay greater than 250 g kg⁻¹, the average plant height varied from 19.9 to 20.6 m. In this group, the most important soil classes were: Latossolo Vermelho clay to heavy clay textures (Oxisol), Argissolo Vermelho-Amarelo loam/clay to clay/heavy clay textures, and Cambissolo Háplico and Cambissolo Háplico argissólico, both with loam and clay textures. Soil fertility was better characterized by sampling in the 10 cm of the surface soil.

Keywords: soil chemical properties, soil physical properties, plant nutritional status
Movement of $^{15}$N-labelled harvest residues in the first 2 years of hoop pine plantations

BLUMFIELD Tim (1,3) and XU Zhi-hong (2,3)

(1) Faculty of Environmental Sciences, Griffith University, Nathan, Queensland 4111, Australia
(2) Queensland Forestry Research Institute, P.O. Box 631, Indooroopilly, Queensland 4068, Australia
(3) Co-operative Research Centre for Sustainable Production Forestry, Australia

The decline in soil fertility, following the commencement of hoop pine (Araucaria cunninghamii) plantations in subtropical Australia, particularly during the critical inter-rotation period, prompted a change to post-harvest residue management strategies. To prevent losses of N through volatilisation and erosion, the practices of broadcast burning and "push and burn" were replaced by windrowing residues along the contours of the slope. An optimal spacing of 15 m was chosen, allowing 3 rows of trees to be planted in the inter-windrow space. It was considered that this spacing would allow nutrients that were released by residue decomposition to be available to the trees of the following rotation. To test this hypothesis, material from $^{15}$N-labelled trees, that had been harvested following research into the uptake of $^{15}$N-labelled ammonium sulphate, were placed in windrows and allowed to decompose under field conditions. Soil sampling at 12, 18 and 24 months following the establishment of the windrows revealed that there was little lateral movement of $^{15}$N. There was significant enrichment of soils within 0.5 m of the windrows, to a depth of 200 mm, indicating vertical movement of N through the soil profile. Soil total N, total C and $\delta^{13}$C data revealed that there was some lateral movement down the slope from the windrows, but that the windrows seemed to be effective in acting as a barrier, preventing the loss of nutrients from the site through erosion.

Keywords: $^{15}$N-labelled, residues, decomposition, hoop pine, windrows
Humic extract color by reflection and transmission of two forest soils

GASCÓ José-maria, GUERRERO Francisca and FERNÁNDEZ-GETINO Ana-patricia

Dpto. de Edafologia. E.T.S.I. Agrónomos, Universidad Politécnica de Madrid. Ciudad Universitaria, 28040 Madrid, Spain

The aim of this research was to study the reflected and transmitted color of total humic substances (THS) determined by chromameter and spectrophotometer measurements. Reflected Munsell hue value/ chroma (H V/C), and CIE-Yxy-1931 lightness (Y) and chromaticity coordinates (x,y) of THS were determined through the bottom of a Petri box (transmittance of 99 %) by Minolta Chroma Meter CR-200. The Petri box was covered with a black mask to avoid external lightness. Transmitted color of THS solution was related to the absorbance measurements by Spectrophotometer Shimadzu UV-1203 at the different wavelengths of the visible spectrum (from 350 to 800 nm) by steps of 5 nm. Color by reflection and transmission were measured in THS extracted with a mixture of Na₄P₂O₅ and NaOH. The ratio soil/solution (w/v) was adequate considering their respective organic matter contents. These THS were from Humic Lithic Dystrocyrepts under pinewood of Pinus sylvestris and Humic Lithic Dystroxerepts under holm oak of Quercus ilex placed in the mountain area of Guadarrama, Madrid (Spain). Total organic matter was determined by the dry combustion method at 540 °C. THS absorption spectrum showed an absorbance peak at 455 nm and a transmittance maximum at 445 nm. In pine soil the maximum absorbance was for THS of A1 horizon, followed by A2, Oi and A|. In holm oak soil the maximum absorbance was for THS of A2 horizon, followed by Oi, Ao and A|. In both cases, this is in accordance with the Munsell hue (for pine soil 15.5, 17.4, 19.2 and 19.5 respectively, and for holm oak soil 17.2, 18.6, 19.7 and 19.8 respectively). The mineral Bw pine horizon showed a displacement of hue to the H 30 (10Y). Surface horizons in both soils showed higher Munsell C than subsurface horizons, as expected for their lower absorbances. Absorbance for THS of pine soil was higher than for holm oak soil. The comparison between the absorption spectrum of the mineral horizons (Bw and C) showed the relation between the absorbance and the V and C values. Absorbance was higher in THS of pine soil than in holm oak soil, according to larger V and C values for pine soil (3.6, 0.4) than for holm oak soil (2.7, 0.7).

Keywords: soil color, humic substances, forest soils
A pedo-geomorphic approach for predicting drought deaths in *Eucalyptus globulus* (Labill.) plantations

HARPER R.J. (1), McGRATH J.F. (1) and CARTER J.O. (2)

(1) Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, WA 6983, Australia
(2) Department of Natural Resources and Mines, 80 Meiers Rd, Indooroopilly, Qld. 4068, Australia

The reforestation of farmland with trees is a rapidly emerging activity in Australia, to produce wood products, to restore hydrological balances, for carbon dioxide sinks or as a source of bioenergy. Irrespective of purpose, the benefits of reforestation depend on its survival and adequate growth. While management affects tree survival and growth, both are also strongly related to soil conditions. To define the soil survey requirements for these new plantations we studied the relationships between the survival of Tasmanian blue-gums (*Eucalyptus globulus* Labill.) and a range of soil and climatic attributes. Widespread tree deaths occurred in years with both average and below average rainfall. Dead trees did not occur everywhere and appeared to be related to soil and geomorphic attributes. These relationships are discussed in this paper.

Soils were examined in three plantations established in 1989. Tree survival two years after planting was independent of all soil and site factors and averaged 79% of those trees initially planted. By seven years of age, tree survival was substantially less on soils (a) <2 m deep compared to >2 m deep (22 vs 70%) and (b) where ferricrete gravels were absent compared to where present (19 vs 68%). Importantly, live standing tree volumes increased between 4 and 7 years of age on sites with deep soils, whereas volume decreased slightly on the shallow soils.

The soil factors important to tree survival are related to soil water storage capacity, with the ferricrete gravels being an indicator of deep weathering profiles, rather than affecting water storage capacity per se. The major limitation to tree survival in this region comes from the overall soil volume. This is due to the limited ability of these soils to store all the annual rainfall and a consequent lack of a supply during the annual summer drought.

There are practical difficulties in routinely surveying soil depths in excess of 2 m over broad areas. The occurrence of ferricrete gravels provides a useful surrogate of the presence of deeper soils. In this region the distribution of soil depth and soil fertility has a geomorphic basis, being related to previous patterns of deep weathering and regolith stripping. Soils have developed on various horizons of deeply weathered profiles, formed from granites and gneisses. These materials have been stripped to a variable extent by erosion, leading to a range of soil depths. The original weathered profiles, which correspond to the soils with ferricrete gravels, comprise the deepest soil/regolith materials (~30 m deep), whereas along drainage lines the regolith has been completely stripped, the soils are shallow and plantations are most susceptible to drought. Regional indications of drought risk can thus be developed from regional soil mapping.

**Keywords:** *Eucalyptus globulus*, plantations, reforestation, greenhouse, soil survey
Spatial variability and isotopic studies of the prairie-forest transition in Louisiana

BEKELE Asfaw (1), HUDNALL Wayne H. (1) and TIARKS Allan (2)

(1) Louisiana State University, Agricultural Center, Baton Rouge, Louisiana, USA
(2) USDA Forest Service, Pineville, Louisiana, USA

The invasion by exotic woody and herbaceous plants has been a major threat to Louisiana prairies. Previous studies have shown that the invasion of grassland by woody plants is associated with an increase in soil heterogeneity. We studied the spatial variability of soil pH, Electrical Conductivity (EC), and Mehlich III extractable K, Ca, Mg, Fe and Mn at three remnant prairie-forest associations in Winn Parish, Louisiana. Surface soil samples (0-15 cm depth) were obtained from four transects with paired transects perpendicular and normal to slope gradient and traversing prairie and forest.

Soil pH separated prairie soil from the forest soil. The prairie soil was consistently alkaline (pH>7.00) and the forest soil was acidic (pH<7.00) with approximately neutral values (pH=7.00) for the transition soil. Geostatistical analysis showed that spatial dependence was expressed over a range of 20-30 m. Local topography was observed to influence the spatial variability of most of the soil properties. Semivariogram shapes were similar among sites, suggesting the greater control of soil parent material on the observed spatial soil pattern. Except for soil pH, the estimated fractal dimension for other soil properties were greater than 1.75. This indicates the dominance of short-range variability. Short-range variability in soil pH emerged when soil data from the forest was deleted, showing the scaling characteristics of soil pH and its susceptibility to plant induced changes. This information serves as a baseline for any future management and species monitoring activities of these and similar prairies.

Keywords: prairie soils, spatial variability, fractals
Chemical properties and classification of Japanese brown forest soils derived from various parent materials

IMAYA Akihiro (1), MORISADA Kazuhito (2) and OHTA Seiichi (2)

(1) Kyusyu Research Center, Forestry and Forest Products Research Institute, Kurokami 4-11-16, Kumamoto city, Kumamoto, 860-0862, Japan
(2) Forestry and Forest Products Research Institute, Matunosato 1, Kukizakicho, Inashikigun, Ibaraki, 305-8687, Japan

Approximately 70% of the forest land in Japan consist of Brown Forest Soils (BFS) which are the zonal soils in the humid temperate and warm temperate regime of Japan. The chemical properties of BFS may vary widely because of their diverse parent materials. We compared the chemical characteristics of 35 sola of BFS derived from various parent materials in montane areas and 3 sola of Black Soils (BLS) in central Japan.

The parent material influenced the clay content, cation exchangeable capacity, base saturation and acidity of the BFS studied. The C and N contents did not differ consistently with the parent material, except for BFS from volcanic ash with remarkably high C and N contents. In addition, the BFS from volcanic ash and the BLS also derived from volcanic ash were not obviously different in basic chemical properties.

The crystalline Fe was dominant in the non-volcanic BFS, and organically complexed Fe and Al was detected in the surface horizons. In the BFS derived from volcanic ash, Alo-Ald value suggested that contents of allophane and imogolite increase with depth and become dominant in deeper horizons. Contrarily, amorphous Fe and non-crystalline Al-hydrous oxides were dominant in the BLS.

According to the U.S. Soil Taxonomy and World Reference Base for Soil Resources, the BFS were divided into two major soil groups at a higher level: Andisols or Andosols from volcanic ash and Inceptisols or Umbrisols / Cambisols from non-volcanic-ash parent materials. The BFS were subdivided into different categories at a lower level of U.S. Soil Taxonomy depending on the parent materials and/or soil moisture regime, which is affected by the topographical position. The dry type BFS found on higher positions of the landscapes and BFS on acid rocks had ochric epipedons, and were classified into typic dystrudepts. On the other hand, moderately moist type BFS on mid-slopes developed from basic rocks had umbric epipedons, and were classified into humic dystrudepts. BFS derived from ultrabasic rocks were classified into eutrudepts having eutric properties. While BFS from volcanic ash showed andic properties in most soil horizons, and fell under Hapludands or Fulvudands depending on the moisture regime. However, some BLS were Melanudands with melanic epipedons.

Thus, the difference in parent material has a strong influence on the chemical properties and the classification of BFS, and must be taken into consideration when multiple functions of BFS are evaluated.

Keywords: brown forest soils, parent material, chemical properties, free oxides, classification
Establishment of some multipurpose tree species with limited water under desert eco-system

JHORAR B.S., MALIK R.S., BHARDWAJ K.K., DAHIYA Rita and HASIJA R.C.

Dept. of Soil Science, CCS H.A.U. Hisar -125004, India

Nine to twelve-month-old samplings of Shisham (Dalbergia sissoo), Neem (Azadirachtan indica), Siris (Albizia lebbek), Rohira (Tecomella undulata) and Khejri (Prosopis cineraria) were planted in double walled earthen pots and in 60 cm diameter and 60 cm deep pits filled, at a ratio of 2:1:1, with a special mixture of field soil: FYM: pond silt/heavy soil at a distance of 2m-6m apart. The planting was done on 20th October, 1995 at regional research station, Balsamand of Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. This research station represents a desert eco-system adjoining to Rajasthan State. Fourteen supplementary basin irrigation (SBI) of water (10 litre/water/plant/irrigation) with varying intervals were given for establishment of above mentioned tree species for conventional method of planting. Whereas, in double walled earthen pots the first four SBIs after transplanting of seedling were given at an interval of 10 days. In the following winter (December, 1995 to February, 1996) and summer (March, 1966 to June, 1996) seasons the SBIs were applied at an interval of 20 days and 7 days, respectively. No irrigation was given during the monsoon season. Each SBI was of 4 litres water per plant. The total volume of water applied per plant during establishment was 104 litres. The data on survival percentage, plant height and collar diameter of all the plants of each tree species were recorded on 0, 6, 12, 18 and 24 months after transplanting. Survival percentage of Dalbergia sissoo, Albizia lebbek and Tecomella undulata were 100 percent in double walled earthen pots and conventional method of planting. Whereas, the survival percentage of Azadirachta indica and Prosopis cineraria was 85 percent in double walled earthen pots and conventional method of planting, respectively. The plant height, collar diameter and rate of growth of all the tree species demonstrates that they are all equally capable of establishing themselves in desert eco-system under SBI system of irrigation in general and particular in double walled earthen pots. This study has shown that a farmer using one pitcher (20 litres) of water each day for SBI system on forest tree can establish 40-50 plants per year successfully in a desert eco-system.

Keywords: Dalbergia sissoo, Azadirachta indica, Albizia lebbek, Tecomella undulata, Prosopis cineraria, supplementary basin irrigation
Clear-cutting effects on soil organic matter content and quality in a temperate maritime pine forest a spatial and temporal assessment

JOLIVET Claudy (1), ARROUAYS Dominique (1), BOURHIS Fabien (1), BOURENNANE Hocine (1), ANDREUX Francis (2), LÉVÊQUE Jean (2), RICHER DE FORGES Anne (1,3), CHAUSSOD Rémi (3), LOUSTAU Denis (4), TRICHET Pierre (4), BERT Didier (4), ANGERS Denis (5), CHANTIGNY Martin (5), CHADOEF Joël (6) and CIESIELSKI Henri (7)

(1) Institut National de la Recherche Agronomique, Unités Infosol et Science du Sol, Avenue de la Pomme de Pin, BP 20619, 45166 OLIVET cedex, France
(2) UMR INRA-Université de Bourgogne n°A111 Microbiologie des Sols-Géosol, Centre des Sciences de la Terre, Université de Bourgogne, 6 Boulevard Gabriel, 21000 DIJON, France
(3) UMR INRA-Université de Bourgogne n°A111 Microbiologie des Sols-Géosol, Institut National de la Recherche Agronomique, Unité de Microbiologie des Sols, 17 rue Sully, BP 1540, 21034 DIJON cedex, France
(4) Institut National de la Recherche Agronomique, Unité de Recherches Forestières, Domaine de l’Hermitage, Pierroton, 33610 CESTAS, France
(5) Agriculture et Agroalimentaire Canada, Centre de recherche et de développement sur les sols et des grandes cultures, 2560 boulevard Hochelaga, SAINTE-FOY (Québec), Canada G1V 2J3
(6) Institut National de la Recherche Agronomique, Unité de Biométrie, Domaine Saint-Paul-Site Agroparc, 84914 AVIGNON cedex 9, France
(7) Institut National de la Recherche Agronomique, Laboratoire d’Analyses des Sols, 273 rue de Cambrai, 62000 ARRAS, France

Natural or human disturbance of terrestrial ecosystems can lead to significant evolution of soil organic properties. This subject is of prime interest for global change and sustainable management of natural soil resources. In Southwest France, silvicultural management (soil drainage, mechanisation and fertilisation) has resulted in highly productive artificial forest, in natural infertile podzolic sandy soils which are characteristic of this area. The objective of this work was to evaluate the effect of clear-cutting on organic matter properties. We first characterised the spatio-temporal evolution of soil organic matter contents attributable to clear-cutting. The effect of clear-cutting was then monitored in situ by measuring seasonal evolution in total organic carbon contents, soil microbial biomass and soil carbohydrates. Clear-cutting modified the spatial structures of organic matter in surface soil layers and lead to significant decrease of organic carbon pools. Soil organic matter quality was also affected by significant changes in soil microbial biomass, related to silvicultural practices. Soil carbohydrates decreased although their composition remained unchanged.

Keywords: soil organic matter, soil quality indicators, silviculture, clear-cutting, spatio-temporal variability, sampling design
Nitrogen in forest soils of the Czech Republic: a problem to be studied

KULHAVY Jiri and FORMANEK Pavel
Mendel University of Agriculture and Forestry, Faculty of Forestry and Wood Technology, Institute of Forest Ecology, Zemedelska 3, 613 00 Brno, Czech Republic

In spite of the generally reduced level of air pollution in Central Europe, nitrogen oxide concentrations in the atmosphere and the level of nitrogen deposits in the Czech Republic are permanently high, several times exceeding critical values. It is supposed that high inputs of nitrogen can on the one hand cover the disconnection of ion cycles caused by acid deposits and thus to increase. On the other hand, there are forest ecosystems which are insufficiently supplied with nitrogen despite increased inputs of the element. In addition to this, internal cycles of N in the ecosystem (mineralization, immobilization) can under certain conditions be an important factor in the unfavourable balance of protons and increasing acidification of soils. These factors can represent a serious danger for forest ecosystems and unexpected responses during stress situations.

The study was carried out on examples of young Norway spruce stands planted in different areas of the Czech Republic. The study evaluates the effect of density of a young Norway spruce stand and reclamation liming on nitrogen transformations in soil and the level of nitrogen nutrition of spruce stands in the ridge part of the Moravian-Silesian Beskids. The area is affected by acid industrial air pollutants and, therefore, it was reclaimed by liming in 1983, 1985 and 1987. Our results showed that the concentration of ammonium and nitrate nitrogen in soil during the growing season considerably fluctuated. On the basis of results from 1999, nitrogen in ammonium form predominated in soil, the content of nitrate nitrogen was lower and nitrite nitrogen was detected only sporadically. Nitrogen concentrations in needles of the first generation were below the limit of sufficient nutrition. For the given intensity of tending measures, the effect of stand density on nitrogen transformation in soil has not been found. The effect of reclamation liming on nitrogen transformations in soil and on the nitrogen content in needles 12 years after the last application has not been also proved in spite of the increased value of soil pH.

Keywords: forest soils, nitrogen mineralization, Norway spruce stands, air pollution, Czech Republic
Effect of site type on medicinal species diversity and biomass productivity in the northern mountain region of Republic of Srpska

LJUBOJEVIC Srdjan

University of Banja Luka, Faculty of Forestry, Av. Stepe Stepanovica 75,78000 Banja Luka, Republic of Srpska, Bosnia and Herzegovina

The aim of this study is to present species diversity and biomass productivity of 95 medicinal and edible plants (62 herbaceous species, 24 species of shrubs and trees and 9 species of mushrooms) on Cambisols developed over serpentine and silicate bedrock.

As a representative of the northern Mountain region of the Republic of Srpska, we took the Teslic forest management region. This region spreads over 48,000 ha of various forests and forest's stands between an altitude of 166 m and 1,383 m. Based on previously researched phytocenoses and soil groups of this region, four main site types have been singled out:

1. Beech forests and mixed beech and fir forests (with spruce) on Cambisols over silicate bedrock.
2. Beech forests and mixed beech and fir forests (with spruce) on Cambisols over serpentine bedrock.
3. Sessile oak forests and mixed beech and sessile oak forests on Cambisols over silicate bedrock.
4. Sessile oak forests and pine forests on Cambisols over serpentine bedrock.

In each site type we spread the sample units network at a 100 m distance in directions N-S and E-W. On every sample plot we checked out soil group and phytocenose, determined plant species, counted individuals of each species, weighed their biomass in fresh and later on in air-dried conditions. Also, we registered parameters that determined site specific relief and light conditions. In this way data from 280 sample plots were gathered in 1999.

Finally, we have come to the general conclusions that:

- Calcisols on serpentine bedrock give higher diversity and bigger biomass of medicinal and edible plants than on silicate bedrock ones;
- within a single soil unit, soil depth has no significant impact on species diversity nor on biomass productivity.

Keywords: biomass, Cambisols, diversity
The effect of slash management on the productivity of *E. globulus* plantations and on soil properties

MADEIRA M., (1), MAGALHÃES M.C. (2), AZEVEDO A. (3) and FABIÃO A. (1)

(1) Inst. Sup. de Agronomia, 1349-017 Lisboa, Portugal
(2) Esc. Sup. Agrária de Coimbra, 3040-316 Coimbra, Portugal
(3) Esc. Sup. Agrária de Santarém, 2000-655 Santarém, Portugal

Sustainable management of forest resources is of utmost importance to ensure long-term productivity of later rotations. Tree growth, tree nutrition and soil properties of *E. globulus* plantations were studied at a site (Furadouro) located in central Portugal, both after replanting and coppicing, under four treatments, in which plant residues from the first crop were utilised. Two areas were considered within the replanted zone, one with coarse textured dystric Cambisols (F1), and the other with medium textured eutric Cambisols (F2). The coppiced area was similar to F2.

Treatments applied both in replanted and coppiced areas were: removal of harvesting residues from the soil surface (R); organic residues on the soil surface (S); as for treatment S, but woody material accumulated between rows (W); incorporation of organic residues in the top soil by harrowing up to 20 cm depth (1). In the replanted area two additional treatments were applied: as for treatment R and harrowing up to 20 cm depth (Rh), and as I, followed by subsoiling up to 50 cm depth (Is).

Tree growth, tree root distribution and biomass, and tree nutrition by root bioassays (*15*N, *32*P, *86*Rb) and foliar analysis were assessed. The amount of organic matter on the forest floor was quantified through samples taken from 1×1 m. Bulk density was determined from undisturbed samples; soil compaction was measured using a penetrometer; soil aggregation index and aggregate size distribution were determined on samples taken from the top soil. The concentration of organic C, N, base cations and extractable P were determined up to 30 cm depth.

After 6.5 years, differences in tree growth between treatments were not significant at Fl site. Planted trees at F2 showed significantly lower growth in R treatment than in the others, and the maximum was in the Is treatment. The growth of coppiced trees was independent of the treatments. Fine (<2 mm) and total root mass showed no evidence of a treatment effect. There were no significant treatment differences in the level of uptake of the three major nutrients by the tree roots, nor as in the nutrient concentration in leaves, along the experimental period.

Bulk density values, soil compaction, soil moisture characteristics, and aggregation index and aggregate size distribution did not show significant differences between treatments. The amount of litter layer mass was significantly lower in R and I treatments than in the others. Nevertheless, no significant differences were found with respect to concentration of organic C, N, extractable base cations and extractable P in the 20 cm top soil layer.

In both zones of the replanted area there were not significant differences between treatments which only involved slash management (treatments R, S, W and I). Treatment Is had a significantly positive effect on tree growth in zone F2, but not in the other (Fl). Results suggest that in zone F2 the physical characteristics of the soil and parent material may limit tree growth by reducing the depth and intensity of rooting, and decreasing the use of water from the deeper layers.

Keywords: *Eucalyptus globulus*, soil, slash management, nutrition
Assessment of soil organic carbon in Japanese forest soils

MORISADA Kazuhito, IMAYA Aakihiro and ONO Kenji

Forestry and Forest Products Research Institute, Matsunosato-1, Kukizaki-machi, Inashiki-gun, Ibaraki 305-8687, Japan

In order to assess the soil organic carbon pool for Japanese forest soils, the information from soil surveys were arranged by the soil type in the classification system for Japanese forest soils. The soil type is the lower category in the classification system, and the suitable unit of soil maps in a large scale as 1:50,000. 88 soil types assembled into 25 subgroups.

Variations of the soil type and soil subgroups in the soil organic carbon stocks were examined. Values of soil organic carbon pools varied with a climatic condition at regional scale. Parent materials seemed to have an influence on the stock of soil organic carbon. Topographic conditions also have an effect on the variation of stock level of soil organic carbon within the soil types.

Keywords: soil organic carbon, carbon stock, soil type, soil classification
Influence of alley crop cuttings on production of food crops

RIZAL Svamsul (1), SISWORO Elshe L. (1), RASJID Havid (1), SISWORO Widjang H. (2) and IDIRS Komarudin (3)

(1) Batan, Office of the Deputy Chairman for Technology Application Public Acceptance Center for Research and Development of Isotope and Radiation Technology, Jakarta, Indonesia
(2) Batan, Centre for Research and Development of Isotope and Radiation, Jakarta, Indonesia
(3) Institute of Agriculture Bogor, Indonesia

Most of the land left to be used by the program to reach self-sufficiency in three food crops: rice, soybean and corn in year 2001 are Red Yellow Podsolic (Ultisols and Oxisols). Many constraints have to be overcome in such soils, of which one is low fertility. The program developed by IAEA was to use N-fixing trees such as legume trees to improve soils having low fertility and to be used as an N-source for other crops.

Methods developed in this program were to determine the N2-fixing ability of the legume trees using 15N, which then could be used as one of many criteria to be applied in soils having low fertility. The legume chosen were implemented in an alley cropping system and food crops: rice and corn were planted between the alley. Here too 15N was used to determine the N-contribution of the legume tree-biomass, legume tree biomass + urea, and urea alone.

Results obtained from this program are, the 15N methodology is able to determine the N2-fixation capability of several legume trees grown in the field, G. sepium grown in an alley crop system could be used as an N-source for food crops grown in a rotation system. Upland rice showed good results when grown between alley crops using the alley crop cuttings as an N-source, 15N methodology could be used satisfactorily to calculate the N-partitioning derived from several sources in plants and their efficiency.

Keywords: alley crop, food crop, 15N
Evaluation of site quality index for teak plantation in Thailand

SAKURAI Katsutoshi (1), YAMADA Yuhki (1), TULAPHITAK Thepparit (2), JUNTHOTAI Kriengsak (2), WACHARINTARAT Chongrak (3), TEEJUNTUK Sakhan (3) and SAHUNALU Pongsak (3)

(1) Faculty of Agriculture, Kochi University, Nankoku, 783-8502, Japan
(2) Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand
(3) Faculty of Forestry, Kasetsart University, Bangkhen, 10903, Thailand

Teak plantation (19 stations and 134 sites) managed by Forest Industry Organization (FIO), Thailand was evaluated in terms of the site quality. At the oldest plantation site of each station, detailed soil survey was carried out and the adjacent sites were also used for soil sample collection.

Using the soil chemical, physical, mineralogical data and the topographical characteristics, Site Index estimated from the growth of the tree and the age established (Sl-meas.) was analyzed by the multiple regression method. Sl-meas. of 19 oldest sites was expressed in terms of electric conductivity, soil hardness of the surface 20cm, exchangeable Mg content, and pH. Using this equation, SI value was estimated for all 134 sites surveyed as (Sl-calc.). Resultant Sl-calc. was compared with the Sl-meas. of 134 sites. Even though the correlation coefficient is rather low (r=0.133, p=0.124) due to frequent fire and the site heterogeneity, SI value using the Sl-calc. value could be considered as the site quality index (SQI) estimated from the soil fertility status in situ.

Keywords: site quality index, site index, teak plantation, soil fertility, multiple regression analysis
Soil recommendations for *Araucaria angustifolia* based on soil chemical and physical properties

SILVA Helton Damin da, BELLOTE Antonio F.J., FERREIRA Carlos Alberto and BOGNOLA Itamar Antonio

Embrapa-Florestas, Caixa Postal 319, 83.411-000 Colombo, PR, Brazil

*Araucaria angustifolia*, known as Paraná pine, is a native species that was intensively explored in southern Brazil. Despite its high quality wood, very few areas are being planted with this species. Possible reasons for this lack of interest in this species are that it requires soils of high fertility and little information about its management. The species can be found on different soil types, since those less fertile soils derived from sandstone, occurring in the highland region of Paraná state, to those more fertile soils derived from basalt, in the southwest part of Paraná state and in the western part of Santa Catarina state. The objective of this paper was to select soils better adapted to the growth of *A. angustifolia*, based on soil chemical and physical properties required by the species. Some data were gathered about productivity and silviculture for different soils, resulting in a soil classification, considering the potential yield of soils for *A. angustifolia*, as follows: 1. Soils highly productive (*) - LATOSSOLOS VERMELHOS Distroférricos, with the following variations - LRd3, LRd4, LRd5, LRd6, LRd7, LRa1, LRa2, LRa3 e LRA6, and NITOSSOLOS VERMELHOS Eutroférricos - Tre5 e Tre6; 2. Soils medium productive - NITOSSOLOS VERMELHOS Distroférricos - TRd1, TRd2, TRd3 e TRd5, and NITOSSOLOS HÁPLICOS Distroférricos and Eutroférricos - TBd1, TBd2, TBe1 and TBe2; 3. Soils low productive - NEOSSOLOS LITÓLICOS Eutroficos - Re5, Re7 e Re11; and 4. Soils not recommended for *A. angustifolia* are specially the GLEISSOLOS HÁPLICOS (HG1).

(*) These notations are in accordance with Brazilian soil mapping and classification.

Keywords: soil chemical and physical properties, growth, *A. angustifolia*
A comparison of the carbon balance in the soil between a natural forest and a young teak plantation

TAKAHASHI Masamichi (1), LIMTONG Pitayakon (2), SUKSAWANG Songtam (3) and HIRAI Keizo (1)

(1) Forestry and Forest Products Research Institute, Ibaraki, 305-8687, Japan
(2) Land Development Department, Bangkok, Thailand
(3) Royal Forest Department, Bangkok, Thailand

The objective of this study was to determine the carbon balance in the soils of tropical seasonal forests, especially for teak, which is widely planted over the country. Soil respiration rates in a natural forest (mixed deciduous forest type) were usually higher than in a young (6 years old) teak forest. In both stands soil respiration rates showed clear seasonal patterns, that is high rates occurred in the wet season from April to November and low in the dry season from December to March. The rates were closely correlated with soil moisture conditions. The amounts of total carbon released by soil respiration annually were estimated to be 19 Mg C ha$^{-1}$ for the natural forest and 13 Mg C ha$^{-1}$ for the teak plantation. A small amount of carbon input though leaf and root litter in the teak plantation was assumed to result in lower carbon sequestration in the soil. Indeed, the storage of soil carbon in the natural forest was larger than that in the teak plantation. We concluded that a young teak plantation would not contribute to the accumulation of carbon in the soil.

Keywords: soil respiration, soil carbon storage, teak plantation, mixed deciduous forest, Thailand
Factors affecting soil acidity in Hungary

SIMON Barbara (1), MICHELI Erika (1), VAN SCOYOC George E. (2) and McFEE William W. (2)

(1) Dep. of Agrochemistry and Soil Science, Szent István Univ., 1. Pater K. St., 2103 Gödöllő, Hungary
(2) Dep. of Agronomy, Purdue Univ., West Lafayette, IN 47907, USA

Twelve soil sites in diverse environments (geographical location, topography, parent material, vegetation, precipitation) were selected from the major soil regions of Hungary. Acidification parameters, cation exchange capacity, mineralogy, organic matter content, and spatial variability of surface pH of selected soils were determined. Correlations among soil variables were examined to elucidate the causes of soil pH variability resulting from differences in soil forming factors. Results from this study will be used to improve sampling procedures and provide insight into observations obtained from the Hungarian Soil Information and Monitoring System (TIM). Acidity, depth of the water table and other soil parameters are measured annually by TIM at the 1,237 sites to track changes in the environment and to plan a national conservation program.

Spatial variability of surface pH indicated that multiple samples must be taken in order to determine relatively small temporal changes. The organic matter and the clay content correlated well with the CEC values. The pH (H₂O) and pH (KCl) values were positively correlated and varied with depth as expected in soils derived in a variety of conditions. The relationships of mineralogy, buffering capacity, organic matter content, and E4/E6 ratios will be reported for soil profiles representing the soil regions of Hungary.

Keywords: acidity, Hungary, organic and inorganic colloids, monitoring
Influence of different harvesting methods in the Black Forest on the site ecology: soil physical point of view

VOSSBRINK Joerg, HORN Rainer, BECKER Stefan and KOESTER Petra

Institute of Plant Nutrition and Soil Science, Christian Albrechts University of Kiel, Olshausenstr. 40, 24118 Kiel, Germany

The estimation of consequences of mechanized harvesting procedures during the transformation from pure spruce stands to close-to-nature mixed forest stands in the southern Black Forest is one part of the BMBF project “Future orientated Forest Management”.

The use of heavy harvesting (“Königstiger”) and transport vehicles on Braunerden (Cambisols) and other forest soils in the High Black Forest Region indicates strong soil stresses and soil displacement. These aspects are obtained in a high resolution by the use of SST (Stress State Transducer) and DTS (Displacement Transducer System) systems. Complete harvesting processes with total lengths of 10 minutes were observed with a resolution of 50 units per second. In addition to these mechanized harvesting methods traditional timber transportation by horses were measured. Therefore we are able to compare the influence of completely different working methods on soils and soil structures and we can show the ecological consequences caused by the change from “old fashioned” horse transport to the “modern” use of heavy transport vehicles.

To determine soil mechanical parameters like cohesion, angle of interior friction and precompaction as well as the important plant ecological aspects: bulk density, pore space and pore size distribution, saturated water conductivity and air conductivity undisturbed soil samples were taken. After saturation the samples rings with a volume of 236 cm³ were drained to a water tension of -60 hPa and the precompression was determined by using the oedometer test. Two procedures were taken, the “Standard Soil Compression Test” and the “Multi Step Soil Compression Test”. The shear parameters were determined with a box shear test.

The induced soil stresses caused by harvesting were in general lower than those under comparable tillage soils. These effects are caused by the stabilization of the soil structure by the dense root system. The maximum soil stresses were higher than the mechanical stability of the soils. Therefore the stresses caused sustainable impact on the soil habitat ecology (air permeability...). The degradation of the soil structure caused by stresses exceeding the precompression stress had effects on the pore continuity and leads to blocked porosities.

Keywords: soil stress and displacement, subsoil compaction, hydraulic conductivity, pre-compression stress, forest soil ecology
Heavy metals in forest soils in the Mediterranean karst of Croatia

VRBEK Boris, PILAS Ivan and NOVOSEL Dunja
Forestry Research Institute, Jastrebarsko, 10000 Zagreb, Croatia

The forest ecosystem in central Europe has been exposed to pollution for decades, some forest stands have even been exposed for more than a century. Gases such as SO$_2$ and NOx not only pollute the leaves but also acidify the soil. At the same time, acid in the soil immobilises heavy metals that have accumulated through atmospheric accumulation. Less mobile heavy metals such as lead and to a certain extent copper accumulate through a long period of time in the upper layers of the soil. Depending on the distance from the pollution’s source heavy metals pollution can be measured in lower or higher concentrations. 55 localities of calci-mollic Cambisols in the Croatian karst were analysed. On average 1 kg of soil was collected from each locality for analysis. Heavy metals were ascertained by an atomic absorption spectrophotometer AAS Perkin Elmer 3001 S, using the extracting method with a 2N HCl. The heavy metal content (lead, copper, zinc and cadmium) per mg kg$^{-1}$ was analysed. Research was undertaken in the karst forest ecosystem area in the Mediterranean region of Croatia. From the results obtained, it can be concluded that there is a higher level of lead, and especially cadmium, in the upper layers of the soil (0-3 cm), while in the mineral layer (5-25 cm) this level is somewhat lower. The amount of cadmium is close to the boundary value of 2.0 mg kg$^{-1}$. The mean value for lead in the upper layer is 43.1 mg Pb kg$^{-1}$ while for the mineral area of the soil it is 29.8 mg Pb kg$^{-1}$, for cadmium the mean value in the upper layer is 1.7 mg Cd kg$^{-1}$ while for the mineral layer it is 1.8 mg Cd kg$^{-1}$. According to data from literature, this is the boundary limit of cadmium content in soils. As such, the soil is polluted with cadmium. The mean values for copper are 9.9 mg Cu kg$^{-1}$ for the upper layer and 10.1 mg Cu kg$^{-1}$ for the mineral layer of the soil, while for zinc they are 19.0 mg Zn kg$^{-1}$ for the upper layer and 7.6 mg Zn kg$^{-1}$ for the mineral area of the soil. Copper and zinc can be found in low concentrations in the karst area of the Mediterranean region of Croatia.

Keywords: heavy metals, Croatian karst, forest soils, Calci-mollic Cambisols
Composition and quality of forest soil nitrogen as revealed by $^{14}$N- and $^{15}$N-NMR spectroscopy

XU Zhi-hong (1,4), MAO Xi-an (2), MATHERS Nicole (3,4) and LUO Ren-sheng (2)

(1) Queensland Forestry Research Institute, P.O. Box 631, Indooroopilly, Queensland 4068, Australia
(2) Laboratory of Magnetic Resonance and Atomic Molecular Physics, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, P.O. Box 71010, Wuhan 430071, People’s Republic of China
(3) Faculty of Environmental Sciences, Griffith University, Nathan, Queensland 4111, Australia
(4) Co-operative Research Centre for Sustainable Production Forestry, Australia

Management practices such as plant residue retention and prescribed burning can significantly affect soil organic matter (SOM) composition and thereby the closely-associated carbon and nitrogen (N) cycling processes, which underpin forest ecosystem productivity and sustainability. Humic acid (HA) is an important SOM component and its chemical composition has attracted much attention. The objectives of this study were: (1) to examine the potential use of $^{14}$N nuclear magnetic resonance (NMR) spectroscopy for studying soil HA composition and quality in relation to forest ecosystem management (particularly residue retention in 3 forest plantations, and prescribed fuel-reduction burning in a natural forest ecosystem); and (2) to investigate the structure and composition of HA-N with $^{15}$N-NMR. Here we report the first application of $^{14}$N-NMR spectroscopy to soil HA study, revealing the surprising existence of nitrate-N and ammonia-N in the HAs. This newly discovered HA nitrate-N, though in a relatively low concentration, is closely related to soil N availability as assessed by an anaerobic incubation in the laboratory and responsive to plant residue management regimes in the 4 contrasting forest ecosystems. The HA nitrate-N may be a useful and sensitive biochemical indicator of SOM quality in response to different ecosystem management regimes. In addition, solution $^{15}$N-NMR spectra of both $^{15}$N-labelled and unlabelled soil HAs have highlighted that heterocyclic N is the major component of soil HA-N, which is significantly different from that of amide-N as the dominant SOM-N component currently reported by solid state $^{15}$N-NMR. The importance of these interesting research findings and their practical implications for sustainable forest management are discussed.

Keywords: soil nitrogen composition, soil organic matter quality, $^{14}$N-NMR, $^{15}$N-NMR, forest ecosystem, humic acid
Symposium 41

Techniques for remediation of contaminated soils: physicochemical techniques

Convenor: LEPP Nicholas W.

Co-Convenor: PARKPIAN Preeda

Oral Session
Saturday 17 August 2002
14:00-17:20
Room: Meeting Room 3

Poster Session
Saturday 17 August 2002
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Contaminated groundwater and permeable reactive barriers: use of natural materials for heavy metal immobilization

AMBROSINI G. and HERMANNSS Stengele R.

Institute of Geotechnical Engineering, Swiss Federal Institute of Technology Zurich, ETH Hoenggerberg, CH-8093 Zurich, Switzerland

Permeable Reactive Barriers (PRBs) are geotechnical engineering measures for addressing treatment of groundwater. They consist of reactive media placed in trenches downstream and across the flow path of a contaminant plume. Since the groundwater moves through the structure, the polluting substances are brought into contact with the reactive material. In-situ geochemical or biological processes assure that contaminants are either transformed to non-hazardous compounds or retained in the reactive zone. Hence the implementation purpose of PRBs is to enable environmental remediation and/or prevent that hazardous substances may further spread and contaminate sensitive receptors (e.g. drinking water aquifers).

At present not many materials are used in PRBs implementations, because reactive media have to satisfy geotechnical, geochemical and economical criteria. For this reason the current project attempts to study a range of geochemical aspects with regard to the selection of potentially suitable reactive materials. Commercially available materials of natural origin are actually investigated to obtain information about their effectiveness to remove target contaminants from aqueous solutions. Clays (attapulgite and sepiolite) and zeolites (chabazite and clinoptilolite) are investigated for their ability to immobilize copper and zinc. Iron splinters and bauxite are examined for the removal of hexavalent chrome. Activated coal is used as reference material.

A laboratory apparatus consisting of up to eight parallel running columns is used to perform dynamic flow experiments. The columns are filled homogeneously with reactive material and flowed with synthetic heavy metals solutions. A peristaltic pump is used to ensure constantly flow rates. At regular time intervals pH values and contaminant concentration changes are monitored until complete contaminant breakthrough is achieved.

Hydraulic properties of the packed material, such as porosity and bulk density are also measured, so that breakthrough curves can be plotted in function of flowed pore volumes and contaminant retardation factors be estimated.

**Keywords:** groundwater, remediation, permeable reactive barriers, reactive materials
Soil contamination of 131I on its uptake and transfer factor in sorghum (Sorghum bicolor L. Moench)

BALAMURUGAN J. and RAJAN A. Raja

Radioisotope (Tracer) Laboratory, Tamil Nadu Agricultural University, Coimbatore-641 003, India

Absorption of radionuclides from soil to plant is usually quantified in terms of transfer factor. The vast diversities in soil, climate and agricultural conditions observed in a country like India pose considerable difficulties in predicting the uptake of radionuclides. Further, there is a definite need for a database on the transfer factors for edible parts of food crops. In spite of the short half-life (8.04 days), 131I merits attention owing to its easier food chain pathway and critical exposure to population groups.

This investigation was carried out to study the effect of four levels of 131I contamination of soil on the soil to crop transfer factor (TF) of 131I in different parts of sorghum, a major food crop in India, in a pot experiment with three soils of different textures viz., a sandy clay loam (Typic Haplustert), a sandy loam (Mixed Typic Ustipsamment) and a sandy soil (Typic Ustrovept).

Twelve kg of 2 mm-sieved soil was placed in ceramic pots with a diameter of 30 cm and 30 cm high. The soils were contaminated with 131I, as carrier-free sodium iodide in dilute sodium thiosulphate medium, at four different levels of 20, 40, 60 and 80 kBq kg\(^{-1}\) of soil. The treatments were replicated twice in a factorial completely randomized design. Three plants of sorghum were raised in each pot and harvested at maturity as root, stem, leaf and earhead. The samples were analyzed for 131I activity using a NaI (Tl) gamma ray spectrometer. From the radioassay data, the 131I content, uptake, and transfer factor (TF) were computed.

The results revealed that soil texture had a significant effect on the 131I uptake by stem, earhead and whole plant. The highest 131I uptake by stem, earhead and whole plant was recorded in the sandy loam soil. The other two soils were on par. With the exception of roots, the levels of 131I contamination did not influence the 131I uptake in other parts of sorghum. The highest 131I uptake by root was observed at the lowest level of 131I contamination.

The influence of different levels of 131I on the soil to crop TF in root, stem, leaf and earhead of sorghum was significant. As the level of 131I was increased, the TF in individual parts decreased up to the highest level of application. The non-linear relationship between 131I uptake by sorghum roots and 131I concentration in the rooting medium might have resulted in decreased TF with increasing contamination levels. The trend of TF observed in different plant parts was: root > stem > leaf > earhead.

Keywords: iodine-131, transfer factor, sorghum
The effect of organic amendments and lime on the bioavailability of heavy metals in contaminated soils

BERNAL M. Pilar, WALKER David J., CLEMENTE Rafael and ROIG Asunción

Department of Soil and Water Conservation and Organic Waste Management, Centro de Edafología y Biología Aplicada del Segura, CSIC, Apartado 4195, 30080 Murcia, Spain

A field experiment on bioremediation of land contaminated with heavy metals from a sludge of pyritic mill tailings and acid waters near Aznalcóllar, Sevilla (Spain) is described. The aim is to decrease the plant-available concentrations of heavy metals in the soil to levels which will permit re-establishment of the natural vegetation. In March 2000, the following treatments were applied to a non-calcareous loamy soil: (i) Control; (ii) Cow manure; (iii) Compost; and (iv) Liming in very acid plots (pH < 5.0). One month later Brassica juncea (L.) Czern. was sown, plants were harvested when 7 weeks old (May 2000), and analysed for, Cd, Pb, Zn, Fe and Mn. A liming procedure was carried out until November 2000, when the organic amendments were repeated, and one month later a second crop of B. juncea was sown and grown for 16 weeks (until April 2001). Soil samples were taken from each plot before each sowing and after each harvest. Soil samples were analysed for pH, total and available metal concentrations, organic-C and microbial biomass.

The soil at the experimental site was characterized by high levels of Zn, Pb, Cu and As, in a wide range between plots (Zn = 568 - 1617; Cu = 158 - 839; Pb = 262 - 839; Cd = 0.7 - 5.5; As = 135 - 634 mg kg\(^{-1}\)), whilst pH values varied from 2.9 to 6.8. Plant survival and biomass production of B. juncea depended greatly upon soil pH, with both being much lower in the strongly acidic plots. At the first harvest the pH values were in general lower than at the beginning of the experiment, which revealed the oxidation of pyritic sulfide, from the remaining sludge. Liming carried out from July until November 2000 increased the pH to adequate values for the second crop. The highest concentrations of available metals were found in the soil with very low pH, decreasing quickly at higher pH values. However Cu did not show a clear tendency with respect to pH, indicating that organic matter may be an important factor controlling the available Cu in soil.

Keywords: bioremediation, Brassica juncea, heavy metals, organic matter, phytoextraction
Australian approaches to improving methods for the analysis of TPH contamination in soil

BUDDHADASA Saman C. (1), BARONE Sebastion (1), BIGGER Stephen W. (2) and ORBELL John D. (2)

(1) Australian Government Analytical Laboratories (AGAL), 51-65 Clarke St., South Melbourne, Victoria 3205, Australia
(2) School of Life Sciences & Technology, Victoria University of Technology, P.O. Box 14428, Melbourne City MC, Victoria 8001, Australia

The USEPA SW-846 series of methods, and variations (validated) thereof, for the analysis of TPH contamination in soil have been used to test the dependence of measured TPH levels on method variation in a series of carefully controlled and statistically rigorous experiments. For example, the importance of using a common method, that minimizes evaporative loss, for the simultaneous determination of volatile TPH (C₆-C₉) and BTEX by either gas chromatography flame ionisation detection (GCFID) or by gas chromatography mass selective detection (GCMSD), has been demonstrated. For general TPH analysis, the importance of using baseline-to-baseline rather than peak-to-peak integration is emphasized. Choice of an appropriate calibration standard for volatile TPH has been discussed, and experimental evidence is provided to support the use of n-octane (n-C₈) over BTEX or a BTEX/n-C₈ mixture, for both P&T/GCFID and for P&T/GCMSD. For the determination of semi-volatile TPH (C₁₀-C₃₆) by a given method, varying the extractant solvent (neat dichloromethane (DCM), 1:1 v/v DCM/acetone or isopropanol), the extraction method (sonication versus soxhlet) and detector type (GCFID versus GCMSD), shows that statistically significant variations in TPH measurements can arise with each type of variation. Therefore, it is concluded that for typical soil samples, standardisation (and optimisation) of method, is an important ongoing issue in efforts to provide a more scientific basis for the measurement of TPH contamination in soil.

Keywords: hydrocarbon, analysis, methods, assessment, soil, TPH
Effects of compost amendment on solubility and transformation of copper in soils

YANG X. (1), CALVERT D.V. (2), HE Z.L. (2), STOFFELLA P.J. (2), LI Y.C. (3) and ZHANG M. (2)

(1) Dept. Resource Sci., Zhejiang Univ., Huajianchi Campus, Hangzhou 310029, China
(2) Univ. of Florida, Indian River Res. and Edu. Center, Fort Pierce, FL 34945, USA
(3) Univ. of Florida, Tropical Res. and Edu. Center, Homestead, FL 33031, USA

Copper (Cu) pollution in soils has increased due to mining, smelting, application of Cu-containing chemicals, solid and liquid wastes. The phytoremediation of Cu contaminated soils largely depends on both plant ability to absorb and accumulate Cu and availability and transformation of Cu in the soils. In this study, effects of compost amendment on solubility and transformation of Cu were examined in different soil types. The results showed that Cu concentrations in soil solution decreased at compost rates lower than 0.5%, and dramatically increased at compost rates higher than 0.5%, especially in the acid sandy soil. Copper concentrations in soil solution of the acid sand soil was 10 and 20 times higher than those of the calcareous fine sandy and clayey soils, respectively, at the same Cu addition level (200 mg kg⁻¹). Significantly positive correlations were observed between compost rates and concentrations of phosphorus (P), potassium (K), manganese (Mn), and aluminum (Al), respectively, in soil solution for both the acid sand and calcareous fine sand soils. However, no similar correlations except for Mn and K were noted in the calcareous clayey soil. After 10 weeks of incubation, about 10-85% of added Cu was extractable, depending on soil types, compost rates, and extraction methods. The extractability decreased in the order: Mehlich 3-Cu > DTPA-Cu > 1M NH₄Ac-Cu or DTPA-Cu > Mehlich 3-Cu > 1M NH₄Ac-Cu when compost rates was lower or higher than 0.5%. The Mehlich 3-Cu was dramatically decreased by compost amendment at rates >0.5%. The 1.0 M NH₄Ac-extractable Cu was best correlated with Cu in soil solution, and may be superior to the DTPA or Mehlich 3 method as an indicator of soil Cu availability or toxicity. The results indicate that compost amendment could increase Cu solubility, especially in acid sand soils.

Keywords: copper, compost amendment, extractability, extraction method, solubility, soil type
Phenolics polymerization catalyzed by inorganic soil constituents and its exploitation for remediation

COLARIETI Maria Letizia, TOSCANO Giuseppe and GRECO jr Guido

Dipartimento di Ingegneria Chimica, Università di Napoli "Federico II", P.le Tecchio 80, I-80125 Napoli, Italy

Some inorganic soil components (clay, Fe and Mn oxides) are able to catalyze phenol oxidation, producing water-insoluble polymers. The catalytic activity of soil samples taken from a site contaminated by phenols has been measured in slurry, aerated batch reactors and in packed-bed columns.

Soil activity towards several phenolic compounds has been tested. High reactivity seems limited to o- and p-diphenols. Removal of reactive phenols in the aqueous phase is accompanied by the release of soluble Mn and Fe. The rate of reactive-phenol removal in aerated slurry batch reactors is first-order in both phenol and soil concentration. Cleavage of the aromatic ring seems to be negligible: polymers are mainly aromatic and total organic carbon is constant during each run (no mineralization occurs). Polymers do not adhere to soil particles: polymerization happens in the liquid phase by the coupling of phenoxyradicals or quinones after oxidation catalyzed by metals. Hydrogen peroxide or molecular oxygen can be used as oxidants.

In aromatics-polluted soils, this phenomenon could be exploited to prevent phenol dispersion into the groundwater, thus improving remediation. Indeed, diphenols are common intermediates in the natural degradation of aromatic compounds.

Keywords: phenol, soil remediation, polymerization, clay, iron oxides, manganese oxides
Temperature effect on chlorophenols desorption adsorbed onto allophanic soil

DIEZ C. (1), NAVIA R. (1), BORNHARDT C. (1) and MORA M.L. (2)

(1) Chemical Engineering Department, Universidad de La Frontera. Casilla 54-D. Temuco, Chile
(2) Chemical Science Department, Universidad de La Frontera. Casilla 54-D. Temuco, Chile

A variety of physicochemical mechanisms/forces can be responsible for adsorption of organic compounds in soils. Chemical characteristics, such as polarity, ionic nature, functional groups, and solubility, determine the nature of bonding mechanisms as well the extent and strength of adsorption. Recent studies with synthetic aluminosilicates, like allophane, with and without iron oxides simulating allophanic soil showed a very high phenolic compounds adsorptive capacity and color removal from bleached kraft mill effluent. However, the adsorbed chlorophenols are toxic substances and therefore must be desorbed from the soil matrix and then treated by an adequate system. The aim of this work was to evaluate the effect of elution fluid temperature on the chlorophenols desorption process from allophanic natural and activated soils.

Natural, calcinated and acidified allophanic soils (50% w/w) and sand (50% w/w) contaminated with chlorophenolic wastewater coming from a pulp kraft mill were desorbed using water at different temperatures. In batch procedures, water temperature was varied between 20 to 60°C. The desorption experiments were carried out in triplicate using 50 mL centrifuged flasks adding 40 mL of water to 4 g of each contaminated soil. Tubes were maintained in a thermostated bath for 24 h, shaking every now and then. They were centrifuged at 10,000 rpm, and then analyzed for color and total phenolic compounds concentration. In continuous procedure, glass columns (32 cm length and 5 cm internal diameter) were filled with 400 g of each contaminated soil; the bulk density (p) was 1.26 g L⁻¹. The hot water (60°C) was fed to the columns at a rate of 1.5 mL min⁻¹. Color and phenolic compounds desorption curves were determined in the fixed bed columns. Analytical methods used were according to Standards Methods. The total phenolic compounds (UV phenols) concentration was measured by UV absorbance in a 1 cm quartz cell at 215 nm, pH 6.0 (0.2M KH₂PO₄ buffer).

The soil chlorophenols desorption increased when elution water temperature increased from 20 to 60°C, showing that contaminated soil with chlorophenols can be desorbed using hot water. This fact is very important considering that some industrial processes eliminate hot water to the environment. In continuous procedure, color and phenolic compounds desorption curves showed that natural soil presented a lesser capacity to retain phenolic compounds and color than calcinated and acidified soils. Zeta point charge (ZPC) increased from 5.5 to 7.8 with calcination treatment suggesting that the positive charge was higher in the calcinated soil than in control soil at the pH studied. This fact explains the higher adsorption capacity in this soil. The surface acidity measured by means of pKa1 and pKa2 increased with the calcination treatment indicating that ligand exchange with hydroxyl from neutral sites is the most important mechanism involved in phenolic compounds from mill effluent in adsorption process (Mora et al, 2001). Calcinated and acidified soils presented higher adsorption capacity than natural soils due to less organic matter content and the activation of Al-OH and Fe-OH sites presented in the soil matrix.

Keywords: allophanic soils, desorption temperature, chlorophenols
Factors affecting cadmium solubility in pastoral soils

GRAY Colin (1), McLAREN Ronald (1) and ROBERTS Ants (2)

(1) Centre for Soil and Environmental Quality, Soil, Plant and Ecological Sciences
Division, Lincoln University, PO Box 84, Canterbury, New Zealand
(2) AgResearch, Ruakura Agricultural Research Centre, Private Bag 3123, Hamilton, New Zealand

Soil quality and the sustainability of the national soil resource is recognised as a critical aspect of maintaining New Zealand’s status as a clean, green country. Heavy metal contamination of soil is a threat to this status and it is essential that NZ has effective measures in place to deal with this issue. Heavy metal contamination of soil is usually quantified (and guidelines set) solely on the basis of total metal content. It is generally accepted however that it’s the solubility of a metal which controls its bioavailability. The aim of this study is to derive empirical relationships which can be used to predict solubility of heavy metals (e.g. Cd) from major soil properties such as total metal content, pH and soil organic matter. The results from one trial are given below.

Twenty topsoils were collected from a phosphate fertiliser trial where treatments were 0, 20, 30, 50 and 100 kg P ha⁻¹ applied either continuously for 21 years or for 5 years and then P application ceased. Field moist samples were raised to field capacity and left to equilibrate for 5 days. Soil solutions were extracted after centrifugation of samples for 30 mins at 5,000 rpm and Cd determined by GFAAS. Total Cd was determined by GFAAS after microwave digestion, soil pH was measured in a 1:2.5 soil:water suspension and total carbon (TC) content was determined by LECO CNS 2000 analyser.

The soils sampled from the trial varied in pH (4.9 - 5.4), TC (6.6 - 12.7 %) and total Cd (0.14 - 0.75 mg kg⁻¹). Soil solution Cd concentrations ranged between 4.6 - 32.8 μg L⁻¹. A multiple regression equation which includes terms for the soil pH, total Cd and total carbon could explain 79% of the variation in soil solution Cd concentration equation (1)

Log soil solution Cd = 7.76 - 0.583 pH + 0.812 log total Cd - 1.67 log TC

The solubility of Cd in this set of pasture soils could be predicted using a simple semi-empirical linear regression model which accounts for pH, total Cd and total carbon. The ability of this model to predict the solubility of other metals from other sources of contamination needs to be evaluated for other NZ soils.

Keywords: heavy metals, solubility, prediction
The influence of soil colloidal components on paraquat adsorption in the different soils of Taiwan

CHENG Shuang-Fu (1), HSEU Zeng-Yei (1) and JIEN Shih-Hao (2)

(1) Department of Environmental Science and Engineering, National Pingtung University of Science and Technology, 1 Sheuh-Fu Road, Nei-Pu, Pingtung 91201, Taiwan, ROC
(2) Graduate Institute of Agricultural Chemistry, National Taiwan University, 1 Sec. 4, Roosevelt Road, Taipei 10617, Taiwan, ROC

The sorption of herbicides in soils is mainly influenced by colloid fractions. The objectives of this study were to evaluate the contribution of organic and inorganic colloidal components of soil on paraquat sorption. Three agricultural soils in Taiwan, derived from different alluvial materials, were used in this study. They were Hoshin series (Typic Udorthents), Taikan (Typic Paleustalfs), and Laopi (Typic Hapludults). The surface soils (0-20 cm) were separated clays into coarse (0.2-2.0 \( \mu m \)) and fine (<0.2 \( \mu m \)) fractions with the treatments of removals of organic matter (OM) and free Fe (Fe\(_4\)) oxides. Results indicated that sorption isotherm of paraquat was fitted by Freundlich equation. The adsorbed amount of paraquat increased with the increase of soil clay content. The fine clay fractions gave a higher contribution on paraquat adsorption than the coarse clay fractions, because the fine clay contained more fine sized clay minerals associated with higher colloidal activities like vermiculite. When OM and Fe\(_4\) of the coarse and fine clays were removed by H\(_2\)O\(_2\) and DCB extracts, adsorption increased. The activated functional groups of organic matter increased the adsorption sites with cationic paraquat, especially when the soil pH value was high. Free Fe oxides reduced the adsorption capacities of paraquat by blocking the adsorption sites in the study soils. It is estimated that the affinity order for paraquat in soil colloids is silicate clay>organic matter>free Fe oxide, respectively.

Keywords: paraquat, adsorption, colloidal component, clay, organic matter, free Fe oxide
Studies on soil bioremediation of p-nitrophenol from soils using microbial cultures

SINGH Om Vir and JAIN Rakesh K.

Institute of Microbial Technology, Sector 39-A, Chandigarh-160036, India

Vast quantities of soil and groundwater resources have become contaminated with nitroaromatic compounds including nitrophenols, nitrobenzoates and nitrotoluenes which are extensively used in the manufacture of pesticides, dyes, explosives and drugs etc. Nitrophenols, one of the major contaminants, accumulate during the hydrolysis of several organophosphorus insecticides. In this study, the microbial strains were isolated from a variety of soil, i.e. garden soil, agriculture field soil and pond soil and from unfertilized soil. Higher percentages of p-nitrophenol (PNP) degraders (25-27%) were obtained by soil enrichment techniques with PNP whereas only 14-15% of PNP degraders were obtained from garden rich soil samples by the same technique. However, almost none of the PNP degraders were recovered in the case of pond soil and unfertile soil. On the other hand, a direct soil isolation method showed 8-9% of PNP degraders from agriculture field soil and almost none from garden soil, pond soil and unfertile soil. Further characterization of soils resulted in isolation of two different PNP degraders designated as ORJ-1 and ORJ-2; identification of these organisms is presently underway. In addition, a PNP-degrading strain *Arthrobacter protophormiae* RKJ100 (Chauhan, A., Chakraborti, A.K. and Jain, R.K. (2000) Biochem. Biophys. Res. Commun. 270, 733-740) available in the laboratory was employed for PNP degradation studies in shake cultures under aerobic conditions. In these studies, approximately 95% PNP depletion was achieved with concomitant release of nitrite molecules under shake flask conditions. To analyze the natural degradation ability of all three organisms, soil microcosm studies in the laboratory were performed. Further various physical and chemical parameters, i.e. pH, temperature, incubation time, aeration rate, flooded and non-flooded soil conditions, organic and inorganic salt constituents, various soil textures etc. are being analyzed for total bioremediation of PNP from soil.

**Keywords:** organophosphorus pesticide, p-nitrophenol, bioremediation, soil microcosm, *Arthrobacter protophormiae*
Kinetics of transformation of applied cadmium in alluvial soils

KHURANA M.P.S., KANSAL B.D. and SINGH Dhanwinder

Department of Soils, Punjab Agricultural University, Ludhiana, India

Disposal and utilization of industrial/municipal waste water for irrigation and a source of essential plant nutrients result in a serious problem of metal loading in the soil environment. This important aspect of pollution is going to be a potent threat in the coming years causing health hazards. Contamination of agricultural land with heavy metals including cadmium has implications to the marketability of crops in the highly competitive international market. Separation of various chemical forms of an element in soils has been useful in studying the release and retention of elements in soil to plant. Organic manure and other elements are used for as a remedy of toxic metals including Cd in soils. However, information available on the transformation and availability of Cd in the presence of organic manure is not only scanty but also controversial in nature. Incubation study at field capacity was carried out on a loamy sand soil to investigate the effect of Cd application (0, 10, 20, and 40 mg kg\(^{-1}\) soil) on its various fractions in the presence (20 t ha\(^{-1}\)) and absence of farm yard manure (FYM). The sequential procedure adopted by Singh et al. (1998) with some modification was used to partition Cd into various fractions namely exchangeable + water soluble (EX + WS), carbonate bound (CARB), Mn oxide (MnOX), Organic (OM), amorphous Fe oxides (A FeOx), Crystalline Fe oxide (C FeOX) and residual. Samples were drawn at 1, 3, 7, 21, 42, 63, 84 and 105 days. All the fractions of Cd in soils increased significantly with cadmium application irrespective of FYM. The EX+WS pool decreased which indicated that this fraction shifted to insoluble oxidisable fractions. An increasing trend was observed in the amount of CARB–Cd, MnOX–Cd, OM–Cd and A Fe OX–Cd but the amount of Cd in C FeOX and RES fractions did not show any change with time. Applied Cd moved to Mn OX–, OM–, A Fe OX–fractions from RES–, CARB– and C Fe OX– with FYM. The substantial amount of added Cd collectively was present in carbonate and oxides forms which conclude that higher rates of Cd pollution could be tolerated. Various kinetic models used to describe the extraction of native and added cadmium were Zero–order, First–order, Pseudo first–order, Simultaneous first–order, Two–constant rate, the Elovich, the Parabolic diffusion and Polynomial. The application rate of 20 mg Cd kg\(^{-1}\) soil was chosen for fitting the above mentioned models both in the presence and absence of FYM. As Crystalline Fe Oxides (C FeOx) and Residual fraction (RES) were least affected by time, any of the above models were unable to describe the kinetics processes in these fractions. These models indicated that in most of the situations, the best results were obtained with Two rate constant and Pseudo first order models except OM and A Fe OX– fractions. The values of rate constants for various fractions indicated that FYM might mitigate the toxic effect of cadmium. Thus FYM appears to be a promising technique in checking the transfer of Cd into the food chain.

Keywords: kinetics models, FYM, Cd fractions
The use of physical and biological methods to remediate soils at a former Tar Distillery

LEPP Nicholas W., (1), EDWARDS Robert (1), COOK J.D. (2), ROUTLEDGE Philip (2) and ROUTLEDGE Robert (2)

(1) Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK
(2) J. Routledge and Sons, Tanhouse Lane, Widnes Cheshire WA8 0WZ, UK

This paper describes the successful remediation of a former Tar Distillery, located in Merseyside, UK, using a structured combination of physical and biological methods. The site was heavily contaminated with a complex mix of organic pollutants (mainly TPH’s, PAH’s and phenols) together with tar residues and heavy metals. Tar residues, tar-impregnated building materials and substrates contaminated with metals were removed to landfill. The remainder of the soil was cleared of concrete and other demolition waste, then mechanically graded into 3 fractions (Coarse, medium and fine). Analysis showed that the coarse and medium fractions contained levels of the key pollutants (Phenols and PAH’s) that were below the acceptance criteria established for the site. These materials were stockpiled to backfill the site during subsequent development. The fine fraction was significantly contaminated with both Phenols (>30 mg kg⁻¹) and PAH’s (>1800 mg kg⁻¹). Acceptance criteria for these were Phenols (<20 mg kg⁻¹), PAH’s (<1,000 mg kg⁻¹). The fine fraction was stockpiled and then constructed into windrows (3m x 3m x 5m). Regular turning over the summer months (May – October) resulted in a significant reduction in TPH’s, PAH’s and phenols to below consent levels for the proposed end use of the site (commercial development). Smaller, experimental windrows that incorporated a range of amendments (lime, synthetic zeolites, NPK fertiliser) showed no significant acceleration or retardation of the remediation process when compared to the regular windrows. Experimental non-aerated biopiles, seeded with PAH-degrading bacteria, were much less effective for remediation, failing to reduce PAH’s and phenols to below the consent levels after 18 months. PAH concentrations in leachates from the large windrows were 0.11 mg L⁻¹. Initial acceptance criteria for leachate PAH concentrations were 2 µg L⁻¹, subsequently amended to 500 µg L⁻¹. These criteria could not be met due to the composition and concentrations of low MW PAH’s present in the soil and the criteria adopted for total soil PAH concentrations; their solubility would give rise to much higher PAH concentrations in the aqueous phase. This has now been resolved and the site has passed all acceptance criteria for its projected end use as a retail site.

Keywords: bioremediation, PAH, phenol, Tar Distillery, zeolites, brownfield
In situ fixation of metals and metalloids using iron-rich co-products

LOMBI Enzo, ZHAO Fang-Jie and MCGRATH Steve P.
Agriculture and Environment Division, IACR-Rothamsted, Harpenden, Herts, AL5 2JQ, UK

Low-input remediation technologies are urgently required to provide cost-effective solutions for soils contaminated with heavy metals. These technologies have to be technically and economically feasible and satisfy the legislative requirements for soil remediation.

In-situ fixation or inactivation of metals using soil amendments has been proposed for the remediation of polluted soils. This approach is based on the ability of some materials to adsorb and eventually fix heavy metals. Therefore, the total concentration of metals in soil is not reduced but their speciation and mobility is significantly changed.

In the UK, the recently published Environmental Protection Act 1990: Part IIA introduced the concept of “pollutant linkage” which establishes a link between a contaminant and a receptor by means of a pathway. Remediation is achieved by removing or treating the pollutant, breaking or removing the pathway or protecting or removing the receptor. In situ fixation aims to treat the pollutant in a way that the receptor is protected.

The present work focuses on the use of Fe-rich co-products, originating from different industrial processes, as fixing agents for heavy metals and metalloids. A series of experiments were performed in microcosms to establish the potential of several co-products, including red-mud, red gypsum and water sludge, to immobilise heavy metals and arsenic. Several chemical methods were used to determine the mobility of metals with special attention to metal concentration and speciation in soil solution and metal fluxes. Furthermore, the effect of these treatments on various biological endpoints (plants and microorganisms) was investigated in order to assess whether the remediation treatment satisfies the legislative requirements in terms of effects on environmental receptors.

Also, the results of a field scale application of this technology are reported. The field trial is conducted in an area severely contaminated by Cd, Zn and Pb due to the activity of a nearby Zn smelter. Total concentrations of Cd, Zn and Pb in the selected area were up to 70, 4000 and 5000 mg kg\(^{-1}\) respectively. Red mud, a co-product of the aluminium industry, was applied at two different rates corresponding to 3 and 5% on a w/w basis. The field experiment was designed as large randomised blocks and the application of red mud was made with equipment adequate for large-scale applications. Finally, the efficiency of the remediation treatment was determined by means of chemical assessment and biological assays.

Keywords: heavy metals, fixation, Fe-rich materials, red mud
Amelioration of copper toxicity in soil through bio-solid compost application

MANI Senniappan (1) and BOLAN N.S. (2)

(1) Dept. of Soil Science, Tamil Nadu Agricultural University, Coimbatore, India
(2) Institute of Natural Resources, Massey University, Palmerston North, New Zealand

Copper (Cu) is one of the essential elements for plants, animals and humans. Copper is associated with soil organic matter, oxides of iron and manganese, soil silicate clays, and other minerals. Recently, there has been increasing concern about Cu accumulation due to the application of copper fungicide (Bordeaux mixture) in orchard soils, especially under organic cultivation. Application of bio-solid has often been shown to increase the retention of cations, resulting in reduced plant availability of heavy metal cations.

The objectives of the study are to examine the effect of bio-solid compost on the transformation of Cu in soil and to study the performance of mustard in Cu contaminated soil at different levels of bio-solid compost.

The study was conducted at Massey University, Palmerston North, New Zealand. The soils of Deer farm (Tokomaru silt loam) were used for the glasshouse experiment. The treatments included six levels of Cu (0, 25, 50, 100, 200, and 400 mg kg\(^{-1}\)) and four levels of bio-solid compost (0, 2, 5, and 10%). Mustard (Brassica juncea) was grown as a test crop. Copper-free nutrient solution was given twice a week. The crop was grown for a period of six weeks and the dry matter yields of shoot and root were recorded. The plant samples were digested (shoot and root) with concentrated nitric acid and the total Cu concentration was measured by atomic absorption spectrophotometry. The incubated soil samples were analysed for exchangeable, organically bound, oxide bound and residual Cu fractions and water soluble and soil solution Cu (ionic and total Cu).

The results showed that there was no significant difference in the dry matter yields of shoot and root up to 50 mg Cu kg\(^{-1}\) level. Above this level, the dry matter yield decreased with increasing levels of Cu. The shoot and root dry matter yields of mustard increased with increasing levels of bio-solid compost application at all levels of Cu. The Cu concentration in both shoot and root increased with increasing levels of Cu. Addition of bio-solid compost decreased the concentration of Cu in plants. The concentration of different Cu fractions in soil increased with increasing levels of Cu. Application of bio-solid compost decreased the concentration of Cu in all fractions except the organic bound Cu. There was a positive relationship between free Cu in soil solution and Cu concentration in shoot and root. Application of bio-solid compost decreased the concentration of free Cu in soil solution.

It is concluded that high levels of Cu enhanced the concentration of Cu in mustard resulting in Cu toxicity. Copper toxicity to mustard could be alleviated with conjoint application of bio-solid compost. The bio-solid compost addition to Cu contaminated soils reduces the Cu content in soil solution and exchangeable complex.

**Keywords:** copper, amelioration, toxicity, bio-solid
In situ remediation of metal-contaminated soils: chemical, biological and isotopic assessments

McLAUGHLIN Mike (1), FERGUSON Verity (1), HAMON Rebecca (1), McGRATH Steve (2), LOMBI Enzo (2), BROWN Sally (3), CHRISTIANSEN Barbara (3), VANGRONSVELD Jaco (4) and RUTTENS Ann (4)

(1) CSIRO Land and Water, PMB 2, Glen Osmond, SA 5064, Australia
(2) IACR Rothamsted, Harpenden, UK
(3) University of Washington, Seattle, WA 98195, USA
(4) Limburgs Universitair Centrum, Diepenbeek, Belgium

In-situ remediation is a low-cost and potentially effective tool to minimise environmental and human health risks of metal-contaminated soils. The principle of the procedure is that the total concentration of metal in the soil is unchanged in the remediation process, but that the bioavailability of the metal is much reduced. This is reflected in either a reduction in the solution activity or concentration of metal, in effect an increase in the solid:liquid metal partition coefficient. The mechanisms are not well understood, but may involve a precipitation of a discrete and less soluble form of the metal (e.g. Pb remediation using phosphate to form pyromorphites), an increase in the energy of metal adsorption, or entrapment of metal in the remediation material. This international inter-laboratory program of research investigated the effectiveness of in-situ remediation of soils contaminated by arsenic (As), cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn), measuring changes in soil and soil solution chemistry, response of plants and soil microbiota and investigated mechanisms of remediation. A total of 14 contaminated soils from Europe, the USA and Australia were collected and treated with remediation materials including lime, phosphorus (P), red mud, red gypsum, cyclonic ashes, biosolids, water treatment residuals (alum sludge) and kaolin amorphous derivatives (KAD). No one single material could be singled out as being successful for all soil contamination scenarios. Soil solution concentrations of cationic metals were decreased by all treatments, with P treatments and some red muds being the most successful. However, use of some red muds and water treatment residuals may cause problems of P deficiency in plants due to their high P retention capacities. Phytotoxicity of metals was also reduced to varying degrees by the amendments used, with P treatments often performing best. Responses of soil microorganisms to the amendments were in line with plant growth responses. Examination of remediated soils by $^{109}$Cd and $^{65}$Zn isotope dilution procedures indicated that several treatments were effective in sorbing/precipitating metals into forms not in equilibrium with the soil solution, but that for many amendments the mechanisms were reversible as soil pH fell back to control levels. By contrast, P treatment removed metals from labile pools by mechanisms relatively insensitive to soil re-acidification.

Keywords: bioavailability, soil solution, fixation
Molecular analysis of hydrocarbon degrading bacteria in Thai soils contaminated with petroleum products

SUPAPHOL S. (2), PANICHSAKPATANA S. (1) and O'DONNELL A.G. (2)

(1) Faculty of Agriculture, Kasetsart University, Bangkok, Thailand
(2) Department of Agricultural and Environmental Science, University of Newcastle, Newcastle upon Tyne, United Kingdom

Bioremediation is often used for the *in situ* remediation of petroleum-contaminated soils. The primary focus of this study was to characterise changes in the indigenous microbial community of soils contaminated with diesel and lubricant following addition of inorganic nitrogen and phosphorus. Soils from a petroleum storage facility in Bangkok, Thailand were sampled from the top 15 cm of the soil in September 2001 and used to construct laboratory microcosms. Following the application of inorganic N and P, nucleic acid methods (DNA/RNA extraction, amplification and denaturing gradient gel electrophoresis) were used to monitor changes in bacterial community structure. DGGE of the rDNA and the reverse transcribed rRNA showed that following fertiliser addition the microbial communities, as judged by differences in banding pattern, changed markedly over the 42 day incubation period. This paper quantifies these changes and shows how using a combination of DGGE and multivariate pattern recognition techniques on the DGGE profiles obtained using rDNA and reversed transcribed rRNA the active microbial taxa can be identified and sequenced. The possibilities of using this approach to select prospective organisms as bioaugments or as candidates for biosensors for contaminated soils will be discussed.

**Keywords:** bioremediation, DGGE, hydrocarbon degrading bacteria, petroleum contaminated soils
An electrokinetic removal of copper and chromium from wood preservation industry contaminated soil

RIBEIRO Alexandra (1), VELIZAROVA Emiliya (1), REFFEGA Antonio (1) and CASTRO Adelia (2)

(1) Departamento de Ciências e Engenharia do Ambiente, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, P-2829-516 Caparica, Portugal
(2) Departamento de Pedologia, Estacao Agronomica Nacional, 2784-Nova Oeiras, Portugal

High levels of copper and chromium have been frequently found in soils in the vicinity of wood impregnation plants due to metal leakage from newly treated and out of service poles, storage places for tanks with preservatives and deposition of sludge associated with dissolved Cu and Cr salts. During the last years, there has been growing interest in the electrokinetic (EK) remediation technique as an emerging method for removing charged contaminants. Systematic studies have been started in our laboratory on the mechanism and the factors controlling the process of removal kinetics and efficiency in different polluted materials, including soils (1-3).

The experiments were carried out in a laboratory cell, developed at the Technical University of Denmark (4), in which the soil was placed in the central compartment, separated from anode and cathode compartments by two passive membranes. In order to get a better insight into the heavy metals availability and mobilisation within the soil compartment, samples were periodically taken by means of a soil solution sampler (Prenart Equipment ApS, Denmark). Two solutions of 0.1 M NaNO₃ were recirculated through both electrode compartments and an electric current density of 0.2 mA cm⁻² was maintained during 35 days of operation by an external power supply.

The results showed that the elements studied were mainly accumulated in the soil solution, followed by the anolyte and the catholyte. Due to water dissociation in the vicinity of the anode, acidic front was generated with a direction from the anode towards the soil compartment. This front favours the mobilisation of the metals and their removal either as free cations or metal complexes depending mainly on the pH value. The results of the experiments performed reveal that the EK technique promotes mainly the liberation of the "soluble and exchangeable" fraction of the metals from the treated soil. This fraction is usually associated with the available part of the total content of groundwater heavy metal pollution and represents the most serious ecological problem. Thus, we have confirmed that the EK technique is a promising solution to the removal of heavy metals from polluted soils.

Keywords: Urbic Antrosol, heavy metals, remediation
Dynamic changes of Cd fractionations in different soils after waterlogged incubation

WANG K.R. (1), XIA Y. (1) and SELIM H.M. (2)

(1) Changsha Institute of Agricultural Modernization, Chinese Academy of Sciences, Changsha, Hunan 410125, China
(2) Agronomy Dept., Louisiana State Univ. Agric. Center, Baton Rouge, LA 70803, USA

This paper studied the dynamic changes of Cd fractionations in six Chinese soils derived from different parent materials after waterlogged incubation. The results showed that the EXC-Cd content would descend while CA-Cd, FeMnOx-Cd and OM-Cd contents would increase during the waterlogged incubation period. There would be different dynamic changes of Cd fractionations because of the effects of different parent material, soil pH, OM content, available P content and incubation time. By simulating Cd fractionations change in the soils with six kinetic equations, we found that parabolic diffusion equation and power function equation could better describe the dynamic changes of EXC and other low active fractions of the soils Hap-Stagnic Anthrosols, Fel-Stagnic Anthrosols, Gen-Stagnic Anthrosols and Fel-Stagnic Anthrosols, respectively, while the dynamic changes of Cd chemical fractionations of Fec-Stagnic Anthrosols and Ust-Sandic Entisols could be better described by Zero-order equation and Simple Elovich equation.

Keywords: Cd fractionations, soils, waterlogged incubation, dynamic change
Pig manure as co-composting material for remediation of PAH contaminated soil

WONG J.W.C., WAN C.K. and FANG M.

Department of Biology, Hong Kong Baptist University, Kowloon Tong, Hong Kong SAR, P.R. China

Bioremediation of polycyclic aromatic hydrocarbons (PAHs) contaminated soil by composting treatment was performed to evaluate the removal efficiency of PAHs from composting mass using pig manure as organic amendment. Pig manure at three different ratios of 12.5%, 25% and 50% (w/w dry weight basis) was amended with a loamy soil spiked with 100 mg kg\(^{-1}\) each of three PAHs (phenanthrene, anthracene, and pyrene). The biodegradation of these PAHs was monitored in a bench-scale computer controlled composting system. An increase in pig manure amendment only improved the removal of pyrene, but had no obvious effect on phenanthrene and anthracene. Maximum removal rate at the end of composting accounted for 90% of the initial concentrations of PAHs at a pig manure application rate of 25%. Another series of experiments was performed to evaluate the effect of non-ionic surfactant addition during composting on PAHs removal for 25% pig manure amended soil spiked with 400 mg kg\(^{-1}\) each of the three PAHs. Tween-80 at a concentration of 20, 40 and 100 mg kg\(^{-1}\) soil were separately added at day 0 and day 14 to the PAH-spiked soil. The results showed that the PAHs degradation rate was faster in soil with surfactant addition than without surfactant addition, while the addition of surfactant at day 14 had the highest PAHs removal efficiency. The enhanced biodegradation of PAH was obtained for all treatments, except 100 mg kg\(^{-1}\), regardless of time of addition. This was probably due to the ample supply of surfactants as a carbon source for soil microorganisms. This study suggested that pig manure was effective in enhancing the PAHs removal during composting while surfactant addition would further enhance the degradation of PAHs. However, carbon balance should be considered when optimizing their concentration in order to enhance bioremediation of PAHs contaminated soil using compost technology.

**Keywords:** composting, pig manure, PAHs, surfactants, biodegradation, pyrene
Symposium 42

Techniques for remediation of contaminated soils: biological techniques

Convenor: McGRATH Steve P.

Co-Convenor: PONGSAKUL Pichit

Oral Session
Wednesday 21 August 2002
8:30 - 11:50
Room: Meeting Room 2

Poster Session
Tuesday 20 August 2002
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Natural remediation processes:
bioavailability interactions in contaminated soils


(1) University of Georgia, Savannah River Ecology Laboratory, Aiken, SC 29802, USA
(2) Massey University, North Palmerston, New Zealand
(3) CSIRO, Glen Osmond, Australia
(4) Brookhaven National Laboratory, Upton, NY, USA
(5) Limburgs Universitair Centrum, Diepenbeek, Belgium
(6) Universität für Bodenkultur, 1180 Vienna, Austria

Metals are very common contaminants at 'Superfund' sites in US, and similarly contaminated sites worldwide. Long-term deposition of metals in soils can lead to accumulation, transport and biotoxicity/zootoxicity caused by mobility and bioavailability of significant fraction of the metals. Because of their immutable nature strict natural remediation processes alone may not be successful in mitigating the risks from metals at these sites. However, accelerating these processes, i.e., accelerated natural remediation that ultimately immobilizes the metals might be a viable option. Applications to soils of certain soil amendments that enhance key biogeochemical processes in soils that eventually immobilize metals have already been demonstrated in Europe and North America on a field scale. Case studies using lime, phosphate and biosolid materials have demonstrated, under field conditions, accelerated natural remediation, resulting in substantially improved vegetation growth, enhanced microbial population and diversity, and reduced off site metal transport. Depending on soil/hydrogeochemical properties, source term and metal form/species, and land use, the immobilization efficacy induced by such accelerated natural remediation may be enduring. While long-term stability of certain metal complexes such as metal pyromorphites has been shown in model systems, the influence of plant roots and its microbial and mycorrhizal association on such stability is unknown. A suite of chemical and biological tests is available to monitor the efficacy of accelerated natural remediation.

Keywords: natural attenuation, metals, bioavailability, risks, biogeochemical processes
Anaerobic bioremediation of toxaphene-contaminated soil: a practical solution

ALLEN Harry L. (1), MANDEL Robert M. (2), DUNKLEMAN Tom (2), SHANE Dan (2), TORRES Michael (3) CROUSE Daniel G. (4) MILLER T. Ferrell (5) and HOPINKA Douglas (6)

(1) U.S. EPA, ERTC, Edison, NJ, USA
(2) U.S. EPA, Region 9, San Francisco, CA, USA
(3) U.S. EPA, Region 6, Dallas, TX, USA
(4) EarthTech, Inc., Mechanicsburg, PA, NJ, USA
(5) Roy F. Weston, Inc., REAC, Edison, NJ, USA
(6) Pueblo Office of Environmental Protection, Albuquerque, NM, USA

For the past several years, studies have been conducted to develop an anaerobic solid-phase bioremediation process for removal of toxaphene from contaminated soil. Medium development studies in bench-scale reactors indicated that adding blood meal promoted the rapid degradation of toxaphene and DDT under anaerobic conditions. Recipes were evaluated in field-scale studies at four general locations: (1) Navajo Vats sites - several livestock dipping facilities on the Navajo Nation in Arizona and New Mexico, (2) Sanders Aviation - an abandoned aerial pesticide applicator facility located in Arizona, (3) Ojo Caliente Dip Vat and three other livestock dipping facilities on the Zuni Nation in New Mexico, and Gila River Indian Community - an aerial pesticide applicator site in Arizona.

In field-scale studies conducted at the Navajo Vats site, results showed that over 75% of the initial level of toxaphene (291 mg kg⁻¹) was degraded in as little as 33 days in test (nutrient amended) reactors, while there was no change in toxaphene concentration in control (unamended) reactors even after 300 days.

Additional field studies were conducted during treatment of 22 livestock dipping sites to clean up toxaphene residues. Toxaphene residues varied widely, with levels ranging from 4 to 100 mg kg⁻¹. Eleven of the sites had initial toxaphene levels of 20 mg kg⁻¹ or higher. At nine of these sites, toxaphene reduction levels ranged from 48% to 91%. At the other two sites, low to negligible toxaphene removal was observed (29% and 6.7%, respectively).

Similar results were found in field studies at the Sanders Aviation site. Results showed that initial toxaphene concentrations, ranging from 930 to 1,530 mg kg⁻¹, were reduced by 94% to 95% in 216 days using recipes containing blood meal.

In more recent studies at the Ojo Caliente Dip Vat site, initial toxaphene levels (14 mg kg⁻¹) were reduced by 70% in as little as 14 days. The Laahty Family (86% in 31 days), Henry O (68% in 71 days), and Old Acoma Stockyard (no performance data available) sites were treated cost-effectively. The Gila River Indian Community site was studied during treatment. Results showed that initial toxaphene concentrations ranging from 29 to 211 mg kg⁻¹, were reduced by about 90% in less than 200 days using a very lean (0.5% blood meal) nutrient recipe.

Keywords: bioremediation, toxaphene, soil, anaerobic, pesticides, native Americans
The use of different earthworms for processing agricultural wastes in Siberia

BABENKO Andrei

Tomsk State University, Lenin av., 36, Tomsk 634050, Russia

The present article centers on the role of different earthworms (Lumbricidae) in agricultural waste processing in the climate conditions of West Siberia. We examined the influence of three earthworm species (local populations of Eisenia foetida, Allolobophora caliginosa and Lumbricus rubellus) on agricultural waste decomposition. Experiments and observations were conducted in 1997-2000 nearby Tomsk, southwestern Siberia. The different wastes (dung, mushroom wastes, sewage sludge) and its combinations were used for studying earthworms activity. The populations of earthworm species were rearing as separately as in different combination (E. foetida + A. caliginosa, E. foetida + L. rubellus). The growth of earthworm population, rate of compost production and waste decomposition were measured. The key factors affecting earthworm activity are discussed.

Keywords: earthworms, agricultural wastes, waste decomposition, Siberia
Biotransfer possibilities of selenium from plants used in phytoremediation

BANUELOS G.S. (1), VICKERMAN D.B. (2), TRUMBLE J.T., SHANNON M.C. (3), DAVIS C.D. (4) and FINLEY J.W.

(1) USDA-ARS, Water Management Research Laboratory 9611 S., Riverbend, Parlier, CA 93848 USA
(2) Department of Entomology, University of California, Riverside, CA 92521 USA
(3) USDA-ARS, PWA, 800 Buchanan, Albany, CA 94710 USA
(4) USDA-ARS, Grand Forks Human Nutrition Research Center, Grand Forks, ND 58203 USA

Plant species are generally selected for the phytoremediation of Se based on their ability to manage Se levels in the soil. As part of our efforts to safely reduce Se contamination in the western U.S., we are investigating the biotransfer of accumulated Se by the plant in several phytoremediation systems. In studies I and II, we evaluated biotransfer of Se from two Se-accumulating plant species, Brassica (mustard) and Atriplex (saltbush), to insects (cabbage looper, Tricholusia ni and beet armyworm, Spodoptera exigria) attracted to the plants. Mortality, deterrence, and biomagnification of Se in both insects was examined. We determined that the feeding behavior of food chain consumers was affected not only by the concentration and species of Se stored in the plant tissue, but also by the mobility of the insects and choice of feed available. In studies III and IV, sheep and dairy cows were fed Se-enriched Brassica and Medicago (alfalfa) plants as part of their feed ration. The amount of Se accumulating in various tissues of each animal, as well as the amount of Se present in the milk form the cows, was determined. The animals did not exhibit any toxic symptoms, but did have increased levels of Se in most tissues sampled (e.g., organs, blood, urine, feces). Selenium levels did not increase in the milk. In study V, we evaluated biotransfer of Se from another Brassica crop (broccoli) to rats in order to determine efficacy of Se for reducing colon cancer. We found that Se-enriched plant material was more effective than inorganic sources of Se for preventing precancerous colon lesions. Results from all studies clearly show that biotransfer of Se is an important occurrence in phytoremediation systems, and Se absorbed by plants can be transferred biologically in an intentional or unintentional manner to insects and animals.

Keywords: phytoremediation, biotransfer, selenium
The influence of oil products on amilolytic microbial community of soil

HALIMOV Erkin M. (1) and GUZEV Vladimir S. (2)

(1) Samarkand State University, Uzbekistan
(2) Moscow State University, Russia

The experiment showed that in unpolluted soil conditions microscopic fungi such as *Humicola grisea* and actinomycet such as *Streptomyces cfr. griseus* were the dominant species of amilolytic microbial community of soil; some frequently observed were bacterium such as *Bacillus polymyxa* and fungis such as *Chaetomium globosum* and *Aspergillus ustus*, very few or seldom observed were mycromycets such as *Oidiodendron griseum*, *Arthrobotrys oligospora*, *Mucor plumbeus*, *Penicillium funiculosum*, *Penicillium vermiculatum* and *Stachybotrys alternans*. Addition of benzene in concentration of 0-2000 mL kg\(^{-1}\) of soil did not change structure and composition of soil community. Higher concentration of benzene (2-20 mL kg\(^{-1}\) of soil) slowly decreased the number of dominant species and frequently observed ones of control treatment, which led to an increase of the number seldomly observed species. But, frequently observed *Ch. globosum* and seldomly observed *St. alternans* became dominant in community. At the rate of benzene of 10 mL kg\(^{-1}\) soil\(^{-1}\), appeared another representative of actinomycets appeared (*Streptomyces* sp.). At the concentration of benzene of 20 mL kg\(^{-1}\), dominant species were: early not observed micromycet and *Streptomyces* sp.. Complete discrimination of growth and development of microorganisms at 500 mL kg\(^{-1}\) of soil rate of benzene not observed. The same results were obtained during application of diesel fuel into soil. Amilolytic community did not change at the rate 1500 mL kg\(^{-1}\) soil\(^{-1}\), but higher rates caused a change in the structure of community; decreased number of *H. grisea* and *Str. cfr. griseus*, at the same time increased number of *B. polymyxa* and *Asp. ustus*. At the rate 3 mL kg\(^{-1}\) of soil and higher they become dominant. But, at concentration 35 mg kg\(^{-1}\) soil\(^{-1}\) second one practically was not observed, and *B. polymyxa* became frequently observed. The microscopic fungi *M. plumbeus* and *St. alternans* became dominant at concentration of 35 mL kg\(^{-1}\) soil\(^{-1}\), which were seldomly observed before in unpolluted soil. Complete discrimination growth and development communities microorganisms after application of diesel fuel was not observed. The structure and composition of microbial community remained constant at application of motor oil at the rate 0-150 mL kg\(^{-1}\) soil\(^{-1}\), and hudron 35 mg kg\(^{-1}\) of soil. The changes occurred during application of benzene and diesel fuel, were not documented during motor oil and hudron application. In contrary, increasing concentration of motor oil and hudron caused to complete discrimination of growth and development of amilolytic microorganisms. In this way, there are range of rates for all oil products, where amilolytic microbial community remains unchanged. But, this range is different for other product. If for benzene and diesel fuel is no more than 2 mL, but for hudron-35 mg and for motor oil - 150 mL kg\(^{-1}\) of soil. More higher rates benzene and diesel fuel result to reshaping of community, and higher rates of motor oil and hudron caused complete discrimination of growth and development of amilolytic microbial community.

**Keywords:** pollution, community, amilolytic, oil-products, microscopic fungi
Reduction of the cadmium transfer in the soil-plant system by the inoculation of micro-organisms: optimisation of the process using immobilised cells

JÉZÉQUEL K., LEBEAU T., BAGOT D. and FABRE B.

Laboratoire Gestion des Risques et Environnement, Université de Haute-Alsace, Antenne de Colmar, BP 568, 68 008 Colmar cedex, France

For economical and also technical reasons, the cleaning up of agricultural soils contaminated by cadmium - relatively low levels, but potentially highly contaminated areas - cannot be realised by the conventional treatments used in the industry. An alternative to cleaning up consists in immobilising the pollutant in the soil in order to avoid high and uncertain transfers to the solution of the soil, and therefore to plants or in the ground water. The adsorption properties of minerals or organic amendments have already been exploited (Bailey et al., 1999) but the treatment must be renewed periodically and cadmium leakage may occur in the solution of the soil in particular climatic conditions due to high biological activity in soil (Morel and Guckert, 1984). Another way to immobilise Cd consists of using cadmium biosorption capacities by viable micro-organisms despite the fact that they constitute a minor fraction of the total solid mass of the soil (Ledin et al., 1999). When micro-organisms are symbiotic to plants, a reduction of the Cd transfer has already been shown (Karagiannidis and Nikolaos, 2000). With non-symbiotic plants, soil inoculation with micro-organisms is necessary. Nevertheless, the success of the inoculation depends on the survival of the micro-organisms that may be improved by their immobilisation into a carrier. It protects them from natural competition within the soil microflora (Hall et al., 1998).

For the present work, we tested 3 micro-organisms: the bacterium ZAN-044 (Valentine et al., 1996), the actinomycete R25 (Amoroso et al., 1998) and the basidiomycete Fomitopsis pinicola (Gabriel et al., 1996). These micro-organisms were inoculated in non-sterile and sterile soil microcosms enriched with cadmium and incubated at 20°C and 28°C. We compared the efficiency of various inoculation processes using free and immobilised cells. In the last case, the microbial cells were entrapped in alginate beads. We tested various alginate concentrations and various inoculum sizes. The colonisation of the soil by the inoculated micro-organisms was studied and the amount of cadmium potentially available was estimated using a chemical reagent miming Cd biosorption by plants.

Keywords: micro-organism, agricultural soil, heavy metal, immobilisation, soil inoculation
Bioremediation of polluted soils: an overview

KARThIKEYAN K. and SINGH Kuldeep

Department of Soil Science, CCS, Haryana Agricultural University Hisar, 125004, Haryana, India

Advance in science and technology since the industrial revolutions have increasingly enabled humans to exploit natural resources. Soil is one of the most vital natural resources. It produces food for the teeming millions and supplies raw materials for a large number of industries on which a danger of soil pollution. Soil gets polluted day by day with hazardous chemicals which originating from industries, mining, operations, intensive agriculture and radioactive wastes. Consequently, environmental awareness is growing among people leading to a need for cost effective control measures. Bioremediation is such a cost effective technique or a process that exploits the catalytic abilities of the living organisms to enhance the rate or extent of pollutant destruction. This bioremediation exploits the genetic diversity and metabolic versatility of microorganisms for the transformation of contaminants into less harmful end products which are then integrated into biogeochemical cycles. Bioremediation achieves contaminant decomposition or immobilization by exploiting the existing metabolic potential in microorganism with novel catabolic functions derived through selection or by the introduction of genes encoding such functions. Many microorganisms are able to accumulate and degrade a wide variety of chemical and metal cations. This bioremediation is a multidisciplinary under taking with cost effective ecologically safe and environmentally sound technique towards which we are striving for. Special emphasis should be given to soil resources and their sustainable utilization for agricultural development. Ecological sustainability should be the major emphasis for all technological innovation involving land and water use. So that there is no adverse effect on the biological productivity of resources base in the long run. Even though there are several barriers hindering the bio-remediation it will proceed with a long steep growth curve in the coming years.

Keywords: bioremediation, biogeochemical cycles, catabolic, ecological sustainability, genetic diversity, metabolic versatility
Bioremediation on salinity land

KIRDMANEE Chalermpol (1), MOSALEEYANON Kriengkrai (1), WANITCHANANAN Praderm (1) and WANUSSAKUL Ruenruedee (2)

(1) National Center for Genetic Engineering and Biotechnology, National Science and Technology Development Agency, Rajdhevee, Bangkok 10400, Thailand
(2) The Reforestation and Extension Project in the Northeast of Thailand, Forest Nursery Center, Chiang Yeun, Mahasarakham 44160, Thailand

Ficus benjamina Linn., Albizia lebbeck Linn., Pterocarpus macrocarpus and Afzelia xylocarpa Roxb. were used as a model for classification of salt-tolerant trees. Seeds were sterilized and germinated in vitro on Murashige and Skoog (1962) medium under 65±5% relative humidity, at 30/27 °C (photoperiod/dark period) until the sixth leaf developed. Culture medium was adjusted to 0, 1, 2, 3, and 4% NaCl. Net photosynthetic rate of seedlings used as a physiological index for classification of salt-tolerant trees was measured. The net photosynthetic rate of plantlets decreased by increasing the NaCl concentration. The salt-tolerant was highest in Ficus benjamina Linn. followed by Albizia lebbeck Linn., Afzelia xylocarpa Roxb., and Pterocarpus macrocarpus. These trees were grown on saline land. The survival was 50% in Ficus benjamina trees and 0% in Pterocarpus macrocarpus trees. One hundred tree species were classified by the levels of salt-tolerance. The high level of salt-tolerant trees was found in Alstonia scholaris, Tamarindus indica, Averrhoa carambola, Melia azedarach, Musa sapientum, Citrus maxima, Gemelina arborea, Artocarpus heterophyllus, Wrightia tomentosa, Peltophorum dasyrachis, Carica papaya, P. pterocarpum, Zizyphus jujub, C. histrix, C. sinensis, C. reticulata, and Feronia limonia. Twenty-two thousand salt-tolerant trees were grown on 100 acres of salinity land at Borabu, Mahasarakham Province decreased the salinity level from 4% to be 0.5% after growing for 4 years.

Keywords: bioremediation, net photosynthetic rate, salinity land, salt-tolerant tree
Heavy metal uptake by barley and sunflower grown in abandoned animal lagoon soil

MADRID F. (1) and KIRKHAM M.B. (2)

(1) Instituto de Recursos Naturales Agrobiologia de Sevilla, Consejo Superior de Investigaciones Cientificas (CSIC), Apartado de Correos 1052, 41080 Sevilla, Spain
(2) Department of Agronomy, Kansas State University, Manhattan, KS 66506-5501, USA

Animal waste storage lagoons are used on farms and at concentrated animal operations. However, due to environmental regulations, lagoons in the USA are being closed. The soils at the bottom of lagoons are polluted by many contaminants, including heavy metals, and need to be remediated. Phytoremediation may be one method to restore them. The use of chelates, in conjunction with phytoremediation, is advocated for enhancing the clean-up of soil contaminated by heavy metals. No information is available concerning the efficacy of chelates applied to abandoned animal-waste lagoon soil for metal removal, and no work reports if chelate-solubilized heavy metals in the lagoon soil can pollute drainage water. Our objectives were to determine 1) if plants (barley, *Hordeum vulgare* L., and sunflower, *Helianthus annuus* L.) would grow in animal waste lagoon soil, and 2) the effect of the chelate, EDTA (ethylenediamine-tetraacetic acid), on uptake and movement of heavy metals in the lagoon soil.

Under greenhouse conditions, plants grew for 60 days in pots (16 cm diameter; 18.5 cm tall) with soil that came from a closed dairy feedlot lagoon. Control pots had no plants. Seventeen days before the end of the experiment, EDTA was added to half of the pots at a rate of 0.5 g kg\(^{-1}\) soil. The plants, especially sunflower, germinated poorly in the lagoon soil. Of 240 barley seeds planted, 45 germinated (19%); of 360 sunflower seeds planted, 7 germinated (2%). High penetration resistance of the lagoon soil appeared to be the cause of the poor growth. Barley grown with the chelating agent EDTA in the soil accumulated higher levels of Fe, Mn, Ni, and Pb than barley grown without EDTA. Even though there was a tendency for sunflower grown with EDTA to accumulate more heavy metals than sunflower grown without EDTA, differences between the two treatments were not significant. With or without EDTA, concentrations of Cd, Ni, and Pb were higher than normal in plants grown in the lagoon soil. This suggested that these toxic heavy metals are concentrated in the lagoon soil. Concentration of Cu in the leachate from the pots with EDTA was not elevated above drinking water standards, except in one instance (pots with no plants). Concentration of Fe in leachate from all pots with EDTA was elevated above drinking water standards. In general, pots without EDTA did not leach detectable amounts of Cu and Fe. The results showed that barley would be better choice for phytoremediation of the dairy lagoon soil than sunflower and that EDTA can solubilize Fe in lagoon soil and raise its concentration in leachate above drinking water standards.

**Keywords:** lagoon soil, barley, crop residues, nitrogen uptake
Phytoextraction of lead from contaminated soil by vetiver grass (*Vetiveria* sp.)

CHANTACHON Somsaguan (1), KRUATRACHUE Maleeva (1), POKETHITIYOOK Prayad (1), TANTANASARIT Sittichai (2), UPATHAM Suchart (3) and SOONTHORN SARATHOOL Varasaya (1)

(1) Department of Biology, Faculty of Science, Mahidol University, Bangkok 10400, Thailand
(2) Department of Conservation, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand
(3) Faculty of Science, Burapha University, Chonburi 20131, Thailand

A soil-culture study was conducted to investigate the phytoextraction of lead (Pb) in two species of vetiver grass (*Vetiveria zizanioides* and *V. nemoralis*) irrigated with increasing levels of Pb(NO$_3$)$_2$ (5, 7, 9 and 11 g L$^{-1}$) for 12 weeks. The removal of Pb from soil was correlated with Pb accumulation by roots and shoots of both species of vetiver grass. High concentrations of Pb (9-11 g L$^{-1}$) resulted in decrease in growth, total chlorophyll content and biomass of *V. zizanioides* while *V. nemoralis* died after one week of application. Based on the data, *V. zizanioides* best tolerated and accumulated the greatest amount of Pb. The vetiver system offers a potential avenue for soil phytoremediation. It is a very cost effective, environmental friendly and practical tool for the control and attenuation of heavy metal pollution when appropriately applied.

**Keywords:** phytoextraction, accumulation, lead, vetiver grass
Chelate enhanced Pb phytoextraction: plant uptake, leaching and toxicity

LESTAN Domen and GRCMAN Helena

Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia

Using disturbed and undisturbed soil column experiments we compared the effect of a single dose and weekly additions of diamine tetraacetic acid (EDTA) and ethylene diamine disuccinate (EDDS) on the uptake of Pb (and Zn, Cd) by Chinese cabbage (Brassica rapa) and on the leaching of heavy metals through the soil profile. The analysis of plant material revealed that both chelates applied to the soil increased the concentrations of Pb in the leaves of test plants. The most effective were single doses of 10 mmol EDTA and EDDS kg⁻¹ soil, which caused the concentrations of Pb in plants grown on disturbed soil profile to increase 94.2- and 102.3-fold respectively, relative to the control. In disturbed soil columns treated with 10 mmol kg⁻¹ EDTA, up to 22.7% of initial total Pb was leached through the soil profile. The same amount of EDDS caused much lower leaching of Pb, only 0.8% of initial total concentrations. In disturbed soil experiments EDDS (10 mmol kg⁻¹) caused 113 to 438-fold less leaching of Pb than EDTA. Biotest with red clover (Trifolium pratense) indicated greater phytotoxic effect of EDTA than EDDS addition. EDDS was less toxic to soil fungi as determined by PLFA analysis and caused less stress, indicated by trans/cis PLFA ratio, to soil microorganisms.

Keywords: phytoextraction, contaminated soil, lead, EDTA, EDDS
Role of arbuscular mycorrhizal fungi in alleviation of Zn phytotoxicity and mineral nutrition of host plants

LI Xiaolin (1), CHEN Baodong (1), FENG Gu (1) and CHRISTIE Peter (1,2)

(1) College of Agricultural Resources and Environmental Sciences, China Agricultural University, Beijing 100094, People's Republic of China
(2) Agricultural and Environmental Science Department, Queen's University Belfast, Belfast BT9 5PX, UK

There is increasing interest worldwide in the maintenance of soil quality and remediation strategies for management of soils contaminated with pollutants including heavy metals. The protective effects of arbuscular mycorrhizas on host plants under conditions of Zn contamination have raised the prospect of utilizing the mutualistic association in soil revegetation programmes, and consequently research has focused on the mechanisms involved. This paper summarizes some of our recent research work which has indicated that the alleviation of zinc toxicity by arbuscular mycorrhiza may involve both direct and indirect mechanisms. Binding of metals in mycorrhizal structures and immobilization of metals in the mycorrhizosphere may have contributed to the direct effects. Indirect effects may include the mycorrhizal contribution to balanced plant mineral nutrition, especially P nutrition, leading to increased plant growth and enhanced metal tolerance. Further research on the potential application of arbuscular mycorrhizas in the bioremediation of metal contaminated soils is also discussed.

Keywords: arbuscular mycorrhiza, Zn toxicity, soil pollution, bioremediation
Hyperaccumulation of cadmium and zinc: physiological background and phytoextraction potential

LOMBI Enzo, ZHAO Fang-Jie, DUNHAM Sarah J. and McGRATH Steve P.
Agriculture and Environment Division, IACR-Rothamsted, Harpenden, Herts, AL5 2JQ, UK

Hyperaccumulation of Cd and Zn by plants is a remarkable phenomenon. Eleven taxa of Zn hyperaccumulator are known but only one species, *Thlaspi caerulescens*, is able to hyperaccumulate Cd. For this reason, and due to the concern associated with Cd contamination, considerable attention has been given in recent years to the understanding of physiological and molecular mechanisms responsible for Cd hyperaccumulation by this plant.

The discovery of different *T. caerulescens* ecotypes that vary significantly in their ability to hyperaccumulate Cd has offered an opportunity to enhance our understanding of how this plant can hyperaccumulate metals. Several aspects of metal accumulation such as rhizosphere effects, metal uptake and translocation, and metal compartmentation have been studied in detail. For instance, there is physiological evidence that Cd uptake in at least one ecotype of this species is probably mediated by a high-affinity Cd transport system which has a high specificity for this element.

This background information is necessary to optimise the process of phytoremediation. In fact, it is likely that the potential of hyperaccumulator plants for phytoextraction has not been completely exploited so far due to a lack of knowledge regarding the basic mechanisms responsible for metal hyperaccumulation.

This work reports some of the most recent and significant findings regarding the mechanism of Zn and, especially, Cd hyperaccumulation by different ecotypes of *T. caerulescens*. Furthermore, the potential use of this plant for phytoextraction is evaluated in a series of pot and field experiments.

Pot experiments showed that an ecotype of *T. caerulescens* from Southern France is very efficient in removing Cd. For instance, in three croppings this plant removed over 40% of the total Cd present in an industrially contaminated soil (total initial amount 19 mg Cd kg\(^{-1}\)). On the other hand, the presence of Cu at a concentration toxic for normal plants seems to impair the growth of this hyperaccumulator. This suggests that its use in phytoextraction may be limited by toxic concentrations of Cu.

The phytoextraction ability of *T. caerulescens* has also been investigated in field experiments that reveal both its high potential and also some difficulties in large scale field applications.

**Keywords**: cadmium, zinc, *Thlaspi caerulescens*, phytoremediation, hyperaccumulation
Comparative study on Zn tolerance and accumulation between two ecotypes of *Sedum alfredii*

NI W.Z.,(1), YANG X. (1), LONG X.X. (1), HE Z.L. (2) and CALVERT D.V. (2)

(1) Dept. of Resource Sci., Zhejiang Univ., Huajianchi Campus, Hangzhou, China
(2) Univ. of Florida, Indian River Res. and Edu. Center, Fort Pierce, FL 34945, USA

Phytoremediation has become an established technology for environmental clean-up and protection. Metal hyperaccumulating plants are potential tools to remove excess metals from contaminated soils. Identifying metal hyperaccumulators with greater biomass and good agronomic characteristics and understanding plant tolerance and accumulation of heavy metals are important for successful phytoremediation of metal contaminated soils. Based on the survey, we found a new Zn-accumulating ecotype and non-accumulating ecotype of *Sedum alfredii* Hance in Southeast China. Nutrient solution culture experiment was conducted to examine Zn tolerance and accumulation characteristics of the two ecotypes of *Sedum alfredii* Hance. The results indicated that the dry matter yields of both stems and roots increased for the accumulating ecotype while decreased for the non-accumulating ecotype of *Sedum alfredii* Hance, with increasing of external Zn levels from control to 160 mg L\(^{-1}\). Zinc concentrations in leaves and stems of the accumulating ecotype increased to as high as 1.9% at external Zn level of 160 mg L\(^{-1}\). Whereas Zn concentration were over 40-fold lower in leaves and over 15-fold lower in stems of the non-accumulating ecotype grown at external Zn 20-160 mg L\(^{-1}\), as compared with the accumulating ecotype. The Zn uptaken by shoots (or accumulated in shoots) of the accumulating ecotype were over 20-fold higher than that of the non-accumulating ecotype. The results showed that the accumulating ecotype has a greater potential for phytoremediation of Zn contaminated soils.

**Keywords:** ecotype, zine hyperaccumulator, zine tolerance *Sedum alfredii* Hance
The impact of application of chlorates in longan plantations on the environment and the remedy

ONGPRASERT Somchai, SUTIKOOLABUD Pathipan and AUMTONG Supathida

Department of Soil Resource and the Environment, Mae Jo University, San Sai, Chiang Mai 50290, Thailand

Chlorates are toxic substances. Thus, sodium chlorate has been used as a herbicide and defoliants. Recently it was found that chlorate could induce the flowering of longan trees. Since then chlorates have been used in most of the longan plantations all over the country.

The environmental impact assessment of the application of chlorates was done. The following are some topics of the studies: the mode and rate of decomposition and movement in various soil types; the effects earth worm and mineralization of nitrogen and selected soil properties; and the residues and contamination in soils, surface water and shallow ground water; and the methods for enhancing the decomposition.

According to the results of the studies, the decomposition of chlorate in the soil is completely biochemical process. It is high in soils that have high contents of organic matter, phosphorous, calcium, magnesium and CEC, and low in soils that have high contents of sand and AEC. The chlorate in the form of potassium chlorate decomposes twice as fast as that in the form of sodium chlorate. There is absolutely no absorption of chlorate in soils. The more chlorate moves in soil, the more decomposition takes place.

It was found that 680 mg ClO3⁻ kg⁻¹ does not effect the transformation of protein-N to NH₄⁺ and NH₄⁺ to NO₂⁻, but 34 mg kg⁻¹ reduces the transformation of NO₂⁻ to NO₃⁻ by 18 - 38 %. The maximum concentration of chlorate that earthworms can survival over a month is 24.2 - 40.8 mg kg⁻¹. Thus, the critical contamination of chlorate on the soil environment should be around 34 mg kg⁻¹.

One year monitoring of chlorate residues in 25 longan plantations indicated that the chlorate found in the topsoils at the application strips a few days after the application were as high as 136 - 340 mg kg⁻¹. Under farmers' management these concentrations decreased to 24.2–68 mg kg⁻¹ with in 55-50 days. Thus, the short-term effect is limited under the application strips within this period. The residue of chlorate decreases over time to 24 mg kg⁻¹ with in 75 to 360 days in low fertile soils and to less than 10 mg kg⁻¹ in high and medium fertile soils. If farmers apply chlorate once a year there is less likelihood for chlorate to accumulate over years. Thus, the long-term effect on the soil environment is nil.

Application of diluted molasses solution under laboratory condition enhances the decomposition of chlorate. This finding is confirmed in a field trial. It is found that urea depresses the decomposition of chlorate, while the effect of liquid manure is neutral.

Keywords: chlorate, longan, earthworm, mineralization of nitrogen, molasses
Enhancement of *Acinetobacter calcoaceticus* in biodegradation of Tapis crude oil

POKETHITIYOOK Prayad (1), SUNGPETCH Acharaporn (2), UPATHAM E. Suchart (3) and KRUATRACHUE Maleeya (1)

(1) Department of Biology, Faculty of Science, Mahidol University, Bangkok 10400, Thailand
(2) Faculty of Natural Resource and Environmental Studies, Mahidol University, Nakhon Pathom 73170, Thailand
(3) Faculty of Science, Burapha University, Chonburi 20131, Thailand

Seven different types of bacteria were obtained from oil contaminated soil in Bangkok area. The enrichment culture was inoculated in mineral salt medium (MSM) with 0.5% Tapis crude oil as the sole carbon source. Four types of crude oil degraders, *Acinetobacter calcoaceticus*, *Pseudomonas aereaegina* strains MU01, MU02 and MU03, could degrade crude oil well. These four dominant types were selected for studying the effects of temperature, nutrients (N and P), and surfactant (Tween 80) on crude oil degradation in batch soil slurry reactor system. The percentage of total hydrocarbon (THC) degradation was highest at 30°C (30.22%) and was lower at 20°C (22.70%) and 40°C (14.29%). Nutrients (N and P) also enhanced crude oil biodegradation (14.11% as compared to 12.62%). Similarly, a surfactant also had a positive effect on crude oil biodegradation.

**Keywords:** *Acinetobacter calcoaceticus*, Tapis crude oil, biodegradation, Tween 80, nutrients
Vetiver grass for remedying soil contaminated with heavy metals

ROONGTANAKIAT Nualchavee (1) and CHAIROJ Prapai (2)

(1) Department of Applied Radiation and Isotopes, Faculty of Science, Kasetsart University, Bangkok 10900, Thailand
(2) Division of Soil Science, Department of Agriculture, Bangkok 10900, Thailand

Three vetiver grass ecotypes, Kamphaeng Phet, Ratchaburi and Surat Thani were planted in soil supplemented with different amounts of manganese (Mn), zinc (Zn), copper (Cu), cadmium (Cd) and lead (Pb). It was found that these heavy metals did not affect the growth of the vetiver grass, even through the uptake amount was increased as the applied amount increased. The Ratchaburi ecotype gave significantly higher shoot dry weight and lower root weight and at the same time had significantly higher Mn, Zn, Cd and Pb amounts in shoots than the Surat Thani and Kamphaeng Phet ecotypes. However, as for copper, the Ratchaburi and Kamphaeng Phet ecotypes showed similar copper uptake. The root of the Ratchaburi ecotype also could absorb significantly higher amount of Zn, Cd and Pb than those of the Surat Thani and Kamphaeng Phet ecotypes. For manganese and copper, the Ratchaburi and Surat Thani ecotypes did better than Kamphaeng Phet.

As expected, the residual heavy metal left in soil was increased as the applied amount increased. The soil which had been planted with Ratchaburi vetiver ecotype had less residual heavy metals than that planted with the other two ecotypes, since it absorbed more heavy metals. Therefore, this specific ecotype would be useful for bioremediating soil contaminated with heavy metals.

Keywords: vetiver grass, heavy metals, phytoremediation, soil remediation
Self-bioremediation potential of a heavily hydrocarbon-polluted soil

SACCOMANDI Flavia, NOCERINO Giulia and GIANFREDA Liliana

Dipartimento di Scienze Chimico-Agrarie, Università di Napoli “Federico II”, Via Università 100, 80055, Portici (Napoli), Italy

Aliphatic and aromatic hydrocarbons are usually hydrophobic compounds and are present as separate water-immiscible organic phases. They may often pollute aqueous (groundwater and surface waters) and terrestrial (soils and sediments) environments.

Hydrocarbon-polluted sites constitute a severe environmental problem due to the high hazardous nature of their contaminants. Consequently, great efforts are spent for devising remediation technologies suitable for an effective restoration of these polluted sites. Biodegradative processes, undergone by microorganisms and leading to the complete mineralization of these pollutants, are an appealing measure for an in situ remediation action.

The goal of this work has been to estimate the self-bioremediation potential of a soil polluted by alkanes and polycyclic aromatic hydrocarbons (PAH). The soil has a long-term history of pollution, dating back to World War II and it is still heavily contaminated. Preliminary laboratory tests have demonstrated that active microorganisms may grow if appropriate growing conditions and easily-available carbon sources are provided. Investigations have been performed by using different experimental conditions, suitable for evaluating the capability of the endogenous microflora to degrade the main pollutants. Soil samples were incubated under aerobiotic conditions in the presence of nutrients and without any carbon source. At different incubation times, several parameters (i.e. the growth of microorganisms as counted by conventional dilution plate counts on plates supplied with either Nutrient broth or Naphthalene or an alkane mixture as sole carbon source; the pH of aqueous and solid phase, and the residual concentration of alkane and PAH in both soil and aqueous solutions) were evaluated. A measurable and consistent growth of microorganisms as well as a decrease in the residual concentration of both alkanes and PAH in samples with time were measured. The maximum removal of both types of contaminants ranged from 20 to 50% of the initial pollutant concentration. Furthermore, fungal and bacterial consortia were isolated from soil samples and their degrading capability towards some of the main contaminants (naphthalene, phenanthrene and esadecane) was measured.

The obtained results indicate that endogenous, situ-specific microorganisms are able to utilize intrinsic contaminants provided oxygen and/or mineral salts are supplied. Furthermore, microbial species can be isolated from the contaminated site, and may be potential inocula for the bioaugmentation of the polluted site. Though obtained under laboratory conditions, these results are encouraging for an intrinsic bioremediation potential at the contaminated site. However, further investigations, mainly under field conditions, are required.

Keywords: aliphatic hydrocarbons, PAH, microbial degradation, polluted sites
Chromium accumulation in soil under long term fertilization: a case for bioremediation

SHANMUGAM Kamarai and PALANIAPPAN Muthuvel

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, India

Chromium, a transition group metal, enters the soil environment both through natural process and as a result of human activities. It is a potential contaminant of soil and also toxic to human beings after entering into the food chain through the food crops raised in chromium contaminated soils. Hence, there is a need to search for innovative methods to minimize the pollution. One approach could be phytoremediation i.e. removing the pollutants by cultivating metal accumulating plants. One such hyperaccumulator that has been proved to remove chromium by higher uptake from chromium contaminated soil is maize. The best tool to monitor the heavy metal accumulation in agricultural soils is the Long Term Fertilizer Experiments (LTFE), where in each treatment a specified quantity of fertilizers is added every year. With a view to assessing the effect of continuous fertilization on the total and DTPA extractable chromium concentration in the soil, surface soil samples from the LTFE located at Tamil Nadu Agricultural University farm, Coimbatore, India were evaluated for chromium accumulation.

This experiment in a medium black soil (Vertic Ustropept) was initiated in the year 1972. The ten treatments each being replicated four times with a net plot size of 200 m² are unfertilized control, addition of NPK at 50, 100 and 150 percent of optimum level, 100 percent optimum NPK with out herbicidal application, 100 percent optimum NPK + ZnSO₄ @ 25 kg ha⁻¹, 100 percent optimum NPK + cattle manure @10 t ha⁻¹, 100 percent optimum NPK through S free sources, 100 percent optimum NP and 100 percent N alone. Fodder cowpea - Finger millet- Maize are the crops being raised in a fixed rotation. Maize alone receives ZnSO₄ in the rotation while cattle manure is applied only to Finger-millet crop. The optimum doses of NPK being applied, based on soil test, are 25:50:0, 90:45:17.5, 135:67.5:35 kg ha⁻¹ for cowpea, finger millet and maize respectively. Soil samples from 1992 and 2000 crop seasons were analyzed for total and DTPA extractable chromium content.

The effect of continuous fertilization and intensive cropping showed differential behaviour of treatments in their influence on the total chromium content. The optimum NPK application did not increase the total chromium content markedly. On the contrary, the treatment which received the maximum dose of NPK application markedly increased the total chromium content over a period of 8 years. Those treatments which received no single superphosphate application recorded lower chromium concentration. The DTPA extractable chromium was found to decrease with the increase in the period of experimentation, possibly due to removal by maize or by the transformation of DTPA extractable chromium to other forms. The reduction in the DTPA extractable fraction was very marked after maize as compared to the other crops in the rotation.

Keywords: chromium, cropping sequence, LTFE
Genotypic differences in effects of cadmium on yield and nutrient composition in *Brassica* plants

SINGH Kuldeep (1) and BRAR J.S. (2)

(1) Department of Soil Science, CCS Haryana Agricultural University, Hisar–125 004, India
(2) PAU Regional Research Station, Bathinda, India

Cadmium (Cd) is one of the most toxic non-essential and mobile metallic elements found in soils which affects plant growth. A greenhouse experiment was carried out to determine the genotypic differences in the effect of different levels of Cd application on yield and on the uptake of Cd and four other nutrients in various *Brassica* plant parts. The *B. juncea* (Indian mustard) genotypes produced higher biomass of different plant parts than *B. rapa*. Significant differences in yield of various plant parts were noted between the treatments. A significant interaction was found between Cd treatment and genotype for yield in all the plant parts. Genotype Vardan had a much greater yield than other genotypes. There was a significant reduction in yield of about 42% for seed, 41% for leaf, 14% for stem and 32% for root at 80 mg Cd kg\(^{-1}\) soil than the control. Increase in Cd concentration of about 5 times in seed, 6 times in leaves and stem and 9 times in roots was noted significantly at 20 mg Cd kg\(^{-1}\) than in control without affecting the respective dry matter yield. Roots had higher concentrations of Cd at all the Cd levels than in other plant parts of *Brassica* genotypes indicated that there is limited transport of Cd from the root system to the above ground plant parts.

The application of Cd increased concentration of Zn, Fe and Mn at lower levels but decreased at higher levels irrespective of genotype and plant part, however, the effect on P was negative even at lower levels of Cd. The *B. juncea* genotype Vardan outyielded all other genotypes at all Cd levels tried and was found to be most resistant to Cd toxicity and it had also much higher Cd concentration in different plant parts indicating that it has better absorbing ability than others and has a higher potential for removing Cd from moderately Cd contaminated soils.

The results of this study also show large, exploitable genotypic variation for tolerance to Cd toxicity in *Brassica* plants.

**Keywords:** *Brassica* genotypes, cadmium, nutrient composition, toxicity
Phytoremediation of selenium and other trace elements in soil and water

TERRY Norman

Department of Plant and Microbial Biology, 111 Koshland Hall, University of California, Berkeley, CA 94720-3102, USA

The multidisciplinary research program in our laboratory focuses on the use of plants and microbes for the cleanup of selenium (Se) contaminated environments, and covers all aspects from the field level to the molecular level. Our field studies show that constructed wetlands were extremely efficient at removing substantial amounts of Se and other trace elements from large volumes of contaminated water from oil refineries and electric utilities. Selenium volatilization, the conversion of toxic inorganic Se to non-toxic volatile forms, was a significant pathway of Se removal by the wetland, and wetland plant species differed in their ability to take up and volatilize Se. In addition to the detoxification of inorganic Se (by conversion to less toxic volatile forms), plants very efficiently detoxified toxic hexavalent chromium (Cr) to trivalent Cr. Synchrotron-based chemical speciation was used to determine the mechanisms of Se and Cr transformations in plants, and together with molecular biology was used to prove that selenate is absorbed and assimilated in a manner similar to sulfate. Overexpression of the genes for sulfate permease and ATP sulfurylase in Indian mustard showed that these enzymes of the sulfate assimilation pathway also mediate selenate uptake and reduction, respectively. Furthermore, ATP sulfurylase was shown to be the pivotal rate limiting enzyme controlling the pathway of Se assimilation. The transgenic Indian mustard plants were more tolerant to toxic levels of Se, and take up and assimilate Se at higher rates than wildtype plants. These plants are superior for the phytoremediation of Se-contaminated soil and water. Additionally, by overexpressing genes for enzymes in the phytochelatin synthesis pathway, we have developed transgenic Indian mustard plants that have superior abilities to tolerate and accumulate heavy metals such as cadmium. Another way to improve the ability of plants to take up and volatilize Se is to exploit plant-microbe interactions. Our microbiology research has shown that rhizosphere microbes enhance the plant uptake of Se, which in turn increased the rate of Se volatilization. Thus, the multidisciplinary research program in our laboratory has elucidated the mechanisms controlling Se assimilation and volatilization in plants, and plant/microbe associations, and developed practical methods for the cleanup of Se from the environment.

Keywords: constructed wetlands, Se volatilization, phytoremediation, rhizosphere microbes, Indian mustard, phytochelatin
Radiophytoremediation: from laboratory to field application

VANĚK Tomáš, SOUDEK Petr and TYKVA Richard

Institute of Organic Chemistry and Biochemistry of the Academy of Sciences of the Czech Republic, Flemingovo nám. 2, 166 10 Praha 6, Czech Republic

Phytoremediation is a relatively young technology to reduce some pollutants in the environment. It is used, especially, for heavy metals. During the last years, different analyses have been described in the literature using phytoremediation also for radionuclides (radiophytoremediation).

Low levels of radionuclides can enter into soils and/or waters by different human activities and nuclear accidents. As it was proved after the Chernobyl accident, the highest, long-term environmental effect, which still exists, has been the distribution of $^{137}$Cs, almost within the whole Europe.

In our experiments we tested the utilization of radiophytoremediation approach for accumulation of $^{137}$Cs, $^{125}$I and $^{63}$Ni using three plant species (Phragmites australis L., Helianthus annuus L., Populus simonii L.) in hydroponic conditions. The decrease of amounts of radionuclides in liquid media, as well as their distribution in plant tissues was measured.

Generally, localisation of the nuclides was found mostly in the areas of the cell expansion and active metabolism and thus in the parts of the increased requirement of water and nutrients i.e., in the node, leaf tips and young leaves and in the young shoot meristems.

The comparison of the above mentioned laboratory results with those obtained during field experiments in the area of an uranium ore waste depot will be presented in our contribution.

On the basis of achieved results it was possible to elucidate most important differences in plant system requirements for “normal” metals phytoremediation and radiophytoremediation, both from practical as well as a theoretical point of view.

The utilization of selected plant species for radiophytomonitoring in the surroundings of a new nuclear power plant in South Bohemia will be discussed too.

Keywords: radionuclides, phytoremediation, environment, pollution, $^{137}$Cs, $^{125}$I, $^{63}$Ni

1344
Symposium 43

Cryosols and cryogenic environments in the 21st Century

Convenor: TARNOCAI Charles
Co-Convenor: PHIMSARN Sathien

Oral Session
Friday 16 August 2002
8:30 - 11:50
Room: Meeting Room 1

Poster Session
Friday 16 August 2002
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The effect of cryogenesis on the accumulation of 
water-soluble compounds in the soil profile

ANANKO Tatiana V.
V.V. Dokuchaev Soil Science Institute, Pyzhevskii per. 7, Moscow 109017, Russia

This study was performed in the Tukuringra Ridge (the Far East of Russia) within the zone of isolated permafrost. Climate: cold humid moderately continental; annual precipitation is from 600 mm (forested foothills) to 800–900 mm (mountainous tundra). Parent rocks: sandy–loamy colluvium of gneiss and schist with considerable amount of coarse rock fragments. The soils of three vertical zones were investigated: (a) Al–Fe-humus Podbur (Spodosol without E horizon: O–Bs–Cf) of the mountainous tundra, (b) Soddy Al–Fe-humus soil and Typical Podzol (AO–A1–E/Bs–C and AO–E–Bs–C) under the larch taiga, and (c) Raw-Humus Brown Forest soil (Cambisol: AO–A1–Bw–C) under mixed coniferous–broad-leaved forests. According to morphological and analytical data, the degree of illuvial accumulation of amorphous sesquioxides and humus in B horizons increases from the Brown Forest soil to Soddy Al–Fe-humus soil and Podzol and reaches its maximum in the Bs horizon of Podbur. All the soils are subjected to long-term seasonal freezing. In the Podbur with permafrost, soil freezing starts both from the top and from the bottom. In wet years, Podbur gets saturated with water above permafrost after strong autumn rainfalls.

In order to reveal the contribution of illuviation processes to morphological differentiation of the soil profiles, lysimetric boxes were installed in the soils at different depths corresponding to soil horizons. Soil solutions collected in them were then analyzed. The experiment was performed during four consecutive summer seasons.

Minimal concentrations of soluble organomineral compounds were found in the lysimeters installed in the Podbur (18 mg L\(^{-1}\), or 100 t ha\(^{-1}\)); these concentrations and the amounts of water percolating through the soil were approximately equal in all horizons, i.e., the substances leached from the litter migrated downward to the profile without their retention in the Bs horizon. Considerably higher concentrations were found in the solutions from Soddy Al–Fe-humus soil (58 mg L\(^{-1}\), or 170 t ha\(^{-1}\)) and Podzol (79 mg L\(^{-1}\), or 300 t ha\(^{-1}\)). Illuviation of organomineral compounds from the litter in the Brown Forest soil reached 33 mg L\(^{-1}\) (150 t ha\(^{-1}\)); most of them were retained in the A1 horizon.

There is an obvious discrepancy between lysimetric and morphological data: maximum illuvial accumulation of organomineral compounds is observed in the Podbur with minimal concentrations of these compounds in lysimetric waters. This is explained by the effect of cryogenesis: in wet years, slow freezing of soil solutions from the bottom leads to their cryoconcentration and precipitation of organomineral compounds above the freezing front, in the Bs horizon. This mechanism is only observed in the tundra Podbur with the impermeable permafrost horizon. Thus, proper illuvial phenomena in this soil are combined with cryogenic concentration of soil solutions.

Morphological differentiation of the soil profile results from the processes taking place not only in the summer period but also in the winter and spring, upon soil freezing and thawing. Cryoconcentration of soil solutions can be an important factor favoring the accumulation of amorphous organomineral horizons in the Bs horizon.

**Keywords:** permafrost, Spodosols, cryogenic concentration of soil solutions
The fate and effects of hydrocarbons in Antarctic soil: preliminary results of an experimental fuel spill

BALKS Megan R. (1), HOLMES David J. (1) and AISLABIE Jackie (2)

(1) Department of Earth Sciences, University of Waikato, Private Bag 3105, Hamilton, New Zealand
(2) Landcare Research, Private Bag 3127, Hamilton, New Zealand

Hydrocarbon contamination of Antarctic soils is evident in areas where accidental fuel spills have occurred, usually near scientific bases or field camps. To understand the long term fate and effects of fuel spills, information is required on how Antarctic soils respond immediately after hydrocarbon contamination. A contained fuel spill experiment was established, at Scott Base in the Ross Sea Region of Antarctica, to quantify the volatile loss and downward movement of JP-5 fuel and to monitor the effects of the fuel on soil temperature and numbers of culturable heterotrophic bacteria. Soil (Typic Anhyorthel, sieved to < 6.7 mm) was packed into 105 cores (10.5 cm diameter and 30 cm high), which were buried so that the core surfaces were level with the ground surface. In order to ensure that conditions were as similar to in-situ conditions as possible the cores were left to equilibrate over winter. In December 2000 (the Antarctic summer), 60 ml of JP-5 was applied to each of 63 cores in droplets from a syringe, thus avoiding saturated flow. The remaining cores were kept as controls with no fuel added. Ten cores (five control and five JP-5 treated) were weighed daily to monitor changes in moisture and snowfall, and to quantify the volatile loss of JP-5 fuel. In-situ temperatures (5 cm and 20 cm depth) were measured in triplicate at hourly intervals using thermistors attached to a CR-10x datalogger. Cores were destructively sampled in triplicate 0.1, 1, 3, 7, 14, 21, 28, 35 and 42 days after fuel application and samples were returned, frozen, to New Zealand for microbial and total petroleum hydrocarbon (TPH) analyses. Following fuel application the soil surfaces of the JP-5 treated cores were visibly darker than the surfaces of control cores. The surface discoloration diminished over time and was markedly reduced after 3 weeks. By weighing the soil cores and correcting for moisture we determined that the volatile loss of JP-5 fuel was 9% after 18 hours, 23% after 7 days, and about 30% after 42 days. Ten days after JP-5 application fuel had penetrated to a mean maximum depth of 15 cm. For the week following fuel application, JP-5 treated cores appeared to be about 2°C warmer than control cores at 5 cm depth during mid afternoon sunshine (diurnal maximum temperature), while no apparent difference was observed at 20 cm depth. The increased temperatures are attributed to greater absorption of solar radiation due to the hydrocarbon darkening, and therefore lower albedo of the JP-5 treated soil surface. Microbial analyses have shown that the initial application of fuel was non-toxic to the indigenous microbial population. No differences were observed in the mean numbers of culturable heterotrophic bacteria between JP-5 treated and control cores up to 42 days after the spill. Levels of total petroleum hydrocarbons were markedly reduced 42 days after fuel application.

Keywords: soil, Antarctic, human impacts, fuel, oil
Turf hummocks on Ellesmere Island, Canada

BROLL Gabriele (1) and TARNOCAI Charles (2)

(1) Inst. of Landscape Ecology, Univ. of Muenster, Robert-Koch-Str. 26-28, 48149, Muenster, Germany
(2) Agriculture and Agrifood Canada, Research Branch (ECORC), 960 Carling Avenue, Ottawa K1A OC6, Canada

Turf hummocks, which are common features in the High Arctic environment, were examined in detail on slopes in the Tanquary and Lake Hazen areas on Ellesmere Island. These hummocks were 20 cm to 40 cm high and 40 cm to 60 cm in diameter. Thaw depth was about 50 cm and soil texture was dominantly silt loam. Soils, which were Regosolic Static Cryosols and Brunisolic Static Cryosols, lacked any sign of cryoturbation except for one soil, which possibly exhibited some signs of weak cryoturbation. Organic carbon and the total nitrogen content were generally high. The high nitrogen content is probably due to the activity of nitrogen-fixing plants (Dryas integrifolia) that dominate these hummocks.

These turf hummocks are different from earth hummocks since their entire development depends on the eolian materials captured by the vegetation growing on the hummocks. Their internal morphology revealed multiple buried, organic-rich layers representing former hummock surfaces. The soil horizons occurring between these buried organic-rich layers also contained a high amount of well-decomposed organic matter, which was dispersed uniformly throughout the horizons. Radiocarbon dates for the buried organic layers suggest that a minimum of 1200 yr was required for a turf hummock to develop to its present stage.

Soil temperatures at the 2.5 cm and 5 cm depths were 3 °C to 5 °C higher under the top of a hummocks than under the adjoining interhummock troughs. The sloping sides of these hummocks, combined with the spacing between them, make them well suited to capture a maximum amount of energy during the days of 24-hour Arctic sunlight.

Three types of turf hummock can be differentiated on the basis of both the analytical data and the internal morphology: 1) hummocks with thick Ah horizons, 2) hummocks with alternating fresh eolian material and thin Ah horizons, and 3) hummocks similar to those in type 2, but having B horizon development.

Keywords: Arctic, Cryosols, hummocks, microclimate, pedogenesis, soil ecology
Fractionation and spectral features of soil organic substances in subtropical subalpine soils

CHEN Jenn Shing and CHIU Chih Yu

Institute of Botany, Academia Sinica, Taiwan

The distribution and composition of organic substances were investigated in subalpine soils lying in succession from forest to grassland in central Taiwan which has an elevation of 2700 m, a mean annual precipitation of 4100 mm and a temperature of 9.5 °C. The soil organic substances were classified as water soluble organic carbon (WSOC), fulvic acids (FAs), and humic acids (HAs). WSOC fraction in the O horizon decreased from the grassland to Tsuga forest. This fraction decreased with soil depth at each site since the high clay content of the mineral horizon retards the penetration of WSOC. The FA fraction was not distinctly different from grassland to Tsuga forest soils. FAs migrate downward apparently than HAs and WSOC, and consequently accumulated in the mineral horizons of each site. Most of the HA fraction was retained over the A horizon except for the Tsuga forest. The deep distribution of root systems in the Tsuga forest resulted in the high content of HAs in the mineral horizon. The polyphenol fraction was higher in the Tsuga forest than in the grassland and transition zones. There was no significant difference in the amount of polyphenol between the organic and mineral horizons in the study sites. Comparatively, most of the polysaccharide fraction was retained in the O horizon and this fraction decreased with the depth. The amount of polysaccharide in both of the O and mineral horizons was in the order of the Tsuga forest > transitional zone > grassland soil. The ionization spectra of polyphenol fraction of FAs suggest that the chemical structure of FAs is associated with the type of HAs in soil which are affected by vegetation. In addition, the humification degree of the humic substances in the study sites was in the order the Tsuga forest > transitional zone > grassland soil.

Keywords: fulvic acids, humic acids, forest, soil
Soil CO₂ dynamics in an Arctic dry heath ecosystem

ELBERLING B. (1), BRANDT K.K. (2) and JAKOBSEN B.H. (1)

(1) Institute of Geography, University of Copenhagen, Denmark
(2) The Department of Ecology, The Royal Veterinary and Agricultural University, Denmark

Carbon pools in arctic soils play an important role in terrestrial ecosystem response to climate changes. An ecosystem response represents an average of spatial and temporal variations reflecting differences in vegetation types and soils over seasons and years. A field study carried out in Zackenberg, NE Greenland from 1999-2001 aims to quantify the variability of soil carbon pools in well-drained soils covered by three types of heath vegetation and to improve the understanding of the controls on soil CO₂ dynamics. Field measurements included soil temperature, water content, soil gasses (O₂ and CO₂), root distribution, soil chemistry and soil CO₂ effluxes. Field measurements were carried out from early June to late August. Laboratory work included chemical analysis and soil respiration tests (microbial respiration) on depth-specific soil samples. The respiration tests were performed at temperatures ranging from −10°C to 37°C. Generally, increasing CO₂ concentrations with depths were observed. A maximum of about 3% CO₂ were observed in Salix arctica corresponding to a measured maximum in CO₂ effluxes (Δ10 g CO₂ m⁻² d⁻¹). Spatial and temporal variations in CO₂ profiles can partly be correlated with changes in the soil diffusion characteristic (the water content) and temperatures during the growing season. This is further confirmed by the laboratory experiment indicating that microbial respiration follows an arrhenius-type of temperature-dependence. The laboratory experiments also reveal that microbial soil respiration can be observed at temperatures as low as −8°C and that the water content in frozen soils is important for trapping CO₂ during winter followed by a CO₂ release (burst events) during the thaw.

Keywords: soil carbon, respiration, arctic, carbon dioxide
Liquid water contents to $-80 \, ^\circ\text{C}$ of pastes saturated with solutions of 1-1 or 2-1 electrolytes

GRANT Steven A. (1), BOITNOTT Ginger E. (1), ISKANDAR Iskandar K. (1) and SLETTESTEN Ronald S. (2)

(1) U.S. Army Engineering Research and Development Center, Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover NH 03755, USA
(2) Quaternary Research Center, University of Washington, Box 351360, Seattle WA 98195-1360, USA

Sets of pastes were prepared from Ottawa sand and 5-μm diameter synthetic silica beads. A set of 12 pastes was prepared from each material by saturating it with 0.01, 0.1, or 0.01 mol kg$^{-1}$ aqueous solutions of LiCl, NaCl, CaCl$_2$, or ZnCl$_2$. The liquid water contents of the pastes were then determined by pulsed nuclear magnetic resonance by measuring the equilibrium magnetization of the free-induction decay curve function as the pastes were cooled from $-0.1$ to $-80 \, ^\circ\text{C}$. The liquid-water contents were determined at 0.2 °C increments between $-0.1$ and $-2.5 \, ^\circ\text{C}$ and at 0.5 °C increments between $-2.5 \, ^\circ\text{C}$ and $-80 \, ^\circ\text{C}$. Liquid water was detected at $-28 \, ^\circ\text{C}$ in the Ottawa sand pastes saturated with 1.0 mol kg$^{-1}$ NaCl and at $-54 \, ^\circ\text{C}$ for those saturated with 1.0 mol kg$^{-1}$ CaCl$_2$. At $-80 \, ^\circ\text{C}$ approximately 20% of the initial water was still liquid in the Ottawa sand pastes saturated with 1.0 mol kg$^{-1}$ LiCl or ZnCl$_2$. Liquid water was detected at $-35 \, ^\circ\text{C}$ in the 5-μm-size synthetic silica pastes saturated with 1.0 mol kg$^{-1}$ NaCl and at $-65 \, ^\circ\text{C}$ for those saturated with 1.0 mol kg$^{-1}$ CaCl$_2$. At $-80 \, ^\circ\text{C}$ approximately 15% of the initial water was still liquid in the 5-μm-size synthetic silica pastes saturated with 1.0 mol kg$^{-1}$ LiCl or ZnCl$_2$. These results indicate that for pastes saturated with NaCl and CaCl$_2$, the soil freezing curve is predictable based on the salt’s eutectic temperature. This is not the case for samples saturated with LiCl or ZnCl$_2$.

Keywords: Cryosols, salinity, soil freezing curves, permafrost
Cryogenic sector of the geoderma and its internal structure

KONYUSHKOV Dmitri Ye. and SOKOLOV Ilia A.
V.V. Dokuchaev Soil Science Institute, Pyzhevskii per. 7, Moscow 109017, Russia

The concept of geoderma. Geoderma - the surface skin of the earth that supports terrestrial ecosystems - is the result of long-term evolution under the impact of various endogenous (volcanism, hydrothermal activity, tectonics) and exogenous (continental sedimentation, weathering, denudation, soil formation, etc.) processes. Geoderma can be subdivided into five sectors - humid tropical, glacial-periglacial, arid, cryogenic, and volcanigenic - differed by their history, substantive composition, and the relationships between proper pedogenic, geological, and biological processes that specify the methodology of the genetic interpretation of soil profiles (Sokolov, 1993, 1997).

The specificity of the cryogenic sector is dictated by the activity of modern processes of cryogenic mass exchange (cryoturbation, solifluction, frost shattering, frost heave, etc.) leading to periodical rejuvenation of soil profiles, burying of surface horizons, and cryogenic microcomplexity of soil cover patterns. This is the sector of generally young and polychronous soils: from full-Holocene soils in well-drained sites without cryoturbation to modern soils. Cryogenic processes delete the results of previous stages of pedogenesis. In conditions when soil development is accompanied by sediment accumulation, buried profiles of ancient soils are preserved in the frozen state for tens of thousands of years forming a "museum of frozen paleosols." The effect of cryogenic processes is minimized in extremely arid conditions with dry permafrost. Cryogenic processes are superimposed over proper pedogenic processes, which creates the highest diversity of soil morphological forms. Judging the intensity of cryogenic processes and their impact on soil formation, it is reasonable to distinguish between noncryomorphic and cryomorphic soils, and cryopedoliths. Generally low temperatures retard the organic matter mineralization, which results in the widespread development of peat horizons. Nonsoil formations (rock outcrops) are also widespread due to active physical weathering and weakness of pedogenic processes. Cryogenic sector roughly corresponds to the area of Cryosols and Gelisols as defined in the WRB (1998) and Soil Taxonomy.

The pedogenetic diversity of the cryogenic sector is no less than in the other sectors of the geoderma: from eluvial–illuvial acid Podzolic soils to Ca-humus Chernozems and Solonchaks. The diversity of mesoxeromorphic soils is higher than that of hydromorphic (cryohydromorphic) soils: the latter include Histosols, Gleysols, Stagnosols, and Cryohydromorphic Nongley soils or Cryozems (Cryosols as defined in the WRB 1994).

The regularities of pedogenic zonation of the cryogenic sector are the same as in the other sectors of the geoderma: qualitative differences in the character of pedogenesis are governed by the degree of climatic humidity: the world (pedocosm) of soils in humid regions is different from the world of soils in semiarid to arid regions. The scheme of the pedogenetic zonation of the cryogenic sector is suggested. It is argued that proper pedogenic features should be put in the basis of classification decisions at high taxonomic levels, whereas the effect of cryogenesis can be reflected at lower levels. This approach allows one to analyze the whole pedosphere from the unified standpoint.

**Keywords:** Cryosols, geoderma, cryoturbation, soil geography, soil zonation
Humus soil profiles of West Siberia Northern Taiga

KOVALEVA Ekaterina I.

Institute of Soil Science and Agrochemistry, Sovetskaya st., 18, 630099 Novosibirsk, Russia

The problem of soil evolution and transformation requires all-round soil study, especially those soil properties which are sensitive and reflex in relation to the environment. One of the components, reflecting, coding and memorizing conditions of the forming of soil profile is humus (Sokolov, 1993). The humus formation process is reflected integrally in soil humus profile (Dergacheva, 1984). Therefore its detailed study is the evidence of humus changes and the soil formation.

The soils of the Noyaborsk ecological range (Tyumenskaya region) were investigated. This territory is the subzone of West Siberia Taiga. Relief is flat and undulating. Parent materials are aqueoglacial sandy deposits.

Humus profiles, some physical and chemical properties of studied soils: iron-illuvial podzols, humus-illuvial podzols, peaty surface gleyed podzolic soils, peaty podzol soils surface gleyed, shallow peat high moor soils formed on humus podzol were studied. All soils except shallow peat high moor soil were determined morphologically as monogeneous.

All studied soils, except shallow peat high moor soil, are sandy. The clay fraction content in the granulometric composition is very low (0.8-2.0 %). Shallow peat high moor soil presents itself as the alternation of peat horizons of the different decomposition degree and colour. The pH value of all these soils changed downwards from 3.5-4.0 to 5.0-6.0. The soils are characterized by the low base saturation; the soil acidity is high and is caused by the hydrogen and aluminium ions present. The amorphous iron distribution is characteristic of each type of soil.

The soils are characterized by fulvic humus composition, the high proportion of non-hydrolizable humus forms and aggressive mobile fulvic acids of the fraction 1a (Ponomareva and Plotnikova method, 1968) and rather high content of brown humic acids. Humus composition characteristics are in the limits of type peculiarities. The humus soil profiles essentially differ, fix soil heterogeneity are polygeneous in their characteristics and reflect the condition changes in the forming process.

Thus, the humus profile of shallow peat high moor soil can be divided into two parts: the slightly differentiated upper and the lower with more essential differentiation by humus indexes. The first one coincides with the profile of shallow peat high moor soil, the lower – buried humus podzol. It is reflected distinctly in the quantity humus change and combinations of humus profile characteristics.

Surface gleyed podzol soil had two stages in its development, too, though the relict features were not revealed morphologically. The humus profile analysis of this soil revealed the second humus horizon present by the totality of all humus characteristics. The features of its low thickness respond to its warmer stage than at present day.

Thus, humus profiles fix changes taking place in different time periods, reveal the heterogeneity and follow up in soil development history.

Keywords: humus, humic, fulvic acids, polygenesis, evolution
Morphogenesis of Cryosols and associated soils in the alpine zone of Tienshan, West China

PING Chien-Lu (1), ZHAO Lin (2), PAETZOLD Ronald (3), KIMBLE John (3), WANG Shaoling (2) and YE Baisheng (2)

(1) Palmer Research Center, University of Alaska Fairbanks, Palmer, AK 99645, USA
(2) CAREERI, Chinese Academy of Sciences, 260 Dunggang W. Road, Lanzhou 730000, China
(3) National Soil Survey Center, USDA-NRCS, Federal Bldg, Rm. 152, 100 Centennial Mall N, Lincoln, NE 68508-3866, USA

Soils were investigated in the Upper Urumoqi River Basin of the Tianshan Mountain Range, Xingjing, China. Cryosols occurred in the bottom lands and north-facing toeslopes in the glaciated valleys at elevations above 3,000 m. Most Cryosols on moraine deposits are Aquiturbels, with hummocky microrelief and cryoturbated surface organic layers. The Bg horizons are either gleyed or mottled with common frost-churned organic matter at depth. Common horizon stratification and buried surface (O and/or A) horizons on gentle sloping or undulating moraines indicate gelifluction processes. Active layer thickness in these soils ranges from 140-200 cm, with reticular structures formed at depth. Organic Cryosols (Hemistels) occur in depressions and north-facing toeslopes with active layer thickness ranging from 90-110 cm. Soils formed on south-facing slopes are Haplocryolls with mollic epipedons 20-25 cm thick and strong brown cambic horizons. The areal distribution of Cryosols is less than the actual extent of permafrost due to the depth requirement of permafrost in Cryosols. However, the existence of permafrost at greater depth cannot be ignored in land use interpretations.

Keywords: Cryosols, Tianshan, cryogenic structures, alpine soils, active layer
Cryosols in a changing environment: their role and research needs

TARNOCAI Charles

Agriculture and Agri-Food Canada, Research Branch (ECORC), 960 Carling Avenue, Ottawa, Canada K1A 0C6

Cryosols cover approximately $18 \times 10^6$ km$^2$, or about 13% of the Earth’s land surface. They occur in the permafrost zones in both the Northern Hemisphere and Antarctica as well as in some alpine regions. Cryosols are of global concern since it is predicted that both Polar Regions will experience a significant increase in average temperature. The primary concern, however, is the impact that global warming will have on these perennially frozen soils and on the large amounts of ice and organic carbon stored in them. The resulting changes could lead to a major re-shaping of the northern landscape, degradation of water quality and the release of large amounts of carbon into the atmosphere. These changes could severely affect living organisms (including human life), which are now more or less in equilibrium with local edaphic and climatic conditions.

In the coming decades research should focus on providing the information needed both to make predictions about these changes and to understand them. Such research should include: carbon dynamics, storage and fluxes; the effect of cryogenic processes on soil genesis; the effect of the melting of permafrost on physical and chemical properties of these soils; the development of reliable soil databases to enhance the classification, modeling and wise utilization of these soils; soil mapping in extensively-used areas and in areas lacking such mapping, and; establishment of long-term global monitoring networks to collect data on the impact of global change on such properties as soil temperature and soil moisture.

This research should be carried out through the international cooperation of scientists in order to provide greater efficiency as well as better dissemination of data and knowledge.

Keywords: Cryosols, permafrost, global change, research, cryogenic environments
Soil processes at well drained sites, Devon Island, Nunavut, Canada

UGOLINI Fiorenzo C. (1), CORTI Giuseppe (1), SLET TEN Ronald S. (2) and CERTINI Giacomo (1)

(1) Dipartimento Scienza del Suolo e Nutrizione della Pianta, Università degli Studi di Firenze, Piazzale delle Cascine, 28 - 50144, Firenze, Italy
(2) Quaternary Research Center, University of Washington, Seattle, 98195 - 1360, WA, USA

At Truelove Lowland, Devon Island, Nunavut, Canada, the Holocene emergence exposed a series of raised beaches of well-established chronology. The coarse texture of the strandline deposits has favoured well-drained conditions, thick active layer, a scanty xeric plant cover, and a minimal frost disturbance. The aim of this work was to examine the soil processes on these raised beaches with special emphasis on the role of the skeleton. For this purpose we combined traditional pedological approach with the study of soil solutions collected with tension lysimeters. Three soil profiles (P1, P2, and P3) were opened on three altitudinally and chronologically separated beaches. The soils were classified as Typic Haplorthels and displayed A, Bwk, and BC horizons. Pebble count reflected the lithology of the nearby outcrops. Bulk density of the fine earth decreased abruptly at the bottom of P1 and P3. This fact should be due to an increased porosity as a result of frost heaving at the interface of the frost table. Illuviation resulted in the formation of “silt caps” containing more fines (fine sand plus silt) than the soil matrix. The fines of these features held moisture and released nutrients, consequently they were preferentially invaded by roots. The skeleton played an important role in entrapping the moving fines and providing platforms for the building of the silt caps. Soil solution was collected from the P2. The solutions were dominated by the inorganic anions HCO3\(^-\), Cl\(^-\), and SO4\(^{2-}\) and contained mean concentrations of dissolved organic carbon between 10 and 20 mg L\(^{-1}\). Calcium and Mg\(^{2+}\) were the most abundant cations, evidently due to the dissolution of dolomite. Iron and Al were at low level, maybe because of low chelating capacity of the organics and the high pH (about 8). Nitrates were low reflecting the scarce biological activity. Silicon was low, indicating minimal silicates weathering, but increased with the warming of the soil. With the progression of the warm season, alkalinity increases coinciding with root respiration, organic matter decomposition and, likely, precipitation of carbonates. In conclusion, the soil processes were mostly manifested by 1) slow weathering because of low production of proton donors, 2) dissolution of dolomite, and 3) development of silt caps above the clasts with formation of secondary carbonates underneath.

Keywords: arctic soils, lysimetry, soil processes
Permafrost distribution and soil climate in the Glacial Lake Agassiz basin in North-central Manitoba, Canada

VELDHUIS Hugo (1), EILERS Robert G. (1) and MILLS Gordon F. (2)

(1) Agriculture and Agri-Food Canada, SPARC, Western Land Resource Group, Rm.362A, Ellis Building, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2
(2) Manitoba Agriculture, Soils and Crop Branch (Retired). 700 Patricia Street, Winnipeg, Manitoba, Canada R3T 3A6

The Glacial Lake Agassiz basin in north-central Manitoba consists predominantly of glacio-lacustrine, clayey uplands and peat-filled lowlands. The region lies within the discontinuous permafrost zone. Permafrost mainly occurs in deep and shallow peatlands, and on uplands under mature closed black spruce-feather moss vegetation. Soil climate and permafrost characteristics along a toposequence, from upland to lowland, were monitored between 1981 and 2001. The study site, covering an area of 225 x 100 m, is under mature vegetation and is located in the northern part of the Boreal Ecozone, near Thompson, Manitoba. Monitoring instrumentation consisted of thermocouples/thermistors, wells, and frost tubes along a 225 long transect. Depth to permafrost was also monitored on a 25 m grid. Vegetation, drainage, and thickness of organic surface layers are the apparent dominant controls of soil climate and permafrost distribution. However, observed permafrost dynamics indicate that weather events, such as early fall or delayed snowfall, and wet or dry summers, also have a significant effect. Water movement during snowmelt occurs primarily over the frost table, and through the peat layer and the upper part of the mineral soil after heavy rains. Maturation of veneer bogs typically extends these shallow peatlands through the process of paludification, and the deepening of the peat generally leads to greater incidence of permafrost. However, if climate change results in more frequent wildfires or warmer summers, it is most likely that the expansion and extent of shallow peatlands and the distribution of permafrost will be reduced.

Keywords: soil climate, permafrost distribution, shallow peatland
Symposium 44

Global and national digital databases on soil and terrain conditions, their compilation and uses

Convenor: SOMBROEK Wim
Co-Convenor: VEARASILP Taweesak

Oral Session
Thursday 15 August 2002
14:00-17:20
Room: Meeting Room 3

Poster Session
Thursday 15 August 2002
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Contemporary stocks of carbon and nitrogen in the soils of Central and Eastern Europe

BATJES Niels H.

International Soil Reference and Information Centre (ISRIC) / World Data Centre for Soils, P.O. Box 353, 6700 AJ Wageningen, The Netherlands

Soil organic carbon and total nitrogen stocks, to a depth of 0.3 m and 1 m respectively are presented for central and eastern Europe. The study uses the soil geographic and attribute data held in a 1:2,500,000 scale Soil and Terrain (SOTER) database, covering Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, the Russian Federation (west of the Urals), Slovakia, and the Ukraine. Means and coefficients of variation for soil organic carbon and total nitrogen are presented for the 72 soil units (FAO-Unesco, 1988) that have been mapped for the region. The mean density of organic carbon, to a depth of 1 m, ranges from 3.9 kg m\(^{-2}\) for coarse textured Arenosols to 72.9 kg m\(^{-2}\) for poorly drained Histosols. Mean carbon density for the mineral soils, excluding Arenosols and Andosols, is 15.8 kg m\(^{-2}\). The top 1 m of soil holds 109.7 Pg C (1 Pg = 10\(^{15}\) g), corresponding with about 7% of the global stock of soil organic carbon. About 44% of this carbon pool is held in the top 0.3 m of the soil, the layer that is most prone to modification upon changes in land use systems or land use conversion.

Keywords: soil organic carbon, soil nitrogen, central and eastern Europe, soil and terrain (SOTER) database
Modeling erosion of soil carbon in the conterminous United States: lessons for SOTER development

BLISS Norman B., WORSTELL Bruce B. and LIU Shuguang

Raytheon ITSS, EROS Data Center, Sioux Falls, SD 57198, USA

The erosion and deposition of soil carbon are being modeled as a contribution to studies of the global carbon cycle. The State Soil Geographic (STATSGO) database for the conterminous United States was used in conjunction with the National Resources Inventory (NRI) and the National Land Cover Dataset (NLCD) to estimate soil erosion rates in a framework suitable for parameterizing an ecosystem model of carbon dynamics. The STATSGO data were compiled at a mapping scale of 1:250,000, and there are several similarities with the development of the world Soil and Terrain (SOTER) digital database. Both the STATSGO and SOTER approaches develop generalized soil data for large areas, and use hierarchical data structures that provide detailed attribute information for multiple soil types in each spatial polygon. The integration of STATSGO data with the NRI and the NLCD involved comparing distributions of land surface properties in spatial units larger than the fundamental unit of any of the source data sets. This approach uses distribution of properties, rather than making an assumption that polygons are homogeneous, and seems realistic for a wide variety of resource analysis applications. An algorithm was developed to use externally defined assumptions to create a model of a joint probability distribution for the intersecting distributions. In this way, the assumption of homogeneous polygons was avoided, and a reasonable framework was provided for modeling changes on the landscape. Similar approaches will be useful for the application of SOTER data to environmental modeling and management.

Keywords: soil data structures, data integration
The use of DEM and satellite data for regional scale soil databases

DOBOS E. (1), BLISS N. (2), WORSTELL B. (2), MONTANARELLA L. (3), JOHANNSEN C. (4) and MICHELI E. (5)

(1) University of Miskolc, Dept. of Physical Geography and Environmental Sciences, Miskolc-Egyetemvaros, 3515 Hungary
(2) Raytheon, USGS EROS Data Center, Sioux Falls, South Dakota, 57198, USA
(3) European Soil Bureau, European Commission, JRC, T.P. 262 21020 Ispra (VA), Italy
(4) Purdue University, Dept. of Agronomy, West Lafayette, IN 47907, USA
(5) Szent Istvan University, Dept. of Soil Science and Agrochemistry, Gödöllő, 2100, Hungary

A potential way of deriving soil databases uses quantitative data sources, such as satellite data and digital elevation models (DEM). These data sources and the derived soil maps will have all the advantages of quantitatively derived databases, including consistency, homogeneity, and reduced data generalization and edge-matching problems.

Three studies using integrated Advanced Very High Resolution Radiometer (AVHRR) and digital elevation data were carried out to map soils for large areas. The test areas were Hungary, Italy and the midwest area of the United States. Temporal data sets of 5 to 8 dates of AVHRR data (including all five bands and the normalized difference vegetation index were used to represent different environmental stages and conditions. These AVHRR data were complemented with DEM-derived variables, such as elevation, slope, aspect, curvature, and potential drainage density. The integrated AVHRR-terrain databases were then processed using a discriminant analysis feature extraction method, and the transformed images were classified to extract soil type (classification category) information.

We concluded that maps created from multitemporal, multispectral satellite data represent a great portion of the natural soil spatial variability. The agreement between the classified soil image and the reference soil maps was further improved by the addition of terrain information to the model. A new terrain variable, the potential drainage density, was developed and found to well characterize soil-landscape relationships on a regional scale, even with low-resolution DEMs.

Although the results from the above procedures are believed to be accurate enough to serve as a basis for global and regional studies, they should be checked and further revised by local and regional experts to ensure quality. Research should continue on improving the procedures, augmenting the pedon data with new field sampling, and incorporating new image and DEM data sources.

Keywords: global soil database, soil mapping, AVHRR, remote sensing, digital elevation model
SOTER as a tool for land use planning: experiences in West Africa and future applications

HERRMANN L. (1), GRAEF F. (1), IGUE M. (1), WELLER U. (2), GAISER T. (1), HAMMEL K. (1) and STAHR K. (1)

(1) Institute of Soils Science and Land Evaluation 310, University of Hohenheim, 70593 Stuttgart, Germany
(2) GSF, National Research Centre for Environment and Health, Biomathematics and Biometry, 85764 Neuherberg, Germany

This paper deals with applications of the SOTER approach in different tropical and subtropical areas. It discusses advantages and constraints, possible sampling procedures, reasonable applications, and presents our view for modifications.

The SOTER approach was developed in order to provide a sound global database at a scale of 1:1,000,000 for land evaluation purposes and soil degradation studies. The chosen scale is a compromise having global resolution and regional/national applicability in mind. However, coastal west Africa with its small countries and a variety of applications for land use planning require a higher resolution mapping (e.g. 1:200,000).

One advantage of SOTER is the open approach allowing different ways for map unit derivation, depending on the availability of data. Studies in west Africa show that satellite data are very useful in arid to semi-arid areas, whereas geology, topography and soil maps are necessary in areas with higher rainfall and denser vegetation. Mapping can be executed on the basis of randomised sampling points or transects. Randomised sampling allows a better statistical evaluation but is time and cost intensive.

Some modifications of the SOTER data structure would lead to better applicability. Experience in different countries has revealed that above the Terrain Unit a fourth unit would be desirable which could be called the Geo-structural Unit. For a sound global legend these Geo-structural Units should be defined by an international commission in order to avoid mapping discontinuities at state frontiers.

Furthermore, we propose to describe Soil Components by a Profile Set rather than one a representative profile in order to provide information for sound land use planning. In addition, our experience gives reason for a limitation of the number of map unit separation criteria.

Our applications were performed on the SOTER Terrain Component level because it has a resolution where single parameters (i.e. slope, texture) are sufficiently homogeneous to decide about the implementation of single measures (i.e. mechanisation of agriculture). Results will be presented from Niger, Benin and Brazil.

In the latest project SOTER maps were used in southern Benin to describe the regional availability of soil water resources. Future projects aim at the incorporation of SOTER maps into regional expert systems concerning eolian erosion and propagation of parasitic weeds (Mediterranean).

Keywords: land evaluation, remote sensing, GIS, RDBMS, Niger, Benin
Application of GIS technology in land management in Croatia

HUSNJAK Stjepan and BOGUNOVIĆ Matko

Soil Science Department, Agricultural Faculty, Svetosimunska 25, 10000 Zagreb, Croatia

It is a known fact that at present planning of sustainable development and land use requires a large quantity of good quality and reliable information, that serves as the basis for adopting of timely and reasonable decisions. The way to such information is a very complex one, requiring a lot of labour and time. However, nowadays it is possible to process such data using GIS technology and to develop adequate Land Information Systems (LIS) which can then serve to obtain the required information in a comparatively easy and quick way, both in the form of specialized maps and of textual and numeric data. The development and application of GIS technology in the Soil Science Department of the faculty of Agronomy, The University of Zagreb, has been well advanced in the recent years, resulting in the development of several LIS for separate counties. This paper present methods of development of LIS in Croatia, giving some examples of information that may be obtained using the systems. The basic data for setting up a land information system are the data from basic soil and topographic maps of the Republic of Croatia at the scale of 1:50,000, as well as data from other studies of projects made for the purposes of agriculture, forestry, environment protection, etc. These data are, together with the results of processing and analysis by digitalization, generalization and interpolation and prepared databases, integrated into a single LIS, using AutoCad, ArcInfo, ArcView, Microstation and Access program packages. The LIS are organized in the way allowing the users to prepare various thematic maps, inventories and access to information on soil characteristics related to soil mapping units – polygons – as well as those related to pedological profiles, either by searching or by putting questions by means of the ArcView program package. Although the LIS were worked out for the purpose of further development of agriculture, they may be used for the development of forestry, environment protection, physical planning, water management and land conservation and development. As an example of the use of LIS for agricultural development, a thematic map was prepared showing soil suitability for vegetable growing in the Sisak-Moslavina County. As an example of the possibility of application of LIS in soil conservation and improvement, the thematic map of soil requirements for liming was prepared for the territory of Zagreb County, defining the position of soils where such an agrotechnical measure is necessary. The third example shows the application of LIS in physical planning, including preparation of the land capability map of the Brodsko-Posavska County.

Keywords: GIS technology, land properties, database, land information system, thematic maps, land management
Medium scale land evaluation application of SOTER in Central Benin

IGUÉ Attanda Mouinou (1), STAHR Karl (2) and GAISER Thomas (2)

(1) Centre National d’Agro-Pédologie/Institut National des Recherches Agricoles du Bénin, 01 B.P. 988 Cotonou, Bénin
(2) Institute of Soil Science 310 University of Hohenheim, D-70599 Stuttgart, Germany

Agriculture is the most important agent of environmental degradation in Benin. The land use systems there, adherent over centuries, is no longer sustainable today. The consecutive reductions in site productivity call for an information system on soil resources which allows analysis with respect to potential use, food production, environmental impact and conservation. On the basis of such a system sound policy formulation, development planning at all levels, efficient use of both internal and external resources, becomes possible.

An adequate information system should consist of:
1. A digital database containing information on topography, soils, climate, vegetation and land use on different levels.
2. A Geographical Information System (GIS), which links each item of information to its precise geographical location.
3. A set of crop models which can calculate the level of production, at a number of different input levels or management systems.
4. Various environmental impact models which allow the calculation of erosion rate.

The soil and terrain information system is being developed using the SOTER approach. On the uppermost level seven so called 'terrain units' can be distinguished in Central Benin. The main differentiating criteria were landscape morphology, geology and hydromorphy. The terrain units are subdivided into a second level into 26 terrain components according to the soil parental material and landform.

In contrast to soil mapping, the SOTER approach allows direct application on different aggregation levels. A stronger emphasis is on the landform-soil relationships and on mapping units which react homogeneously on cultivation techniques. The next step will be the inclusion of crop growth models. Applications for land evaluation and erosion risk assessment are presented.

Keywords: SOTER, aggregation levels, crop yield models, environmental impact models
Soil geographical database of Eurasia and Mediterranean countries at 1:1 m


European Soil Bureau - EU - Joint Research Centre, Ispra, Italy and INRA - Orléans, BP 20619, Olivet Cedex, France

Agriculture and environment were initially managed by the European Union through different "Program Committees". A major topic was the elaboration of a Soil Map of the European Communities (EC) at 1:1 M., published in 1985. It has been elaborated using data from a previous FAO European mapping program. Digitisation of the map in 1986 produced the first European geographical soil database (version 1.0). However, the data derived from that work were insufficient to fulfil the needs of soil data. FAO archives were thus used again to produce a version 2.0 of the database. Addition of new attributes and complementary data from countries improved the soil characterisation, resulting in a version 3.0 of the soil database. The data sets were managed within a Geographical Information System.

The creation of the European Soil Bureau by the European Union (EU) gave a spectacular development to the program. The geographical coverage of the database was extended successively to the Central and Eastern European countries, to the Scandinavian and Baltic countries, to the New Independent States (NIS), and, more recently, to Southern and Eastern Mediterranean countries.

To help countries in giving data to that program, the general organisation of the database was presented in a Users Guide. For the extension to NIS and Mediterranean countries, several modifications of the data base structure were made leading to a version 4.0. Consequently, the guide was updated to become an "Instructions Guide for the elaboration of the Soil Geographical Data Base of Eurasia and Mediterranean countries at 1:1 M".

To help in using the database, a set of pedotransfer rules was developed based on elements available in the database and also expert knowledge. These pedotransfer rules provide elements to answer some thematic questions.

Co-ordination and harmonisation with different world programs of soil survey from international organisations like FAO or UNEP have also been made. An example is the integration of the collected European data in a world SOTER database at 1:5 M.

The Geographical Soil Data Base of Eurasia and Mediterranean countries represents the present stage of our knowledge concerning the main soils in that part of the world, and would be useful for management and protection of soil resources.

Keywords: soil database, geographical information system, Europe, new independent states, Mediterranean countries
ASRIS - Australian soil resources information system

JOHNSTON R.M. (1), BLEYS E. (1), BARRY S.J. (1), BUI E.N. (2) and McDONALD W. (3)

(1) Bureau of Rural Sciences, P.O. Box E11, Kingston ACT 2604, Australia
(2) CSIRO Land and Water, GPO Box 1666, Canberra ACT 2601, Australia
(3) NLWRA, GPO Box 2182, Canberra ACT 2601, Australia

The Australian National Land and Water Resources Audit (NLWRA) commissioned the Australian Soil Resources Information System (ASRIS) to improve access to and quality of national scale information on soils in Australia. ASRIS is a collaboration between Commonwealth research agencies (BRS, CSIRO) and State and Territory natural resource management agencies. ASRIS provides for the more intensively used agricultural regions of Australia:

- a national database of existing data relating to soil and land resources (soil profile and map data), and
- modelled spatial estimates of soil properties and their uncertainties at a grid cell resolution of 1 km.

About 160,000 soil profiles from a range of sources have been compiled into a single dataset. All soil profile data have been converted to a standard format and are held in an Oracle database. Soil and land resources map data at scales between 1:50,000 and 1:1,000,000 have been compiled into an ArcInfo database, which can be linked to the soil profile data. Other datasets related to soil have also been compiled in digital format, including: lithology; terrain attributes (based on the national 9” digital elevation model); climate data; and Landsat MSS imagery.

The compiled database was used as the basis for predicting soil properties at regional scales. Soil attributes predicted for topsoil and subsoil include: clay content, pH, organic carbon, saturated hydraulic conductivity, bulk density, available water capacity, total nitrogen, total phosphorus, texture and thickness. Two different methods were used, depending on data availability for different properties. A methodology was developed by CSIRO where each soil attribute was predicted individually, on the basis of correlations between soil properties (from soil profile data) and other environmental variables, such as terrain descriptors, MSS imagery, and climate data. Attributes for which soil profile data were limited were estimated using map-based interpretations, where the dominant soil classes in each map unit were identified, and values for specific properties assigned to each map unit on the basis of the range observed for those soil types. A statement of reliability and certainty is attached to estimates of each attribute to reflect the source of the information and the nature of the interpretation.

The modelled surfaces of soil properties have wide applicability in models of landscape processes, and have been used as inputs to assessments of water-borne erosion and sediment/nutrient transport, current and projected soil acidification and landscape productivity. The derived datasets are available through the NLWRA Data Library and the Australian Natural Resources Atlas (www.nlwra.gov.au/atlas).

Keywords: soil, land resources, database, GIS, modelling
A method for generalization of a soil geographical database: the example of the transfer of the European database EUSIS at 1:1m to the world SOTER program at 1:5m

KING Dominique (1), SABY Nicolas (1), LE BAS Christine (1), NACHTERGAELLE Freddy (2), VAN ENGELEN Vincent (3), EIMBERCK Micheline (1), JAMAGNE Marcel (1), LAMBERT Jean Jacques (1) and MONTANARELLA Luca (4)

(1) INRA Orléans, Science du Sol - InfoSol, BP20619 - 45166 Olivet, France
(2) FAO GLS Via delle Terme di Caracalla 00100 Roma, Italy
(3) ISRIC, 6700 AJ Wageningen, The Netherlands
(4) JRC European Soil Bureau, 21020 Ispra (va), Italy

In many instances, soil maps or geographical databases at a given scale must be transferred into a mapping program realised at a smaller scale and covering larger areas. The objective is to develop a scale transfer methodology making use of some of the automated procedures already built in geographic information systems. The final result must correspond to the norms and specifications defined for the smaller scale target program. But the end product should also retain some ascending compatibility with the information initially available at the larger scale.

The work presented makes use of the European soil geographical database at scale 1:1,000,000, part of the European Soil Information System (EUSIS). The objective is to transfer the available information in the European database to the world soil mapping program SOTER at scale 1:5,000,000. The SOTER program methodology is respected as scrupulously as possible while using the EUSIS data when the required information is available (for example, lithology) or using external data (for example, a 1x1 km grid Digital Elevation Model for the landform morphology).

Based on the two specific SOTER criteria of lithology and landform morphology, the EUSIS mapping units with identical characteristics are regrouped within the new SOTER terrain units. In order to achieve ascending compatibility between SOTER and EUSIS, semantic information in EUSIS (i.e. attributes of soil profiles) is used to describe the SOTER units created. The last step consists of smoothing SOTER map unit boundaries to improve legibility at 1:5,000,000 scale.

The results of this work are compared to previously realised projects that were based on expert knowledge. Main geographical domains are similar and differences lie in the drawing of boundaries. However older maps take into account other criteria, especially climate, not considered as an attribute in the SOTER methodology. Moreover, a sensitivity analysis is performed to evaluate if the order followed in the geometric and semantic scale transfer procedures affect the final result. The method developed is not specific to EUSIS and SOTER information. Scale transfer methods can be easily adapted to any other program requiring a transfer of information from one database to another.

Keywords: European soil database, SOTER program, geographical information system, scale transfer
Land use planning using a soil and terrain database in the Berau regency, Indonesia

MANTELS S. (1), TYRIE G.R. (2) and GUNAWAN A. (2)

(1) International Soil Reference and Information Centre (ISRIC) / World Data Centre for Soils, P.O. Box 353, 6700 AJ Wageningen, The Netherlands
(2) Berau Forest Management Project (BFMP), Gedung Manggala Wanabakti, Block IV 7th Floor, Wing A, Jl. Jend. Gatot Subroto Kav. 32, Jakarta 10270, Indonesia

The Berau regency is located in the northwestern part of East Kalimantan province and covers about 24,000 km². It is one of the largest and least populated regencies of Indonesia, with a population of around 100,000. In the past three years a dramatic increase in deforestation has been observed as compared to the past three decades, with a current deforestation rate of 42,500 ha y⁻¹. The recent transfer of power from the central government to the district governments, the increased in recognition of local land rights, and the influx of migrants from other islands brings about an increased dynamic in land use changes and requires planning.

A district soil and terrain database (1:250,000) was compiled in cooperation with the spatial planning unit of the Berau regency government. The database was linked to a set of models for a land management zoning. With this zoning land use options are balanced to support the annual spatial (land use) planning at the district level.

A high variation in terrain and soil conditions was found, mainly related to topography and parent material. Much of the land in Berau, with dominantly aluminium saturated Acrisols, is unsuitable for subsistence and low-input cultivation of food crops as evidenced by low yields. The undulating part of the terrain overlying limestone (7% of the total area) is covered with high potential soils (Vertisols and Vertic Cambisols) for agriculture. The land management zoning includes a range of analyses such as potential erosion risk, environmental stability, land suitability, definition of forest production zones and priority areas for biodiversity conservation. The zoning of defined areas with forest use potential (natural forest production, plantation forestry, and areas with priority for protection or biodiversity conservation), potential for perennial and annual crops and associated management requirements. The high vulnerability to erosion is a major constraint to the use of most soils in Berau. Potential for eco-tourism development was indicated for selected areas in Berau, such as the karst area (scenic value), part of the primary forest area (biodiversity) and the marine islands (diving).

Keywords: SOTER, soils and terrain database, land use planning, forest management planning, Acrisols, Indonesia
World soil and terrain database (SOTER): past, present and future

NACHTERGAELE Freddy O. (1) and OLDEMAN L. Roel (2)

(1) Land Classification, Land and Water Development Division (AGL). Food and Agriculture Organization of the United Nations, (FAO), Rome, Italy
(2) International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands

A historical overview is given of the development of global soil information systems since the first call for a world soil map by the ISSS congress in 1960 and the need to update this paper map to produce a digital global soil and terrain database (SOTER) by the IUSS congress of 2006.

The progress and related developments in particular the links made of this SOTER database in regional studies with land degradation assessments in Southeast Asia and in Central and Eastern Europe are discussed. The latter studies used the soil and/or terrain units inventoried in SOTER as the basic units in which land degradation is assessed, using an expanded methodology involving the description of the type, extent, severity and effect on crop yields of land degradation taking place. All data collected by national soil institutes are easily accessible and retrievable in a GIS environment.

It is concluded that the global SOTER exercise needs additional resources if it is to be finalized soon to serve as a basis for applied studies and models. The soil degradation studies in Southeast Asia and Central and Eastern Europe are examples, to be discussed briefly, where the SOTER methodology for describing and delineating mapping units has been applied to assess soil degradation.

Keywords: soil and terrain databases, SOTER, world soil map
Land and soil data for the entire country (India) was generated by a systematic survey and mapping at 1:250,000 scale. A large volume of data was generated on land and soil characteristics and their spatial distribution. The data was published in the form of maps and reports. In order to overcome the limitations of manual methods of data handling, especially when the volume of data is large, we took recourse to digital processing using the computerised Geographical Information System (GIS). The authors have developed a digital database of soils of four southern Indian states. For limited areas digital data sets at a much larger scale of (1:4,000 to 1:50,000) was also created.

The spatial and attribute data sets on land and soils were converted to digital format by manual digitisation of analog soil map data and keyboard entry of attribute data. The attribute data sets was organised as relational tables with necessary links to spatial data. The 1:250,000 scale soil map data is on the base of one degree Survey of India topographic sheets.

The digital data sets created include terrain features, land use, agro-climate, soil morphology, physical and chemical properties of soils and their classification. Each terrain unit is described in terms of it’s topography, dominant surficial features and their use. Terrain units are often further delineated into soil map units, each representing an association of soil families. Each soil map unit is composed of a dominant, subdominant and one or more inclusive soils classified at family level of Soil Taxonomy. The data on morphological, physical and chemical properties of the pedon typifying the mapped soil families are held as the attribute data sets. The attribute data sets on land and soil can be extracted for the desired subsets and linked to the spatial data for spatial analysis. The climatic data is held as point data sets and interpolated over the surface for spatial analysis in conjuction with land and soil data whenever necessary.

The digital data sets are currently used for land suitability evaluation for different purposes, especially agricultural land use planning at regional and state levels. The process normally followed is the defining of land use requirement of the intended use and matching with land qualities. Spatial data analysis functions provided by GIS software are used in the process. The other uses of the digital data include extraction of specific terrain, soil and land use features for assessing land degradation, land qualities for specified uses and environmental studies.

**Keywords:** digital data, GIS, land use planning, land quality
A great amount of soil information is available in Hungary due to agrogeological surveys conducted in the past. In the 1990s a great deal of Hungarian soil data were organized into computerized geographic soil information systems by RISSAC GIS Lab. In the beginning small-scale (1:100,000-1:2,500,000) systems were compiled (Agrotopo, HunSOTER, MERA). Recently the more challenging large-scale systems are coming to prominence. As primary importance digital reambulation and GIS adaptation of the results of the practical 1:25,000 scale soil-mapping programme hallmarked by Lajos Kreybig is under construction.

The national soil-mapping project initiated and led by Kreybig was unique being a national, large-scale survey based on field and laboratory soil analysis and in the meantime serving practical purposes. By its completion, in the early 1950s, Hungary was the first country in the world having such detailed soil information for the whole country. The Kreybig maps are still timely, because the temporal changes in the mapped soil characteristics are not significant. On this basis, the maps and the data of the supplementary explanatory notes can serve as a reference to the study of anthropogenic effects, and are suitable for the foundation of the soil module of the Hungarian production database facilitating Hungary’s EU-accession, and for spatially supporting the national large-scale mapping.

GIS processing of the Kreybig archives started in 1998 at the GIS Lab of RISSAC. The experimental project financed by RISSAC endeavors the GIS application and the integration of soil data available at various institutions, in different scale and processing levels. A user module fitted to the GIS software (Kreybig module) and a data loading and control program (Kreybig point data manager) were developed to enable the better and more suitable compilation and application of the system.

Compilation of the Kreybig Digital Soil Information System (KDSIS) has been going step by step on smaller and larger sample areas. Processing of data is carried out by map sheets. Having completed geometric and thematic digitization of neighboring sheets they are fitted together (edge correction!) then they are merged. At the same time primary reambulation is carried out by taking into consideration the changes reflected by recent digital topographic and/or land use databases which are simultaneously used within the same GIS environment. A secondary, thematic reambulation of the database seems to be also necessary which needs the cooperation of the experts of the county Plant and Soil Conservation Stations and of research institutes.

The spatial entities of Kreybig maps are (i) the soil units characterized by physical and chemical properties and (ii) representative and non-representative soil profiles characterizing the main features and the heterogeneity of soil units respectively. At present compilation of the spatial pattern (i.e.: polygon structure of soil patches) of KDSIS has been completed for about 40% of the country. Compilation of a profile database module is a bit lagging behind. However the spatial pattern provided by the soil polygons together with their features are suitable for various applications in themselves.

**Keywords:** GIS, soil information system, reambulation, micro-regio scale
Digitized natural landscape units and associated soil point data as framework for Amazon biomass and biodiversity assessment

RAMALHO FILHO Antônio (1), DE SOUZA CARVALHO Albertino (2), CAMARGO DE MIRANDA Luiz (3) and SOMBROEK Wim (4)

(1) Embrapa-CNPS, Rio de Janeiro, Brazil
(2) UFAAM/IPAAM, Manaus, Brazil
(3) MMA-SPDS, Brasilia, Brazil
(4) GTZ/IPAAM, Manaus, Brazil

The Brazilian federal soil survey organisation Embrapa-Solos co-operated in the first SOTER sub-regional pilot area in adjoining parts of Argentina, Uruguay and southern Brazil in the eighties. Since then the concept has been applied explicitly in parts of the Amazon region such as the Beni-Pando area of Bolivia and the Rondônia state of Brazil, and implicitly in Acre, Amazonas and Pará states of Brazil in the framework of its Ecologic-Economic Zoning programme. The physiographic building blocks of the approach have received different names, but they all concern major natural landscape units. The point data subsystem on soil profiles, in combination with one ha. measurements of the natural vegetation and recent Landsat imagery, which serve as reference material for estimating the carbon stock and -sink function of the old-growth forest, of the edaphic savannahs and the anthropogenic secondary vegetation, as well as the composite biodiversity value of each landscape unit. Much of the data set was already collected during the RADAMBRASIL project of the seventies. It needs only to be digitized in SOTER format, with some extra sampling of representative soils for their physical data in-situ in respect of total carbon storage, rooting depth and moisture storage capacity. Details of such a programme are being negotiated with the international pilot programme for the protection of the tropical forests of Brazil (PPG7).

Keywords: SOTER, Amazon, landscape units, biodiversity assessment, carbon stock and -sink, soil physical point data
Distribution of the reserves of organic matter in the soil cover of Russia

ROJKOV Viacheslav, KONJUSHKOV Dmitry and KOGUT Boris
Dokuchaev Soil Institute, Pyzhevsy Lane, 7, Moscow 109017, Russia

The problem of evaluation of the reserves and balance of carbon in various components of ecosystems and in the biosphere as a whole is a growing concern for scientists interested in investigating the possibility of global warming of the climate of the Earth. Calculations of soil carbon (organic and mineral) were done on a soil map of Russia at a scale of 1:2,500,000 and entered in a database of typical profiles using GIS technology.

The average pool of organic carbon in soils of Russia is estimated at 296 Gt, including 236 Gt in soils of plain territories and 60 Gt in soils of mountain regions. The stores of organic carbon in arable lands constitute about 27 Gt, in other lands of agricultural use (meadows, gardens, fallow, etc.) 20 Gt. The data obtained were used to compile a small-scale map (1:16 M) of the reserves of humus in soils of Russian Federation. The zonal distribution of humus reserves is very distinct within the European part of Russia, whereas for Siberian territory the general picture is much more complicated. This is explained by the fact that a considerable portion of Siberia is occupied by mountainous landscapes; thus the character of humus formation and accumulation in soils is controlled by the specifics of vertical zonation of soils. Also, vast areas within the West Siberian lowland are occupied by bogs, which stand out from the adjacent soils due to their high humus reserves. However, zonal regularity of humus distribution is observed in Siberian plains for the automorphic soils. The zones of tundra soils, the soils with low humus reserves (podzolic, taiga frozen soils), and the soils with high humus reserves (steppe soils) are vividly manifested.

Keywords: carbon, digital soil, landscape, carbon maps
On-line soil resource inventories: status and prospects

ROSSITER David G.

International Institute for Geo-Information Science & Earth Observation (ITC), P.O. Box 99, 7500AA Enschede, The Netherlands

Since 1997 the author has maintained the website “A Compendium of On-Line Soil Survey Information”. During these five years, the amount and quality of digital data sets at global, national, regional, and local scales has increased dramatically. Some of this is freely-available on-line, via the World Wide Web. This paper presents an inventory of such data, categorised by region, scale, and theme. There is a large discrepancy among countries with respect to their philosophies of public access to foundation data such as soil maps. Key problems remain, most notably the lack of accurate metadata and searchable indices, and thematic and geometric compatibility with related digital data. Emphasis must be given to ease of user access and application by professionals who are not soil specialists.

Keywords: digital databases, world wide web, soil survey, soil resource inventory
Development of world soils and terrain digital databases for South Africa

SAMADI Massoud (1), BEUKES Hein (1) and REMMELZWAAL Arie (2)

(1) ARC-Institute for Soil, Climate and Water, Private Bag X79, Pretoria, South Africa
(2) International Soil Reference and Information Centre, P.O. Box 353, Wageningen, The Netherlands

The objective of this project has been the development of relevant algorithms for the translation of South African soil and terrain data into an internationally accepted format developed by World Soils and Terrain Digital Database (SOTER). To achieve this goal, the national land type data at 1:250,000 scale was translated into a SOTER database at 1:1 million scale. For transferring the land type terrain units to the SOTER landform classification, a 400 m Digital Elevation Model (DEM) was used. Some revisions needed to be made to the major landform definitions in the SOTER Procedures Manual in order to render them suitable for use in South Africa. To transfer the soil forms and series of the South African Soil Classification System into the lower units of reference soil groups in the World Reference Base for Soil Resources classification (WRB) the central concept and the most typical appearances of these soils have been used. The correlation exercise was done using computer programming.

Products of the South African SOTER database to date are as follows:

a. A digital, “Soil Associations of South Africa” map at 1:1 million scale based on the 1998 version of WRB classification comprising 15 map units, consisting of soil units or associations of soil units covering at least 40% of the mapping unit.

b. A digital, “Dominant Soils of South Africa” map at 1:1 million scale composed of dominant soils each covering ≥ 25% of the mapping unit. A list of the dominant soils of South Africa comprises 22 WRB Reference Soil Groups.

c. A digital, “The broad SOTER Terrain Unit” map at 1:1 million scale.

The SOTER database is also being used for applications such as Automated Land Evaluation System (ALES) for qualitative crop suitability ratings in the context of resource-poor agriculture in South Africa.

Keywords: SOTER, WRB, DEM, land type data, SADC
BORIS 2001 - soil information system of Austria

SCHWARZ Sigrid, TULIPAN Monika, HUBER Sigbert, SCHREIER Ingrid, WEBER Martin and FREUDENSCHUSS Alexandra

Federal Environment Agency, A-1090 Vienna, Spittelauer Lände 5, Austria

Austria with an area of 84,000 km² (46% forests, 43% agricultural area, 11% others e.g. artificial surfaces, bare rock) possesses comprehensive soil data. Yet, these data are structured heterogeneously as they have been collected by different institutions with varying objectives. So, to make them jointly available, the Federal Environment Agency developed the Soil Information System BORIS. Data from more than 40 different investigations were harmonised according to the "Data Key for Soil Science" ("Datenschlüssel Bodenkunde") Schwarz et al. (1999). In 2001 the soil information system holds about 1.5 million records from about 10,000 sites. These are data from the Environmental Soil Surveys of the Federal Provinces of Austria, data of several special investigations and of Austria-wide investigations such as data of the Forest Soil Monitoring System (Federal Forest Research Centre) and radio caesium data.

The Austrian Soil Information System BORIS provides – as one of its specific features – access to soil information via Internet. BORIS INFO is open to the public (http://www.ubavie.gv.at/umweltsituation/boden/boris) and contains detailed information about site and profile description, as well as meta data about analytical parameters. Internet users get an overview of existing data and information about ownership and possible access. BORIS EXPERT provides access to the complete database for those institutions concerned with soil issues and which are included in the list of licensed institutions with granted access. These are mainly the institutions which provided data for BORIS.

Austria-wide evaluations of organic matter, lead and cadmium concentrations in upper soils according to land use are described as well as the special situation of the Alps which are assumed to function as a sink of European air pollutants.

Keywords: soil information system, internet, Austria, organic matter, lead, cadmium
The digital land resources inventory of Rwanda and its applications

VAN RANST Eric, IMERZOUKENE Saadia and VERDOODT Ann

Laboratory of Soil Science, Ghent University, Krijgslaan 281 (S8), B-9000 Ghent, Belgium

A conventional national soil survey in Rwanda (scale 1:50,000) was started in 1981 and was completed in 1994. In order to make this huge amount of information more effective for clients' needs and to facilitate users' access, an automation of the data was carried out using adopted geographic information systems (GIS) and soil information systems (SIS). On each of the topographic maps of Rwanda (scale 1:50,000), different themes were digitized and stored in separate coverages. The soil data were digitally stored (i) as a polygon theme, representing the digitized version of the soil mapping units that were manually drawn on the topographical maps and (ii) as a point theme, indicating the observation points (soil profiles and augerings). The final layout of the 43 maps for publishing was established by use of ArcView. In each of these 43 ArcView projects, the soil profiles theme was used to make a connection with the Access Data Base which contains the general soil profile data, physical and chemical analysis data of the horizons, graphs showing correlations between these parameters, and the soil map explanatory reports. The 3-dimensional digital terrain model of each map was made in ArcView. Digital thematic maps not only for traditional agricultural purposes, but also for settlement planning, disaster-preparedness planning, high-input agriculture, and so on, can be derived from the digital inventory and plotted automatically. The system allows easy updating, modification or reorientation depending on the requirements of the different Ministerial departments who are going to use it. As such, the land resources information can be used more efficiently and accurately and will assist the Government of Rwanda in investigating specific agricultural and environmental issues in appreciable time limits.

Keywords: land resources, soil survey, Rwanda, GIS
Applications of the small-scale and large-scale SOTER databases in Hainan, China

ZHANG Gan-Lin (1), GONG Zi-Tong (1), ZHANG Xue-lei (1), ZHAO Yu-guo (1), QI Zhiping (2), VAN ENGELEN Vincent (3) and MANTEL Stephan (3)

(1) Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China
(2) Chinese Academy of Tropical Agricultural Science, Hainan 571737, China
(3) International Soil Reference and Information Centre, Wageningen, The Netherlands

SOTER methodology was set up upon the demand of updating global and national soil and soil environmental information by combining spatial information of soil–terrain units and their attribute data. The system was tested in the South America and has been used extensively in Kenya, Central Europe and other regions and has been proved as a useful tool in regional land management.

When its traditional industry of rubber production meets a falling profit, and meanwhile more competent products such as tropical fruits are finding their increasing share in domestic and international markets, the local government of Hainan, China, is looking for an effective tool in order to plan the provincial land according to physical land quality.

Medium (1/250,000) to large scale (1/50,000) SOTER was adopted for the sustainable land management plan in Hainan, China, oriented for agricultural production. Two spatial scales were adopted in which medium scale SOTER was designed for the whole Hainan province (HaiSOTER), an area of 34,000 square kilometers, while large-scale SOTER was for four typical "windows" of the island (WinSOTER). Both SOTER databases contained standard attribute data and geo-referenced ploygon data as well as annexed climate and land use data.

Locally-tailored application models, including land quality evaluation models based on ALES (Automated Land Evaluation System) and a model for soil water erosion assessment based on USLE principles were established. Physical suitability for main tropical crops, such as rubber tree, banana, mango, coffee, in different input and technology levels were assessed. Soil water erosion in current land use and different scenarios were estimated.

HaiSOTER provided overall guidance for the provincial plan of the main kinds of tropical cash crops and the county SOTER helped to set a regional demonstration of crop production. Comprehensive use of the two SOTER databases should be very helpful for the sustainable land management of the tropical island.

Keywords: SOTER, land quality, land management, Hainan, China
Soil pollution monitoring as a comprehensive system

ZUPAN Marko, VRSCAJ Borut and LOBNIK Franc

University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Centre for Soil and Environmental Science, Jamnikarjeva 101, 1000 Ljubljana, Slovenia

Soil pollution monitoring system is a comprehensive system that provides procedures for soil sampling, analytical procedures, data evaluation, data storage and data presentation. Soil sampling is done on predefined sampling sites, distributed in a regular grid of 2 km resolution in non-forested areas below 600 m of altitude, and in 4 km resolution above 600 m without land use limitations. Dense grid with 1 km resolution is used for areas where pollution is expected (industrial areas, intensive agricultural areas, etc.). Sampling strategy and design and chemical analyses are carried out according to national and international standards; QA&QC is an obligatory part of the system. Soil pollution databases represent a part of Soil Information System (SIS). Data are geocoded and processed with geographical information system (GIS) techniques. Interpretation of soil pollution data is based on Slovenian legislation that provides limit, warning and critical concentrations of potentially toxic substances: 10 metals, fluorides, and 7 groups of organic pollutants. Presentation of soil pollution consists of site description, analytical procedures and results as well as interpretation of data according to the legislation. Detailed presentation gives an opportunity to end users to understand the degree of pollution and to prevent misleading interpretations. This system ensures the soil samples collected to be as representative as possible as well as high degree of reliability of the soil pollution data.

Keywords: pollution assessment, monitoring system, data processing, data evaluation, pollution maps, GIS
Symposium 45

Soil carbon dynamics and the greenhouse effect

Convenor: LAL Rattan

Co-Convenor: CHAIROJ Prapai

Oral Session
Tuesday 20 August 2002
8:30 - 11:50
Room: Meeting Room 3

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Tuesday 20 August 2002
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An assessment of potential carbon storage in the soils of France

ARROUAYS Dominique (1), LE BAS Christine (1), BALESDENT Jérôme (2) and GAILLARD Jocelyn (3)

(1) INRA – INFOSOL – BP20619 - 45166 OLIVET CEDEX, France
(2) INRA-CEA Cadarache, 13108 Saint-Paul-lez-Durance, France
(3) INRA Informatique, BP 20619 – 45166 Olivet cedex, France

In the present context of global climatic change, carbon cycling in soils appears as particularly important: on one hand soils can act as sources or sink of carbon, on the other, soil organic matter levels and then soil quality can be greatly affected in the future it is therefore necessary to determine the present storage of carbon in soils, in order to enable assessment of the impact of land use or climatic changes on the carbon content of soils. This work presents a methodology to assess the potential carbon storage of French soils with a particular attention to their spatial extent.

For this assessment a model, named MORGANE, has been used. MORGANE is a semi-mechanistic model of carbon dynamics in soils. It includes 5 carbon pools defined by their turnover rates and 2 pools of microbial biomass. Input data are 3 soil variables, 2 climatic variables, and a set of variables describing land use, vegetation type and agricultural practices.

Data on soil, climate and crops are needed. Soil data are provided by the Soil Geographical Data Base at scale 1:1,000,000 for France which describes the geographical extent of soil types through complex units. The main soil characteristics available are not generally corresponding to the data needed by the model. Pedotransfer rules were then defined to derive the needed data. The daily interpolated climatic data, provided by the MARS project, are available on a 50 km x 50 km grid for 25 years (1975-1999). For each cell, a daily mean was calculated on the 25 years for rainfall, minimum and maximum temperature, and PET.

Soil and climatic data are combined within a Geographical Information System giving all the soil descriptive parameters present in a climatic grid cell. For each soil-climate combination, a water balance is calculated to determine the water content in the first 30 cm of the soil.

The use of statistical data on agriculture enables to estimate the inputs in terms of primary production, fertilizers and so on.

Results on potential carbon storage are then compared to present stocks derived from point measurements data. Mapping the difference between the two estimates enables i) to point out the areas where carbon sequestration could be enhanced, ii) to point out gaps in data or gaps in the current knowledge of C dynamics processes.

Keywords: carbon content, French soil database
Crop rotations and reduction in tillage is commonly recommended for sustained crop production and for enhancing soil quality. The objective of this study was to evaluate the effects of long-term crop rotations, established in 1968, on soil structure, carbon storage and the quality of soil organic matter. The study was conducted on a silt clay loam soil (Typic Cryoboralf) near Beaverlodge, Alberta. The treatments consisted of: (a) continuous barley (*Hordeum vulgare* L.); (b) continuous bromegrass (*Bromus inermis* L.); (c) continuous forage legume (*Medicago sativa* L. until 1977, and *Trifolium pratense* L. since 1978); and (d) 3 years bromegrass-legume forage + 3 years barley. Our data showed that rotations with forage and/or legume had more stable aggregates with greater mean weight diameter (MWD) than soils under continuous barley (CB). Organic C, total N and the light fractions in soil under continuous bromegrass (CG) and continuous forage legume (CL) were higher than those of the other two treatments. Glucose was the most abundant monosaccharide in all treatments followed by arabinose, xylose, mannose and galactose. Soil under CG had the highest and under CB the lowest amounts of total sugars amongst the treatments. Our data on the type of C in organic matter of soil, as characterized by the $^{13}$C NMR spectroscopy, showed that soil under CB rotation contained the highest amounts of aromatic and the lowest content of aliphatic-C. The CL rotation had the lowest phenolic-C and the least aromaticity. Of all the cropping systems studied, soil under CG and the rotation with 3 years of forage had the highest amounts of aliphatic-C as well as carbon storage.

**Keywords:** soil organic matter, $^{13}$C NMR spectroscopy, crop rotation, forage, carbon storage
Temperature response and carbon processing by soil microbial communities from two grassland ecosystems

BALSER Teri C., WALDROP Mark and FIRESTONE Mary K.

Department of Environmental Science, Policy and Management, University of California, Berkeley, CA 94720. T.C. Balser, Present address: Geological and Environmental Sciences, Stanford University, Bldg. 320, Rm. 118 Stanford, CA 94305-2115, USA

Recent work has shown that microbial communities can alter the pool of carbon accessed under different climate conditions. This is in contrast to common assumptions about carbon cycling and first order kinetics. To investigate the importance of microbial community adaptation to different climate regimes in soil carbon cycling, we incubated soil from a tropical and a temperate grassland (Puerto Rico and California), for five months at three temperatures (20°, 27°, and 35° C). We traced the flow of carbon into the microbial community, and the atmosphere using a $^{13}$C stable isotope tracer. The two soils were treated with either $^{13}$C-labeled acetate, or vanillin. We measured the amount and composition of CO$_2$ evolved throughout the incubation period. In addition, at three times (initially, and after one and five months), we harvested soil and measured community enzyme activity (a suite of nine enzymes involved in decomposition), and community lipid profiles (PLFA). To perform a mass balance for our label, we quantified the carbon isotope ratio in CO$_2$ produced, in each microbial lipid, and remaining in soil. The microbial communities in each soil differed initially in their composition and temperature sensitivity, and throughout the study there were differences in CO$_2$ production and enzyme activity between the two soils. Enzyme activity in the California grassland soil was consistently higher than in the Puerto Rican soil. The microbial community from the Puerto Rican soil was less affected by temperature, whereas the community from the Californian soil showed more of a temperature optimum at 27° C. After five months, most of the added substrate had been metabolized. While acetate was utilized faster than vanillin, vanillin use appeared to be more sensitive to incubation temperature. In a previous study, we showed that the microbial communities from these two soils have very different patterns of carbon utilization at different incubation temperatures. In this study, we used the $^{13}$C ratios of the microbial lipids to determine whether the change in carbon use was due to a shift in the microbial community composition, or due to a change in the behavior of extant populations. The results have implications for modeling the response of soils to global scale changes in climate.

Keywords: tropical soil, microbial community composition, lipid analysis, genetic analysis, enzyme activity
Storage, structure and transformation of organic matter of the larch forest soils in the Northern Taiga

BEZKOROVAINAYA I.N. and MUKHORTOVA L.V.

Institute of Forest Russian Academy of Sciences, Siberian Branch Krasnoyarsk, Russia

The evaluation of the biosphere role played by boreal forests in the accumulation of carbon is connected with the evaluation of organic matter (OM) stocks in soils.

Quantitative evaluation of the structure, the correlation and the rate of turn of various organic matter fractions in soils of boreal forest ecosystems is the basis for the creation of models of the dynamic of accumulation and transformation of OM in dependence on hydrothermal conditions and for the prognosis of forest ecosystem reaction to climatic change.

In dependence on biological decomposition resistance constituents of OM are united in two fractions: light mineralized OM and stabilized OM. Light mineralized OM consist of labile OM and mobile OM. Forest litter, dead root material in mineral profile, microbic and zoomass are main components of labile OM in forest ecosystems. Light mineralized OM is a main source for formation of mineralized carbon flow in the atmosphere and synthesis in new humus. Stabilized OM consists of humus matter which is solidly connected with mineral soil particles.

The aim of our investigation is to estimate the stocks, structure and transformation of organic matter in soils of the larch forests in the northern taiga.

The investigation site, larch forests, are situated on the Nizhne-Tungusskaya plato. Larch forests (green-moss larch and lichen larch 120 and 400 years old) were formed on ochre podbur. These soils are characterized by feeble distinguishing horizons, and conservation of soil light mineralized OM. There is wet eternal frost. During vegetative periods all soil profile defrosted. Litter stocks are 3.5-4.5 kg m\(^{-2}\) and thickness is 10-25 cm.

Cryomezomorphic northern taiga soils are accumulated 38-73 t C ga\(^{-1}\). Light mineralized OM is accumulated in mean 38.1 t C ga\(^{-1}\), including 20.5 and 6.4 t C ga\(^{-1}\) of labile compound on surface and in soil, 11.2 t C ga\(^{-1}\) of mobile OM.

Microbic mass is accumulated 1.78-3.47 t C ga\(^{-1}\), their part makes up 3.6-4.9 % in the total stock carbon OM. Zoomass of green-moss larch is accumulated 0.20-0.61 \times 10^2, in lichen larch - 0.01-0.07 \times 10^2 t C ga\(^{-1}\).

The storages of resistant biological decomposition and solidly connected with mineral soil part OM make up 17.7 t C ga\(^{-1}\) and in green-moss larch change from 18.6 to 29.0 t C ga\(^{-1}\), in lichen larch from 6.4 to 17.0 t C ga\(^{-1}\).

A long field experiment was made to determinate the transformation rate of various plant fractions and to select pedobionte roles in these processes. During two years this experiment showed the participation of all biota groups in the decomposition of plant matter which caused weight loss of larch-needles and root mortmass. In mean it made up 52.4 and 15.7 % accordingly.

Isolation of organic matter from all size invertebrate groups lead to some decrease of decomposition activity. Weight loss of larch-needles made up 50.2 %, mortmass 10.4 %.

Keywords: soil organic matter, storage, structure, transformation, microbic mass, zoomass
Influence of disturbance on soil C dynamics in Canadian boreal forests

BHATTI J.S. and APPS M.J.

Canadian Forest Service, Northern Forestry Centre, 5320, 122nd Street, Edmonton, Alberta, Canada T6H 3S5

In Canadian boreal forest ecosystems, estimates of carbon (C) in the forest floor and total soil were compared and the influence of disturbance was evaluated. The soil C estimates were based on data from: (a) analysis of pedon data from the national-scale soil profile database; (b) the Canadian Soil Organic Carbon Database (CSOCD), which uses expert estimation based on soil characteristics; and (c) model simulations with the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2). Estimates for soil C from the three approaches ranged from 1.3 to 5.3 kg C m$^{-2}$ for the forest floor and from 7.8 to 19.2 kg C m$^{-2}$ for the total soil column. Variations in litter input rates due to different type of disturbances cause most of the variation in the soil carbon pools. Changes in disturbance history, litter fall rate, site characteristics, and climatic factors alter the processes regulating both inputs and outputs of carbon to soil stocks. Thus, understanding the dynamics of C as determined by disturbances is essential for quantifying past changes in soil C stocks and for projecting their future change.

Keywords: carbon, soil, litter, disturbances, forests, boreal
Effects of soil microorganisms on the behavior of CO$_2$ and O$_2$ gases in soil

FUJIKAWA Tomonori and MIYAZAKI Tsuyoshi

The University of Tokyo, 1-1-1 Yayoi, Bunkyou-ku, Tokyo 113-8657, Japan

Concentrations of CO$_2$ and O$_2$ gas in soils are affected by the respiration of soil microorganisms, gas diffusion movement and chemical reactions, mainly the dissolution of CO$_2$ gases into soil water. In many previous studies, which investigated gas concentrations in fields, the measurement of gas concentration and other soil physical properties has not been conducted simultaneously so far. Due to this limitation, relationship among soil gas behavior, soil respiration, diffusion and dissolution, has not been proved. The objective of this study is to clarify the behavior of CO$_2$ and O$_2$ gases in an agricultural field.

At the surface (0-20 cm), CO$_2$ and O$_2$ concentrations were similar to those of atmosphere. Around 20 cm, in which bulk density of soil was higher than in other depths, CO$_2$ concentration remarkably increased and O$_2$ concentration decreased, and below 20 cm, gas concentrations varied randomly with depth. It is interesting that, despite large fluctuations of CO$_2$ and O$_2$ concentrations through the year, the number of soil bacteria and fungi were almost constant. The simulation of CO$_2$ migration revealed that the respiration and gas diffusion were predominant in forming profiles of gas concentrations in soil. Relatively high CO$_2$ concentration in October, after rice paddy, was attributed to by the high activity of soil microorganisms due to the high water content and high soil temperature.

Keywords: soil air, soil microorganisms, gas diffusion, field
Paired site sampling to estimate soil organic carbon changes following land clearing in Queensland

HARMS Ben, DALAL Ram and POINTON Shane
Department of Natural Resources and Mines, 80 Meiers Road, Indooroopilly, Queensland 4068, Australia.

Using a paired-site sampling approach, changes in soil organic carbon following land clearing were estimated at 49 sites in central and southern Queensland. The sites were stratified on the basis of climate (temperature, rainfall), vegetation, time since land clearing, soil type, and land use following clearing. Soil organic carbon quantities were calculated for various depth ranges and corrected for bulk density.

For grazing sites, organic carbon (excluding litter, roots & coarse charcoal) decreased by 7.0±2.9% for the depth range 0-0.3 m and by 4.3±2.2% to 1.0 m depth. This corresponds to a loss in organic carbon of 2.6±1.1 t ha⁻¹ in the top 0.3 m of soil and 3.2±1.7 t ha⁻¹ for 1.0 m soil depth.

For cropping sites, organic carbon (excluding litter, roots & coarse charcoal) decreased by 16.9±4.0% to 0.3 m depth and by 7.0±2.9% to 1.0 m depth. This corresponds to a loss in organic carbon of 6.4±1.5 t ha⁻¹ in the top 0.3 m of soil and similar losses (5.9±2.5 t ha⁻¹) for 1.0 m soil depths.

Despite the overall pattern of decline, trends in soil organic carbon change following land clearing were variable. A significant decrease was observed at 19 of the 49 sites, while a significant increase was observed at four sites.

Statistical analysis indicated that approximately 80% of the variance in soil organic C can be accounted for by soil, climate and vegetation factors. The change in carbon stocks following land clearing was also positively correlated with soil and climate factors.

Keywords: paired-site sampling, soil organic carbon change, land use change, greenhouse gas emissions
Climate of genetical horizons, carbon dioxide emission and accumulation of organic matter in cryogenic and cold soils

HUDYAKOV O.I.

Institute of Physical, Chemical and Biological Problems of Soil Science of the Russian Academy of Sciences, 142290 Pushchino Moscow region, Russia

The histories of the analysis of soil climate and offered classifications of soil climate based on climatic and temperature component are being analyzed.

The classification of genetical horizon climate of cryogenic and cold soils has been offered on the ground of hydrological horizons and temperatures 0°, the first biological minimum (5°C), the second biological minimum (10°C) and ecological favorable range of 20-30°C.

The climate of series of cryogenic soils (cryogenic-taiga, soddy-taiga and also meadow-wood and meadow-wood gley deep cryogenic soils) and cold soils (chernozem and chestnut soil) of southeast of Hangay (MPR) is being analyzed from the designed classification of genetical horizon climate.

It has been shown that the greatest carbon dioxide emission and accumulation of organic matter is marked in meadow-wood and meadow-wood gley deep cryogenic soils formed in the cold conditions of semi-humid and humid climate.

In chestnut soils with arid moderately warm, interleaving with semi-humid warm climate the carbonic acid emission and the accumulation of organic matter in soils is commensurable with cryogenic-taiga soils with very cold semi-humid climate.

The designed classification of genetical horizon climate is used for the analysis of "Hothouse" effect in connection with the forecast of 2.5-4.5°C thawing of the climate in 2050. It is shown on the example of the European part of Russia soils that the increase in temperature of 2.5-4.5°C will result into occurrence in genetical horizons of tundra soils climate, reference for genetical horizons of forest-steppe that really can intensify the process of salinity of organic matter of tundra soils and increase carbon dioxide emission from these soils. However, in chernozem there will be created the conditions of the arid climate of soils of desert and semi desert steppes. In this case in chernozem and chestnut soils, at high temperature and with the absence of easily accessible moisture, the salinity of humus and emission of carbonic acid will sharply decrease, the conservation of huge reserve of Carbon of humus will occur, and, consequently, the concentration of carbonic acid in atmosphere will decrease.

The conclusion is that the contents of carbonic acid in air in general balance will decrease. It is connected with strong lowering of carbonic acid in soils in connection with aridization.

* The work is supported by RFFR (grant 01-04-48538).

Keywords: soil climate, carbon dioxide emission, organic matter accumulation, carbon dioxide balance, global climate change, cryogenic and cold soils
The effect of drainage on CO$_2$ production in peat soils of boreal zone

IKKONEN Elena and KURETS Vladimir

Institute of Biology, Karelian Research Center of Russia, 185610 Puskinskaja, 11, Petrozavodsk, Russia

Peatlands are known to be an important source of greenhouse gases in the atmosphere. We studied gas regime (CO$_2$ emission, CO$_2$ content in soil air, gas diffusion coefficient and CO$_2$ production) in peat soils of virgin and drained sites of the same open meso-oligotrophic swamp.

In the virgin site the main factor affecting CO$_2$ production is hydrological regime; the effect of thermal regime increased after drainage. Maximum CO$_2$ content in soil air in the virgin site equalled 0.7-1.2 % of soil air volume. After drainage CO$_2$ content in soil air of deep layers is 2-3%.

During a vegetative season mean CO$_2$ fluxes from peat soils without root systems and above ground litter were 1.56 and 2.25 g CO$_2$ m$^{-2}$ d$^{-1}$ for the virgin and drained sites, respectively. A significant contribution to the total CO$_2$ emission is made by early summer CO$_2$ flux from the litter fall. The fluxes of CO$_2$ from the aboveground litter in June were 2.2 and 4.1 g CO$_2$ m$^{-2}$d$^{-1}$ for the virgin and drained plots, respectively. CO$_2$ diffusion rate throw peat pores show no changes after drainage of the mire. Diffusion coefficient is influenced only by pore volume filled with air.

The basic generation of carbon dioxide occurs in the upper (0-5 cm) layer of peat deposit on the virgin mire while in the drained one - at a depth of 15 cm. Maximum intensity of CO$_2$ flux resulting from the root and microorganisms respiration was observed at a peat moisture of 70-75%. Before the drainage about 70% of CO$_2$ production in sphagnum peat is a result of organic matter mineralization. The drainage root-derived respiration accounted for 40% of total soil respiration in mid-summer at the site with a grass-shrub vegetation.

Two kinds of mathematical models were used to evaluate the dynamics of CO$_2$- exchange in the peat soil: multiple non-linear regression and dynamic models of gas transport. The multiple regression consists of two affecting factors: air temperature and water table level. CO$_2$ flows estimated by the statistical model are 2-3 times higher than those yielded by the dynamic model. This is due to the fact that only the diffusion part of CO$_2$ emission has been defined by a dynamic model. Presumably, the convection transfer of CO$_2$ in the soil air may reach 50 % of CO$_2$ emissions from peat. In addition, convection diffusion of dissolved carbon dioxide also contributes to the process of gas transfer.

Peat soil drainage for 10 years has resulted in the decrease of medium ground water level from 10 to 30 cm and in the 1.5 times increase of CO$_2$ emission from the soil. Predicted global climate warming may cause greater changes in CO$_2$ emission from the drained peat in comparison with the virgin ones. However, in the case of increasing average level of ground water at higher air temperatures CO$_2$ production by the mire reduces.

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Keywords: mire, CO$_2$ emission, respiration, peat, litter
Changes in carbon and nitrogen accumulation after afforestation: a case study in nursery stands

INAGAKI Masahiro (1), SAKAI Hisao (2), TAKAHASHI Masamichi (3), NOGUCHI Kyotarou (3), and TANAKA Tadashi (4)

(1) For. and Forest Prod. Res. Inst., present address: Japan Intern. Res. Cent. for Agric. Sci., Ohwashin 1-1, Tsukuba city, 305-8686 Ibaraki, Japan
(2) Hokkaido Res. Ctr., For. and Forest Prod. Res. Inst.; Hitsujigaoka 7, Toyohira-ku, Sapporo city, 062-8516 Hokkaido, Japan
(3) For. and Forest Prod. Res. Inst.; Matsunosato1, Kukizaki, 305-8087 Ibaraki, Japan
(4) Yamanashi For. Res. Inst., Saisyouji 2290-1Masuho, 400-0502 Yamanashi, Japan

To mitigate increases of carbon dioxide (CO₂) in the atmosphere, forest ecosystem is expected to be one of the important carbon sinks. Soil stores a greater amount of carbon than plant biomass in terrestrial ecosystem and can do so for a long period. We should make a precise estimation of carbon accumulation in the soil, but the estimation method has not been established. In the Kyoto protocol, carbon accumulation by afforestation is counted as carbon sink. This means that the count is applicable only to comparably young stands afforested after 1990. Land use and land-use change also affect the accumulation of nutrients as well as soil organic matter. Nutrient status of soil such as nitrogen content affects carbon sequestration by plant growth. There was, however, little information for nitrogen accumulation in soil by afforestation. To determine the accumulation rates of soil carbon and nitrogen after afforestation practice, we investigated soil organic matter, including organic layers, accumulated in 4 nurseries with different ages.

We selected 4 sampling stands, one stand was in the Yamanashi Forest Research Institute (M-C) and the others were in the Fuji-yoshida branch (Y-B, Y-PP, and Y-C). In the M-C, 2 years old Cryptomeria japonica D. Don was planted, and 6 years old deciduous broadleaved trees consisted of several species were in the Y-B. The stand in the Y-PP was 17 years old Pinus parviflora Sibb. Et Zucc. and that in the Y-C was 33 years old C. japonica. In every stand, samples were collected from 9 grids in 2 m mesh set on 4 m by 4 m quadrant. In the M-C stand, the samples were collected from 5 layers: 0-1, 1-2, 2-5, 5-10, 10-20, 20-30 cm, and in the other stands, from 4 layers: 0-2.5, 2.5-5, 5-10, 10-20, 20-30 cm using a soil core sampler with 5 cm in diameter. The samples for chemical analysis were air-dried and sieved by 2 mm. Total carbon and nitrogen concentrations were measured by the dry combustion method.

Stand age and carbon and nitrogen contents in the soil of 0-10 cm depth were positively related. In the 33 years old Y-C stand, carbon accumulation rate calculated from its stand age was 35 g m⁻² y⁻¹. This result was within the range of other studies reported. The accumulation rate was not linear: the rate was very high in the young stands, then decreased.

For organic layers, carbon and nitrogen accumulations were not correlated with stand age. The contributions of organic layer to total organic matter accumulation were different among stands and the contribution was higher in carbon than nitrogen.

There are three problems for estimating organic matter accumulation. First problem is evaluation of change in soil bulk density with stand age, second is reference soil condition before afforestation, and third is spatial heterogeneity of forest soil. For more precise estimation of soil organic matter accumulation, solutions for these problems are requisite.

Keywords: global warming, forest soil, soil organic matter, afforestation, organic layer
Offsetting global CO$_2$ emissions by soil carbon sequestration

LAL Rattan

School of Natural Resources, The Ohio State University, Columbus, OH 43210, USA

Increase in atmospheric concentration of CO$_2$ from 285 ppmv in 1850 to 370 ppm in 2000 is attributed to emissions of $270 \pm 30$ Pg C from fossil fuel combustion and $136 \pm 55$ pg C by land use change. Present levels of anthropogenic emissions involve $8.0$ Pg C by fossil fuel emissions and $1.8$ Pg C by land use change, especially tropical deforestation. Out of the historic loss of terrestrial C pool of $136 \pm 55$ Pg, $78 \pm 12$ Pg is due to depletion of soil organic carbon (SOC) pool comprising $25 \pm 6$ Pg due to accelerated soil erosion. A large proportion of the historic SOC lost can be recovered through soil C sequestration involving net removal of atmospheric CO$_2$ and transforming it into the long-lived SOC pool through conversion to an appropriate land use and adoption of recommended management practices. The strategy is to return biomass to the soil in excess of the mineralization capacity through restoration of degraded/desertified soils and agricultural intensification. Technological options for agricultural intensification include conservation tillage, residue mulching, integrated nutrient management including nutrient recycling, crop rotations involving cover crops, and those practices which enhance use efficiency of water, plant nutrients and energy. The potential of soil C sequestration is estimated at $1$ to $2$ Pg C y$^{-1}$ for the world, $0.3$ to $0.6$ Pg C y$^{-1}$ for Asia, $0.2$ to $0.5$ Pg C y$^{-1}$ for Africa and $0.1$ to $0.3$ Pg C y$^{-1}$ for North-Central America and also for South America, $0.1$ to $0.3$ Pg C y$^{-1}$ for Europe and $0.1$ to $0.2$ Pg C y$^{-1}$ for Oceania. Soil C sequestration is a win-win strategy; it enhances productivity, improves environment moderation capacity, and mitigates global warming. It is a bridge to the future.

Keywords: desertification, soil quality, carbon sequestration, global warming, arid regions, soil restoration
Carbon sequestration in Russian soils
as affected by grassing regime

LARIONOVA A.A., ROZANOVA L.N., YEVDOKIMOV I.V., YERMOLAYEV A.M. and KURGANOVA I.N.

Institute of Physico-Chemical and Biological Problems in Soil Science, Pushchino, Moscow Region 142290, Russia

The impact of land use on sequestration and emissions of CO$_2$ - C in soil were investigated in 80-90-ths on gray forest soils in Pushchino, and on soddy podzolic soil in Prioksko-Terrasny Biosphere Reserve, Moscow Region, Russia (54° 50' N, 37° 35' E).

Most of the agroecosystems tested showed zero C balance in the soil. Application of mineral fertilizers separately and in combination with low rates of organic fertilizers promoted the establishment of mainly positive C balance in the agroecosystems but did not cause substantial increase of C storage in stable form, i.e. in soil humus. Afforestation of arable soil during some 100 years led to a doubling of the soil C pool.

Over 18 years –grassing also increased substantially the C$_{org.}$ accumulation in soil. The mean annual rates of C sequestration in SOM ranged from 60 to 90 g C/(m$^2$×year) and from 98 to 182 g C/(m$^2$×year) for 0-20 cm and 0-60 cm soil layers respectively. Hay mowing led to an increase of C and N accumulation in soil compared to unmown plots. Statistically significant extension of C and N pools, microbial biomass and intensity of CO$_2$ emissions in soil after application of low rates of mineral fertilizers (N$_{60}$P$_{60}$K$_{60}$) was found only in mown treatments.

The C accumulation rate in soil decreased after the 13-th year of grassing and became insignificant. The Mean annual C accumulation in soddy podzolic soil under 47-year grassland was two times lower than in gray forest soil. The difference between the rates was mainly explained by grassland age rather than by soil type.

Incubation of soil sampled on grassed meadow over 6 months at 22°C and 70% WHC demonstrated that though application of mineral fertilizers as such led to C accumulation, the new formed humus was less sustainable to decomposition than that in unfertilized soil. Intensive soil respiration and a high decrease of microbial carbon evidenced the enhanced degradability of new formed humus in fertilized grasslands in comparison with unfertilized treatments. Hence, grassing combined with hay mowing is the optimal agricultural technique that enables us to improve sufficiently the C balance in ecosystems without excluding them from agricultural use.

Keywords: carbon sequestration, carbon balance, soil organic matter, grassing
Influence of land-use management on soil carbon stores in South-western Australia

MENDHAM Daniel S., GROVE Tim S. and O’CONNELL Anthony M.

CSIRO Forestry and Forest Products, Private Bag No. 5, Wembley, 6913 WA, Australia

Large areas of native vegetation have been cleared for agriculture within the last century, and significant areas of that cleared land are now being used to grow short-rotation eucalypt plantations in south-western Australia. Understanding the effects of land use change on soil organic carbon (SOC) quality and quantity is currently of much interest world-wide, as soils have the potential to be a significant sink or source of CO₂. We examined the changes in SOC quantity and quality by comparing native forest, pasture and plantation soils at 10 sites in south-western Australia. SOC quality was evaluated by measuring soil C:N and C:P ratios, permanganate oxidisable C, 13C NMR spectral regions, microbial biomass, and microbial respiration (under optimal soil temperature and moisture conditions). There were only minor differences in SOC quantity between the land uses, with lower SOC in the 5-10 cm depth range under native forest in the <2 mm soil fraction. This was mostly offset by a higher quantity of SOC in the 0-5 cm depth range in the 2-5 mm soil fraction. Root C under pasture was significantly lower than the native forest at all depths below 5 cm, but the quantity of C in roots was generally about 5% of that in the soil. Root C under plantation was generally higher than under pasture, and was similar to that under the native forest in most depth ranges. Litter was a significant store of C, with average magnitudes of approximately 10% of that in the soil profile to 1 m depth in the plantation and native vegetation. Quantities of litter were negligible under pasture, due to the relatively intensive grazing. Changes in SOC quality were also relatively small for most parameters, although the C:N and C:P ratios under native forest were much higher than under pasture/plantation, reflecting the low fertility of soil under the native forest. No differences were found between land uses in microbial biomass or soil respiration. Main differences in NMR spectral regions between the land uses were higher carbohydrates under pasture, compared to the plantation and native forest, and higher aromatic compounds under native forest, compared with the pasture. The quantity of aromatic compounds was related to the time since pasture establishment, with the proportion of aromatics slowly decreasing over time. Permanganate oxidisable C was not sensitive to changes in land use, or to the form of C respired in an incubation, suggesting that it was not a useful indicator of labile C in the soils of South-western Australia.

Keywords: land use change, soil carbon stores, soil carbon quality, microbial biomass, 13C NMR, soil respiration
Organic carbon storage in surface agricultural soils of Jiangsu province, China and its recent trend of carbon sequestration

PANG Genxing (1), LI Lianqing (1), ZHANG Xuhui (1), ZHANG Pingjiu (1) and XU Ying (2)

(1) Institute of Resources, Ecosystem and Environment for Agriculture, Nanjing Agricultural University, Nanjing, China-210095
(2) Agricultural Extension Service, Wujiang County, Jiangsu Province, China 215200

Data of soil organic carbon (SOC) in surface agricultural soils were collected respectively from the second provincial soil survey, and from a number of field pilot agricultural experiments together with our analytical works made in recent years. The total SOC pool of the province was estimated as 0.2 Pg, of which almost a half (45% of this pool) was shown to be located in the Great Tai Lake region. The paddy soils, a dominant soil order of Anthrosols of the Chinese Soil Taxonomy, made up also nearly a half of this total provincial pool. Data supported a definite increasing trend for SOC storage in the last 20 years despite a decreasing tendency during the period of 1950-1970. Agricultural management practices such as irrigation, straw return and rotation of dry land crops with rice or wheat crops contributed significantly to the increased SOC storage. The annual sequestration of carbon in the soils appeared to be 27–350 g cm\(^{-2}\) a\(^{-1}\). Thus, the agriculture in China, despite of the high input, could be one of the practical contributions to mitigating the increasing air CO\(_2\).

**Keywords:** SOC storage, agricultural soils, carbon sequestration, Jiangsu, China
Soil carbon stocks among natural and manmade land use systems: a comparative analysis

NAGARAJA M.S. (1,2), REDDY G.V.P. (2) and RAVINDRANATH N.H. (3)

(1) Symbiotec Research Associates, Bangalore – 560 034, India
(2) Karnataka State Council for Science and Technology, IISc, Bangalore-560 012, India
(3) Centre for Ecological Sciences, Indian Institute of Science, Bangalore-560 012, India

Understanding the role of terrestrial ecosystems in the global carbon cycle has become increasingly evident, as they are associated with climate changes. Conversion of natural systems to agriculture in the last century has contributed to the extent of one sixth of atmospheric greenhouse gases through reduction in vegetational and soil carbon stocks. It is also well established that these trends could be reversed through various management practices leading to sequestration and conservation of carbon stocks. Thus, soil can function both as a sink and a source for atmospheric CO$_2$. By keeping this in mind, a study was undertaken in the Eastern Dry Zone of Karnataka, India, to assess the soil carbon stocks (0-50 cm soil) under different land use systems, both natural and manmade, comprising of forests, grasslands, horticultural and agricultural systems.

The carbon stocks in soils ranged from 26.46 t ha$^{-1}$ in dryland agricultural systems (without manure) to 89.20 t ha$^{-1}$ in mixed forest. Among natural systems, ungrazed grassland (71.78 t ha$^{-1}$) and mixed forest (89.20 t ha$^{-1}$) recorded higher levels of soil-C while grazing in grassland and litter removal in teak plantations resulted in its reduction (39.32 and 32.74 t ha$^{-1}$ respectively). Intensively managed horticultural systems namely grapes (85.52 t ha$^{-1}$) and pomegranate (78.78 t ha$^{-1}$) maintained higher carbon stocks. However, agricultural systems recorded moderate to lower levels of soil carbon. Total carbon stocks in top 0-50 cm soils of agricultural systems was of the order irrigated lands with manure (52.77 t ha$^{-1}$) > irrigated lands without manure (44.47 t ha$^{-1}$) > drylands with manure (37.79 t ha$^{-1}$) > drylands without manures (26.46 t ha$^{-1}$). Interestingly, seasonal changes were also recorded in all the land use systems.

The soil-C of an ecosystem is dictated by the quality and quantity of biomass additions and its loss through decomposition. Adoption of conservation tillage, good irrigation practices, incorporation of crop residues, manure application etc are some of the important management practices. Utilization of marginal and low productive lands for perennial fruit tree crops and other non-timber crops along with annuals can increase vegetation carbon. Similarly, adoption of suitable management practices can enhance the soil carbon pool by decreasing the loss of existing carbon mass and encouraging carbon accumulation. Thus, there is a great scope in mitigating atmospheric CO$_2$ through better management practices.

Keywords: soil organic carbon, global climate change, land use systems, mitigation
Carbon sequestration in soils proposals for land management of arid and tropical area

ROBERT Michel
Visitor Scientist in FAO (AGLL), INRA and French Ministry of Environment, INRA 78026 Versailles cedex, France

In the framework of the Kyoto Protocol, carbon sequestration to mitigate the greenhouse effect in the terrestrial ecosystem has been an important subject of discussion in numerous recent international meetings and reports. The present synthesis focuses on the specific role that soils of tropical and dryland areas can play in carbon sequestration and on the land management strategies involved.

A review is made of carbon dynamics and the fundamental role of organic matter in soil. To increase carbon sequestration in soils in the dry land and tropical areas, as a contribution to global atmospheric CO₂ mitigation, new strategies and new practices in agriculture, pasture use and forestry, including conservation agriculture and agroforestry, are essential. To ensure permanent soil cover and to limit the cultural practices (tillage) are the main ways for land management; a priority being application to degraded lands.

The main benefits concern C sequestration but also an increase in soil fertility, a decrease in soil erosion and degradation and an increase in biodiversity.

Such practices, facilitated by the application of the Kyoto protocol or by other international or national initiatives, would promote a more sustainable agriculture. A method for monitoring and verifying the changes both in C sequestration and in the degree of land degradation, is proposed based on a soil-monitoring network.

Some gaps concerning environmental budgetting and economical balances which need urgent answers are also presented.

Keywords: carbon sequestration, drylands, tropical soils, organic matter, conservation agriculture
Simulation of SOM balance of Eastern Europe arable lands based on EuroSOMNET database

SIROTENKO Oleg (1), SHEVTSOVA Lyudmila (2), ROMANENKOV Vladimir (2), SMITH Pete (3), SMITH Jo U. (3), ASHMAN Mark (4) and LEACH Penny (4)

(1) All-Russian Research Institute of Agricultural Meteorology, Lenina Ul.,82 Osninsk, Kaluga Region, 249030, Russia
(2) All-Russian Institute for Fertilizers and Agricultural Soil Science named after Pryanishnikov (VIUA), ul. Pryanishnikova, 31 127550 Moscow, Russia
(3) Department of Plant and Soil Science, University of Aberdeen, Cruikshank Building, Aberdeen, AB24 3UJ, UK
(4) Agriculture and the Environment Division, IACR Rothamsted, Harpenden, Herts, AL5 2JQ, UK

Exploration of the impacts of global climate and land management change on long-term soil sustainability needs a linkage of models which describe SOM dynamics over time with datasets from a global network of long-term experiments which are suitable for model development.

Construction of SOM database for the Russian Federation field experiments in the frame of the European Soil Organic Matter Network Project within the Global Change and Terrestrial Ecosystems (GCTE) programme in an international standard format made it possible to revise accepted views about the role of specified agricultural management options in SOM transformation for Eastern Europe. At present, the Russian EuroSOMNET database includes 24 long-term experiments after checking of data quality, compatibility with model input requirements and availability of associated soil and climate parameters. Selected for the simulation were the datasets from soddy-podzolic soils zone (podzoluvisols).

The main aim of the work was to simulate SOM dynamics for the European part of the former USSR with Rothamsted SUNDIAL model after recalibration for local conditions and 2 Russian models: static Model of Humus Balance and dynamic SCAD model. SUNDIAL simulations suggest that some NPK treatments in European Russia lose SOM more quickly than the control treatment despite higher yields (and therefore residue returns) on the NPK treatment. This finding is in contrast to most other long term experiments in the west which show lower SOM on control plots than on NPK plots. Similar results have been found by statistical analysis of SOM with Model of Humus Balance which have been used for calculation required FYM rates in achievement specific SOM level; optimization of field structure in crop rotation for providing high crop yield and soil productivity maintenance. Based on the Model of Humus Balance, regional maps of annual SOM dynamics for the same fertilization rates and crop rotation, soil texture and initial SOM level were generated. A regular effect of climatic conditions on SOM dynamics for European Russia was found. Among different scenarios checked, the most important resource for preventing SOM decrease in the long-term period for intensive agriculture of the Moscow Region was the increase of grasses percent in crop rotation at the expense of row crops. The SCAD model revealed the role of climate factor on SOM mineralization, which helps to improve the accuracy of the long-term estimates.

Keywords: land management, long-term field experiments, soil organic matter, SOM dynamics, soil quality, climate change
Assessment of soil carbon in Syria and potential for sequestration through crop management

RYAN John, MASRI Samir and DE PAUW Eddy

International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria

The issue of climate change, in essence global warming, is now of major concern to mankind. Its adverse consequences will be most severely felt in the drier areas of the world where the majority of the poor live and struggle to survive. Indeed, extremes of climate are, and will, impinge on the developed world as well. It is now accepted in scientific and political circles that man is responsible for the disruption of the normal weather patterns through the emission of so-called greenhouse gasses, notably carbon dioxide resulting from the burning of fossil fuels.

Apart from significantly reducing such emissions, the main approaches to tackling global warming from the agricultural point of view are adaptation and mitigation. While the former involves crop breeding to cope with increased drought and a shorter growing season, the latter involves removal of carbon dioxide, i.e., sequestration or incorporation in the soil. Good soil and crop management can contribute to this objective and is compatible with ICARDA’s goal of agricultural development in the semi-arid areas of the Central and West Asia and North Africa region.

This presentation provides a synthesis of soil organic carbon in the major soils of Syria across a rainfall-gradient transect from the steppe with less than 100 mm mean annual rainfall to the most favorable zones with over 500 mm. Using depthwise sampling, estimates were made of the total soil carbon in each zone or major soil type. Soil carbon data from long-term trials show that total, labile and microbial biomass carbon could be increased in legume-based cereal rotations, similarly with fertilization which increases root biomass. Soil incorporation of crop residues, i.e., cereal stubble, and the elimination of the common practice of stubble-burning can reduce atmosphere carbon. Minimum tillage, if adopted in the region, has the potential to improve the carbon balance by reducing soil organic carbon mineralization while adding to soil stocks through crop root biomass. Though the equilibrium levels of soil carbon are limited by the higher temperatures in the region and low moisture from limited rainfall, because of the large areas of land involved, the overall contribution of the region to carbon sequestration can be considerable.

Keywords: carbon stocks, dryland areas, cropping systems
Relationship between organic matter, biomass C and CO₂ production rates in an ecosystem of the 9th region Chile

SALAZAR Itilier and QUILODRAN Karina

Dpto. Ciencias Quimicas. Facultad de Ingenieria, Ciencias y Administración. Universidad de La Frontera. Casilla 54-D. Temuco

It is known that CO₂ contributes to a great extent to this greenhouse effect (globally the fluxes of C-CO₂ are considered C-CO₂ y⁻¹ in 68-75 Pg (1)) and part of this value is a product of organic matter loss of the soil. The cutting down of forests and the land use contribute to the loss of the balance between the emissions and the carbon sequestration. Soil is an important carbon deposit, it is estimated that the C content amount in the soil doubles that in the atmosphere, i.e. 1,500 Pg of C in soil vs 750 Pg of C in the atmosphere (2). Organic C is important for the sustainability of ecosystems and is very sensitive to the effect of land use and soil management, so as the labile fraction of the organic matter is easily mineralized to C-CO₂ by soil microorganisms.

In this research, the relationship between the organic matter of the soil (determined by humid digestion, Walkley-Black), the microbial biomass (determined for the fumigation-incubation method. \( B_C = \frac{F_C}{K_C} \)) where, \( F_C \): (C-CO₂ liberated from sample of fumigated soil) - (C-CO₂ from sample not fumigated), and \( K_C \): proportion of microbial-C liberated like C-CO₂ (3)), and the C-CO₂ evolution was studied in catens of two ecosystems with red loamy soil, one degraded soil and the other under native forest soil.

The organic matter content increased from the upper to the lower catens in both systems, attributable to the runoff of rain waters. The differences in the level of organic matter of the degraded soil compared with the native forest soil were from 69% at the bottom to 50% at the top, and they would be explained by the use of a subsistence agriculture without appropriate management of the degraded soil. Similar correlation was observed in the biomass C.

The rates of evolution of C-CO₂ by microbial action in the soils were from 12 mg C g⁻¹ h⁻¹ under forest and 4 mg C g⁻¹ h⁻¹ in degraded soils, due to the higher contribution of organic material for the forest in quality as well as in amount.

Keywords: biomass C, C-CO₂ evolution, land use, caten
Dynamics of humus content in Uzbekistan’s soils

SATTAROV Jurakul and KUZIEV Ramazan

Institute of Soil Science and Agrochemistry, Kamarniso 3, Tashkent 700179, Uzbekistan

In the variants in which cotton was grown in monoculture with no fertilizers, decrease in humus content was observed for all the soils involved in the experiment, caused by the conditions of multiple watering and inter-row cultivations bringing about accelerated mineralization of soil organic matter. The biggest decrease in humus content occurred in desert meadow soil (by 42.2%). Humus content decrease has been also very significant in irrigated typical sierozem (humus content has dropped by 35.5%). The smallest degree of humus content decrease (8.1%) has been observed in irrigated light sierozem. In the variants in which cotton was grown with systematic application of mineral fertilizers the humus content in soils has been somewhat higher than in the variants in which no fertilizers were applied. However, the former variants have also exhibited a decrease in humus content: it fell by 37.6% in desert meadow soil, by 22.2% in irrigated typical sierozem, and by 6.3% in irrigated light sierozem.

Introduction of crop rotation schemes brings about cyclicity of soil humus content with an increase in the periods of alfalfa growing and a decrease in the periods of cotton growing. In order to secure extended reproduction of soil humus, application of organic fertilizers is needed. The greater the amounts of organic fertilizer applied to irrigated soils of the country, the higher is the increase of humus content. Thus, in a long-term experiment involving typical sierozem, annual application of manure to cotton at a rate of 30 t ha\(^{-1}\) for 50 years has maintained humus content at a level close to the initial (1.76% vs. 1.86%).

For every combination of the type of irrigated soil and agricultural practices, including the kind of organic-mineral fertilizers used and the rate of their application, there is an equilibrium by humus content: in the case of typical sierozem and normal rotation of crops in crop rotation schemes such state is reached at humus content of 1.1-1.4% (1.7-1.9% if organic fertilizers are applied systematically). As regards cotton monoculture practiced for a long time with application of mineral fertilizers, equilibrium-state humus content is 1.1-1.2% for irrigated typical sierozem, 1.0-1.2% for irrigated light sierozem, and 0.8-0.9% for irrigated desert meadow-soil.

Keywords: soil organic matter, organic fertilizers, soil quality
Long term effect of tillage and manure on soil carbon sequestration and biological activity in the Sahel

MANDO Abdoulaye (1), OUATTARA Badiori (1), STROOSNIJDER Leo (2), SEDOGO Michel (1), OUATTARA Korodjouma (1) and VANLAUWE Bernard (3)

(1) Institut de l’environnement et des recherches agricole (Inera), 03 B.P. 7192, Ouagadougou 03
Burkina Faso
(2) Wageningen Agricultural University, Department of Environmental Sciences, Erosion and Soil & Water Conservation Group, Nieuwe Kanaal 11, 6709 PA Wageningen, The Netherlands
(3) Tropical Biology and Fertility Programme (TSBF), PO BOX 30592, Nairobi, Kenya

Human induced-degradation of natural resources in general and soil degradation in particular, is a major problem in soudano-sahelian zones. In order to find efficient soil-management practices that maintain and/or improve soil fertility, research was conducted in a research station (Saria) located in the center of Burkina Faso (12° 16’ N, 2° 9’ W). This research aimed at studying the combined effects of tillage and organic input on Lixisol properties and on crop performance. A Fisher blocs design with four treatments (hand hoeing alone, hand hoeing + manure, ploughing alone, oxen ploughing + manure) and three replications was set in 1990. Ten years later, total carbon, soil organic matter fractions, microbial biomass and CO₂ production were measured in all plots.

It came out that the total carbon content increased in hand hoeing + manure plots and drastically declined in ploughed plots without organic input. During the ten (10) years experiment on continuous farming under soudano-sahelian conditions, carbon content dropped from 400 mg 100 g⁻¹ soil to 205 mg 100 g⁻¹ soil in ploughed plots without organic input and from 400 mg 100 g⁻¹ soil to 250 mg 100 g⁻¹ soil in hoed plots without organic input. Organic material addition mitigated the decrease of soil organic matter (SOM) in ploughed plots and built up soil carbon stocks in hoed plots where carbon stock increased from 400 mg 100 g⁻¹ to 580 mg 100 g⁻¹. Manure had a tremendous effect on the fractions in which soil carbon stored. In ploughed plots maximum SOM stored in fraction of size larger than 0.250 mm while the maximum SOM stored in finer fractions in non ploughed plots. In the topsoil, hoeing and organic input resulted in better total carbon storage than ploughing with no organic input. In the deeper layers, ploughing with organic input led to better carbon sequestration and therefore can contribute to the sustainability of the agricultural system in the soudano–Sahel.

Keywords: ploughing, organic-input, carbon mineralization, microbial biomass
Soil carbon dynamics under different tillage practices in Ghana

YEBOAH Edward (1) and JULIUS A. Natenor (2)

(1) Soil Research Institute, Academy Post Office, Kwadaso, Kumasi, Ghana
(2) Soil Science Department, Faculty of Agriculture, P.O. Box 245, University of Ghana, Legon

Research on the effects of global change has been accepted as a matter of high priority by scientists and policy makers alike. While developed countries have an urgent need to reduce carbon emissions, Semi-Arid and Sub-Humid countries of Africa on the other hand, have great potential for storing carbon in the soil. Soil carbon storage can offer economic benefits to landowners in developing countries in the form of credits from investors seeking carbon transfers. The fate and residence time of sequestered carbon stocks however, is not well known and the technology to measure and monitor changes in soil carbon is least developed. Again much of the uncertainty in the values of CO₂ flux from the tropics is a result of inadequate estimates of these parameters. In particular, there is little information on the carbon sequestration potential of many of the land use systems of the tropics. In combination with management, bioclimatic models have been found to be simple to use and to accurately predict carbon storage in soil profiles and across landscapes. In this paper the effect of tillage practices (ploughing and conventional tillage) on soil organic carbon and some soil nutrient dynamics at three depths (0-15, 15-30 and 30+ cm) along the catena of a Calciustert in the coastal savanna agroecological zone of Ghana is reported. Soil nutrients generally declined with depth and also with topography. Soil nutrients were significantly higher at the 0-15 cm depth, followed by the 15-30 cm depth and least at the 30+ cm depth. With the exception of available phosphorus and % N which were highest at the lower slope, the trend of soil nutrients variations along the catena was: upper slope > middle slope > lower slope. There was 23 % more carbon in the upper slope compared to the lower slope. Ploughing and cultivation led to a decline of about 21 %, 16 % and 11 %, respectively of soil pH, soil available phosphorus and soil potassium while % N improved by almost 62 % with ploughing. It is concluded that the knowledge of carbon dynamics under different tillage practices, along the catena and the entire soil solum is a prerequisite to accurately describe carbon sequestration in tropical soils.

Keywords: catena, tillage, sequestration, models
Responses of agro-ecosystem to free-air CO₂ enrichment

ZHU Jianguo

Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China

The fast rise in atmospheric CO₂ concentration is a unique challenge for scientists in China because of its implications for crop productivity and food security for a population over 1.3 billion. The use of the Free-Air Carbon dioxide Enrichment (FACE) technology to evaluate the effects of full-season CO₂ enrichment on agronomic crops has proven to be successful. A FACE system has been set up in Wuxi, near Shanghai, China. The FACE site is located in rice-wheat growing region near Taihu Lake, 31°37'N and 120°28'E. This project is designed to address the questions of how rising atmospheric CO₂ affects crop productivity, nutrient cycling, and other ecosystem processes.

The project has five main objectives: (1) to understand mechanisms of crop (rice and wheat) responses to elevated CO₂, (2) to quantify CO₂ effects on crop yield and quality, (3) to estimate changes in nutrient and water use efficiencies under elevated CO₂, (4) to contribute to model development for C and N uptake, transfer, and cycling in the agro-ecosystem, and (5) to evaluate potential effects of elevated CO₂ on exchanges of greenhouse gases in the agro-ecosystems with atmosphere.

The experiment has five control plots with ambient CO₂ and three FACE rings with ambient +200 ppm CO₂. Each ring is 12.5 m in diameter with pure CO₂ injection adopting the Japanese design. The first experiment period was from June to October 2001, which is the growing season for rice in that region. The second experiment period was from November 2001 to early June 2002, which is the growing season for winter wheat in that region. The CO₂ fumigation system is expected to operate fully for 365 days a year from June 2001 to June 2006.

Since China is one of the largest rice and wheat producing countries, the project has the potential to evaluate the impacts of global environmental change on food supply and feedbacks of agro-ecosystems to climatic changes through greenhouse gas exchanges.

Keywords: CO₂ enrichment, agro-ecosystem, carbon cycling, global change
Symposium 46

Land degradation and desertification: confronting the realities of the 21st Century

Convenor: ESWARAN Hari
Co-Convenor: VEARASILP Taweesak

Oral Session
Friday 16 August 2002
8:30 - 11:50
Room: Meeting Room 2

Poster Session
Friday 16 August 2002
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Overview of environmental and natural resource degradation of agriculture in Bangladesh

ALI Md. Mohsin and WAKATSUKI Toshiyuki

Faculty of Life and Environmental Science, Shimane University, Matsue 690-8504, Japan

This paper is an overview of the various contributing factors to the natural and environmental resource problems of agriculture particularly relating to the degradation of soil resource bases in Bangladesh. The land use has been changed in terms of net and total cropped areas and areas not available for cultivation and forest areas. A decrease in the hectares of net cropped area and an increase in the area not available for cultivation are due probably to land being taken up for the development of infrastructures. The increase in the total cropped area is mainly due to the increase in cropping intensity. The hydrologic regimes have been changed considerably due to irrigation, drainage and flood control embankments, newly developed roads and highways in recent years. The cropping practices have been changed which include the use of agricultural inputs especially irrigation, fertilizers and crop types within the past few decades. More than 80% of the people were directly engaged in agriculture during the early 1970s, but their employment in agriculture has been alarmingly decreasing and the total production is not coping with the ever-growing population of the country. Crop production potential is low compared to other countries of the world perhaps due to the depletion of soil nutrients. Nutrient balance analysis shows that nutrient removal by crop harvests often exceeds addition to soils from fertilizers. This depletion of the soil fertility is mainly due to the exploitation of land without proper replenishment and the problem is enhanced by intensive land use with high yielding varieties. A recent study shows soil acidification with depletion of the levels of exchangeable cations, available phosphorous, total carbon and total nitrogen during the period 1967-1995 in Bangladesh. Soil erosion problem in the eastern hill tracts is significant and has been compounded by the environmental impact of settlements and infrastructure development as well as by shifting cultivation. Widespread salinity intrusion during the dry season in the huge southern floodplain has been due to the abstraction of Ganges water at the Farakka by India. In water analyses from 1210 tube wells, 61 percent have been found to have arsenic levels higher than the acceptable limit set by the WHO of 0.01 mg L⁻¹.

Thus, land degradation is an outcome of depletive human practices and their interaction with the natural environment in Bangladesh. The intensification of these practices due to an increased in population pressure had a negative influence on the fertility status of soils. Soil management practices, however, have not kept pace with these changes in agriculture, neither in the use of such inputs as the fertilizer increase to compensate for nutrient uptake in the crops and nutrient loss through various ways such as leaching and/or soil erosion. Soil fertility decline has been the major pattern exacerbating the low level of crop productivity in Bangladesh.

Keywords: overview, environmental and natural resource, degradation, Bangladesh agriculture
Lands degradation in the savanna region in Northern Togo: perspectives for the future

AYEVA Tchatchibara

ITRA / CRA.SS, B.P. 128, Dapaong, Togo

Togo is situated in west Africa, between Ghana and Benin. It is bordered by Burkina Faso in the north and the Atlantic Ocean in the south. The Savanna Region, one of the five economic regions of the country has a characteristic of a broken relief and an aggressive climate. It’s main activity is agriculture. The western zone of the region undergoes perverted effects of demographic pressure, of over pasture and the effects of inappropriate culture systems on the lands which are very fragile already. The combined effects of all these factors is at the origin of the erosion and the loss of land fertility.

Land erosion is in diverse forms of which manifestations more spectacular are understandable by some gullying, coming from the erosion in sheet. The ravines sometimes reach 15 to 20 meters length and 5 to 8 meters deep and move at a speed of 10 to 15 meters per year. That kind of erosion is aided by wind erosion which takes the ampler in the area. The fertility losses are characterized by the progressive decrease of yields and of the soil productivity, despite the increased doses of fertiliser.

This situation, which does not cease to get worse, has led to the realisation of the important work of soil conservation and land fertility restoration (ravines correction, contour bounds construction and practice of the agroforestry). The work has been done on small basins, pouring besides farmers. Lands have then been rehabilitated and the fertility of a number of plots abandoned a long time ago has been restored. These actions must be reinforced by biologic dams seeping through and laid to other zones.

Keywords: Togo, savanna region, demographic pressure, fragile lands, erosion, loss of fertility
Degradation of soils in Azerbaijan

BABAYEV M.

The Institute of Soil Sciences and Agrochemistry of A.S., Baku, Azerbaijan

Many years of anthropogenic influence has resulted in soil degradation, soil cover and environment pollution.

For the rational organization of agriculture, guarding and re-establishment of natural resources it is necessary to examine them in evolutionary historical order. Analyzing their contemporary conditions, prognosing their changes and ways of their removals and managing these processes.

All these processes demand to examine them in complex, with the calculation of many years of man's activity.

The main reasons of soil degradation and soil cover:
- many years intensive use and irrigation:
  a) Loss of organic matter and of biological activity: On a territory of 1.5-1.8 mln. ha organic matter losses of 1.5-2.0 times.
  b) Physical degradation: decrease of structure stability, destruction of the aggregates compaction, lowering of Soil Surface - on a territory of 0.5 mln. ha.
  c) Loss of chemical fertility: N.P.K. - NPK, 2-3 times.
- salting: Salted soils in Azerbaijan mainly spread in Kur – the Araksin lowland and the Apsheron peninsula. The area is 1.3 mln. ha. Salt composition: soda, chloride, sulfate, sulphate-chloride and chloride-sulfate. 500 thousand ha salting soils are meliorated. The length of collector-drainage net 25 km.
- erosion process: For the part of mountain territories comes about 4.21 mln. ha or 60% from the general area in Azerbaijan. Mountain territories are characterized by considerable amplitude of height and strong crossing of relief. Namely that's why about 41.8% of land is subjected (3.61 mln. ha) by erosion of different degrees. More spread types of erosion are wind, water and irrigation.
- pollution (of soil, water and air): In the last 60-70 years a new problem has appeared. In connection with carried wide water economic measures in irrigated waters is sharply reduced turgidity. Specific gravity of mineral salts is increased, among ions predominate. It is widely used of kyagrise artesian and underground mineralizing water. Mineralizing of waters is increased in average 2-3 times (from 0.2-0.3 till 0.8-1.0 h L⁻¹). With irrigated waters in irrigated field enters 3 450 kg ha⁻¹ salt hydrocarbonate sulfate composition.

Potential soda in the waters of the Arak river have been discovered.

- technogen (oil and mountain - deposit pollution): At present intensive pollution of suburban lands happens by oil, industrial and building wastes. Territory is violated by different channels, kapbp-rapid, gallop, sandlot, pipeline and etc. It is formed typical technogen landscape.

Keywords: degradation, anthropogenic, salting, erosion, pollution, technogen
Degradation and rehabilitation of land and water resources: examples from Africa

COFIE Olufunke O. and PENNING DE VRIES Frits W.T.

International Water Management Institute, HQ. P.O. Box 2075, Colombo, Sri Lanka

In recent times, the rapid increase in population and development as well as the attendant challenge of food security in developing countries has put land and water resources under multiple pressures. This is has led to the expansion of infrastructure (houses, roads, industrial areas) and the increase of intensive agriculture to take care of the needs of expanding population. This has resulted in reduced productivity of these resources. Although farmers have developed strategies, based on their experiences, to rehabilitate some degraded lands, there is still need for action at policy and research levels. This paper presents examples of degradation and rehabilitation and concludes with recommendations of strategies to combat degradation and enhance productivity in Africa.

Keywords: degradation, pollution, nutrient depletion erosion
Triggering agricultural intensification through an integrated use of locally available resources and inorganic fertilizers

FOFANA B., BREMAN H., TAMELOKPO A.F., GNAPENOU K.D. and OKADA K.
International Institute for Soil Fertility Management (IFDC-Africa), BP:4483, Lomé, Togo

Food production in Sub-Saharan Africa (SSA) has not kept pace with the population growth. In order to become self sufficient in food, the production in SSA has to increase. This is forcing farmers to continuous planting of their already exhausted fields. Loss of soil fertility in SSA, due to nutrient mining by crop removal without adequate replenishment, has resulted in soil degradation and is leading to negative environmental consequences including desertification. To meet the challenge of food security and to stop environmental degradation, it is imperative to develop new and sustainable technologies. Important factors in this respect are (i) the maintenance/enhancement of soil fertility through an appropriate and integrated use of organic matter and inorganic fertilizers, and (ii) the reinforcement of agricultural and macro-economic policies in order to improve access of farmers to external inputs and strengthen their role vis-à-vis decision makers.

In most of the West African savannah and Sahel zones, the availability of organic materials is very limited. However, household waste, compost and cattle manure have long since been accumulating on the compound fields. IFDC-Africa identified an option for farmers to start using inorganic fertilizers linked to this accumulation. Soil quality of the compound fields is known to be higher than the average quality of arable land, leading to a more efficient, and therefore economically more feasible use of external inputs. Two soil fertility management practices relevant to smallholder farming systems in West Africa were tested. These practices were the addition of inorganic fertilizers and the retention/recycling of crop residues in the compound as well as the bush fields. The paper presents the option, using illustrations from the West African savannah and Sahel zone. It shows the increased recovery and agronomic efficiency of plant nutrients in the case of fertilizer use on compound fields, and presents a first analysis of the mechanism behind this synergistic effect.

Keywords: overpopulation, land degradation, soil fertility management, compound fields, fertilizer use efficiency, agricultural and macro-economic policy
Runoff and sediment transport under field simulated rainfall in the eastern part of the loess plateau in China

GABRIELS D. (1), SCHIETTECATTE W. (1), JIN K. (2), CAI D. (2) and HARTMANN R. (1)

(1) Department of Soil Management and Soil Care, Ghent University, Coupure 653, B-9000 Gent, Belgium
(2) Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences, 30 Baishiqiao Road, Beijing 100081, China

The loess plateau of China is very susceptible to soil erosion by overland flow. In order to assess runoff and soil loss, experimental plots were laid out near Luoyang (Henan province). In addition to the field plots under natural rainfall, field rainfall simulations were done on a bare plot under conventional tillage. The sediment load measurements were highly correlated with the stream power of runoff. This was in good agreement with laboratory rainfall simulations carried out in China and Belgium. With regard to the particle size of the eroded sediment no indication of selective erosion was found. The enrichment ratios of the different particle sizes were close to 1. Only at low erosion intensities enrichment ratios up to 2 were found for the smallest particles (< 20 μm). Experiments are still continuing in order to estimate the influence of different tillage practices on runoff and erosion.

Keywords: runoff, erosion, rainfall simulation, enrichment, loess, China
Characterizing the environmental conditions of land use/land cover classes towards the assessment of desertification: a case study in northwestern coast of Egypt

GAD A.

National Research Center, Egypt

The study area represents the arid Mediterranean ecosystems, as it is located along the Northern Mediterranean coast of Egypt. Large parts of this zone have been desertified during the past few centuries and the process is still converting many vulnerable areas into deserts. Remote sensing, with the advantages of synoptic view, multi-temporality and multi-wavelength bands could be used effectively to monitor the environmental variables and to manage the natural. The purpose of this study is to use the advantages of remote sensing in combination with GIS to define the environmental characteristics of each class. This approach will hopefully give a clue to evaluating desertification processes in arid areas.

The imagine 8.3 system was used in classifying a recent ETM image and to obtain a land use land cover map. A number of 132 field observation sites were described. A number of 65 soil profiles were dug and soil samples were collected. AutoCAD 14 software was used in data conversion (tablet digitizing) different theme layers from topographic maps of the Military Survey Authority (MSA) at scale 1:50000. Arc/Info 7.2 system was used for map features coding, editing, building topology, edge matching and map projection. Generating check plots, compared with source maps, was fulfilled for quality assurance. ArcView 3.2 (module 3D analyst) software was used to interpolate the data to trace the spatial distribution of different criteria. Map layout was performed using the same system. These layers include water bodies, altitude points, contour lines, roads, railways, tracks, pipelines, and telephone lines. Also soil attributes were added to the study sites location map, including field description and physico-chemical soil properties.

It was possible to find out the environmental and soil characteristics for each land unit. These data can be used to proceed with algorithms for evaluating the status, and inherent risk of desertification. It is recommended we use the bottom up approach of remote sensing and GIS for obtaining all information needed to detect environmental changes and to evaluate adverse conditions, leading to desertification, in arid areas.

Keywords: environment, land use, land cover, remote sensing, desertification, Egypt
Soil degradation and desertification in the Western Sierra Madre of Mexico

GONZALEZ-BARRIOS J.L. (1), DESCROIX L. (2), VIRAMONTES D. (3) and ANAYA E. (4)

(1) INIFAP CENID-RASPA, ITESM-CL, AP 225-3, Gomez Palacio DGO 35071, Mexico
(2) IRD-LTHE UMR 5564 CNRS, BP 53, 38041 Grenoble, Cedex 9, France
(3) IMTA, Paseo Cuauhnahuac No. 8532 Jiutepec Mor. 62550, Mexico
(4) UJED, Gomez Palacio DGO, Mexico

Experimental studies carried out on the Western Sierra Madre of Mexico (sub-humid watershed of the Nazas river at 1,600-3,000 meters altitude) show a process of desertification induced by soil and vegetation degradation.

Deforestation and over grazing increase the effects of rain (splash) on soil surface; the diffuse erosion provokes great soil losses and diminishing water retention capacity in soil environment. The ecosystem becomes extremely arid in areas of intense activity such as: cattle breeding (grasslands and points of water supply), new agriculture areas (forage cultures) and forestry production (excessive deforestation).

The soil and vegetation degradation mean today: a harder dry season, a higher vulnerability to fire and a higher risk of biodiversity loss.

A more rational management of soil and vegetation is required with the effective control of deforestation, over-grazing and new lands opened to agriculture. More research work is required in order to improve the comprehension of ecosystem functioning for leading management practices to reverse the environmental impact observed in the Western Sierra Madre of Mexico.

Keywords: Mexico, Western Sierra Madre, land degradation, desertification
Actuality of comprehensive agricultural configuration in the middle and lower reaches of the Tarim River and consideration of its adjusting countermeasure

HUANG Ziwei and REFUKAITI Xiaolei Zhang

The Institute of Ecology and Geography Research, Chinese Academy of Sciences, China

The Tarim River is the largest inland river in China. Its total length from headstream is 2,437 km. And the length of the main steam is 1,321 km from Xiaojiake, the converging point of three headstreams (Ye’erqian River, Hetian River and Akesu River), to its coccyx (Taitema Lake). The middle and lower breach of the main stream is 826 km, in which 614 km are in Yuli county, which includes almost the whole middle breach and a majority of the lower breach. Therefore, Yuli county could be seen as typically representative of this area.

Keywords: Tarim River, land degradation, agricultural configuration
Characterization of land degradation in Central Argentina with hyperspectral AVIRIS and EO-1 data

HUETE Alfredo (1), GAO Xiang (1), KIM Ho Jin (1), MIURA Tomoaki (1), BORGHI Carlos (2) and OJEDA Ricardo (2)

(1) University of Arizona, Tucson, Arizona, USA
(2) CRICYT, Mendoza, Argentina

Ground, air- and spaceborne hyperspectral data sets were collected over several land cover types, representative of various stages of land degradation in the Mendoza region of Argentina. EO-1 Hyperion satellite imagery, airborne AVIRIS imagery, and field-measured ASD spectroradiometer data were acquired over the protected Nacuñán Reserve composed of floristically diverse vegetation communities, including mesquite shrub (algorrobol), sand-dune (medanal), creosotebush (jarillal), and severely degraded (peladal) sites. Field-based biophysical measurements included soil, litter, vegetation cover, and leaf area index (LAI) measurements. The field data were co-registered with AVIRIS and Hyperion imagery for a landscape analysis of land degradation. We investigated various remote sensing based degradation indicators including albedo, spectral vegetation indices, pixel variance, first derivative analysis of spectral signatures, and soil, litter, and vegetation mixture component analysis. Our goal was to assess the utility of hyperspectral data in discriminating the gradient of land conversion vegetation types at various stages of degradation. Spectral mixture modeling was utilized to assess the amounts and structural properties of the various canopy components and to independently assess the soil and vegetation components in characterizing land degradation. We were able to distinguish the stages of land conversion through both spectrally decomposed soil and vegetation components. However, we found soil optical parameters to be more useful than vegetation spectral measures in characterizing land degradation. Hyperspectral data were found to contain more information on soil and vegetation properties than conventional spectral vegetation indices and thus offer more useful information for the identification characterization of land degraded areas.

Keywords: remote sensing, land degradation, hyperspectral, mixture models
Soil degradation assessment through remote sensing techniques of Tamil Nadu

MAHARAJAN Elayarajan, SUBRAMANIAM Natarajan, RAMASAMY Sivasamy and VENUGOPAL Arunkumar

Remote Sensing Unit, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, India

In the total 327 m ha of the geographical area of India, of which 188 m ha. (58 % of the area) is affected by soil degradation at varying degrees. Soil degradation by wind erosion is the dominant factor in the arid and semiarid regions of western India and affects 13 m ha of lands. Soil deterioration due to chemical processes and waterlogging was in the area of 15 m ha and 7 m ha respectively (Abrol, 1994).

Information on the nature, extent and spatial distribution is a prerequisite for planning efficient utilisation of available cultivable resources and degraded ones. To obtain such information over a large area, application of remote sensing techniques is one of the most efficient tools used nowadays to predict soil degradation.

The present investigation deals with the identification and mapping of areas affected by various land degradation types by using remote sensing data. The study area covered an area of 29,119 ha located at the southern part of Tamil Nadu (India) between 10° 02' 00" and 10°14'15"N latitude and 78°16'22" and 78°31'35"E longitude. Landsat TM FCC on 1:50,000 scale corresponding to the study area were visually interpreted and the Imagery Interpretation Units (IIUs) were identified. The IIUs were assessed in respect of the kind, degree, extent and rate of soil degradation and the causative factors for degradation following the guidelines given by Oldeman et al. (1990) and Lyden (1995).

Sixteen soil mapping units were identified and grouped under different degradation types. Four kinds of soil degradation viz., water erosion, soil compaction, low fertility /organic matter and alkalinisation were recognized. The total area degraded due to water erosion was 6,766.38 ha (23.23%). Out of this, the strongly eroded land was 107.88 ha (3.69%) and the moderately eroded land was 5,690.50 ha (19.54%).

Low fertility status/low organic matter due to poor agricultural practices and application of inadequate organic manures occupied an area of 10,170.12 ha (34.93%). Lands degraded by alkalinization was significant along the epimeral streams and microdepressions, to an extent of 6,837.50 ha (23.48%). Soil compaction due to heavy soil texture and deficit soil moisture was noticed in an area of 1,700.50 ha (5.83%).

Keywords: land degradation, remote sensing
Heavy metals in soils damaged with pyritous barren soil

MARIC Miroslava (1), ANTONIJEVIC Milan (2) and MILUTINOVIC Sinisa (1)

(1) Agricultural Research Institute "SERBIA", Beograd, Center for Agricultural and Technological Research, Grljanski put bb, 19000 Zajecar, Yugoslavia

(2) Technical Faculty, 19210 Bor, Yugoslavia

The copper mine in Bor, since the moment of its opening in 1902/1903, has been a great polluter of the environment. The storing of the flotation barren soil, dust from the storage, waste waters, as well as constant emissions of polluters through air, have been polluting the soil, air and water.

More than 2,000 ha of fertile soil in the valley of the Veliki Timok river have been damaged by discharges of the flotation barren soil from the copper mine of Bor. The sulphide mineral pyrite, FeS₂, in the flotation barren soil is present in the greatest amount.

It can be seen from literature that various forms of iron and sulphur are created by the oxidation of pyrite, as well as the formation of the $\text{H}^+$ ions which acidate the soil. The aim of this study is to establish the influence of chemical melioration additives on decreases of soil acidity, as well as on other physical, chemical and microbiological characteristics of soil. The damaged soil was used as a base on which oats were sown, and it was also established the oats yield and the influence of chemical melioration additives on absorption of biogenic elements and heavy metals in plant material. The following meliorate additives were used: CaCO₃, NPK, stable manure, lumbricum, hay and coal dust. CaCO₃ was used to maintain the pH value in soil, while by usage of the mineral and organic materials, the chemical composition should be improved, as well as some microbiological processes activated.

Aiming to investigate all the above mentioned, the vegetation trials with pyritous barren soil and various combinations of meliorate materials were set, and oats were sown. The vegetation containers in which the trial was set included 10 kg of soil.

Determination of the total amount of some heavy metals (Cu, Pb, Zn, Fe) was carried out for the sake of obtaining a general inspection of their content in the soil. The content of heavy metals was determined in the oat leaves and grains. The heavy metals determination was carried out by the method of atomic absorption spectrophotometry (AAS). The splitting procedure with HNO₃ and 30% H₂O₂ was used for splitting samples.

Concerning accumulation of heavy metals in soil, greater amounts of copper than permitted were established, most in the variants with added organic materials - lumbricum and hay. The plant material (the ear and grain) were analysed, too. It was found that all metals in oats cultivated on the pyritous barren soil are in surplus in relation to the content of the metals present in the oats cultivated on normal soil.

Keywords: soil, heavy metals, pyritous barren soil, oats
Degradation and desertification of lands in Russia

MOLTCHANOV Erik and KARMANOV Ivan

Dokuchaev Soil Institute, 7 Pyzhevsky Lane, Moscow 109017, Russia

Degradation and desertification subject, firstly, soil cover of intensively used agricultural lands. Usually degradation and desertification are taking place under the combined influence of natural and anthropogenic factors and it is rather difficult to distinguish them. Two or more degradation variations are developing simultaneously on many territories. Combinations of water and wind erosion; high acidity and waterlogging; waterlogging, bogging and secondary salinization; salinization and solonetzization; water or wind erosion and desertification are often recorded. As a rule, processes of dehumification and compaction leave traces on these combinations.

Water erosion of soils for arable lands covers 23% of the total area and during the past 25 years its annual increase is 0.5-0.6 mln. ha. In general, water erosion of soils is recorded on 26% of natural greenlands in the country.

Soils with obvious development of wind erosion characteristics cover about 6% of arable lands. About 7.5% of the country’s natural greenlands soils are deflated.

Almost all soils of arable lands, excluding insignificant areas of high cultivated ones have lost either one or other quantity of humus. Humus reserves in arable soil cover are from 55 to 80% in comparison with 0-20 cm layer of analogous virgin territory.

Most of the country’s arable land is compacted to some degree. Soil compaction is registered on significant depth (70-100 cm) on the most fertile chernozem soils and it is mainly in the higher profile part of the others.

Waterlogging and bogging of soils are recorded on 7% of the country arable lands. Such soils have increased on average by 150-200 th. ha annually during the past 25 years in connection with numerous big and small reservoir construction, irrational irrigation, etc. Waterlogging and bogging of soils are registered also on 54% of natural greenlands.

Secondary salinization of soil covers on average approximately 3% of the country’s arable land. During the past 25 years, areas of secondary salinization soils are increasing annually by 70-90 th. ha. mainly due to irrational irrigation. Secondary salinization covers about 25% of natural greenlands.

Solonetz soils occupy 8% of the country’s arable lands and about 28% of natural greenlands. Presently, reclamation of alkali soils is not practically carried out.

Acid soils on arable lands occupied 30 % up to 1990, but they have now reached 45% due to sharp reduction of liming.

Mainly low pollution of soils with radionucliei, pesticides, heavy metals has been registered over separate areas of Russia.

Processes of desertification cover about 7% of the total land resources of the Russia and they are mostly intensive in arid and semi-arid zones in the south of Russia’s European part, as well as in zones of insufficient moisturing in several Central European regions and southern areas of Asian part of the country.

For the purpose of preventing land degradation and desertification in Russia, the Government is undertaking urgent measures.

Keywords: degradation, desertification, water erosion, wind erosion, dehumification
Hindrance from degradation in rootzone of soils under saline groundwater table in Egypt

MOUKHTAR Mohamed M. (1), ABDEL-AAL Aly I.N. (1), ABDEL-MAWGOUDE A.S.A (2), EL-SHEIKH M.A.B. (3), ABDEL-KHALIK M.I.I. (3) and EL-HAKIM M.H. (1)

(2) Al-Azhar University, Agricultural Faculty, Assuit, Egypt
(3) El-Serw Agriculture Research Station, Agric. Res. Centre, Egypt

Agricultural salt affected heavy textured lands of poor productivity are commonly found throughout the northern periphery of the Nile Delta. Clay-salt affected soils are known to be difficult to manage. The present work is conducted in El-Serw Farm, north Delta. The salinity is due to a shallow saline groundwater table (EC = 39 dSm$^{-1}$ at 40 cm depth) The aim is to develop suitable local techniques for land improvement in rootzone and sustainable agriculture. An experimental field was designed with different treatments of mole drain spacing 0, 3.0, 2.0 and 1.5 m combined without or with gypsum addition. Rice was cultivated in the summer of 1999 and 2000. All agricultural practices are similar to that in neighbour fields. Irrigation water salinity ranges from 1.5 to 2.0 dSm$^{-1}$.

In the first year, results revealed that only negligible reduction in salinity occurred in the plots under 3 m mole spacing with or without gypsum. Better desalinization is obtained in plots under 2 m and 1.5 m without gypsum up to 60 cm soil depth. Salinity reduction is clear enough under the same spacing with gypsum, since the EC dropped to values around 6 and 5 dSm$^{-1}$, respectively. For exchangeable sodium percentage, ESP, the soil at all depths is initially highly sodic ESP>40. The sodicity almost persists in the different treatments, even in plots under 2 and 1.5 m mole spacing either without or with gypsum, the sodicity is still high (ESP~26). The rice yield in the control being 1 t fd$^{-1}$ reached 2.6 and 1.75 t fd$^{-1}$ under 1.5 m treatment with and without gypsum, respectively. Almost the same yield is obtained with 2 m spacing.

In the second year, there is a progressive improvement in soil conditions. In general, salinity decreased with decreasing mole drain spacing; EC dropped to less than 4 dSm$^{-1}$ in 1.5 m mole drain spacing with gypsum treatments comparing to the other treatments. Regarding exchangeable sodium percentage, there is a relative reduction in ESP at the soil surface than in the deeper depth especially with gypsum and narrow drain spacing. The ESP is still high. Concerning plant growth and production, there is a good cover plant for mole drain spacing especially with gypsum treatments compared to that without gypsum addition. The best treatment is 1.5 m mole drain spacing with gypsum. Data of rice yield follows the same trend to that in the first year with a relative increase in all treatments.

Keywords: preventing deteriorated soil, mole drainage, salty clay, rice yield
Degree of phosphorus saturation (DPS): an indicator for predicting water quality degradation

NAIR Vimala D., GRAETZ Donald A. and WALKER Megan L.

University of Florida, 106 Newell Hall, P.O. Box 110510, Gainesville, FL 32611-0510, USA

The need for an indicator to assess the potential of phosphorus (P) moving from the site of its intended use to surface waters either via surface runoff or subsurface drainage is apparent. The “Degree of P Saturation” (DPS), which relates a measure of P already adsorbed by a soil to its adsorption capacity, could be a good indicator of that soil’s P release capability. The sandy soils of the Suwannee River and Lake Okeechobee Basins in Florida, USA, which receive significant loadings of animal manure, and have the potential for subsurface P movement, are ideal testing sites for the DPS indicator. Various farmer-owned sites were selected within the basins and four soil profiles obtained from each site. The soil samples were divided by horizon and DPS was determined for each horizon using different methods. While several methods of DPS determinations produced positive results as good indicators, determining DPS as a function of Mehlich 1 P and the sum of Mehlich 1 (Fe+Al) seemed to be the most practical one for calculating DPS for the sandy soils of Florida. There was either a linear or a curvilinear relationship between DPS values and water-soluble P indicating that DPS could be used in a routine manner for “environmental soil testing” in watersheds impacted by organic fertilizer applications. The information obtained from this study allows identification of soils and landscapes where application of excessive amounts of manure P may result in degradation of nearby bodies of water, even in the absence of soil erosion hazards. A threshold DPS value will have to be identified so as to assess the “life” of a soil for continued P addition without detrimental effects to water quality.

Keywords: environmental soil testing, animal manure, sandy soils, vertical P movement, farmer-owned sites
Investigations were made into the accumulation of DTPA extractable and total cadmium and lead in surface soils (0-15 cm) of a Long Term Fertilizer Experiment (LTFE) in progress since 1972 in a medium black soil at Tamil Nadu Agricultural University, Coimbatore, India under irrigated conditions. The experimental soil is a sandy clay loam with a pH of 8.2 and 2.0 percent calcium content. The organic carbon content is 0.3 percent. The treatments consist of NPK application at 50, 100 and 150 percent of optimal level, 100 percent optimal level of NPK; without herbicidal addition, through sulphur free sources, with zinc sulphate at 25 kg ha$^{-1}$ and with cattle manure at 10 t ha$^{-1}$. Besides there are two other treatments in addition to unfertilized control, viz., application of NP alone and N alone at 100 percent of optimal level. Each treatment has been replicated four times in a randomized block design and has a net plot size of 200 m$^2$. A fixed crop rotation of finger millet - maize - fodder cowpea in a year is being followed. Soil samples have been collected and stored every year commencing from 1992. From the soil samples of the 1992 and 2000 crop seasons the DTPA extractable and total lead and cadmium contents were determined. The results revealed that the concentration of DTPA extractable cadmium did not differ among the treatments in the 1992 samples. However, the results of the 2000 season revealed that the accumulation of DTPA and total cadmium was the highest in those plots which received NPK at 150 percent of optimal level. The increase in the total the cadmium concentration was 25.6 percent over a period of eight years under this treatment. The rate of increase in the cadmium content was lower in N alone and control plots. The concentration of DTPA lead did not differ in the samples of the 1992 season. In the samples of 2000, the DTPA lead was the highest in 150 percent NPK level and the least was in control plots. Marked differences were there in total lead content among the treatments. Continuous application of NPK at 150 percent of optimal level resulted in the highest total lead concentration followed by the treatment 100 percent NPK with zinc sulphate. The least was in control plots. The rate of increase in the total lead content was the highest in the treatment 100 percent optimum NPK + zinc sulphate which recorded an increase of 43.8 percent in 2000 over that of 1992.

Keywords: long term fertilization, cadmium, lead accumulation
Remote sensing and GIS techniques for land degradation assessment due to water erosion

SUBRAMANIAM Natarajan and CHINAPPA GOUNDER Palaniswami

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, India

Among the different kinds of degradation, water erosion is the major land degradation problem in many parts of the world. About 1093 million ha in the world have been degraded due to water erosion, followed by 549 million ha by wind erosion, 134 million ha by nutrient depletion, 77 million ha by salinisation, 22 million ha by pollution and 108 million ha by compaction (ISRIC, 2000). Investigations on the major land degradation viz, water erosion are essential for national and regional developmental plans.

A study was carried out to prepare thematic maps by using remote sensing tools, using GIS technology for the integration of maps and developing Distributed Soil Erosion Model (DSEM) for the Dharmapuri district of Tamil Nadu, India. In the DSEM model, the procedures described in the WEPP manual (Flanagan and Nearing, 1995) for the development of soil and land cover parameters based on the empirical equations representing relations between erodibility and soil texture and organic matter content were used. The adjustment factor for freeze and thaw to the erodibility parameter was dropped due to its irrelevancy in the study area. The procedures adopted by the SIMWE model (Mitas and Mitasova, 1998) were also employed for the bivariate solution to the overlandflow and erosion equations. The rainfall detachment was added to the source term of the erosion continuity equation. The flow tracing was obtained by the pyramiding approach of the ANSWERS model (Beasley et al., 1980) and the upslope contributing area was estimated by the method used by Pilesjö (1992). Topography, soil, land use and weather data were used as inputs for the development of the model.

The erosion severity map of the study area prepared by DSEM showed that 59.12% of the areal extent was affected by water erosion. In the forest soils, due to the presence of vegetative cover, the erosion problem was not severe. It was found that among the land use types, rainfed sorghum, rainfed groundnut in valleys and irrigated ragi-cotton, irrigated sorghum - cotton and plantation crops recorded low water erosion. Piedmont plains cultivated to rainfed groundnut was most was affected by the water erosion. By employing remote sensing tools, the land degradation due to water erosion was observed in 6,08,047 ha, but the same problem was found to exist in 5,71,014 ha as estimated by DSEM. The results showed that DSEM can be effectively employed for water erosion studies at regional levels.

Keywords: remote sensing, GIS, erosion model
Desertification study at life-size scale: human-soil interactions on land degradation in semi-arid West Africa

TANAKA Uru, MIYAZAKI Hidetoshi, NODA Etsuko and KOSAKI Takashi

Graduate School of Agriculture, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyo-ku, Kyoto, 606-8502, Japan

Inter-relations between local farming systems and soil characteristics were studied in two villages (Silguey and Takabangou), Northern Burkina Faso, where potential risks for desertification have been increased due to daily activities by local people.

In Silguey village, we surveyed nutrient input through indigenous fertilization system (so-called parcage system) and its significance for maintaining soil fertility under pearl millet cultivation. The coverage of parcage was estimated to 0.38 ha for a single cropping year with the density of cattle feces of 11.3 t ha⁻¹. Considering the area of permanent cultivation field of sample households is approximately 2 ha out of the total 8 ha, the fertilization to the entire permanent field can be achieved with in 5 years. Removal of nutrients from cattle feces by the harvest of above-ground biomass of pearl millet was estimated to 22.6% for total N, 13.2% for available P and 47.0% for available K. It roughly implies that the nutrient input is approximately equivalent to 4.4 years of harvest for total N, 7.6 years for available P and 2.1 years for available K, although these values are over-estimation in reality. If the density of cattle feces is reduced by frequent shift of the position of parcage, the fertilization may be almost done for the permanent cultivation field every year. This result provides us an interesting insight in considering the establishment of rational and practical fertility maintenance systems in the Sahel for harmonious co-existence of cultivators and nomads over land resources utilization.

In Takabangou village, we found unique micro-morphological structure in the profile of the sandy dune soil, a major place of upland cultivation. At the depth between a few cm and 50 cm, the soil possesses structure with multiple thin layers of fine materials (silt and clay). According to the field observation during dry season, the wind erosion occurred in soil loosened by stocking of livestock and cultivation practices. On the other hands, the movement of soil was halted when the thin layer appeared at the surface. We may call it “self-protection mechanism of ancient dune soil against wind erosion” and conclude that the current soil management practice (non-tillage weeding with push-hoe and sand trapping) is suitable for conserving this nature of soil and, thus, for prevention of further acceleration of desertification. To improve the local farming practice, we also discussed possibility for technology transfer, e.g. non- or minimum tillage harrow for weeding from semi-arid India to the Sahel as a labor-saving, rapid-operating and soil-friendly cultivation tool.

Keywords: desertification, soil characteristics, fertility maintenance, horizontal technology transfer, local husbandry, Sahel
Quantitative and qualitative analysis of aeolian material flux in the Sahel

THIOMBIANO L., SEDEGO M.P., KABORÉ O. and BAKIONO G.

Institute for Environment and Agricultural Research (INERA), BP 71 92 Ouagadougou, Burkina Faso lamourdia, Burkina Faso

The sahel agroecological zone is characterized by soil degradation due to wind and water erosion. Several studies have been conducted on the phenomenon of land degradation, but there is a lack of knowledge on the quantitative and qualitative fluxes of aeolian materials. This study was conducted in the Sahel zone with an average rainfall of 500 mm y\(^{-1}\) and a wind velocity ranging from 2 to 13 m s\(^{-1}\). The soils are mainly according to FAO Legend, Arenosols, Leptosols and Lixisols. The use of a catcher named «KATSOLS» allows the possibility of quantifying the aeolian material. This static catcher has a catching area of 4 m\(^2\) oriented toward the main wind direction (EEN/WWS). The aeolian deposit is collected each 30 min and the wind velocity is measured simultaneously by an automatic meteorological station. Samples of this material are analysed to determine the C (Walkey and Black method), N (Kjedahl method), available phosphorus (Bray 1 method) and available potassium (spectrophotometer method) contents. A granulometric separation is obtained with a set of three sieves with 20, 53 and 75 \(\mu m\) size.

The results obtained revealed quantitative fluxes of 329.1 t ha\(^{-1}\) y\(^{-1}\), with 60% of this total amount of aerosols obtained in the period from June to August. This aeolian material is characterized by a net predominance (98%) of coarse fraction with a size above 75 \(\mu m\). The total annual lost is: 26 kg ha\(^{-1}\) of C, with 50 kg ha\(^{-1}\), 24 kg ha\(^{-1}\) and 74 kg ha\(^{-1}\) respectively for N, P and K.

The quantity of aeolian fluxes measured is similar to the data obtained in Niger and revealed clearly that 90% to 98% of this material can be collected from 0 to 2 meters above the soil with the new type of catcher (KATSOLS). Regarding the quality of the aeolian soils, it appears an important transfer of nitrogen and phosphorus due to wind erosion occurs.

These data show the severity of wind erosion in the Sahel and its impact on land degradation and desertification. The relative quality of the aeolian material can explain the status of agricultural Arenosols where mulch is used to catch this material.

**Keywords:** wind erosion, aeolian material, Sahel, granulometry, mineral content, desertification
Acidification of soils: the indicator of chemical soil degradation process

VEITIENE Rima

Lithuanian institute of Agriculture, LT 5845 Vezaiciai, Klaipeda district, Lithuania

Acidification of soils is one of the reasons for chemical degradation processes in soils. Liming is the most effective and universal means for the improvement of acid soils. Using of manure decreasing acidity of soils too. By the fertilisation with mineral fertilisers especially with KCl, nitrogen fertilisers, process of acidification of soils is more active.

The plants growing in the acid soils experience deficiencies of many elements. In acid soils the micro-biological activity as well as mineralising of nutrients are effected. In Vezaiciai has been established that after liming of soils the pH increased from 4.4 to 6.5, the yield of barley increased from 0.5 to 4.4 t ha\(^{-1}\). Decreasing in acidity due to liming depends upon dose, kind and course of liming, physical properties of soil, amount of precipitation, amount of nature of mineral fertilisers, amount of humus.

Results of field experiments carried out in Lithuanian Institute of Agriculture showed that in the absence of liming the soil acidity increased in 0.1 unit pH during every year. As a result of this process the was an increase in the content of elements such as aluminium, zinc, potassium and decrease in the amount of bases, phosphorus in the soil.

Due to periodical fertilisation of soils with manure soil acidity and amount of available aluminium decreased, amount of mobile phosphorus and potassium increased in the topsoil. The largest rate of manure (120 t ha\(^{-1}\)) has increased the amount of available boron, copper and manganese and increased amount of zinc.

Anthropogenical activity (liming, manuring, fertilising) disbalanced a ratio of nutritious matter in the soils. Balanced fertilisation is the only way to bridge the gap between nutrient supply of the soil and crop uptake, in order to sustain productivity in modern farming without deteriorating soil health.

In this article analysing impact of some agrochemical means on the amount of nutritious matter in acid morain Dystict Albeluvisols (Abg) as well as change of elements in acidification process of soils.

Keywords: acid soils, liming, fertilisation, ratio of nutritious matter
The recultivation problem of oil industry soil in Absheron Peninsula

YAGUBOV Gasham Shamil oglu, AHMADOV Vazir Albaba oglu and HAKIMOVA Nargiz Firuz gizi

5, str. M. Arif, Baku 370073, Baku 99412, Azerbaijan

The Absheron peninsula is famous for its natural resources in the world. It is enough to say that the first rich oil and gas deposits were found here and began being exploited in 1948 by industrial methods. 1.2 mld. tonnes of oil is extracted to in the Absheron peninsula. As a result of oil extraction in such quantities, and it’s processing and transport without regard to it’s effects on the environment, this has dealt a blow to nature Absheron.

Use of natural resources in oil extraction in the Soviet empire ideology was built on the motto of “We can’t expect charity from nature, we must get all what we need from it by force” had made difficult problems in the Absheron peninsula. So, for more than 150 years as a result of oil deposits cruel exploitation soils having high fertility spreading in 33.3 thousand ha zone, soiling with oil wastes are overturned into “Dead zone”. It is enough to say that being continuous soiling process in oil industry areas in result of the filtration from oil products surface to low layers in soil profile absorbing neftogen layer by oil products, in surface cover consisting of mazut and bitumen stable for eczogen influence were created. Mazut and bitumen layers dense change between 10.5-25.7 sm, but the calculation of oil compound change between 5.6-74.8%. Oil compound calculation forms 1.2-27.5% in the same layers being 21.3-75.6 sm of neftogen layer dense.

In future with the purpose of same soils recultivation it was carried out the investigations on a large scale and the oil-industry places were classified for their soiling situation. It was informed that the oil industry places in the peninsula were distinguished into 3 types, 5 and a half type, 18 kinds for their soiling peculiarities. These soils were distinguished into 5 groups for their soiling-weakest, weak average, high and sharp.

We had carried out many variant experiments for these soils fertility restoration in 1981-1990 and got positive results. But there is a great need for the special technology preparing for soils recultivation high and sharp soiling by oil wastes. For these soils fertility recultivation though some internal and foreign companies displayed initiative it wasn’t got any result. As it wasn’t met Absheron soils polluting oil wastes in any oil and gas extracting country of the world. That’s why till the present period the recultivation problem of high and sharp polluted oil industry soils isn’t solved.

Keywords: resoil, reclamation land, mazut, craft, oil generate land, bitumen
Land degradation factors in the Mediterranean region

ZDRULI Pandi (1), STEDUTO Pasquale (1), MONTANARELLA Luca (2) and JAMAGNE Marcel (3)

(1) CIHEAM-Mediterranean Agronomic Institute, Via Ceglie 9, 70010 Valenzano, Bari, Italy
(2) European Commission, JRC, European Soil Bureau, T.P. 290, 21020 Ispra, Italy
(3) Institut National de la Recherche Agronomique (INRA), Orléans, Avenue de la Pomme de Pin BP 20619, Ardon 45166 Olivet, Cedex, France

In the frame of the activities of the European Commission’s European Soil Bureau (ESB) several soil databases have been compiled covering the EU Member States and the bordering countries. Since the last quarter of 1999, work has been going on to extend the EUSIS into the North African and the Middle and Near East to complete a network of soil information for all the countries surrounding the Mediterranean Sea. The first draft of this network is set to be functional by September 2001. The methodology will be the same with that developed in Europe in order to make the results compatible.

The area is faced with many challenges. Preliminary reports from many countries show that large areas are affected by several land degradation factors. In order of magnitude and intensity they are reported as follows:

- Soil erosion (including wind and water erosion);
- Desertification;
- Salinization;
- Scarcity of water resources;
- Urbanisation;
- Heavy metal contamination and soil pollution;
- Reduction of soil fertility and of organic matter content;
- Siltation of reservoirs.

Often, mismanagement and human induced degradation accelerate many of these factors, therefore it is imperative that they be addressed quickly. Existing local governmental structures as well as international institutions that are involved in the region have a great role to play towards the promotion of sustainable development and environmental protection of the natural resources.

During the last decades, the repeated occurrence of severe environmental conditions like drought, desertification, soil erosion, and landslides, including extended areas of the Southern Europe and specifically of the Mediterranean countries, has highlighted the need to develop effective monitoring tools and to pursue research on the immediate and long-term impact of these events. This need will become more important in the future, as current global climate change scenarios suggest that the frequency and impact of these events are likely to increase in the region causing even more serious environmental and socio-economic implications.

Despite general awareness of the problems, appropriate and standardised policies for a regular monitoring of the soil resources and their sustainable use are still missing in many countries. These policies are essential for the appropriate management of these resources and are linked with various technical and political levels.

Keywords: Mediterranean, desertification, salinisation, erosion, urbanisation, networking
Natural restoration of degraded grazing land

ZOEBISCH M. (1) and MASRI Z. (2)

(1) Asian Institute of Technology (AIT), P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
(2) International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5460, Aleppo, Syria

Ground cover, plant diversity and total biomass production are indicators of the scale of degradation of open natural grazing lands. To assess the potential for natural restoration of degraded grazing areas, it is necessary to study the diversity and degree of the plant cover under protected and unprotected conditions. If plant cover and plant diversity can recover quickly on protected sites, then the effects of degradation (e.g., low quality and productivity of the plant biomass) can be reversed easily. Results are presented from in situ trials in a typical degraded dryland valley in northwestern Syria. The area receives an average annual rainfall of about 200 mm. At six sites, fenced (i.e., not grazed) and open (i.e., grazed) plots were monitored.

Four years of observation showed that at the end of the dry season, plant cover on the grazed plots decreased to about 12%, while on the protected plots, the vegetation had stabilized at around 60%. For the same period, observations also showed that the total aboveground biomass production on the fenced sites was four times higher than on the open sites. Already after one season, seventy-one plant species were identified in the monitoring areas; 81% of all the species were found on the fenced plots, while only 39% of the species were found on the grazed plots. After four consecutive seasons, the number of plant species found in the area increased from 73 to 150; 89% were found on the protected plots and 56% were found on the grazed plots. Only thirty-five percent of these species had a medium to high palatability, i.e., feed value.

In the fenced plots, soil properties improved markedly. After three years of protection from grazing, the soil organic matter content increased from 2.3 percent to 3.2 percent, and the proportion of water-stable aggregates >0.5mm increased from 9.7 percent to 23.4 percent. This is a clear indication of the positive effects that good vegetation cover has on soil physical properties.

The high degree of diversity on the protected plots indicates that degraded grazing land in the area can be brought back to its potential productivity. After a longer time, the protected plots will show the site-specific plant diversity under undisturbed conditions. This will then be the best possible protective plant cover, which can re-establish itself in the area without costly rehabilitation measures. Protected plots may also serve as plant-diversity pools for in situ conservation and seed multiplication.

Keywords: aggregate stability, dryland degradation, plant diversity, soil physical properties
Symposium 47

Soil mineral – organic component – microorganism interactions and the impact on the ecosystem and human welfare

Convenor: HUANG Pan Ming
Co-Convenor: VITYAKON Patma

Oral Session
Monday 19 August 2002
8:30 - 11:50
Room: Meeting Room 4

Poster Session
Monday 19 August 2002
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Effect of nonhumified organic acids on phosphate reactions in calcareous soils of arid region

AL-HADETHI Akram A., MUHAWISH Noor M., AL-SAIQUALY Ali A. and HASSAN Sadik J.

Soil and Water Department, Agriculture and Biology Research Center, Iraqi Atomic Energy Commission, Baghdad, Iraq

The purpose of this study was to determine the effects of mode of organic acids addition and concentration on the phosphate (P) reactions in calcareous soils of arid regions. These soils seem to have high P sorption capacity as indicated by sorption isotherms. The amount of P remained in equilibrium solution markedly increased with the increase of organic acid concentration when acid introduced after P equilibrated with soil. While increasing acid concentration did not show a measurable increase in the amount of P remained in equilibrium solution when acid and P added at same time or acid added before P. The addition of acids to soil before adding P is the most effective mode of addition while adding acids after P was the least effective in reducing P sorption by soils. Under the three mode of addition tartaric, tannic, citric, and malonic acid were the most effective, while benzoic, ferulic, lactic and malonic were the least effective in maintaining P in solution.

Keywords: concentration, mode of addition, phosphate-sorption, isotherms, Equilibrium solution
Modelling boron adsorption kinetics in benchmark soils of Punjab, India

ARORA Sanjay and CHAHAL D.S.
Department of Soils, Punjab Agricultural University, Ludhiana 141 004, India

As plants respond primarily to the boron (B) activity in soil solution, understanding the mechanism of B adsorption on soil materials is vital. Batch studies were conducted to investigate the adsorption behaviour of B in twenty-one surface soils representing major soil series of Punjab. Six mathematical models viz. zero order, first order, second order, Elovich, Power function and Parabolic diffusion were used to describe B adsorption. Boron adsorption pattern was characterized by an initial fast reaction followed by a slow process and it was complete in 24 hours of equilibrium. The Elovich equation was best to describe the rate of B adsorption followed by Power function. Adsorption of B on soils conformed to the Freundlich isotherm and adsorption capacity constant (K) ranged between 1.086 and 5.445 µg g⁻¹ which correlated significantly with clay content (r= 0.569**) and CEC (r= 0.639**) of the soils.

Keywords: boron, adsorption, kinetics, modelling, elovichian kinetics
Organic carbon quasi-equilibrium as influenced by nature of clay minerals in Indian soils

BHATTACHARYYA Tapas, PAL Dilipkumar, VELAYUTHAM Mariappan, CHANDRAN P., RAY Sanjaykumar and MANDAL Champa

Division of Soil Resource Studies, National Bureau of Soil Survey and Land Use Planning, Nagpur 440 010, India

Rainfall and temperature regimes are the most important factors influencing soil organic carbon (SOC) build-up. The SOC content can also be influenced by the quality and quality of organic inputs and clay. However, the influence of the nature of clay minerals in enhancing the SOC has not yet been highlighted. Therefore, the present study was carried out to examine the role of the nature of clay minerals in SOC build-up in associated Mollisols-Alfisols-Vertisols sequence of the central and western India. Associated Mollisols, Alfisols and Vertisols are formed in the Satpura ranges in central India (humid subtropical climate) and the western Ghats of western India (humid tropical climate). Vertisols have been under cultivation for the last 30-40 years whereas Mollisols are mostly under forests. The Alfisols are partly under forest and cultivation.

The clay fractions are dominated by smectite-kaolinite interstratified minerals (Sm/K) with minor amounts of smectite in the soils of the western Ghats whereas the soils of the Satpura range are predominantly smectitic with a subordinate amount of Sm/K. The total smectite content of the soils of Satpura is greater than those of the western Ghats. The SOC content has reached a quasi-equilibrium stage of 2.63%, 1.83% and 0.80% for Mollisols, Alfisols and Vertisols, respectively in the first 30 cm depth of soils on Satpura. Values for the similar soil sequence in the western Ghats are 1.50%, 1.25% and 0.80%, respectively. This clearly indicates that the smectites have a considerable influence in organic carbon sequestration to reach a quasi-equilibrium value under the present set of climates. The study also shows that the SOC quasi-equilibrium value of Mollisols and Alfisols formed in a humid tropical climate is lesser than those formed in a humid subtropical climate. However, irrespective of climatic variations SOC quasi-equilibrium value for Vertisols remain almost the same because of comparable smectite content.

Keywords: soil carbon equilibrium, clay minerals, carbon sequestration, smectites
Impact of soil minerals - organic component - microorganisms interactions on restoration of terrestrial ecosystems

BOLLAG Jean-Marc (1), BERTHELIN Jacques (2), ADRIANO Domy (3) and HUANG P.M. (4)

(1) Laboratory of Soil Biochemistry, The Pennsylvania State University, University Park, PA 16802, USA
(2) Centre de Pédologie Biologique, CNRS, Nancy, France
(3) University of Georgia, Aiken, SC 29802, USA
(4) University of Saskatchewan, Saskatoon, Saskatchewan, Canada

Soil is a dynamic system in which continuous interaction takes place between soil minerals, organic matter and organisms. Each of these three major soil components influences the physicochemical and biological properties of terrestrial systems. Interactions between the mineral, organic and biological factors have enormous impact on terrestrial processes critical to environmental quality and ecosystem health; they control the cycling and bioavailability of nutrients and xenobiotic substances in the environment through physical, chemical, biochemical and biological processes.

Human activities and industrialization development generate by-products and waste that must be disposed of in a way that should not affect the environment. Even when such by-products are used on agricultural lands as a resource, e.g. organic waste that may contribute to maintain or increase the organic matter and nutrient content in the soil, there are growing concerns about the fate of undesirable constituents they may contain. A wide variety of naturally occurring toxic and recalcitrant organic compounds exist on earth; however, nature has evolved ways of mineralizing many of them without human intervention. Microorganisms are ultimately responsible for mineralizing most organic matter to carbon dioxide, water and inorganic components. However, soil mineral colloids also play a role in abiotic transformation of organic compounds through catalysis.

Over a very long period of time, natural degradation might remove many of the organic contaminants, but may possibly result in an accumulation of heavy metals. Affordable novel technologies are needed to enhance natural remediation processes (natural attenuation) and reduce health risks by restoring natural balances. Therefore, ecosystem restoration can best be achieved through the development of innovative management strategies involving interactive processes.

Keywords: mineral-organic-microorganisms interactions, terrestrial ecosystems, soil remediation, contaminant elimination
Characterization of soil organic matter in different particle size fractions in humid subalpine soils by CP/MAS $^{13}$C NMR

CHEN Jenn-Shing and CHIU Chih-Yu

Institute of Botany, Academia Sinica, Nankang, Taipei 11529, Taiwan

The particle size separation of subalpine soils was used for delineating the different functional C pools of soil organic matter (SOM) by solid-state CP/MAS $^{13}$C NMR spectroscopy. The soils collected from hemlock forest and dwarfed bamboo grassland along the slope positions at elevations from 2500 to 3200 m in central Taiwan, received high precipitation (>3000 mm). The obtained data show that organic matter fractions differ according to particle size distribution and vegetations. Being more aliphatic, clay-size fractions were significantly different from whole soils. Sand-size fractions generally gave very similar results to whole soils. Alkyl C (mainly polymethylene) increased from coarse (50-2000 μm) to clay (< 2 μm) particles size in all sites, suggesting an accumulation of recalcitrant material in fine particle size fraction. O-alkyl C (mainly carbohydrate) content decreased from coarse to fine particle size under the hemlock forest, whereas no consistent trend was found in dwarfed bamboo grassland soils. Aromatic C decreased, whereas the carboxyl C increased from coarse to fine particle size fraction but not with big difference. High amount (>35%) of O-alkyl C in all particle size fractions in dwarfed bamboo grassland soils were attributed to that the linkage of phenolic acids to cell-wall polysaccharides in bamboo litter. Based on a humification index of alkyl/O-alkyl C, the humification degree in particle size fractions are in the order: clay > fine silt > coarse silt > fine sand > coarse sand in both the vegetations of hemlock forest and dwarfed bamboo grassland. The alkyl/O-alkyl C ratios in hemlock forest soil were consistently higher than those in dwarfed bamboo grassland soils, suggesting that humification of SOM is higher in the former than in the latter. The $^{13}$C NMR analysis of the particle size fractions indicates that the accumulation of recalcitrant material in fine particle size favors alkyl C rather than aromatic C in these subalpine soils.

Keywords: CP/MAS $^{13}$C NMR, forest, particle size, subalpine
Relationships between clay minerals and microorganism population of soil

CRACIUN Constantin and DUMITRU Sorina

Research Institute of Soil Science and Agrochemistry, Bucharest, 61 Marasti Bldv., Romania

This paper is an attempt at the quantification of clay minerals influence on the population of certain groups of microorganisms in six Mollisols (Chernozems and Cambic Chernozems) from the Romanian Plain, by the correlation of some biological indicators (bacterial number, fungi number) with some mineralogical (smectite and illite content of clay fraction), physical (clay content, air porosity) and chemical (exchangeable potassium) parameters. For the statistical relationships a number of 36 soil samples were used.

The established relationships between microbiological indicators and mineralogical parameters indicate that the bacterial and fungi numbers are closely related to the clay quality than to the clay quantity. The same relationships show that between the same biological parameters and the illite clay content there is a linear direct correlation, while between the same biological indicators and smectite clay content this linear relation is an inverse one. These types of relationships are similar with those established between the same mineralogical characteristics and physical (air porosity) and chemical (exchangeable potassium) indexes.

The obtained results show that the clay minerals can affect an entire array of factors, while in turn, will influence the succession and proliferation of specific microbiota groups in a heterogeneous soil population.

Keywords: soil clay minerals, clay minerals, microorganism relationships
Relationships between abiotic soil factors and epidemiology of *Pasteuria penetrans* parasite of *Meloidogyne javanica*

**DABIRE Kounbobr Roch (1), NDIAYE Saliou (2), FOULD Sabine (3), DIOP Mamadou Thiam (1), MOUNPORT Danamou (1) and MATEILLE Thierry (1)**

(1) Laboratoire de Nématologie, BP 1386, IRD Bel-Air, Dakar, Sénégal  
(2) Ecole Nationale Supérieure d’Agriculture ENSA, B.P A 26, Thiès, Sénégal  
(3) Laboratoire d’Ecologie Microbienne UCB, Lyon, 43 Boulevard du 11 Novembre 1918, 69622 Villeurbanne Cedex, France

*Pasteuria penetrans* a bacterial parasite of nematodes is used to control populations of *Meloidogyne javanica* in vegetable crops. But the predicted results are variable due mainly to the heterogenous distribution of the spores in the cultivable areas.

Relationships between abiotic characteristics such as aggregate size fractions, water holding capacity, irrigation and biotic factors namely nematode population, density of free spores in the soil and the infection of the nematodes by *P. penetrans* were investigated in the same vegetable area. One hundred rhizospheric soil samples were taken from an egg-plant (*Solanum aethiopicum*) and abiotic and biotic analysis were realized.

Soil physical characteristics were studied with principal component analysis (PCA) and showed an opposition between clays and sands. Similarity between the parameters according to bioctic and abiotic variables was established by hierarchical classification which distinguished specific groups. Discrimin analysis performed on these groups permitted us to extract the relationships between the parameters.

The results revealed that the coarser particles (sands and fraction size >200 μm) were positively correlated to intensive irrigation whereas the finest fractions (<20 μm) and free spore of *P. penetrans* were abundant in the areas moderately irrigated. Futhermore the greatest proportion of juveniles of *M. javanica* infected by *P. penetrans* was positively correlated to the presence of clay particles, water content (water holding capacity and pF4). The abundance of *M. javanica* was correlated with coarser sand and potassium (K).

These results suggest that the control of the *Meloidogyne* population in the vegetable crops by *P. penetrans* exerted the management of soil abiotic factors such as homogenous land tillage and irrigation system during vegetable growth.

**Keywords:** *Meloidogyne javanica, Pasteuria penetrans, soil abiotic factors, relationships*
Olive oil mills waste waters and clay minerals interactions: organics transformation and clay particles aggregation

D'ACQUI Luigi P. (1), SPARVOLI Enzo (1), AGNELLI Alberto (2) and SANTI Carolina A. (1)

(1) Istituto per la Genesi e l'Ecologia del Suolo, CNR, Piazzale delle Cascine 28, 50144 Firenze, Italia
(2) Dipartimento di Scienza del Suolo e Nutrizione della Pianta, Università degli Studi di Firenze, Piazzale delle Cascine 15, 50144 Firenze, Italia

Agro-industry produces an increasing amount of organic wastes. Olive mills waste waters (OMWW) in the Mediterranean area can constitute a serious organic pollution risk for superficial and underground waters. OMWW have been spread on cultivated soils to reduce the environmental impact, and for exploiting their amendment properties. Positive effects on chemical fertility have been generally reported, but less attention has been paid to the effect of OMWW on soil physical properties. The aim of this study is to investigate the organic transformations, the particles aggregation and their water stability in two different clays incubated with fresh OMWW. Studies of interactions between clay particles (considered the more active soil mineral fraction) and these organic substances can provide an assessment of the physical fertility improvement when OMWW are used as soil amendment. Therefore, OMWW have been added to a standard kaolinite and montmorillonite, incubated for 90 days and subjected to wetting and drying cycles. The organic matter transformation was characterized by CP/MAS $^{13}$C NMR spectroscopy. Aggregation was assessed by water-aggregate stability measurements on size-selected clay aggregates obtained after incubation. Organic matter from incubated OMWW-clay samples has shown an enrichment of alkyl groups and a decrease of O-alkyl in both clays. Incubation of OMWW with kaolinite promoted a sensible increase of aggregation and water stability. These findings revealed that the mineralogy of clays can substantially influence both the transformation of OM and the aggregation processes that, in turns, could affect the amendment properties of OMWW applied to the soil.

Keywords: clays, soil structure, organic matter, olive mills waste waters
Interactions between microbial anaerobic activities and geochemistry: model and batch experiments

DASSONVILLE Fabrice (1), RENAUT Pierre (1) and VALLES Vincent (2)

(1) INRA, Unité « Climat, Sol et Environnement », Domaine Saint-Paul, Site Agroparc, 84914 Avignon Cedex 9, France
(2) Laboratoire de Chimie et Environnement, Case 29, Université de Provence, 3 place Victor Hugo, 13331 Marseille Cedex 3, France

Anaerobiosis can impact on soil functions as well as on the deep vadose zone, the underlying aquifer, and the atmosphere. In anaerobic conditions, microbial activities are closely linked to geochemical reactions in the solution and at the solid-solution interfaces. The aim of this work was to (i) propose a model that combines anaerobic microbial activities to soil geochemical transformations, and (ii) assess this model on batch experiments. The model account for several functional microbial communities, describes their dead biomass decomposition and the catabolism of carbohydrates – including denitrification and dissimilatory NH₄⁺ production, FeIII reduction, fermentation, acetogenesis, SO₄²⁻ reduction and their dynamics that depends on anabolic and maintenance requirements. It has been combined to a geochemical model that describes acid/base, reduction/oxidation and complexation reactions in solution according to thermodynamic equilibrium, and kinetic precipitation, dissolution, adsorption, and desorption at the solid/solution interfaces. Batch anaerobic incubations were performed for a calcareous soil, which previously experimented in situ well-aerated conditions. It was either incubated without amendments (reference), or supplemented with an electron donor (glucose or cellulose) and for half of these samples an electron acceptor (NO₃⁻). Gases, mineral cations and anions, glucose, volatile fatty acids and alcohols were measured at several times during 2 months. The net production of CO₂, which was similar for the two glucose treatments, was approximately 40 times this production for the reference and the soil amended with cellulose. The negligible hydrolysis of cellulose and the absence of CH₄ production probably resulted from the lack of methanogens and anaerobic bacteria hydrolyzing cellulose. For the glucose treatments, main microbial activities deal with fermentations, acetogenic transformation of ethanol, and the oxidation of H₂; when the soil was simultaneously added with NO₃⁻, microbial activities were inhibited by NO₂⁻ accumulation and there was no transient H₂ production. The model reflect all these trends, as well as other geochemical characteristics, including pH and reduction/oxidation potential Eₐ. Nevertheless, it is necessary to confirm the actual microbial dynamics, acetogenic transformation of butyrate and the actual mechanism of H₂ oxidation that we assume to be linked to the microbial reduction of FeIII.

Keywords: soil geochemistry, anaerobic microbiology, models, coupled transformations, batch experiments
Lead adsorption characteristics of selected calcareous soils of Iran and their relationship with soil properties

GHARAIE H.A. (1) and N. KARIMIAN M. Maftoun (2)

(1) IROST, P.O. Box 114-71555, Shiraz, Iran
(2) Soil Science Department College of Agriculture, Shiraz University Shiraz, Iran

Most soils in Iran are calcareous in nature. High pH and carbonate levels are common characteristics of these soils. In these conditions the heavy metals tend to occur in insoluble forms, mainly precipitates as carbonates or oxides. The heavy metal Pb contaminates soils, plants, water, the atmosphere, animals and humans, especially in areas of heavy traffic. This experiment was conducted to find the relationship between Pb adsorption and selected properties of calcareous soils.

Twenty surface (0-20 cm) soil samples with pH ranging from 7.6 to 8.2 and calcium carbonate equivalent (CCE) ranging from 27 to 64% were used in the Pb adsorption study. Two-gram subsamples of each soil were equilibrated with 50 ml of 0.01 M KNO₃ solution initially containing 30,000 to 300,000 mg Pb L⁻¹.

The Pb disappeared from the solution (after 2 h shaking at 25 °C) and was considered as adsorbed Pb. The adsorption data showed a highly significant fit to the Freundlich and Langmuir adsorption isotherm. The coefficients of both isotherms showed significant positive correlations with CCE, OM and clay, except for a Freundlich and OM to which the correlation is negative. Distribution coefficient (also called maximum buffering capacity) calculated as the product of Langmuir K and b, was also found to be significantly related to CCE and OM.

Keywords: calcareous soils, lead adsorption, contamination, heavy metals, pollution, lead, soils of Iran
Kinetics of soil organic matter particle size and consequences for the cation exchange capacity of Alfisols

GUIBERT Herv

CIRAD, Annual Crops Department, 34398 Montpellier Cedex 5, France

The kinetics of soil organic matter (SOM) in cultivated tropical soils are characterized by rapid mineralization. The SOM level achieved in traditional cropping systems without long fallow periods is below the threshold generally agreed to be compatible with maintaining at acceptable level the soil productive functions. However, the SOM is made up of heterogeneous elements in terms of size, origin and chemical composition, and those different constituents can make very varying contributions to the properties of a given soil. So, knowing the kinetics of the SOM taken as a single unit is not enough to predict changes in soil properties linked to the SOM. Fractionating the soil according to particle size without destroying the SOM is one way of identifying the specific contribution of the SOM fractions to soil properties. This technique was applied to soils with and without manure or compost applications, from trials in Chad and the Ivory Coast. Five organo-mineral fractions were isolated: coarse sand, fine sand, coarse silt, fine silt and clay, comprising elements measuring between 2000 and 200, 200 and 50, 50 and 20, 20 and 2, and 2 and 0 μm respectively. Fractionation was carried out by mechanical and chemical dispersion of the soil, wet sieving of the fractions larger than 20 μm and sedimentation of the clay and fine silt fractions. Half the SOM in these tropical soils was of clay size. Compared to soils without organic applications, amendments proved to increase all the SOM fractions, although the coarse fractions were the most affected. When applied to the different soil size fractions from the Ivorian trial, the HHnin-Dupuis model revealed different kinetics for the SOM granulometric fractions, e.g. a half-life of two, eight and nineteen years for the SOM fractions of the size of sand, silt and clay respectively. Although its level was more stable, the clay-sized SOM fraction decreased also substantially in time without organic amendments. The CEC of the fractions was inversely proportional to their size. The clay-sized organo-mineral fraction accounted for around 80% of the CEC of the top-soils studied. The CEC of the fractions was primarily a function of their C content, but the organic CEC of the clay fraction per unit of C proved to be four times greater than that of the other size fractions (1000 vs. 270 cmol, kg⁻¹ C). Although manure or compost applications do not significantly increase the global SOM level of tropical soils, they help to maintain at a higher level the fine SOM fraction and thus ensure a greater soil CEC.

Keywords: particle size fractions, carbon, mineralization, dynamics, turnover
Soil minerals and organic components: impact on biological processes, human welfare and nutrition

HAIDER K. (1) and GUGGENBERGER G. (2)

(1) Kastanienallee 4, D-82041 Deisenhofen; formerly: BFA-Landwirtschaft (FAL), Braunschweig, Germany
(2) Institute of Soil Science and Soil Geography, University of Bayreuth, D-95440 Bayreuth, Germany

The mineralogical characteristics of a soil can influence soil stability and the relationship between organic matter contents and soil fertility. Separation of soil into primary organomineral complexes shows that soil organic matter is associated with mineral particles which differ in sizes, structures and functions. A trend towards lower C/N, C/OP and C/S ratios in finer sized particles has been observed. Soil structure is an important soil property and mediates many biological and physical processes. The spatial arrangement of the solid particles in the soil ecosystem results in a complex and discontinuous pattern of various sizes and shapes of pore space that are more or less filled with water or air. They form the habitat of microorganisms in a microenvironments characterized by a variety of physical and chemical conditions and involve simultaneous biological, chemical and physical processes. The spatial complexity and heterogeneity of micro-environments within soil aggregates form sites of accumulation of organic residues through physical protection mechanisms by spatial isolation of substrates from decomposer cells and enzymes resulting from their interaction with soil inorganic materials and from their association with biologically resistant humic substances. Microporous properties of soil materials are also considered to be important for the physical sequestration of organic or inorganic contaminants and influence the risk assessment of chemicals in the environment.

Bacteria and fungi synthesize extracellular polymers, such as polysaccharides or proteins. These polymers adhere microorganisms to organic and inorganic particles and thereby prevent their leaching from soil and inhibit the spreading of contagious organisms into the environment. Water quality is controlled by the ability of soils to retain organic matter and to prevent it from entering the aqueous phase.

Roots growing through soil are exposed to infections by pathogens, especially of fungal origin. The specialized vascular wilt fungi such as Fusarium sp and Verticillium sp attack juvenile roots. Once inside the roots they cause great damage to the plants. Clay contents of soils can be suppressive to these diseases, but our understanding of suppressiveness is not yet complete.

Keywords: microorganisms, soil contaminants, soil minerals, soil organic matter, soil pathogens, soil structure
Effects of organic acids on desorption of phosphate from the surfaces of aluminum hydroxide and complexes

HU Hongqing, LI Xueyuan and HE Jizheng

Department of Resource, Environment and Agrochemistry, Huazhong Agricultural University, Wuhan 430070, P.R. China

The desorption of phosphate from aluminum (Al) hydroxides by 0.01 mol L\(^{-1}\) KCl in the presence of different organic acids and from Al-OH, Al-P and Al-Oxalate, Al-Citrate complexes by organic acids was studied. When phosphate adsorbed on Al(OH)\(_x\) in the presence and absence of oxalate was desorbed sequentially twice using 0.01 mol L\(^{-1}\) KCl, total desorption rates of phosphate adsorbed in the presence of 0.5 - 2.0 mmol L\(^{-1}\) oxalate were 4.10% - 4.75%. However, in the absence of organic acid, the desorption rate was only 2.05%. The amount of P desorbed by 0.01 mol L\(^{-1}\) KCl increased with increasing concentration of organic acids in adsorption solution. Some phosphate, which could not be desorbed by oxalate, would be desorbed by citrate at the same concentration. When phosphate was desorbed using a series of oxalate and citrate, the total desorption rate of phosphate from Al-oxalate complex was less than that from Al hydroxide, while the rate from Al-citrate complex was the highest. Citrate released the phosphate from Al-P complex, and the amount of phosphate desorption increased with the increment of citrate concentration used. All these indicated that the mechanism of phosphate desorption involved ligand exchange and dissolution by organic acid. Organic acids increase the desorption of phosphate and improve the efficiency of phosphate in acid soil.

Keywords: Al oxide surface, organic acid, phosphate desorption
Maillard reaction catalyzed by \( \delta\text{-MnO}_2 \): a significant mechanism in formation of “unknown nitrogen” in soils

JOKIC A. (1), SCHULTEN H.R. (2), SCHNITZER M. (3) and HUANG P.M. (1)

(1) Department of Soil Science, University of Saskatchewan, Saskatoon, SK, Canada S7N 5A8
(2) Institute of Soil Science, University of Rostock, Justus-von-Liebig-Weg 6, D-18051 Rostock, Germany
(3) Eastern Cereal and Oilseed Research Centre (ECORC), Central Experimental Farm, Agriculture and Agri-Food Canada, Ottawa, ON, Canada K1A 0C6

Approximately 34-45% of total soil N remains either unknown or poorly understood. Recently, it has been demonstrated that heterocyclic N compounds bound to pedogenic metal oxides constitute a significant portion of “unknown” nitrogen. However, their mechanisms of formation in natural environments remain poorly understood. The catalytic role of birnessite, a Mn (IV) oxide common in soils and sediments, in the Maillard (browning) reaction (involving the polycondensation of sugars and amino acids) and the resultant formation of humic substances was recently reported (Jokic et al., 2001). The great appeal of the Maillard reaction in forming such compounds lies in the two proposed precursors (sugars and amino acids) being among the most abundant constituents of all living organisms. Therefore, the present study was initiated to examine the unknown role of heterogeneous catalysis of birnessite in the Maillard reaction as a pathway for the formation of heterocyclic N compounds in natural environments.

Experiments were performed at 45°C, which is the approximate temperature of the soil surface on a day when the air temperature is 25°C, and thus is frequently encountered in tropical and subtropical regions, and even in temperate regions during the summer. Fulvic acid isolated from the supernatant of the glucose-glycine-birnessite system (following reaction at 45°C for 15 d at an initial pH of 7.00 and ambient light intensity of 0 to 3.1 ± 0.9 μE s\(^{-1}\) m\(^{-2}\)) was analyzed by \(^1\)H solution Nuclear Magnetic resonance (NMR) spectroscopy, \(^{15}\)N cross polarization magic angle spinning (CPMAS) NMR spectroscopy. Both the fulvic acid and lyophilized solid phase of the glucose-glycine-birnessite system were also analyzed by pyrolysis-field ionization mass spectrometry (Py-FIMS).

In the present study we can report that the action of Mn (IV) oxide on the polycondensation reaction between glucose and glycine at a temperature and pH typical of natural environments leads to the abiotic formation of heterocyclic and amino nitrogen compounds. Various imidazoles, pyrazoles, pyroles, and pyrazines were identified, all of which are heterocyclic N compounds reported to be present in soils and are known to be characteristic Maillard reaction products. These results shed new light on the formation of such compounds in nature and demonstrate the potential significance of manganese oxide catalysis in the Maillard reaction as a pathway in the formation of “unknown nitrogen” in soils.

Keywords: maillard reaction, unknown nitrogen, heterocyclic nitrogen compounds, \(^1\)H NMR, \(^{15}\)N CPMAS NMR, pyrolysis-field ionization mass spectrometry
Sequential fractionation of Cu, Zn and Cd in soils in the absence and presence of rhizobia

HUANG Qiaoyun, CHEN Wenli and GUO Xuejun

Key Laboratory of Agricultural Microbiology, Ministry of Agriculture, Department of Resources and Environment, Huazhong Agricultural University, Wuhan, 430070, China

Red soil and cinnamon soil were collected from Chenzhou of Hunan and Gongyi of Henan, respectively. Soils were treated with Cu(NO$_3$)$_2$, Zn(NO$_3$)$_2$ or Cd(NO$_3$)$_2$ respectively for 2 weeks. *Rhizobium fredii* strain HN01 was inoculated into the two soils polluted with three heavy metals. Sequential extraction method was employed to investigate the forms of Cu, Zn and Cd in the examined soils with the absence and presence of rhizobia. Results showed that the total amount of solid-bound Zn decreased 10% after the inoculation. The decrease for the amount of Zn associated with carbonate, Mn oxides and organic matter fraction was from 9% to 26%. No significant change was observed for the total amount of Zn combined with solid phase of red soil in the presence of rhizobia. However, the amount of specifically adsorbed and Mn oxides bound Zn decreased, while the amount of exchangeable Zn increased. Inoculation of rhizobia depressed the release of Cu to the soil solution and increased the total amount of Cu associated with solid phase in cinnamon soil. The increase for the amount of exchangeable Cu and the Cu in fractions of carbonate, Mn oxides and organic matter ranged from 20% to 54%. There was no significant change for the level of Cd in the solution in both soils after rhizobia inoculation. The amount of Cd in the fractions of exchangeable and organic increased 22% and 11%, while that in the fractions of specific and Mn oxides decreased 14% and 29%, respectively. The different influence of rhizobia on the distribution of three heavy metals in two soils was mainly ascribed to the growth status and pH changes exerted by the metabolites of rhizobia. These data are fundamental for further researches on the chemical behavior and biogeochemical cycle of heavy metals in environment. The studies are also important with respect to the utilization of microorganisms in the bioremediation of heavy metal contaminated soils. In soil bioremediation practices, it is possible to adjust the quantity and metabolic activity of microorganisms to lower or raise the mobility of heavy metals. Measures and approaches for the microbial remediation vary with the type of metal and soil.

Keywords: soil, heavy metal fractionation, rhizobia, copper, zinc, cadmium
Competitive adsorption of sulfate and organic anions on allophanic synthetic compounds

JARA A. (1), VIOLANTE A. (2) and MORA M.L. (1)

(1) Departamento de Ciencias Químicas, Universidad de la Frontera, Casilla 54-D, Temuco, Chile
(2) Dipartimento di Scienze Chimico-Agrarie, Università di Napoli “Federico II”, Portici (Napoli), Italia

Anion adsorption on variable charge clay minerals and soils is often affected by the interactive adsorption of different ligands. In general, interaction effects between ions for adsorption on soil clays can be either indifferent, competitive, or promotive and can influence the bioavailability and mobility of nutrients in soils.

This work studies the competitive adsorption of sulfate ($SO_4^{2-}$) and multicarboxylic ligands such as oxalate (OX) and citrate (CIT) on allophanic synthetic compounds as affected by pH (3.0-8.0), in order to simulate the chemistry interaction on interface soil-plant behaviour. When sulfate was added alone its adsorption decreased of 40 percent by increasing pH from pH 4.0 to pH 6.5; negligible amounts of sulfate were adsorbed at pH > 7.0. When equimolar quantities of $SO_4^{2-}$ and OX (or CIT) were added at pH 6.5, $SO_4^{2-}$ adsorption was reduced of 21 and 37 percent in the presence of OX and CIT, respectively.

Being phosphate more strongly bound on allophanic clays than sulfate, experiments were carried out on the desorption of sulfate by phosphate. The results indicated that phosphate easily replaced sulfate and organic ligands, previously adsorbed on the surfaces of the synthetic allophanes. At an initial $HPO_4^{2-}/SO_4^{2-}$ (Rp) molar ratio of 1.0 the adsorption of $SO_4^{2-}$ decreased of about 90 percent, but a Rp > 1, negligible amounts of $SO_4^{2-}$ were adsorbed on the variable charge minerals. Furthermore, the concomitant presence of phosphate and organic ligands (OX or CIT) tremendously reduced $SO_4^{2-}$ adsorption. The amounts of sulfate adsorbed were reduced six times in the presence of citrate and twenty times in the presence of oxalate.

These results present useful information on the influence of organic and inorganic ligands and pH on sulfate adsorption on a variable charge minerals and are important for understanding the possible role of biomolecules present in the rhizosphere on the availability of nutrients by plants.

Keywords: allophane, adsorption, sulfate, organic ligands, phosphate
Copper and zinc desorption kinetics from soil: effects of pH

KHATER A.H. and ZAGHLOUL A.M.
Soil and Water Use Department, National Research Center, Dokki, Cairo, Egypt

Metal concentrations in soil solutions and hence bioavailability is controlled by sorption-desorption reactions at the surfaces of soil fractions. Compared with the numerous studies on the desorption of metals by soils, there are relatively few that examine desorption kinetics. The objectives of this study are to examine different models developed previously to evaluate the effect of changing pH according to acidification with nitric or phosphoric acid on the subsequent desorption kinetics of copper (Cu) and zinc (Zn) from natural sandy loam Egyptian soil.

The obtained results revealed that, according to the kinetic parameters of used models, copper was less readily desorbed from the sandy loam soil than zinc (Zn) when nitric acid (NA) was the source of acidification of the irrigation water. However, a reversible result was obtained when phosphoric acid (PA) was applied in irrigation water. The kinetic of Cu and Zn release were found to be described well by both modified Exponential and Freundlich equations but less by the first-order equation. Reaction half lives derived from the applied models suggested the movement of Cu and Zn to slower desorption reactions on the source of pH controlled acidification of irrigation water.

Keywords: kinetics, desorption, sandy loam soil, copper, zinc, pH
Effect of carrier, incubation period and method of sterilization on survival of *Bradyrhizobium japonicum* in soybean inoculant

KHAVAZI K. and REJALI F.

Soil and Water Research Institute, Ministry of Jihad-e-Agriculture, North Kargar Ave., Tehran, P.O. BOX 14155-6185, Iran

Commercial production of any inoculant is decided by two factors namely 1) quality factor resulting in acceptable bacterial population surviving for a given time (normally 6 months). Cost of production, both of which depend on the characteristics of the selected carrier, as well as on the incubation period and the sterilization procedures. This experiment was designed to evaluate the least expensive carrier, the possibility of eliminating incubation after injection and the sterilization process. A completely randomized factorial experiment was designed with six carriers, nine periods of bacterial count (0, 7, 14, 30, 60, 90, 120, 150, 180 days) and three reps. Survival of *Bradyrhizobium japonicum* which was effective and compatible with Iranian conditions were also evaluated. Experimental results showed that perlite by itself or combined with bagasse, coal, Malt residue, rice husk, charcoal and calcium carbonate is able to maintain a bacterial population of more than $10^9$ per gram for six months or more. A second experiment with variables of the first experiment plus two sterilization procedures were tested with three reps. The results showed that in the absence of gamma rays for sterilization one can use steam. Even though a significant differences between bacterial counts was found in response to gamma rays and steam for up to six months, if survival at six months was to be used as a criterion, no significant differences were observed. In the third experiment the same variables as in experiment one plus incubation at 28 °C for two weeks or no incubation as a variable were considered. The results showed no significant differences in bacterial count after 2 weeks of incubation or after two weeks, without incubation. In conclusion we observed that a perlite based carrier, without incubation after injection can be combined with a simple sterilization procedure to produce a high quality inexpensive inoculant, maintaining bacterial counts of more than $1x10^9$ per gram for at least six months.

**Keywords:** carrier, *Bradyrhizobium japonicum*, soybean inoculant
Physico-chemical characterization of organic-mineral complexes

KSIEZOPOLSKA Alicia

Institute of Agrophysics, Polish Academy of Sciences, ul. Doswiadczalna 4, 20-290 Lublin, Poland

As a result of reaction of the surfaces of soil clay minerals with humus compounds by way of their exposed functional groups, such as carboxyl, phenol and others, a variety of complex clay-humus compounds are formed (Greenland, 1971), (Greene-Kelly, 1955). The study of the character of mineral and organic substance combinations is very difficult. This results from technical problems related to the identification of such compounds in situ, as well as to the extraction of such compounds from the soil. It is much easier to conduct experiments on preparations of organic-mineral complexes obtained artificially in the laboratory. This study presents model studies which took into consideration the type and varied structure of clay minerals used in the experiments, as well as the rather complex structure of humus substances. For the purposes of the study, preparations of humus acid complexes (humic acids and β-humus fulvic acid fractions) were made, at 10, 5, 2.5%, with clay minerals (Na-montmorillonite, mica-montmorillonite, and kaolinite), in the presence of Fe and Ca salts as binding agents, and at pH 4 and 2.5.

In the study the author characterizes the above preparations on the basis of thermal analyses, surface properties, and electrolytic conductivity measurements, which permitted the determination of the structure of the complexes, as well as of the degree of complex-formation.

Keywords: organic-mineral complexes, specific surface area, electrolytic conductivity, thermal analyses, water vapour adsorption isotherms
Nature and properties of natural organo-mineral complexes in some Inceptisols of India

KUMAR Manoj and KANCHIKERIMATH Manjaiah

Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi-110012, India

Clay and organic matter both being the most reactive parts of soil, their interaction among themselves and with other soil constituents have an important bearing on soil health and productivity which needs thorough characterization. Organo-mineral complexes (<2 μm, 2-5 μm and 5-20 μm) from some inceptisols of Himachal Pradesh, India were separated ultrasonically, analyzed for organic carbon and nitrogen and thereafter treated sequentially to remove complex forming components viz., organic matter, sesquioxides and allophanes by H2O2, citrate-bicarbonate-dithionite (CBD) and acidic oxalate treatment. At every stage of the above treatment, release of elements/cations, cation exchange capacity (CEC), specific surface area (SSA), K-fixation capacity and thermal properties (DTA & TGA) were measured. Compared to bulk soils, the organo-mineral complexes in general were enriched with organic C the highest being in fine silt size (2-5 μm) fraction, while, the C/N ratio decreased with the decreasing size of the fractions. The sesquioxide content decreased with the increasing size of the fraction, which was contributed mainly by iron oxides besides Al2O3, Mn2O3 and Ni2O3. Allophanes also decreased and tended to become more siliceous with the increasing size of the fractions. The cations and polyvalent elements seemed to play a vital role in the formation of complexes, as there was a release of large amounts of these with each of the treatments. Fe, Al, Ca, Zn and Mn were the dominant cations in peroxide extract; Ca, Mg, Si, Zn and Cu besides sesquioxides in CBD extract and K, Ca, Zn, Cu plus allophane in ammonium oxalate extract. The CEC, SSA, K-fixation capacity and thermo gravimetric weight loss decreased with the increasing size of the fraction. Peroxidation and CBD treatment in general decreased CEC, SSA, thermo gravimetric weight loss and increased K-fixation capacity. The removal of allophanes had relatively less effect on different properties, and in general led to an increase in CEC and K-fixation capacity but a decrease in SSA and thermo gravimetric weight loss. DTA curves showed three stage oxidation peaks for complexed organic matter i.e., exothermic reactions around 340, 436 and 510°C which were attributable to organic matter adsorbed on clay mineral surface, complexed with sesquioxides and with allophanes, respectively. The information obtained through these studies helps us to understand the sequestration of carbon in different sized mineral fractions thereby reducing the atmospheric CO2 concentration.

Keywords: organo-mineral complex, cation exchange capacity, specific surface area, thermal analysis, Inceptisols, K-fixation capacity
The effect of organic matter and chemical properties on sulphate adsorption in Chilean volcanic soils

MORA M.L. (1), SHENE C. (1), DEMANET R. (1) and VIOLANTE A. (2)

(1) Departamento de Ciencias Químicas, Universidad de La Frontera, Casilla 54-D, Temuco, Chile
(2) Dipartimento di Scienze Chimico Agrarie, Università Federico II, Napoli, Italia

The difference on sulphate adsorption capacity of the Chilean Ultisol and Andisol, with different organic matter content and soil acidity conditions and the effect of different cations on sulphate adsorption and surface charge were determined. Sulphate adsorption experiments were carried out in batch system to determine adsorption as function of pH solution between 3.5 and 8.0 at 25 °C in 0.1 M KCl using 0-600 mg L⁻¹ of sulphate in solution. Experimental data were fitted by Freundlich model. Humic and fulvic acids of the Metrenco and Pemehue soils were removed. The remaining fraction was treated with 30% hydrogen peroxide to remove the humin fraction. In the second experiment the soils were incubated for 48 h at 60°C with 200-600 mg kg⁻¹ of CaSO₄, MgSO₄ and K₂SO₄ and afterwards the charge was determined.

The results indicated that sulphate sorption capacity for both types of these ash derived soils studied were pH dependent, when the pH increased, sulphate sorption decreased, and the initial acidity condition influenced the adsorbed sulphate amount. The largest amount of sulphate adsorbed by these soils to pH 3.5 was markedly reduced over pH 5.5. Adsorption capacity was higher in the acidic soils than the control soils, caused by the high Al exchangeable content in the soils that increased the amount of reactive sites in both soils and the higher amount of positive charge found. The sulphate sorption amount decreased stronger in Andisols than Ultisols consequently with the mineralogical composition and the permanent charge of the Ultisols. On the other hand, sulphate adsorption capacity was concentration dependent showing a great adsorption even at pH 8.0 at high sulphate concentration in solution (600 mg L⁻¹). In summary sulphate adsorption process in Chilean Andisols and Ultisols was strongly controlled by pH, humic fraction, iron oxide and by the type of cation present in the soils.

Keywords: sulphate adsorption, Andisol, Ultisol, charge minerals
Adsorption and forms of phosphorus in Oxisols: influence of mineralogy and use

MOTTA Paulo Emilio Ferreira (1), CURI Nilton (2), SIQUEIRA José Oswaldo (2), RAIJ Bernardo van (3), FURTINI NETO Antônio Eduardo (2) and LIMA José Maria de (2)

(1) Embrapa Solos, Rua Jardim Botânico 1024, CEP 22.460-000, Rio de Janeiro (RJ) CNPq Program, Brazil
(2) Soil Science Department of UFLA, Caixa Postal 37, CEP 37.200-000, Lavras (MG), Brazil
(3) Embrapa Meio Ambiente, Rodovia SP 340 km 127.5, Caixa Postal 69, CEP 13.820-000, Jaguariúna (SP), Brazil

The aim of this study was to verify the influence of mineralogy and former soil use on adsorption and forms of P in Brazilian Latosols (Oxisols). In order to include a wide range of contents of hematite, goethite, kaolinite (Ka) and gibbsite (Gi), we used five soils (cohesive Yellow Latosol, dystrophic Yellow Latosol, acric Red Latosol, and two dystroferric Red Latosols, one developed from gabbro and one from tuffite), never cultivated and already cultivated, in adjacent areas, during long periods, receiving liming and phosphated fertilization periodically. Physical, chemical and mineralogical characterizations were performed, involving: particle-size-distribution, Fe in less crystalline forms (Fc), free oxides (Fe0) and “total” (Fs) forms, beyond P fractionation and availability. P adsorption was studied using 24 h of shaking and concentrations of 0, 5, 10, 25, 50, 75, 100 and 200 mg kg⁻¹, for obtaining the adsorption isotherm from which it was obtained the maximum capacity of P adsorption. Using x-ray diffraction analysis, mineralogical composition of Fe-free and Fe-concentrated clay fractions were obtained and, through differential thermal analysis, Ka/(Ka+Gi) ratio in the Fe-free clay fraction. As the mineralogy of the Latosols becomes more oxidic, P adsorption, total P and the forms more strongly linked to Fe and Al increase. The cultivation differentially influenced P adsorption and increased the forms of P linked to Ca in all the soils. Less labile P forms predominate in the studied Latosols, with emphasis on the organic ones associated with humic compounds in the non-cultivated soils and to the inorganic ones linked to Fe and Al in the cultivated soils.

Keywords: phosphorus sorption, phosphorus fractionation, mineralogy, Latosol (Oxisol)
Tribenuron-methyl adsorption on two Moroccan soils

MOUNTACER H. (1) and MANSOUR M. (2)

(1) Département de chimie appliquée et d'environnement, Faculté des sciences et Technique de Settat B.P 577 Settat, Marocco
(2) GSF-National Research Center for Environment and Health, Institut für Ökologische Chemie. Ingolstadter Landstrasse 1. D-85764 Neuherberg, Germany

The environmental fate of sulfonylurea herbicides in ecosystems is strongly influenced by their sorption to natural sorbents. Soil and sediment colloids are the most important contributors to fixing pesticides, and hence they are also the main carriers of bound pesticides from point sources by runoff and leaching.

The adsorption study of the sulfonylurea herbicide tribenuron-methyl (TRB) [methyl -2-[4-methoxy-6-methyl-1,3,5 triazin-2-yl (methyl) carbamoyl sulfamoyl] benzoate] in formulation (Granstar) and pure active matter has been carried on two Moroccan soils. The soils chosen for this study have the different physico-chemical characteristics. The adsorption isotherms follow the Freundlich model equation. A regression analysis has indicated that the Freundlich constants $K_f$ were better correlated than those of others models. The results have showed that the TBR herbicide adsorption is affected by the clay content.

Keywords: tribenuron-methyl, pesticide, adsorption, soil, clay
Sequestration and bio-availability of chromium in soils

NATESAN R. (1) and BOLAN N.S. (2)

(1) Department of Soil Science, Tamil Nadu Agricultural University, Coimbatore, India
(2) Institute of Natural Resources, Massey University, Palmerston North, New Zealand

Tannery and timber treatment effluents are enriched with toxic heavy metals and are considered to be the major sources of chromium (Cr) contamination in terrestrial and aquatic environments. Chromium occurs in trivalent [Cr(III)] and hexavalent [Cr(VI)] forms. Hexavalent Cr is more mobile in soils and is more toxic than trivalent Cr. Chromium toxicity can be minimised by reducing Cr(VI) to Cr(III) and by increasing the adsorption of Cr in soils. Reduction of Cr(VI) to Cr(III) is enhanced by the addition of organic matter, which serves as an electron donor. The retention of Cr in soil is important in order to reduce ground water contamination and uptake by plants. In this study the effect of bio-solid compost on the retention and bio-availability of Cr in soil and its effect on growth of mustard crop were examined.

Tokomaru silt loam was used for the plant growth experiment. The treatments include: four levels of Cr(VI) (0, 300, 600, 1200 mg kg\(^{-1}\) soil) and four levels of bio-solid compost (0, 2, 5 and 10% w/w soil) with three replications. The soil was incubated with these levels of Cr and bio-solid compost for 10 days. The incubated soil samples were extracted with 0.01 M Ca(NC\(_2\))\(_2\) and analysed for Cr(VI) in spectrophotometer using azide reagent (s-diphenyl carbazide) at 540 nm.

Mustard (Brassica juncea) was grown as a test crop. Hogland complete nutrient solution was applied twice a week. The crop was grown for a period of six weeks and the dry matter yield of shoot and root were recorded. The plant samples were digested (shoot and root) with concentrated nitric acid and the total Cr concentration was measured by atomic absorption spectrophotometry.

The results showed that the shoot and root dry matter yield decreased with increasing levels of Cr. There was no mustard growth at the highest level of Cr. The shoot and root dry matter yields of mustard increased with increasing levels of bio-solid compost. In the presence of bio-solid compost adequate plant growth was observed even at higher levels of Cr. Increasing levels of Cr increased the Cr concentration in plants (> 10 mg kg\(^{-1}\)) but the bio-solid compost showed the opposite effect.

The increasing level of bio-solid compost application decreased the hexavalent Cr in soil, indicating the reduction of Cr(VI) to Cr(III). From the study, it could be concluded that the application of bio-solid compost enhanced the reduction of Cr(VI) to Cr(III) and the subsequent retention of Cr in soil. Chromium toxicity in mustard was recorded beyond the 300 mg Cr kg\(^{-1}\) soil level. It is demonstrated that the bio-solid could safely be used to remediate the Cr toxicity in soil and plants.

Keywords: sequestration, bio-availability, chromium, bio-solid compost
Are silicate dissolving microorganisms the same as phosphate dissolving microorganisms?

NOSRATABAD R. Fallah and KHAVAZ1 K.
Soils Department, Tarbiat Modarres University, Tehran, Iran

Silicate dissolving microorganisms (SDM) refers to a heterogeneous group of organisms which convert unavailable forms of soil potassium into available forms through special mechanisms such as secreting organic acids and dissolving silicate minerals. Chinese scientists are the forerunners in this field, producing a biological potassium fertilizer by using SDM. Various investigations have shown that this kind of fertilizer can improve the yields of agronomic seed crops, industrial and vegetable crops by 10-25 and 20-30 percent respectively. Phosphate solubilizing microorganisms (PSM) likewise, refers to a heterogeneous group of microorganisms that through mechanism such as secreting organic and mineral acids, are capable of dissolving soil minerals or organic forms of phosphorus. These microorganisms producing the same yield increases as SDM are currently being produced in many countries especially India. The question is whether the two groups of microorganisms are the same, since they produce the same plant yield increases through the same modes of operation in soils. To answer this question three experiments were carried out:

First: Eight isolates from SDM and 8 from PSM were prepared and each isolate was grown on both the growth media formulated for SDM or PSM organisms. A Sperber culture medium was used for PSM, and an Aleksandrov medium for SDM organisms. Four SDM isolates produced a light zone around their colonies (a characteristic of PSM group) when grown on Sperber and four PSM isolates grown on the Aleksandrov medium produced tear drop colonies (a characteristic of SDM group).

Second: In a completely randomized design having 16 microorganism treatments (8 SDM isolates and 8 PSM isolates), one control (no inoculant), 5 incubation periods (one, six, twelve, eighteen, and twenty four days) and three replications; the microbial potential for releasing potassium from biotite was considered as an indication of being from the SDM group. The data showed the greatest rates of potassium release for all the incubation periods to belong to isolates 6-S and 7-S significantly different from the rate of other isolates and the control at 1% level; the rates from 6-S and 7-S were three times as much as that from the control. The PSM isolates while showing increases in the rates of potassium released significant at 5% level compared with the control; they did not produce increases significantly different from those of the SDM isolates.

Third: A completely randomized experiment with 16 microorganism treatments (8 SDM isolates and 8 PSM isolates), one control (no inoculant) 5 incubation periods (one, six, twelve, eighteen and twenty four days) with three replications was conducted in which the apatite-phosphorus releasing potential of the organisms was used as an indication of being from the PSM group. The data indicated that all the isolates increased the rate of phosphorus release from apatite significantly, with the greatest rate increase coming from 6-S which belongs to the SDM group.

In conclusion, the experiment showed that any organism identified as a PSM or SDM organism through the use of the above mentioned standard solid culture media, can demonstrate the potentials of those two groups of organisms in releasing potassium from biotite or phosphorus from apatite in a solid or a liquid culture medium (broth), but one can not say for sure that any silicate dissolving organism is also a phosphate dissolving organism or vice versa.

Keywords: silicate dissolving microorganisms (SDM), phosphate dissolving microorganisms (PSM), soil potassium, biological fertilizer
The phosphorus absorption by inorganic salts of soil and its distribution in water of Balkhash Lake

ROMANOVA Sofia

Al-Faraby Kazakh National University, Chemical Faculty, Karasay Batyr av., 95, Almaty, 480012, Kazakhstan

The study of biogenious elements, particularly phosphorus, is connected with the fact that biological productivity of water bodies, and the water quality depends on their concentration. The union of phosphors coming into this system “water-silt” with the help anthropologic factor can influence on the processes of soil-formation.

Phosphorus is distributed unevenly in the water area of the Balkhash Lake. Its concentrations varies within the limits of $0-0.13 \text{ mg L}^{-1}$ for western Balkhash, and $0-0.15 \text{ mg L}^{-1}$ for eastern.

The phosphorus concentration has increased nearly 5 times in the last 30 years (from 0.008 to 0.038 \text{ mg L}^{-1})

Phosphorus has been found to settle at the carbonization stage during the concentrating of Balkhash water, when calcium and magnesium carbonates are crystallized intensively. Thereby, experiments aimed at the study of phosphorus absorption by inorganic salts (carbonates of Magnesium and Calcium, Calcium sulfate) have been carried out. The experiments have shown that solid phases can be distributed according to the degree of absorption in the following order: magnesium carbonate – calcium sulfate – calcium carbonate. That order is explained by that the product of solubility coefficient of Calcium sulfate and Magnesiumcarbonate which are more the than the solubility coefficient of calcium sulfate. Therefore, the solutions of the first pair of salts contains more calcium and magnesiumions which add larger quality of phosphorus to form more stable complexes of insoluble compounds $(\text{Ca(H}_2\text{PO}_4)_2$, $\text{CaH}_2\text{PO}_4$, $\text{Ca}_3(\text{PO}_4)_2$, $\text{Mg}_3(\text{PO}_4)_2$).

Hence, the phosphorus absorption takes place due to the chemical interaction of calcium (magnesium) ions with the proper phosphate ions.

One can expect the body to be purified naturally provided that the phosphorus concentration does not exceed $0.2-0.5 \text{ mg L}^{-1}$. Otherwise phosphorus will be accumulated in the liquid phase.

Keywords: phosphorus, absorption, inorganic salts, system “water-silt"
Metal ion complexes of humic acids extracted from an Alfisol and Vertisol in relation to their plant availability

SAILAJA Gurram and RAO Palli Chandrasekhar

Department of Soil Science and Agricultural Chemistry, College of Agriculture, ANGRAU, Agricultural University, Rajendranagar, Hyderabad–500 030 (AP), India

Studies on interactions between metal ions and humic acids extracted from an Alfisol and a Vertisol of ANGRAU, Hyderabad Campus in relation to their availability to rice and corn were conducted with a view to characterising the nature of humic acids, the complexes formed by the interaction of humic acids with Cu(II), Zn(II), Fe(II) and Mn(II) and to evaluate the relative effectiveness of zinc carriers in improving the zinc nutrition of rice and corn. The humic acid fractions were extracted, purified and characterised for functional group analysis. The contents of total acidity, -COOH and phenolic-OH groups were higher in humic acid obtained from Vertisol as compared to that obtained from Alfisol. Potentiometric titration curves of humic acids were similar irrespective of the sources from which they were extracted and the curve obtained was sigmoidal in nature. The UV spectra of these fractions were featureless with a decreasing optical density with an increase in wavelength. Metal complex formation of humic acids was studied by potentiometric titrations and the curves of metal humates showed no inflection indicating that formation of metal hydroxides was suppressed when metal ions were added to form the complex. Reduction in pH on titration of humic acids in the presence of metal ions followed the order:

Cu(II) > Zn(II) > Fe(II) > Mn(II) at pH 7.5
and Zn(II) > Cu (II) at above pH 8.0

Stability constants of humic acids with these metal ions were determined at pH 7.0 and at 30°C by Schubert's ion exchange method. The stability constants (log K values) varied from 6.14 to 6.84 and humic acid extracted from Vertisol had higher log K value than Alfisol.

The stabilities of metal complexes followed the order Cu(II) > Fe(II) Zn(II) > Mn(II). The negative ΔGr°C values indicated that the reactions were spontaneous. Among these zinc carriers (zinc humate and zinc chelate) were evaluated to see the effects of their application on the zinc nutrition of rice and corn and were compared with ZnSO₄ at 2.5 and 5.0 mg kg⁻¹ levels of applied zinc. The dose of 2.5 mg kg⁻¹ zinc was found to be optimum for rice and corn grown under pot culture conditions. The effectiveness of different zinc sources followed the order ZnSO₄ > Zn humate > Zn chelate.

Keywords: stability constants, potentiometric titrations, humic acids, zinc humate, humic acid metal complexes
Adsorption-desorption of $^{14}$C-bifenox in soil

SUH Yong Tack (1) and SEO Jung Mi (2)

(1) Department of Agricultural Chemistry, Institute of Agricultural Science and Technology, Chonnam National University, Kwangju 500-757, Republic of Korea
(2) Health and Environment Institute of Kwangju, Kwangju, 502-243, Republic of Korea

In order to elucidate the behavior of $^{14}$C-bifenox, a diphenyl ether herbicide, the adsorption-desorption properties in soil were analyzed. Using $^{14}$C-bifenox in sandy loam soil (SL) containing 0.75% organic matter and silty clay loam soil (SiCL) containing 1.80% organic matter, we found that each adsorption rate was 74.8-78.0% for SL and 82.1-85.3% for SiCL depending on the initial concentrations of bifenox.

Adsorption rate and coefficient ($K_{d}^{ads}$) decreased as initial concentration increased. In the case of using organic C normalized distribution coefficient, the difference of coefficient between two soil environments was diminished. The order of adsorption rate of bifenox for each soil under different pH conditions was the pH 4.01 (SiCL) > pH 4.01 (SL) > pH 9.18 (SiCL) > pH 9.18 (SL) > pH 6.86 (SiCL) > pH 6.86 (SL). Freundlich isotherm constant ($K_{f}^{ads}$) remarkably increased as the pH decreased. Desorption rate of bifenox was about 20.3-29.9% for SL and 13.0-20.2% for SiCL. As initial concentration increased, the desorption coefficient ($K_{d}^{des}$) decreased, while desorption rate increased. The order of desorption was the highest in pH 6.86, followed by pH 4.01 (SL) > pH 9.18 (SL) > pH 4.01 (SiCL) > pH 9.18 (SiCL). The desorption rate generally was lower at basic and acidic conditions compared to neutral condition. Therefore, it was found that the desorption rate of bifenox decreased as the adsorption rate increased and vice versa. As above results, adsorption increased at acidic condition, whereas desorption decreased at basic condition, which means that bifenox is degraded rapidly in these conditions.

Using soil TLC to evaluate the correlation between mobility and adsorption of bifenox, solute center of mass ($R_{m}$) values ranged from 0.38 to 0.40 for SL and 0.27 for SiCL. Also, sorption distribution coefficient ($K_{d}$) of SiCL was relatively higher than that of SL. Therefore, it suggests that SiCL is more adsorptive and less mobile than SL.

The total amount of $^{14}$C activity leached from the soil columns with SL and SiCL for 110 days was 1.44% and 1.08% of the originally applied $^{14}$C, respectively. $^{14}$C-radioactivities in soil layers after leaching were distributed mainly in the 0-10 cm depth with low activities at 10-20 cm and 20-30 cm.

Keywords: adsorption, desorption, bifenox
Oxalic acid perturbation of imogolite formation and the impact on cadmium adsorption

TANI Masayuki (1), LIU Chen (2) and HUANG Pan Ming (2)

(1) Department of Agro-Environmental Science, Obihiro University of Agriculture and Veterinary Medicine, Inada, Obihiro, Hokkaido 080-8555, Japan
(2) Department of Soil Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8, Canada

The role of oxalic acid, which is predominant in soil solutions of Andisols and Spodosols, in affecting the formation of imogolite and noncrystalline aluminosilicates (initial Si concentration of 1.6 mmol L\(^{-1}\), Si/Al molar ratio of 0.5 and OH/Al molar ratio of 2.0) and their morphological features observed by using atomic force microscopy (AFM) was investigated. The subsequent effects of oxalate perturbation on the surface properties and Cd adsorption of these clay materials were also studied.

Oxalic acid perturbed the formation of imogolite remarkably at the higher concentrations (oxalate/Al molar ratios of 0.08 and 0.10). However, the effectiveness in impeding the interaction of hydroxy-Al ions with orthosilicic acid was four to five times lower compared with citric acid and other strong complexing organic acids, as indicated by the results of amounts of H\(^+\) released into solutions during the reaction, x-ray diffractograms and IR absorption spectra. The morphological features of synthetic imogolite and x-ray noncrystalline aluminosilicates formed as affected by oxalate were observed distinctively by using the contact-mode AFM. Optimum ultrasonification and sufficient air drying of imogolite on the sample holder at room temperature before AFM scanning are critical to avoid the breakdown of imogolite particles and the etching of a sample surface. At the oxalate/Al molar ratios of 0 and 0.02, the imogolite appeared in the AFM three-dimensional deflection images as threads and curved. With the increase in the oxalate/Al molar ratio, the threads-like structures, which are characteristic of imogolite, decreased and the spheroidal and ill-defined amorphous particles increased in the AFM images. At the oxalate/Al molar ratio of 0.10, any threads-like structure was not observed. The present AFM study also shows that oxalic acid induced the change in the size of threads-like structures of imogolite and spheroidal particles of noncrystalline aluminosilicates. The length and width of threads-like structures decreased and the diameter of spheroidal particles decreased with the increase in the oxalate/Al molar ratio from 0 to 0.10.

Kinetic studies of Cd adsorption on imogolite and noncrystalline aluminosilicates were conducted at pH 5.0, using 10\(^{-5}\) mol L\(^{-1}\) Cd(NO\(_3\))\(_2\) solution. The adsorption of Cd by these particles was a very rapid reaction and actually completed within 10 min. After 240 min, 9.4% of the added Cd was removed from the solution of the imogolite suspension system. Less Cd was adsorbed by the perturbed imogolites than by imogolite. The percent adsorption of Cd decreased with the increase in the oxalate/Al molar ratio from 0.02 to 0.10. At the highest oxalate/Al molar ratio of 0.10, no more than 3.2% of the added Cd was adsorbed on the aluminosilicate. From a pedological viewpoint, the incorporation of oxalate in the noncrystalline aluminosilicates would hamper the retention of Cd in the surface and illuvial horizons of Andisols and Spodosols.

The present results thus suggest that the influence of oxalic acid on the shape and size of particles, the subsequent surface properties, and Cd adsorption of imogolite and poorly ordered aluminosilicates merits further attention in understanding the dynamics of Cd in the environment.

Keywords: atomic force microscopy (AFM), cadmium adsorption, imogolite formation, noncrystalline aluminosilicate, oxalic acid perturbation, structural properties
Location and mobility of trace metal elements in soils in an intensive farming region in Brittany (France)

TROLARD Fabienne and BOURRIÉ Guilhem

INRA, Unité de Géochimie des Sols et des Eaux, CEREGE, BP 80, F13545 Aix-en-Provence cedex 04, France

In intensive farming regions under Atlantic conditions, the distribution of Cu and Zn in soils depends on agricultural activity and on the variations of the oxido-reduction conditions in the milieu. Horizons were sampled in a toposequence of soils, with a cultivated area upslope (site C), a grassland at intermediate level (site I) and a non-cultivated area downslope, near a thalweg (site W). Redoximorphic features are present from the surface and deeper in sites I and W. In site C, soil is a typical Alocrisol, in site I a Luvisol-Redoxisol and in site W a Redoxisol. Horizons and specific subsamples defined from pedofeatures such as mottles, concretions, coatings, root channels or a distinct colour from the matrix were analyzed by X-ray fluorescence and selective dissolution techniques by EDTA, DTPA and CB were used under kinetic mode, under nitrogen atmosphere in a glove-box for reduced horizons and in the air for oxidized horizons. The results of the chemical analyses show: (i) that the horizons and the sprolitic schist underlying are genetically related, as demonstrated by the constancy of Ti content; (ii) that Cu and Zn are positively correlated with Fe, suggesting that iron oxides are host minerals for these trace metal elements (TME); (iii) that in the oxidized domain (C), TME, Fe and Ti are homogeneously distributed; (iv) that in the intermediate domain (I), and at a lesser extent in the downslope domain (W), the Fe/Ti ratio increases in the concretions and ferruginized root channels, which implies an absolute accumulation of Fe, simultaneously with Cu and Zn increases. The selective extractions show that TME are associated both with iron oxides and with organic matter. Horizons of the cultivated zone act as a source of diffuse pollution via manure spreading at a rate of about 40 m$^3$ ha$^{-1}$, twice per year on corn cultivation. The maximum mobility of TME is thus observed in the intermediate domain, at the interface between oxidizing and reducive conditions. This study shows thus: (i) that intensive application of fertilizers and of manure such as pig slurry results in a general increase of TME contents in well-drained soils; increases of Ca and P contents are simultaneously observed in the upper horizons of the cultivated soils; (ii) that horizons from hydromorphic zones act both as a trap by segregation of iron and concentration of metals and as a source by the release of Fe(II), Cu and Zn in the soil solutions during the reducing periods in these soils. The mobility of TME is controlled by the stability of iron oxides, which follows the alternating periods of aerobiosis and anaerobiosis.

Keywords: metals, Cu, Zn, oxidoreduction, manure, diffuse pollution
Factors affecting arsenate adsorption/desorption on/from variable charge minerals and soils

VIOLANTE Antonio, PIGNA Massimo and RAGUSA Raffaella

Dipartimento di Scienze Chimico-Agrarie, Università di Napoli “Federico II”, 80055 Portici, Napoli, Italy

Arsenic is a toxic pollutant and its presence in soils is an environmental concern. The presence of arsenate in soil is due both to the parent materials and anthropogenic waste. Indiscriminate use of arsenical pesticides until the mid-1900’s has led to extensive contamination of soil worldwide. The presence of phosphate has been reported to suppress the adsorption of arsenate and to displace adsorbed arsenate from soils. However, only large additions of phosphate to high-fixing soils and alkaline pH may affect arsenate solubility. To present, there is a lack of detailed information on the factors (inter alia pH, presence, nature and concentrations of inorganic and organic anions and nature and surface properties of sorbents) which influence arsenate adsorption, desorption and transport in soils.

The purpose of this work is to provide information on i) the adsorption of arsenate onto various metal oxides (gibbsite, goethite, pyrolusite, birnessite, ferricydride and mixed Fe-Al gels), variable charge soils (Andisols, Terra Rossa) and kaolinite as affected by pH and the presence of inorganic (phosphate, sulfate) and organic (oxalate, malate or citrate) ligands; ii) the capacity of increasing concentrations of low molecular mass organic anions to desorb arsenate previously adsorbed on Al, Fe and Mn oxides and variable charge soils.

Phosphate was more effective in preventing arsenate adsorption than citrate, malate, oxalate and sulfate (in the order listed). By adding arsenate and phosphate as a mixture (As + P systems; arsenate/phosphate molar ratio of 1) more arsenate than phosphate was adsorbed on pyrolusite, birnessite and goethite, but more phosphate than arsenate was adsorbed on gibbsite, allophanic Andisols, Terra Rossa soils and kaolinite. At pH 5.0 the adsorbed arsenate/adsorbed phosphate molar ratio (Rf) was 1.31 for pyrolusite, 1.07 for goethite, 1.19 for ferricydride, 0.64 for gibbsite and 0.81 for an Andisol. When arsenate and phosphate were adsorbed on Fe-Al gels, containing different amounts of Fe and Al (Fe/Al molar ratio of 1, 2, 4, 10 and ∞) the Rf values increased from 0.51 to 1.19 by increasing Fe content in the oxides. Furthermore, it has been ascertained that the Rf values usually decreased by increasing the pH, indicating that on all the samples used arsenate competed with phosphate more in acidic than in neutral or alkaline environments. Sulfate showed a poor influence in preventing arsenate adsorption, particularly at pH > 5.0.

Organic ligands inhibited arsenate adsorption particularly at ligand/arsenate molar ratio > 1, when added before arsenate and more in acidic than in neutral or alkaline environments. The efficiency of organic ligands in preventing arsenate adsorption was influenced by the nature and surface properties of variable charge minerals and soils. In fact, strongly chelating ligands (oxalate and malate) poorly prevented arsenate adsorption on pyrolusite and goethite, but strongly inhibited arsenate fixation on gibbsite, kaolinite and an Andisol.

Keywords: arsenate, phosphate, organic acids, metal oxides, adsorption/desorption
Gaseous fluoride emission from soils at high temperature in brick-making process

XIE Zheng Miao, WU Wei Hong and XU Jian Ming

College of Environmental and Natural Resource Sciences, Zhejiang University, Hangzhou 310029, P.R. China

Characteristics of fluoride emission from 12 soils at temperatures of 400-1100°C related to the brick-making process were studied. The results obtained in this study indicated that the fluoride emission as gaseous HF and SiF$_4$ was related with the firing temperature, soil total fluoride content, soil composition and calcium compounds added to soils. Soils began to release fluoride at the temperatures between 500-700°C. Marked increases of the average fluoride emission rate from 57.2% to 85.4% of soil total fluoride were noticed as the heating temperature was increased from 700°C to 1100°C. It was found that the major proportion (over 50%) of soil total fluoride emitted from soils at approximately 800°C. The amount of fluoride released to the atmosphere when heated depended on the total fluoride contents in soils. Correlation analysis showed that the soil composition, such as CEC, exchangeable calcium and CaCO$_3$, had some influence on fluoride emission below 900°C, while it had no influence at temperatures above 900°C. Addition of 4 calcium compounds (CaO, CaCO$_3$, Ca(OH)$_2$, and CaSO$_4$) at the level of 1.5% by weight raised the temperature at which fluoride began to release up to 700°C. The greatest decrease in fluoride emission in the treatment of CaCO$_3$ was found among 4 treatments of calcium compounds.

Keywords: fluoride pollution, brick-making, soil, high temperature, silkworm
Dynamics of extractable and bound residues of $^{14}$C-metsulfuron-methyl in soils

XU Jianming, WANG Haizhen and XIE Zhengmiao

Institute of Soil and Water Resources and Environmental Science, Zhejiang University, Hangzhou 310029, China

The bound residues of metsulfuron-methyl herbicide applied in soil were found to inhibit the growth of following crops. A laboratory study was conducted to determine the dynamics of extractable and bound residues of $^{14}$C-metsulfuron-methyl in soil, and the distribution of $^{14}$C-bound residues in soil humic substances during a 224-day incubation period. It was found that the extractable residues of $^{14}$C-metsulfuron-methyl decreased continuously with time, while the bound residues increased rapidly during the initial 28 days, and then did not change significantly with time. The degradation of extractable residues could be described using a first-order equation, with a half-degradation time ($T_{1/2}$) ranging from 75.1 to 90.1 days. The main portion of $^{14}$C-bound residues was found in fulvic acid fraction (FA) followed by humin fraction, and the least in humic acid fraction (HA). The amount of FA-bound residues increased during the initial 28 days, and then decreased with time. The HA-bound and humin-bound residues did not change significantly with time from 28 to 224 days after application (DAA). The fact that most $^{14}$C-bound residues existed in FA fraction in this study would provide evidence as to why the bound residues of metsulfuron-methyl in soil could still cause high phytotoxicity to sensitive rotational crops.

Keywords: $^{14}$C-metsulfuron-methyl, extractable residues, bound residues, soil humus
Adsorption behavior of copper in red soils from China as affected by anions

YUS. (1), HE Z.L. (1,2), HUNANG C.Y. (1) and CHEN G.C. (1)

(1) Department of Resource Science, College of Environmental and Resource Sciences, Huajiachi Campus, Zhejiang University, Hangzhou 310029, China
(2) University of Florida, Institute of Food and Agricultural Sciences, Indian River Research and Education Center, 2199 S. Rock Road, Fort Pierce, FL 34945-3138, USA

Adsorption of copper (Cu$^{2+}$) in two red soils (acidic and enriched with Fe, Al oxides) from China and the influence of nitrate (NO$_3^-$), chloride (Cl$^-$), sulfate (SO$_4^{2-}$), and acetate (Ac$^-$) present in the media were investigated. Adsorption of Cu$^{2+}$ in the red soils could be well described by the Freundlich and the simple Langmuir models, with correlation coefficients ($r$) ranging from 0.95 to 0.99. The red soil derived from the Quaternary red earths (REQ, clayey, kaolinitic thermic plinthite Aquult,) adsorbed more Cu$^{2+}$ than the red soil developed on the Arenaceous rock (RAR, clayey, mixed siliceous thermic Typic Dystrochrept). The adsorption maximum of Cu$^{2+}$ ($M$), obtained from the Langmuir equation for different anions present in the medium decreased in the order: Cl$^->$Ac$->$NO$_3^->$SO$_4^{2-}$ in both soils. Adsorption of Cu$^{2+}$ decreased soil pH, by 0.84 unit for the REQ soil and 0.63 unit for the RAR soil at the highest loadings in the 0.01 mol NaNO$_3$ L$^{-1}$. Decline of solution pH during Cu$^{2+}$ adsorption at different Cu$^{2+}$ concentrations varied with different anions in the following order: NO$_3^->$SO$_4^{2-}>$Cl$^->$Ac$^-$ for the RAR soil and SO$_4^{2-}>$NO$_3^->$Cl$^->$Ac$^-$ for the REQ soil. The smallest pH decline in the Ac$^-$ medium was due to the buffering effect of the NaAc/HAc system. The distribution coefficient ($Kd$) decreased exponentially with increasing Cu$^{2+}$ loadings for all the tested media. The $Kd$ value was lower for the RAR soil than for the REQ soil and decreased in the order of Cl$^->$NO$_3^->$SO$_4^{2-}>$Ac$^-$ at low Cu$^{2+}$ concentrations but at the highest Cu$^{2+}$ concentration the $Kd$ values were similar for all the anions.

Keywords: anions, copper adsorption, red soils
Phosphate kinetics in some soils of Egypt: I. kinetic parameters of phosphate release in relation to soil properties

ZAGHLOUL A.M., YOURSY M. and METWALLY A.I.

National Research Centre (NRC) and Ain Shams University, Egypt

Phosphate release kinetics in both the alluvial (Typic Torrerets) and calcareous soils (Typic Calcids) of Egypt was best described by empirically modified Freundlich (power function) and Elovich equations and to a lesser degree by theoretical diffusion and first-order equations. The factor affecting P release was largely different in both soils.

The rate of P release from the alluvial soils was positively and highly correlated and largely controlled by the clay content and surface area as indicated by the simple correlation coefficient and $R^2$ in the multiple stepwise regression analysis. These soil properties largely controlled the variations in the kinetic parameters that describe the rate of P release, and also P intensity, in the four tested kinetic models. On the other hand, Calcium phosphate and active CaCO$_3$ contents in the calcareous soils were negatively correlated and largely controlled the variations in the rate, and also, intensity parameter in the kinetic models. These results suggest that surface precipitation on CaCO$_3$ surfaces controls P release in calcareous soils while conversely phosphate adsorption on clay surface controls P release in the alluvial soils.

Keywords: alluvial soil, calcareous soil, soil properties, kinetic parameters, and regression analysis
Symposium 48

Development in soil data processing

Convenor: VAN MEIRVENNE Marc
Co-Convenor: NILNOND Chairatna

Oral Session
Friday 16 August 2002
14:00-17:20
Room: Meeting Room 2

Poster Session
Friday 16 August 2002
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Soil survey activities and correlations by major land resource areas

ANDERSON Deborah

USDA-NRCS, 4405 Bland Road, Suite 205 Raleigh, North Carolina 27609, USA

When the National Cooperative Soil Survey program in the United States reorganized in 1995, Major Land Resource Area (MLRA) Regions were established. Their primary responsibility is to coordinate all soil survey activities across specific major land resource areas. There are currently 18 MLRA Regions in the United States. MLRA Region 14 is in Raleigh, North Carolina. The areas of responsibility for MLRA Region 14 are the mid-Atlantic section of the eastern United States which includes the Southern Piedmont and Coastal Plain.

Within the areas of responsibility for MLRA Region 14, there are 63 soil survey projects. Correlation teams have been established within the MLRA Region. These teams operate under the guidance of a soil data quality specialist from the MLRA Regional Office who provides quality assurance and advises the team according to guidelines from the USDA National Soil Survey Handbook and Soil Survey Manual. Correlation teams consist of soil survey project leaders, soil survey project members, resource soil scientists, state soil scientists, soil data quality specialists, and soil scientists from cooperating universities and other agencies. Reorganization was made to MLRA Regions to ensure that soil survey mapping and delineation were based on geomorphic and landscape positions and not on a political or local boundary or bias. In this way, continuity and joins across political boundaries are achieved and a specific soil type does not end because of the limits of a local soil survey project. A more complete picture of the landscapes and landforms across the MLRA Region is achieved.

It is the responsibility of the correlation teams to coordinate soil survey activities within a specific MLRA. The group works as a team to design and implement research studies. The team members agree upon data collection and other responsibilities. Special studies that have been investigated include a study of water tables using peizometers. This study was performed on soils that had no obvious redoximorphic features in the profile yet were known to have water table restrictions for use and management. Other studies performed by various teams involved identifying, quantifying, and describing glauconite, identifying kandic horizons, and recognizing and quantifying plinthite. Another team activity includes correlation decisions involving setting up new soil series or making recommendations for revisions to established soil series. Evaluating interpretations for data map units and populating and sharing databases are also team activities.

Soil survey correlation teams have proven successful within MLRA Region 14. Members participate in annual field reviews of active soil survey projects and have shared in the collection and use of information gathered on specific data map units. Correlation teams exist across parts of nine different states. Professional development workshops sponsored by MLRA Region 14 have been conducted in three different regions, and attendance has been high. Cooperating personnel from the universities have helped to teach and coordinate local field trips. Feedback by attendees has been good. By allowing field soil scientists as a team to make decisions, the quality and enthusiasm for the soil survey program have improved.

Keywords: correlation, MLRA (Major Land Resource Area), soil survey activities
New approaches to the exploitation of former soil survey data

BORUVKA Lubos, KOZAK Josef, NEMECEK Jan and PENIZEK Vit

Department of Soil Science and Geology, Czech University of Agriculture in Prague, 165 21 Prague 6 – Suchdol, Czech Republic

A number of soil data are available from the soil and land resource surveys carried out in the past. Modern mathematical and statistical methods and computer developments enable new analyses and exploitation of these data. This is required for more complex understanding of soil functions, danger of soil degradation, and different agricultural practices, etc. This contribution shows some examples of the new exploitation of soil data resulting from a soil survey done in the 1960's.

The selected region is characterized by high heterogeneity and variability of soils and natural conditions in general. Characteristics (pH, CEC, organic carbon content, texture, etc.) of more than 600 profiles of agricultural soils were used. Different pedometric methods were applied to evaluate these data. Those included: 1) geostatistics for the analysis of soil spatial dependence and kriging for spatial prediction; 2) multivariate statistical and geostatistical methods for the analysis of interrelations among soil properties and for the determination of principal factors controlling soil heterogeneity in the region; 3) numerical classification for the delineation of soil categories defined according to different objectives (classical soil categorisation, soil vulnerability to pollution by risk elements, suitability to agricultural production, and; 4) pedotransfer functions for modelling the behaviour of chemicals in soils. The results of numerical classification were compared to the results of traditional soil classification. The technology of geographical information systems was used for processing of the resulting applied maps.

It was shown that the data of the former soil survey may be used for current purposes using modern methods for their processing. New soil surveys should be therefore focused mainly on special tasks on limited areas, verification of the older data, and validation of the results of mathematical simulation and prediction.

Keywords: soil survey, pedometrics, geostatistics, GIS, spatial distribution, soil classification
Assessment of soil thickness spatial uncertainty using simulation techniques

BOURENNANE Hocine and KING Dominique

Unité de Science du Sol-INRA (Orléans), BP 20619 Ardon 45166 Olivet Cedex, France

The general purpose of this paper was to apply stochastic simulations to assess spatial uncertainty of soil thickness (ST) and to spatially delimit soil areas below 35-cm thickness. For these areas, agricultural practices such as nitrates and pesticides applications should be managed accordingly to avoid a pollution of the limestone aquifer over the study area. Sequential Gaussian simulation algorithm (sGs) and turning bands method (TB) were used to assess spatial uncertainties of ST and the probability maps that ST to be below 35-cm value. According to mean values of 200 simulations and the standard deviation at each simulation node, TB method performs well than sGs in our study. Thus, in a second step only TB method was used in conditional simulations accounting for second information. Colocated cosimulation and simulation with external drift were thus carried out to assess spatial uncertainty of ST and the probability maps that ST to be below the threshold value of 35-cm by integrating an exhaustive secondary information. Slope gradient derived from DEM and linearly related to ST was used as secondary exhaustive information to improve the spatial uncertainty of the target variable. The results indicated that accounting for secondary information allowed improving the spatial uncertainty of the target variable and showed large areas with thickness probably below the threshold value than in simulations accounting for single attribute. Moreover simulation with an external drift results are more precise and more realistic than those obtained using colocated cokriging simulation.

Keywords: spatial uncertainty, stochastic simulations, colocated cosimulation, simulation with external drift, soil thickness, topography attributes
The suitability of quantitative soil-landscape models for predicting soil properties at a regional level

CHAPLOT Vincent (1,2) WALTER Christian (1).

(1) USARQ, ENSA-INRA, 65 rue de Saint Brieuc, 35042, Rennes cedex, France
(2) IRD, Ambassade de France, BP 06 Vientiane, RPD Laos

Quantitative soil-landscape models, based on topographic attributes, allow the characterization of large surface areas such as regions. This is possible due to the widespread availability of Digital Elevation Models (DEM). However, these models, which are usually generated and validated on detailed, single research sites such as hillslopes or elementary catchments, may show high prediction errors when applied to a region. The effect of the regional variations of topography, climate, geological substrates, land use and/or soil context has seldom been analyzed. The objective of this study was to test the regional applicability of two existing soil-landscape models generated from the data of a gently sloping area of 2 ha within a granitic catchment of eastern Armorican Massif (30,000 km²). Validations catchments located all over this region differed in topography (mean altitude and slope gradient from 39 to 202 m and 3.4 to 7.9 %, respectively), geological context (granite and schist) and climate (700 to 900 mm y⁻¹). Existing models were multiple regressions between a morphological index for soil hydromorphy (HI) and the elevation above the stream bank, the compound topographic index (regression 1) or the upslope drained area (regression 2). Models were validated using 565 data points collected over 4 sites. On each data point, systematical soil observation for HI estimation was compared to terrain attributes derived from DEM at a 30-m resolution. Results showed small prediction errors for all studied sites with mean absolute errors between 5 and 15 % of HI range. Errors were not spatially distributed. Minimum prediction errors were encountered in the catchment for which the models were generated, but also in one other that only differed in the geological substrate. In the other validation sites, models systematically over-estimated HI. This may be explained by a hypothetical climate effect. But, in addition, the soil context including extensive artificial drainage of soils and the re-forming of bottomlands for intensive agriculture may be involved. At the site of generation both regressions were accurate. However on the other sites, predictions errors using regression 2 were systematically higher than for regression 1 that uses topographic index with a physical basis. These results revealed that soil-landscape models might be useful for predicting soil hydromorphy over a region but only when selected after validation under several environmental conditions.

Keywords: soil-landscape model, DEM, soil hydromorphy, validation, regional scale
Mapping soil properties from an existing national soil data set using freely available ancillary data

HENGL Tomislav (1), ROSSITER David G. (1) and HUSNJAK Stjepan (2)

(1) Soil Science Division, International Institute for Geo-Information Science and Earth Observation (ITC), P.O. Box 99, 7500AA Enschede, the Netherlands
(2) Soil Science Department, Faculty of Agriculture, Svetosimunska 25, 10000 Zagreb, Croatia

The paper demonstrates how NOAA’s 1x1 km NDVI images, downloaded from the web, together with free coarse resolution elevation and climatic data, can be used to improve spatial details of the Croatian national soil-data set consisting of 2,349 profile observations. Two regression models were developed: to map pH (measured in H2O) and organic matter (%) in topsoil. Environmental predictors used are standard landform parameters (elevation, slope, curvature, aspect, wetness index), climatic data (rainfall, temperature) and vegetation components derived from the annual NDVI time series. Results show that these two soil properties can be mapped using the CLORPT approach with equal or better precision than with using the existing 1:50,000 soil class map and averaging the properties per soil mapping unit. While the precision of prediction for pH did not improve significantly (residual standard error: 0.60 versus 0.61), the precision for OM was considerably better (residual standard error: 2.81 versus 3.85). The models accounted for 54% (pH) and 66% (organic matter) of the total variation. Principal components of the NDVI time series proved to be most significant predictors of the soil properties, showing clearly general vegetation types and their dynamics. The prediction of pH indeed seems to be more difficult than the prediction of OM. The achieved coefficient of variation for pH was 16.8%, while the model for OM 10.8%.

Keywords: soil survey, environmental regression, CLORPT, NOAA’s AVHRR, Croatia
A prognosis computer model for natural and technogenical processes in multilayer soil structures

ISACOV Gennady N. and KUZIN Alexander Ya

Tomsk State University, Lenin Str. 36, 634050 Tomsk, Russia

The mathematical model for natural and technogenical processes in soil profiles with regard to the cyclic recurrence of atmospheric and climatic conditions on the surface is presented. Data on granulometric and microaggregated analysis are used for this model, as well as the thermophysical and kinetic properties, as the total soil density and soil solid phase densities' values. The soil water regime trends in moisture and pollutant transport in soil structures are a function of climate. Problems of similarity methods application to the generalized descriptions of physical-chemical processes operative in soil horizons are considered.

Keywords: mathematical model, heat-mass transport, soil, pollutant
The concept of preparation of electronic maps of soils of Azerbaijan

ISMAYILOV Amin

Institute of Soil Science and Agrichemistry of Academy of Sciences of Azerbaijan Republic, 5 M.Arif str, 370073 Baku 73, Azerbaijan Republic

Starting from the beginning of the 20th century soil researchers have been implemented in a systematic way. During the last century the research of the republic’s soils was covered fully. The results of many years’ activities of soil scientists have been reflected in the maps produced in different years. Besides the soil maps, the maps of soil erosion, soils ecological valuation, agriproduction grouping of soils, and salting of soils have been produced by different scientists. These maps are very important due to their purpose and time of issuance. These maps are of big importance for revealing the changes which took place in earth soil over decades. Along with positive aspects the maps prepared in a traditional way have also some imperfections. Soil maps prepared by means of simple technology carry only a presentation character. To measure the square of the object reflected in the map or to receive the data according to contour creates difficulties. It is very difficult to identify any changes which took place in soil with time on the basis of such maps. In order to eradicate such imperfections, it has been suggested to produce in electronic format digital maps for soil surfaces of Azerbaijan. Electronic soil maps carry besides connection with certain co-ordination systems a multi-functional character. The first project of electronic soil map was prepared on the basis of AutoCad program. The privileges of this project are the following:

• dynamics of the objects reflected on the electronic map;
• definition of length and square measurements in an automatic way and with high accuracy;
• automation of transfer to different scales and printing;
• collection of information on the map on different levels considering their specifications;
• to carry on monitoring observations transparently together with changes taking place in earth soil;
• to achieve additional possibilities for planning of economical use of soils and forecasting;
• to co-ordinate land data base directly with its dissemination area;
• to widen the possibilities of systemization and dissemination of mapping materials about soil;

Lots of necessary information are used for preparation of soil maps. In preparation of soil maps with simple technology data characterizing different soil taxons are applied to the map in the form of a report or explanation. Only an electronic soil map gives the opportunity to combine these works. For the co-ordination of a soil data base with corresponding contours reflected in the land map it is proposed to issue a new variant of electronic soil maps on the basis of the ArcView program. The proposed new project has all the above-mentioned privileges. Only by using this variant it is possible directly to see on the monitor comprehensive information about a selected land unit.

Keywords: soil, maps, electronic, digital map
Soil quality evaluation with a fuzzy logic expert system

KAUFMANN Manfred and TOBIAS Silvia

Swiss Federal Institute of Technology, Institute of Land Improvement, CH-8093 Zuerich, Switzerland

Recently, there has been increasing awareness of the importance of soil quality in the context of land evaluation and sustainable land use and management. Modern definitions of soil quality take the multi-functionality of soil into account and numerous different soil properties have been suggested as indicators for soil quality. However, the scientific base of the soil quality concept is rather vague and there is a lack of methods to assess soil quality in this context of vagueness and uncertainty.

It is the aim of this contribution to investigate the potential of fuzzy logic for soil quality assessment. Fuzzy logic is useful whenever we have to describe ambiguity, vagueness and ambivalence in conceptual models of empirical phenomena. A fuzzy logic rule-based expert system is developed for soil quality evaluation of restored soils. Soil restoration often negatively affects the soil’s physical condition and results in compaction and water logging. Therefore, our expert system for soil quality evaluation of restored soils will focus on physical parameters.

Our fuzzy logic rule-based expert system transforms sets of measurable soil indicators into soil quality statements with regard to the considered soil functions. The knowledge base of the expert system consists of fuzzy sets that describe to what extent a measured value of a given soil indicator is optimal, critical or restricting for a specific soil function. The rule-base of the expert system is a set of IF-THEN inference rules such as “IF soil indicator A is optimal for crop production AND soil indicator B is critical for crop production THEN soil quality for crop production is medium”. All the inference rules are fired parallel to define the overall soil quality for the considered soil function. The input values of the experts system are the measurable physical soil indicators, bulk density, macro-porosity, penetration resistance, saturated conductivity and precompression stress. Expert knowledge is gained with a questionnaire in which soil experts define the membership functions for the fuzzy sets and the IF-THEN inference rules. The fuzzy logic expert system allows us to include uncertainties in the soil quality evaluation process.

A rule-based fuzzy logic expert system for soil quality evaluation is presented and applied for quality assessments of restored soils in Switzerland. The knowledge base of the expert system defines for 5 physical soil indicators a valuation standard on the base of fuzzy sets. The rule base of the expert system indicates how the combination of the considered soil indicators contributes to physical soil quality in respect of specific soil functions. The potential of the fuzzy logic expert system to map the human reasoning process and to help us to understand the expert’s views on soil quality is discussed.

Keywords: soil quality, fuzzy logic, expert system, physical soil indicators
Geographic information system for soil land use in Rajburi Province, Thailand

KERDCHOECHUEN Orapin and PASURAWONG Pommuch

Natural Resource Management, School of Bioresources and Technology, King Mongkut’s University of Technology Thonburi, Bangkok, Thailand

This study was carried out to investigate soil land use in Rajburi Province using geographic information system. In order to make the best suitability soil land use for the agricultural system, multi-criteria Decision Making (MCDM) was used to analyze the physical attributes of soil and social characteristics of the study area and farmers. The first part of the study used ARC/VIEW version 3.1. The results show that the physical agriculture area of 1,471,140 rai is covered with 17 groups of soil type. The characteristics of most of the soil in Rajburi is sandy loam texture, medium organic matter, low soil fertility, and high water drainage. In addition, the irrigation system covers 57.87% of the agricultural area and 2.65% is high risk to flooding. About 16% of the land is under drought. Most of the agricultural land area is used for single cropping system. However, 36.19% of the total farmers grow paddy rice and 11.72% grow sugarcane. The second part of the study was analyzing the type of planting crops and the suitable new integrated cropping models for Rajburi using multi-criteria decision making (MCDM) including physical, biological, socio-economic, farmer’s needs, physiological and soil land use and soil characteristic factors. The type of the suitable crops is divided into 5 groups: paddy rice, field crops, fruit crops, vegetables, and floriculture crops. It is found that the highly suitable land for field crops; sugarcane and maize, is in the central and western parts of Rajburi. In addition, the highly suitable land for fruits; mango, guava, young coconut, jujube, and pomelo, is the whole area of Rajburi. Furthermore, the highly suitable land for vegetables; baby corn, yard long bean, snake eggplant, white-ball eggplant, Chinese bitter gourd, Chinese cabbage, and morning glory or water spinach, is in the east, south and north of Rajburi. All floriculture and rice are considered as moderate suitable crops for growing in the east and central parts of Rajburi.

Keywords: soil land use, geographic information system, multi-criteria decision making, Rajburi
Spatial variability of soil and plant parameters on a Podzoluvisol

KUZYAKOVA Irina (1) and RICHTER Christel (2)

(1) Institute of Soil Science and Land Evaluation (310), University of Hohenheim, D-70593 Stuttgart, Germany
(2) Institute for Plant Production, Humboldt University of Berlin, D-10115 Berlin, Invaliden str. 42, Germany

The connections between soil and plant parameters have been evaluated by means of the coupling of classic statistics and spatial statistics on a field trial without treatments on a Podzoluvisol. The following parameters were analyzed: total carbon content in soil ($C_t$), sum of fine silt and clay content (FAT), available K and P, $pH_{KCl}$ in upper (0-30 cm) and second (31-40 cm) soil horizons; soil genesis factors: depth of underlying loam and micro-relief; and plant yield parameters: growth height of silage maize (1988 and 1990) and dry matter yield of spring barley (1989).

The smoothing of raw data by means of block kriging eliminated the small-scale variability (nugget variance). The smoothing raised the range correlation coefficients between soil parameters up to two fold and reached $-0.52$ for $C_t$-FAT, $0.69$ for $C_t$-K, and $0.55$ for $C_t$-P. The smoothed maps allowed performing much better visual analysis of spatial distribution of parameters compared to the raw data maps. The semi-variogram analysis allowed detection or confirmation relationship between parameters, unless these connections were insignificant by means of classical statistics. Spherical models with the range of about 130 m were used to estimate parameters of experimental semi-variograms of $C_t$, FAT, and P in the upper and in the second soil horizons. As it was shown by significant correlations, similarity of maps and semi-variograms of the parameters, the same factors were responsible for spatial distribution of FAT, $C_t$, K, and P in the upper soil horizon. The depth of underlying loam and micro-relief were the main factors affecting the variability of soil parameters on the site. The range correlation coefficients of smoothed detrended micro-relief data in the upper soil horizon reached $-0.63$ for FAT, $-0.77$ for $C_t$, $-0.71$ for K, and $-0.57$ for P. This shows the main role of the water-affected redistribution of fine silt and clay particles with humus in the variability of soil parameters despite very low inclination ($1.2^\circ$- $1.7^\circ$).

No significant correlations between the yield parameters in different years were obtained for the whole field. However, similar trends and high significant correlations ($0.61 - 0.88$) were found in some parts of the field (2 to 5 ha).

Keywords: variability of soil and plant parameters, geostatistics, variogram analysis, block kriging, mikro-relief, loam depth
A tool for assessing land suitability for Europe

LE BAS Christine (1), BOULONNE Line (1), KING Dominique (1) and MONTANARELLA Luca (2)

(1) INRA, INFOSOL, 45166 Olivet Cedex, France
(2) EI, JRC, ISPRA (VA), Italy

In the framework of the Common Agricultural Policy (CAP), the European Commission (EC) needs tools for managing and monitoring agricultural production, including sustainability aspects. This objective leads to develop standard methods that could be used on the whole territory for decision making. The aim of this work is to build an expert system to assess the agronomic constraints to crop production for Europe at a large scale. This assessment will be then combined with results from other works focusing on environmental problems, in order to have an assessment of the sustainability of European agriculture.

Data on soil, climate and crops are needed for this assessment. Soil data are provided by the European Soil Geographical Data Base at scale 1:1,000,000 which described the geographical extent of soil types through complex units. The main soil characteristics available do not generally correspond to the data needed by the model. Pedotransfer rules were then defined to derive these needed data like available water capacity, volume of stones, rooting depth, cation exchange capacity, etc.

The daily interpolated climatic data, provided by the MARS project, are available on a 50 km x 50 km grid for 25 years (1975-1999). For each cell, a daily mean was calculated on the 25 years for rainfall, minimum and maximum temperature, and PET.

The crops data correspond to the crops requirements in term of soil and climate, and were found in the literature. We focused our work on the main European crops: cereals, maize, root crops, oilseed crops, olive trees, vine and grasslands. The spring and winter crops are distinguished.

Soil and climatic data are combined within a Geographical Information System giving all the soil descriptive parameters present in a climatic grid cell and which constitute a land evaluation unit. The expert system is based on a qualitative assessment of the main agronomic constraints for each crop: temperature requirements, moisture availability, physical rooting conditions, oxygen availability to roots, natural chemical fertility, and conditions for mechanization. These constraints are assessed by the combination of the land characteristics and the comparison with the crop requirements for each land evaluation unit. All the constraints are combined to define a global land suitability for each type of crop.

The results of this land suitability assessment will be combined with a land erosion risk assessment produced by INRA-JRC (Le Bissonnais et al., 2000). This combination will permit us to enlarge the information about agriculture suitability integrating environmental problems for decision making. The use of agricultural statistics will also allow a comparison between potential and actual agricultural production.

Keywords: European soil database, land suitability, expert system, geographical information system, land sustainability
Determining optimized unit size for clean-up in contaminated soils based on dispersion variance

LEE Dar-Yuan, JUANG Kai-Wei and TSENG Chieng-Chih

Graduate Institute of Agricultural Chemistry, National Taiwan University, Taipei, 106, Taiwan,
R.O.C.

In contaminated soils, the spatial distribution of pollutants is essential for delineating hazardous areas and risk assessment. The spatial distribution of pollutants in contaminated soils is non-homogeneous. The data of pollutant concentrations are usually found to exhibit great variation. Assessing the spatial variability of soil pollutant is thus important for setting up a clean-up regime. In practice, for a cleanup action, it is necessary to determine a unit volume suitable for clean-up. However, an observed value of pollutant concentration is measured as the average over a certain volume, called support, which is usually smaller than the unit for clean up. If there are not enough observations in each unit, it is difficult to determine whether clean up is needed or not in each unit. Moreover, changing support will lead to different results when assessing the spatial variability. For instance, the shape of the variogram model will change, too. Thus, to determine the unit size for cleanup should be dependent upon the support size and the number of observed values. In this study, we used the additivity property, called Krige’s relationship, to measure the dispersion variance, which can be used to describe the support effects on determining the unit size for cleanup. A real data set of heavy metal concentrations in a contaminated site located in Taiwan was used as an illustration. We found that the dispersion variance indicates the variance ($\sigma^2_b$) of pollutant concentrations between clean up units. The variance ($\sigma^2_w$) of pollutant concentrations within each clean up unit can also be measured from the variogram models corresponding to various support sizes. We proposed a concept to simultaneously maximize $\sigma^2_b$ and minimize $\sigma^2_w$ given finite observed values for determining the unit size. An optimized unit size for clean-up can then be determined by a function of $\sigma^2_b$ and $\sigma^2_w$.

Keywords: spatial variability, dispersion variance, support effect, contaminated soils
Spatial variability of soil properties within the horizons and in the vicinity of the pedogenetic boundaries

LIPATOV D.N.

Radioecology Laboratory, Faculty of Soil Science, Moscow State University, Moscow 119899, Russia

Spatial variability of soil properties reproduces changes of soil types in a lateral direction. In many cases, the magnitude of such variation increases in the vicinity of the natural boundaries between soil map units. In the study reported here, the objective was to test the performance and value of the moving variance technique on observations of soil physical properties and carbon content along three transects in grey forest soils of the Vladimirskoe Opol'e (Russia).

The transects were made across distinct areas of approximately 1.5 km. The length of each transect is equal at 40 m. Observations of soil morphology and collection of soil samples were made at 0.25 m intervals. The sampling depths were centred at 10 cm, 35 cm, and 50 cm on average. Soil cores (40 mm x 40 mm) were obtained to measure bulk density, moisture and carbon content. Frequency distributions for each variable approximated a normal distribution. The moving variance was calculated through window with the width ranging from 7 to 21 points (1.5 to 5.0 m). The soil cover along transects exists as a pattern of soil possessing the second humus horizon (Ah) and grey forest soil with signs of podzolization (horizon EB). Based on the morphological properties, it is possible to recognise the pedogenetic boundaries (A1-Ap, Ah-AE, AE-EB, EB-B, B-Bca) in the lateral direction.

Graphs of the moving variance constructed for each soil property revealed some degree of spatial structure. The moving variances were normalised by dividing by the total variance. The width of peaks was ranged from 4 to 40 points (1 to 10 m). The moving variances for bulk density of Ap horizon are higher on intervals in which values of this property are smaller. The compacted areas demonstrated less variability, than the uncompacted areas. The high moving variances of soil bulk density and moisture were obtained for untilled horizon A1. Data from subsoil horizons were compared using t-test. The average values of soil bulk density and carbon content for four soil horizons (Ah, AE, EB, B) are significantly different (P=0.05). Variations observed within soil horizons are smaller than variations due to pedogenetic boundaries between these horizons. The moving variance values increased in the vicinity of the boundaries. The graphs of the moving variance for soil moisture were less sensitive to the changes of soil units along transects than graphs for bulk density and carbon content.

It is of interest that the periodicity was obtained for moving variances of soil properties. Data were analysed by geostatistical techniques, specifically variogram computations. The longer-range variability is related to the soil combinations. Microvariability appeared to be very high for soil moisture and bulk density, especially in Ap horizon. The utility of moving variance techniques in pedological studies is related to the determination of boundaries for spatial structures.

Keywords: spatial variability, soil boundaries, soil transects, moving variance
Making the most out of limited soil spatial data

MCBRATNEY A.B. (1), MORAN C.J. (2) and MENDONCA SANTOS M.L. (3)

(1) Department of Agricultural Chemistry & Soil Science, Ross St Building A03, The University of Sydney, NSW 2006, Australia
(2) CSIRO Land and Water, GPO Box 1666, Canberra, ACT 2601, Australia
(3) EMBRAPA Solos, Rua Jardim Botânico, 1024, 22.460-000 Rio de Janeiro-RJ, Brazil

Soil scientists in all countries are now called upon to respond to requests from governments and communities for soil and land resource information. The requests are largely to develop plans to manage the environment responsibly and sustainably. In some countries spatial soil and land resource data are dense. In other parts of the world particularly those countries with large land areas (and a large environmental responsibility and imperative), and small populations or limited economies, the data infrastructure is relatively poor compared with Western Europe and North America. Australia and Brazil are such examples.

In this paper we present examples from Australia and Brazil where the data could be thought of as inadequate, because of small sample sizes or unknown or purposive sampling schemes, for conventional pedometric analyses. Nevertheless, in such cases, additional assumptions and modified soil data processing methods allow the estimation of maps and quantities that provide useful information for environmental management. Of course, it is important to understand the (spatial) uncertainties associated with such procedures in order that sensible environmental decisions can be made and further investment into the soil data infrastructure can be justified and further sampling effectively targeted.

Keywords: pedometrics, uncertainty, soil data
Probability models of soil properties

MIKHEEVA Irene V.
Institute of Soil Science and Agrochemistry of Siberian Branch of Russian Academy of Sciences, 18, Sovetskaya Street, Novosibirsk 630099, Russia

Variability needs to consider soil properties as random values. Probability distribution is a full and universal characteristic of random value, as many other characteristics may be obtained from it. To make a priori theoretical suggestion about the type of probability distribution is rather difficult, because the soil is an open complex system and has hierarchical space structure, so to predict how the sum of different processes results in this or that probability distribution is difficult. Information about the kind of statistical distribution of soil properties in science literature is contradictory. At the same time, the probability distributions are necessary for an accurate and correct evaluation of soil properties and their changes under nature and anthropogenic processes, for technique and land evaluation calculations, for mathematical modeling of soil processes using a probabilistic approach, besides they are needed for keeping information about soil variability in databases.

We determined probability distributions of properties of Kastanozems having different texture: sand, loamy sand, sandy clay loam, sandy clay. These soils were formed from coarse-textured Quaternary alluvium. Input data were obtained after large-scale (1:25,000) soil survey of big part (16,000 km²) of the Kulunda steppe. Data were grouped according their taxonomy type and texture. Numbers of observations in each group were large (n=50-600) that provides the opportunity to carry out this statistical investigation.

A new approach is considered for the determination of the function as well as parameters of probability distribution. Optimal data grouping, the evaluation of parameters according to the method of maximal probability, the multiplicity of testing alternatives and polycriterial checking of hypothesis provide receiving specific types of function from large numbers of functions and its parameters more precisely and reliably.

Probability distributions of values of clay and silt content were identified as S_n-Johnson’s distribution with different parameters. Values of fine sand content (this fraction is predominated) distributed as distribution of minimum value and the values of coarse sand content – as Weibull’s distribution. Parameters of probability distribution of clay content in upper horizon is rather different from such in underlying horizon, were a bigger variance appears, as a consequence of illuvial processes. Variability distributions of silt content in upper and underlying horizons are practically identical, while distributions of values of sand content are different as a consequence of deflation processes. Position of soil in macro- and mezo-relief has an influence on type of probability distribution of texture. For example, the form of distribution of values of clay content in soil at the lower part of slope seems as Laplas’s distribution as a consequence of accumulation. As well we obtained and discussed probability distributions of values of humus and salt contents, pH and horizons depth. We revealed regularity of the changing of form of probability distribution in different conditions that explain a large variety of types of probability distributions of soil properties that may be used as a base for the creation of a universal model, which should describe different cases by changing its parameters.

Keywords: soil properties, variability, probability distribution
Soil inference systems

MINASNY Budiman and McBRATNEY Alex. B.

Department of Agricultural Chemistry and Soil Science, The University of Sydney, Ross St. Building A03, NSW 2006, Australia

Pedotransfer functions (PTFs) have become a ‘white-hot’ topic in the area of soil science and environmental research. Most current PTF research focuses only on the development of new functions for predicting soil physical and chemical properties for different geographical areas or soil types. This seems to be a continuing process, while there is little effort to collate and use the available PTFs.

We propose the concept of the soil inference system (SINFERS), where pedotransfer functions are the knowledge rules for inference engines. A soil inference system takes measurements we more-or-less know with a given level of (un)certainty, and infers data that we do not know with minimal inaccuracy, by means of properly and logically conjoined pedotransfer functions. The soil inference system has a source, an organiser and a predictor. The sources of knowledge to predict soil properties are collections of pedotransfer functions and soil databases. The organiser arranges and categorises the PTFs with respect to their required inputs and soil types from which they were generated. The inference engine is a collection of logical rules selecting the PTFs with the minimum variance. Uncertainty of the prediction can be assessed using Monte Carlo simulations. The inference system will return the predictions of soil physical and chemical properties with their uncertainties based on the information provided. Uncertainty in the prediction can be quantified in terms of the model uncertainty and input data uncertainty. In order to avoid extrapolation, a method was developed to quantify the degree of belonging of a soil sample to the training set of a PTF.

With this first approach to a soil inference system, we can optimally predict various important physical and chemical properties from the information we have utilising PTFs as the knowledge rules.

Keywords: expert systems, soil surveys, decision support systems, error propagation, information management
Soils and topography: accumulation zones and non-local approaches

SHARY P.A. (1), RUKHOVICHB O.V. (2), SHARAYAC L.S. (3) and MITUSOV A.V. (1)

(1) Institute of physical, chemical and biological problems of soil science of the Russian Academy of Sciences, 142290 Pushchino Moscow region, Russia
(2) Institute of basic problems of biology of the Russian Academy of Sciences, 142290 Pushchino Moscow region, Russia
(3) Institute of Volga basin ecology of the Russian Academy of Sciences, 445003 Tolyatti, Kamzina street 10, Kuybyshevskaya oblast, Russia

A recently introduced extended system of quantitative methods of topography (Shary, 1995; Shary et al., 2002) permits to consider the problem of quantitative approaches use in soil science from a new point of view. Soil properties have been measured at 33 points of a transect that has a length of 1.5 km and is located in predominantly soddy podzolic soils in the southern part of Moscow region, Russia; an accumulation zone was detected at this transect, and relationships between soil property changes and topography near this zone were studied using non-parametric statistics. Profits of non-parametric statistics use (in comparison with a usual statistics) in soil science are elucidated. It is shown that the general nature of accumulation zones results in importance for soil property studying and spatial predictions to take into account both non-monotonic dependencies of soil properties on topography as well as on other ancillary raster data (satellite images, and so on), and taking integrals in calculations of relative position in landscape. Models that do not pay sufficient attention to one of these issues (e.g. current geostatistical models) appear to have little effectiveness both for accumulation zone description and for spatial predictions outside a given area with measured soil properties. A critical consideration of current quantitative topography methods is given and their major disadvantage in applications for soil science is revealed and analyzed; it is shown, in which direction corresponding development of quantitative topography needs to go in order to be most significant for soil science.

Keywords: topography, Digital Elevation Model, soil spatial distribution, soil spatial prediction, accumulation zone, non-parametric statistics
Modeling spatio-temporal changes in soil salinity and water-logging in Marvdasht Plain, Iran

MOAMENI Aziz (1) and STEIN Alfred (2)

(1) Soil and Water Research Institute P.O. Box: 14155-6185, North Kargar Ave., Jalale-Ale-Ahmad St., Tehran, Iran
(2) International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands

This research concerns the semi-arid area of Marvdasht, a large intermontane plain in Fars Province, located in south-central Iran, about 50 km northeast of Shiraz, the provincial capital. The area, one of the most productive in Iran, is very susceptible to land degradation. Soil salinity and water-logging are the main constraints to sustained crop production in the salt-affected areas. In the Marvdasht plain, salinity is brought about partly by naturally occurring salinization processes and partly by long-continued irrigation agriculture. Salinity severely threatens the permanence of irrigated agriculture affecting more than 50% of the arable lands, located mostly in a lacustrine depression. In this research, the spatio-temporal changes in soil quality controlled by salinization and water-logging were modeled using geostatistical techniques. To investigate changes in soil salinity over time and space, a sample area was selected for which historical and modern soil EC\textsubscript{i} values were available. The parameters of the variogram for each data set were used as input to ordinary kriging to interpolate soil EC\textsubscript{i} values and produce a contour map for the historical and the modern salinity values. Similarly, the spatio-temporal changes in the depth to the ground-water table were also investigated in a sample area by applying kriging techniques. Change detection in soil salinity and water-logging was performed by comparing the contour maps created for the historical and modern soil EC\textsubscript{i} values and those produced for the past and modern values of depth to the ground-water table, respectively. The cross operations were utilized to detect changes, using ILWIS software package. Significant changes in soil salinity have occurred in the lacustrine depression during the last 30 years. In 1972, all the soils had a salinity value above 4 dSm\textsuperscript{-1}. In about 560 ha (95% of the studied area), the salinity range was 8 to 32 dSm\textsuperscript{-1}. In 1996, in contrast, the area covered by soils with a salinity range of 0 to 4 dSm\textsuperscript{-1} increased to about 620 ha (89%) and the area covered by soils having EC\textsubscript{i} values above 4 dSm\textsuperscript{-1} decreased to only 65 ha (11%). The ground water was about twice as deep in 1996 as in 1967. The average water table in the lacustrine depression has dropped by about 70 cm over the last 30 years as a result of improved drainage. This is a significant achievement, because the removal of excess ground water favors the leaching of salts, improves soil aeration, creates deeper rooting conditions, increases crop choice and extends the period in which tillage operations can take place.

Keywords: spatial variability, temporal variability, interpolation, salinity, groundwater
Geophysical survey of Mediterranean soils in a Tunisian floodwater harvesting system

MONTOROI Jean-Pierre (1), NASRI Slah (3) and SCHMUTZ Myriam (2)

(1) IRD, UR027 Geovast, 32 avenue Henri Varagnat, 93143 Bondy Cedex, France
(2) INRGREF, Rue Hédi Karray, BP 10, 2080 Ariana, Tunisia
(3) Université P. et M. Curie, Département Géophysique Appliquée, 4 place Jussieu, case 105, 75252 Paris Cedex 05, France

Applied geophysics is a useful tool for preserving the structure and the functioning of soils, and providing spatialized and well sampled information. Based on surface measurements, the principle is to determine the physical properties of a soil volume, and the vertical and horizontal variations. The measured variable is the apparent soil resistivity and a 2-D imaging survey is performed using inversion modelling.

After a short presentation of the 2-D imaging method, an application to Mediterranean soils in a flood harvesting system widely extended in Tunisia is presented. Water scarcity, owing to low and erratic rainfall, always poses problems to farmers and herders. In the last century, world-wide population has grown tremendously increasing the pressure on water resources. To secure water supply and intensify agricultural production, water harvesting is traditionally used under varying rainfall rates and population densities. In Tunisia, the government has undertaken since the early 1990's the implementation of the "National Strategy of Surface Runoff Mobilization" which aims at building numerous large dams, small earth dams and other works for irrigation and water table recharge (1). For some reservoirs, the water balance is highly negative and suggests a water loss by infiltration leading to a reservoir leakage and an alluvial aquifer recharge. The goal of our study consists of using the geophysical approach to characterize the soil structure in the vicinity of an infiltrated reservoir.

Each apparent resistivity unit of the electrical sections performed by the 2-D method is constrained by field observations (pits, groundwater levels...) and is semi-quantitatively interpreted in terms of soil thickness (clayey soils formed from marl deposits, hydromorphic soils and calcareous materials). The 2-D images reveal the morphology of the downstream alluvial aquifer supplied by the hill reservoir and an upstream sandy layer partly explaining the reservoir infiltration.

Geophysics provides accurate parameters to complete the hydrological and geochemical data sets (2, 3) and to define a behavioral model of the reservoir functioning.

Keywords: applied geophysics, apparent soil resistivity, Mediterranean structure, small reservoir, Tunisia
Spatial variability of surface soil moisture in a sloping grassland field

MOROIZUMI Toshitsugu (1), SATO Yuichi (2), SATO Koichi (2) and MIURA Takeshi (1)

(1) Faculty of Environmental Science and Technology, Okayama University, 3-1-1 Tsushimanaka, Okayama 700-8530, Japan
(2) School of Veterinary Medicine and Animal Sciences, Kitasato University, 23-35-1 Higashi, Towada, Aomori 034-8628, Japan

Surface soil moisture is an important variable which significantly affects the hydrological environment of a region. It is necessary to better understand the spatial distribution of surface soil moisture in order to account for the balances of water and energy at the land-atmosphere boundary. In this paper, the characteristics of the spatial distribution of the surface soil moisture in a sloping grassland field at the School of Veterinary Medicine and Animal Sciences, Kitasato University, Japan are discussed. The experimental site was a 3.6-ha field (150 m by 240 m). The elevation of the field site was 74.1 m at the highest point and 54.8 m at the lowest point. The soil at the field site was volcanic ash soil (Kuroboku soil). Field data on the surface soil moisture were explored at fifty-four sampling locations using a 100 cm$^3$ (Ø5.0 cm by L 5.1 cm) sampling tube and measured by the gravimetric method. The samplings were taken on August 28, October 11, and November 19 of 1996. The data were then analyzed using fundamental statistics and geostatistics. Typical results include the following: The distribution of surface soil moisture approached normal distribution as the levels of field-scale soil moisture increased. The coefficients of variation for the surface soil moisture content grew smaller as the mean levels of field-scale soil moisture increased. Among the average levels of area-scale soil moisture for each area, the average levels of soil moisture for the low area were the highest, and the levels of area-scale surface soil moisture differed according to each area. For the three sampling dates, the coefficients of variation for the surface soil moisture in the slope area were about 1.1-1.8 times larger than those in the high and the low area. This finding indicates that the spatial variability of the soil moisture was the largest in the sloping areas. From the geostatistical analysis, it was clarified that these levels of soil moisture were spatially correlated. It was also found that the range and the sill in the semivariograms differed according to the direction and the average level of field-scale soil moisture.

Keywords: surface soil moisture, spatial distribution, sloping grassland, sampling, geostatistics
Spatial variation of macronutrients and micronutrients on soil of the eastern savannas –Venezuela

NAVAS Mariela (1), REY Juan Carlos (2) and RODRIGUEZ Tania (1)

(1) Instituto de Investigaciones Agrícolas, Centro de Investigaciones del estado Anzoátegui (INIA-Anzoátegui), El Tigre, estado Anzoátegui-Venezuela, apartado 212
(2) Instituto de Investigaciones Agrícolas, Centro de Investigaciones del estado Aragua (INIA-Aragua), Maracay, Avenida El Limón, Estado Aragua

Soil exhibits continuous changes in space and time. These changes depend on several factors which affect them. Knowledge and understanding of the variability of soils are necessary to improve the control of their physical, chemical, and biological properties and, in this way, to confront the modern problems of the use of this natural resource. Actually, it becomes imperative for the use of appropriate levels of nutrients, in order to obtain yields compatible with the potential of soil (Ovalles et al., 1989). Soil analysis for the diagnosis of fertility is one in of the ways of giving valid recommendations. It is based on the requirements of nutrients of a specific crop. Nowadays, it is of great importance due to the substantial increment of fertilizer prices. The accuracy of the chemical analysis is a direct function of the quality of the sample. The way a sample is taken has more influence on the final result than the possible human or equipment failures during the subsequent laboratory procedure. The objective of this work was to know the spatial distribution of the macronutrients and micronutrients in soils of savannas located at the South of Anzoátegui State, Venezuela. A sampling methodology was established (numbers of composed samples and sampling distance) involving the spatial variability of nutrients. It guaranteed that the chemical analyses reflected the real concentration of these macro and micronutrients in a given area. To achieve this objective intensive and systematic samplings were carried out in 10 representative farms of the region. In each farm 50 samplings points were marked at 100 m between them. Each point had a 20 cm depth and were identified with coordinates (X,Y). A total of 50 soil samples were obtained per farm pH, texture, organic matter and concentrations of Ca, Mg, P, K, Zn, Fe, Mn and Cu were determined on each soil sample. The data was subjected to different statistical analysis: detection and elimination of the atypical values, regression models, and a geostatistical analysis. Results showed that concentrations of macro and micronutrients had means degree of spatial dependence. It is recommend to take a composed sampleper 6 ha. Each composed sample has to be made up by 25 subsamples. This research settled a methodology of soil sampling with purpose of fertility in the Venezuelan savannas.

Keywords: spatial variability, macronutrients, micronutrients, soil methodology
Effects of soil types and variable-rate irrigation on maize yield variability

NICOLLAUD Bernard, BOURENNANE Hocine, COUTURIER Alain and KING Dominique

Unité de Science du Sol-INRA (Orléans), BP 20619, Ardon 45166, Olivet Cedex, France

Farmers have known for a long time that yield crops vary within fields. Quantitative methods of measuring yield confirm these observations. Generally the yield variations are handle in terms of applications of fertilizers, irrigation etc. which are applied uniformly over the field. This farming approach might be wasteful if more is applied than can be removed by the crop this could lead to pollution of ground or surface waters. Thus, ideally fertilizers, irrigation etc. should be applied in a way that takes account of the local requirements of the crop. With the increase in the need of a sustained environment, more attention is given to trying to manage the variations in yield by varying the inputs accordingly. As one form of management, we considered agronomic practices and soil types.

Our main purpose in this study was to assess the effects of soil types and precision irrigation on the yield variation of maize.

To examine the purpose above, a field of 55 ha in the southwest of Paris was surveyed. Two main soil types were determined according to FAO classification: Haplic Calcisols and Rendzic Leptosols, which have high and low available water capacity respectively. The maize was sown in April 2000 and differential irrigation management corresponding to 60, 90, 150 and 180 mm ha$^{-1}$ was performed for each soil type. The maize yields were determined using the Proserie-system from RDS technology.

The effects of soil types and precision irrigation on the yield variations were assessed using ANOVA analysis. The results showed significant effects of soil type on the variation of maize yield. Moreover, differential irrigation management allows sparing of water (about 80 mm ha$^{-1}$) for the deep soils without decrease of yields.

Keywords: precision irrigation, soil types, yields variability, Anova analysis
Application of logistic-regression and classification trees to prediction of soil classes at a regional scale

DUNBAR Marian S. and ODEH Inakwu O.A.

Australian Cotton CRC, Dept. of Agricultural Chemistry & Soil Science, The University of Sydney, Australia

Soil classes, created by the so-called natural classification systems, are as a result of five factors of soil formation, namely- climate, lithology, organisms, parent materials and time, jointly termed CLORPT. The CLORPT are generally well described by surrogate or ancillary variables which can be remotely observed. As the soil classes are factor variables generally coded in a nominal alphanumeric format, it is illogical to apply classical regression methods to predicting them from the ancillary variables. In order to take advantage of the readily available ancillary variables, new quantitative methods of rapidly predicting soil classes would enhance the quality of soil survey maps. Logistic regression and classification trees are such methods which are based on a logical sequence of decisions. While logistic regression is designed specifically for situations in which dichotomous dependant variables are used as the predictants, classification trees are used to predict classes at unknown locations through a series of rules formulated from ancillary data at known locations.

The aim of this study is to use a variety of ancillary information in association with the two methods- logistic regression and regression trees, to predict the soil classes (created with the Australian Soil Classification or ASC) at a regional extent. The study region, located in northern NSW, Australia, has a diverse geomorphology and geology. Consequently, a wide range of soil classes exists. Different combinations of ancillary variables, generated either by remote sensing or DEM, were used to compare the performance of the two prediction methods. The results display soil class maps which show spatial continuity of the soil class (mapping) units that are well contiguous with each other. The methods could be used to rapidly classify and predict the soil types in areas with similar patterns of soilscape.

Keywords: soil classes, soil classification, logistic regression, regression trees, soil mapping, remote sensing.
Spatial variability of soil horizons thickness in natural forested landscapes of Northern Europe

SIDOROVA Valeria (1), KRASILNIKOV Pavel (2) and SOLOMATOVA Elena (1)

(1) Institute of Biology, Karelian Research Center of the Russian Academy of Sciences 11, Pushkinskaya str., Petrozavodsk 185610, Russia
(2) Departamento de Ecologia y Recursos Naturales, Facultad de Ciencias, Universidad Nacional Autonoma de Mexico, D.F. 04510, Mexico

For a successful soil survey we need to know the spatial distribution and variability of soil horizons. The aim of the work was to estimate soil horizons thickness variability in natural forested landscapes of Northern Europe.

The studies were carried out in Middle Karelia: plot 1 – island Klimetskiy, plot 2 – region of settlement Gomselga and plot 3 – near the Kask Lake. The first plot was an old-age bilberry-spruce forest. The age of the spruce stand was about 100 years. In the past, the whole territory of plot 2 and 3 was covered with spruce forests, which were almost totally cut. The eldest clear-cut areas (the 1930s and 1940s) are now replaced by secondary forests. Plot 1 is dominated by Umbric Entic and Rustic Podzols with some Gleysols, Reptosols and Eutric Histosols. Plot 2 is dominated by Umbric, Rustic and Carbic Podzols with a significant area covered by Fibric and Dystric Histosols. Plot 3 is absolutely dominated by Rustic Podzols and Fibric Histosols.

The spatial variability of different soil horizon thickness was estimated. We used the data of soil survey on the territory about of 15-20 km². At each sampling point we recorded the thickness of forest floor (O), humified (A), albic (E) and illuvial (B) horizons. About 15 measurements were made at each plot.

There was no dependence between variables of interest and location of sampling point. The coefficients of linear regression were of no significance. We applied the geostatistical method of the determination of characteristic variance as depending on the distance among sampling points. We used a standard computing formula for estimating the semivariance at a given lag. We used lag h equalled 50 m. On the basis of the data obtained, the variograms were constructed.

Forest floor is the most heterogeneous horizon, and its variability is depends on the forest type (natural or disturbed forests). In natural forest (plot 1), the variogram for forest floor thickness was described by exponential function. In disturbed forests (plot 2 and 3), the shape of model variogram is more complicated, and the model of the best fit is a wave model. The wavelength was about 150-300 m. This complicated form of the variogram is connected with the following. On plots the sites of different remoteness of clearing are presented, so great scatter of forest floor thickness on different stages of ecosystem development after the cleaning.

For A and E horizons, the overall shape of model variograms was properly described by exponential model. All variogram ranges were about 250-450 m for horizon A and 1,000-1,400 m for horizon E.

For B horizons, variations give the variograms reflecting almost 100% nugget-effect. The sill approximately equalled the total sample variance. So, B horizon is more homogeneous.

Keywords: spatial variability, soil horizon thickness, variograms
Spatio-temporal variability of red soil fertility in low hill region

SUN Bo and ZHAO Qi-guo

Institute of Soil Science, Chinese Academy of Sciences, P.O. Box 821, No. 71 East Beijing Road, Nanjing 210008, P.R. China

Studies of the evaluation of the effects of land use alteration on the spatial variability of soil properties have been limited. Research to address the spatio-temporal variability for properties of soil fertility was conducted with geostatistical methods in slow hill regions in subtropical China. Soil samples from 0 to 15 cm depth were collected from 105 locations on a 100 by 100 m grid within a 112 ha field in 1985 and 1997 respectively. A significant decrease of soil organic matter was detected in the conditions keeping the original land use patterns of wasteland and paddy field, while other properties showed non-significant changes. With the alteration of wasteland, the fertilization in upland increased soil available P and K, whereas the opposite appeared in a forest restoration system. Changing wasteland into paddy field has a tendency to increase soil fertility. Geostatistical analysis revealed that 4 properties of soil fertility were spatially structured. The nugget-to-sill ratio showed a strong spatial dependence for soil pH, and a moderate spatial dependence for other properties. The ranges for soil properties sampled in 1985 were roughly equal or larger than the diameter of the hills which has a mean value of 470 m. Changing the land use patterns decreased the ranges for soil chemical properties. The ranges for soil pH and available K were about the radius of hills which is usually the length of sloping upland. The differences of soil properties between two sampling times exhibited also a spatial structure, which were consistent with the properties in 1997. The contour map by kriging showed, to a certain extent, a spatial similarity among the estimated values for soil properties in two sampling times. The higher estimate for soil properties sampled in 1985 were observed in the area of paddy field, while the higher estimate occurred in an upland area changed from previous waste land for most properties sampled in 1997.

Keywords: geostatistics, spatio-temporal variability, soil fertility, hill region, subtropical China
Saturation, reduction and redox morphology of paddy soils in different landforms of Guilan Province, Northern Iran

TORABI H. (1), EGHBAL M.K. (2) and KALBASI M. (2)

(1) College of Agric. Ramsar, Shahed Univ. of Iran. Or Rice Research Institute of Iran, Rasht, 41638/1658, Iran
(2) College of Agric. Isfahan Univ. of Technology, Iran

Rice is the most important agricultural product in Gilan Province of Northern Iran. Nutrient availability in wetland soils is influenced by redox potential. This study was conducted in the Langroud area, which is located in eastern Gilan Province. Changes in redox potential were studied for one year in four rice paddy fields, located on mountainous, basin, marshy, and coastal regions. The Eh values were measured with permanently installed platinum electrodes and a voltmeter at 25, 50, 100 cm depths, but redox potential for the depths of <5 cm and 10-15 cm were recorded by hand electrode. Redoximorphic features were evaluated by both measurements of redox potential and reaction to α, α’-dipyridyl dye. Soils on the mountains (Aeric Epiaqualfs) are submerged by irrigation water during the growing period and may be saturated for 1 to 2 months during the year by rain water. In these soils the reduced layer extended to the base of the topsoil layer. The soils in the basins and seashores (Aeric Epiaquepts) have two reduced layers, one at the base of tillage layer and the other within the depth of 75-100 cm. Excluding the growing period, the surface of these soils are saturated for about 2 to 4 months during the year. The soils in the marshy areas (Fluvaquentic Endoaquolls) were permanently saturated and thus had a reducing condition all year round. Towards the end of the growing period, the Eh showed variation, but lower values for all soils studied in different landforms. Eh variations in different landforms could be related to redoximorphic features of the soils being developed under the influence of ponded water at soil surface and fluctuations of the water table. During the growing period the lowest Eh values were recorded for the months of June and July. During these months the recorded Eh values were +170, +100, +30, -100, and +60 mV in mountainous soils; +110, +80, -50, 0, and -120 mV in basin’s soils; +50, +30, -180, -210, and -130 mV in marsh’s soils; +105, +65, -50, +96, and +5 mV in seashore’s soils for 5, 10, 25, 50, and 100 cm depths, respectively.

Keywords: redox potential, paddy soils, redoximorphic features, aquic, guilan
Spatial variability of soil particle size distribution in Poland

USOWICZ Lukasz Bernard (1) and USOWICZ Boguslaw (2)

(1) Institute of Physics, University of Marie Curie-Sklodowska pl. Marii Curie-Sklodowskiej 1, 20-031 Lublin, Poland
(2) Institute of Agrophysics, Polish Academy of Sciences ul. Doswiadczalna 4, P.O. BOX 201, 20-290 Lublin 27, Poland

Evaluation of soil spatial variability is an important issue in agrophysics and environmental research. Studies of spatial variability enable a better understanding of the physical processes that take place in the soil and their result can be useful in the elaboration of the best methods for the control of thermal-water-air relationships in the plant environment and for the prevention of land degradation. The knowledge of the spatial variability which is one of the fundamental soil physical properties, is of special importance for the modelling of energy and mass transportation processes.

The aims of the present study were to:
• recognise soil particle size distribution patterns in the territory of Poland and the features of its spatial variability,
• use semivariograms and fractal analysis to characterise and compare the spatial variability of soil particle distribution in three soil horizons (A, B, C).

Data collected on particle size distribution of the mineral soil representative for the territory of Poland, was used to describe its spatial variability by using geostatistic techniques and fractal theory. Based on data calculated for some points over the whole area and for selected directions, values of semivariance were determined. The slope of the regression line of log semivariance versus log distance was used to estimate a fractal dimension (D).

All variables studied, i.e. clay, silt and sand fractions, were space dependent. The range of spatial dependence for coarse and fine-textured soils decreased with depth. For medium-textured soils, the range of spatial dependence was higher in the B horizon than in the A and C horizons. Variogram surfaces showed anisotropy of all particle size fractions with a trend in the W to E directions.

Fractal analysis indicated the dominance of a short or long-range directional variation in the soil particle fractions for all three horizons. The smallest fractal dimensions were obtained for medium-textured soils, with intermediate values for coarse-textured soils and the highest values for fine-textured soils.

Keywords: spatial variability, particle size distribution, semivariogram, fractal dimension, Polish soils

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Spatial variability of nutrients in successive years

VIEIRA Sidney R. (1), PAZ-GONZÁLEZ Antonio (2), DECHEN Sonia C.F. (1) and DE MARIA Isabella C. (1)

(1) Instituto Agronômico, Caixa Postal 28. 13001-970, Campinas (SP), Brazil
(2) Facultad de Ciencias, Campus A Zapateira s/n 15071, Coruña, Spain

The objective of this study was to examine the changes in spatial variation in soil fertility on an acid soil of the subtropical area in Sao Paulo State, Brazil. A case study of soil chemical properties (pH, organic matter content, Ca, Mg, K, Al, CEC and Base Saturation (V)) in a field (160 m x 120 m) is used to explore sampling issues. Soil samples were taken, first, in a recently tilled soil, just after the land had been abandoned, and later on in the same soil managed according to minimum tillage practices for successive years. A regular sampling grid scheme (20 m x 20 m) with 63 sites was used to identify the magnitude and scale of spatial variation of selected nutrients and soil properties. Data sets were collected from two depths within this single field and for three different times, 1985, 1987 and 1988 in a long-term experience. The statistical results indicate that, the initial soil condition was found to be more diverse, providing evidence that in the studied Ferralsol, clearing and long-term cultivation tend to increase soil heterogeneity at both studied depths. Experimental variograms of individual variables were computed and modelled by a nugget component plus a spherical structure. The nugget effects were important, generally higher than 50% for most of the studied variables, in the first sampling date and tended to decrease in successive sampling dates. Thus, the effect of agricultural soil use was to improve the continuity of the studied attributes at close distances. The autocorrelation ranges for most of the studied soil properties varied between 40 and 80 m. Semivariograms provided a description of nutrients spatial structure and some insight into possible processes affecting their distribution. Kriging maps allowed the identification of small regions with distinct nutrient concentrations and illustrate the diversity of the soil nutrient status in the different sample dates. In addition, bivariate geostatistical methods, cokriging and colocated cokriging using elevation as ancillary information, were tested. The prediction performance of the various geostatistical techniques was evaluated, as different techniques produced a different error of interpolation.

Keywords: Ferralsols, geostatistics, mapping, spatial variability, time diversity
Temporal dynamics of soil quality indicators spatial patterns at the field scale

ROMANENKOV Vladimir (1) and VIEN Duong M. (2)

(1) All-Russian Institute for Fertilizers and Agricultural Soil Science named after Pryanishnikov (VIUA), ul. Pryanishnikova, 31 127550 Moscow, Russia
(2) Kantkho University, Vietnam

Geostatistical methods were used for estimating main temporal trends in spatial changes of agrochemical soil properties at a field scale based on landscape experiment representing 22 ha field plot size (the Moscow Region). Spatial patterns were the most sustainable over time for organic carbon, available P, and to a less extent, for available K. Comparison of standardized semi-variograms before and after crop rotation is a suitable method to study the similarity of patterns. Sustainability of spatial patterns of available P was estimated based on the estimation errors of the contour maps after the rotation based on the variogram models for available P before and after rotation. Block kriging was carried out with original 120 data points (randomly chosen among 563 points on a 20 x 20 grid). A comparison of the two maps shows that application of 1991 variogram for kriging interpolation with 1996 original data provides a similar pattern with non-significant relative increase of block kriging variance based on the tolerable error of the original contour map (with original 1996 variogram) at P = 0.05. The difference between the two maps was connected with local accumulation or depletion of the available P along the direction of intensive temporal surface water flows in the catchments, pronounced during snowmelting and rainshowers.

Acid-base patterns (exchangeable bases and pH) were very dynamic during the rotation revealing reproduction of soil acidity on preliminary limed soils. For pH and exchangeable bases estimation errors plotted against different numbers of observations decrease steeply from 40 to 70 sample points and then gently. Temporal variability of spatial patterns of exchangeable cations was connected mainly with redistribution of Ca along the main direction of field slope. This was revealed based on a linear model of sample variogram, as well as on the contour map of the exchangeable Ca after elimination the effect of heterogeneity of soil fertility, with distinct patches stretched along the main slope where lateral redistribution of Ca (about 2-3 cmol$_c$ kg$^{-1}$ during the rotation) was the most intensive. Manifestation of natural translocation processes was evident even after the long-term cultivation based on geostatistical approach.

Keywords: geostatistics, spatial variability, temporal variability, field level, data processing, soil fertility
Towards a quantitative assessment of soil organic carbon using proximally sensed digital imagery

VISCARRA ROSSEL Raphael A. (1,2) and WALTER Christian (2)

(1) ACPA, Department of Agricultural Chemistry & Soil Science, McMillan Building A05, University of Sydney, NWS 2006, Australia
(2) INRA Laboratoire de Science du Sol, 65 rue de St Brieuc, 35042 Rennes, France

Various soil properties exhibit spectral response in the visible range of the electromagnetic spectrum and these properties have been shown to have good correlations with measurements of soil colour, e.g. soil organic carbon (SOC). The main objectives of this work were to establish relationships between soil colour and SOC and to determine whether measurements of soil colour could be used to predict the SOC content in agricultural soil. Soil colour was determined using different systems for representing colour space: qualitatively using the Munsell Soil Colour Charts and quantitatively using RGB (red, green, blue) tristimulus values from soil images acquired using a digital camera. The RGB values were converted to CIE XYZ tristimulus and their resulting CIEL*a*b* (CIELAB) and CIEL°u°v (CIELUV) transforms. To establish relationships between SOC and soil colour, forty-three different soils were collected from various locations across Brittany, France. Visual measurements of Munsell soil colour and digital images of these soil samples were acquired in the laboratory under ‘ideal’ lighting conditions. The soil was also analysed for SOC using conventional laboratory analysis. Statistical relationships between Munsell value units, RGB image-intensities, CIEL*a*b* and CIEL°u°v coordinates and SOC were derived for predictions of SOC content of field soil. Field soil was sampled from two different fields with different levels of SOC and transported to the laboratory for image acquisition and SOC analysis. Predictions were validated against chemical analyses and statistics that relate the accuracy of predictions to their precision and bias were used to quantify their quality. Quantitative soil colour measurements using either RGB image-intensity values or CIELAB / CIELUV colour coordinates showed good response for SOC. Using an appropriate calibration model, accurate predictions of field SOC are possible. It appears that the CIELAB system may be more appropriate for predictions of SOC in Brittany soils, be it using either the L or the b coordinates, depending on the inherent characteristics of the soil and its range in SOC content.

Keywords: soil organic carbon, soil color, digital images
Spatial variability of soil water and inorganic nitrogen at the different scales

ZIZHONG Li and YUANSHI Gong

Department of Soil and Water Sciences, China Agricultural University, Beijing 100094, P.R. China

This paper was about spatial variability of soil water and inorganic nitrogen at the different scales. Nine hundred soil samples were collected from summer maize field and analyzed. Spatial variability of soil water and inorganic nitrogen at the different scales 10 m x 10 m, 30 m x 30 m, 90 m x 90 m in summer maize field were mainly studied using traditional statistics and geostatistics. The results showed that semi-variograms of soil properties were described by sphere model or pure nugget effect model. Spatial structures of selected soil properties showed anisotropy and nested structure at the different scales. Range values of semi-variograms increased with scale increasing. Nested models of each soil property had high fitting precision. Soil water content and water-storage capacity could be estimated finely using kriging estimator and nested models. But it was poor to estimate soil nitrate content, ammonium content and inorganic nitrogen content using such a method.

Keywords: different scales, soil water, soil inorganic nitrogen, spatial variability, geostatistics
Symposium 49

Paleosols as a memory for understanding landscape history and environmental problems

Convenor: BRONGER Arnt
Co-Convenor: KANYAWONGHA Pornthiwa

Oral Session
Thursday 15 August 2002
8:30 - 11:50
Room: Meeting Room 4

Poster Session
Thursday 15 August 2002
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Symposium no. 49  
PAPER no. 2165  
Presentation: poster

Botanical and soil survey of kurgans  
(Great Hungarian Plain, Hungary)

BARCZI Attila and JOO Katalin  
Department of Landscape Ecology, Szent István University, H-2103 Gödöllő, Páter K. u. 1, Hungary

Basically the Great Hungarian Plain which is part of the Carpathian basin has a mosaic-like structure, and is rich in living areas because of its hydrographical conditions. The isolated hillocks called “kunhalom” (it means: Cumanian hillock, kurgan) by Hungarian people belong to the landscape of the Great Hungarian Plain. The values of kurgans in soil science can be understood when you think about the task of the soil. The functions are well-reconcilable with the possible kurgans researches so we can get useful information for the soil-formation, and the properties of the buried soil layers with the investigation kurgans in soil science.

Based on the assumptions above we begun the soil investigation of kurgans. Along a N-S directed line across the Plain four specific hillocks were chosen and the soil exploration was started on the botanically most intact one. After surveying the kurgan and it’s environment on a 100 x 100 m field the body of the hill was bored on about 6 m depth for five times. The ditch (ring) enclosing the hillock as well as the characteristic types of soil of the surrounding territory were bored in a 1.60 m depth. The morphological examination of the core samples were made, the boring places positioned, and also the first laboratory examinations were made (pH, CaCO₃, texture, humus, humus quality, AL-soluble phosphates, total salt content, Na, Fe). Relying on these findings the soil layers, the ground levels and the buried soil could be identified. For the description of the genetical processes of the soil as well as for the more precise description of the buried, ancient soil formations, estimated to 3-4000 years old soil formation and for the reconstruction of the former and present soil formations we plan further investigations (paleoecology, mineralogy, humus examinations, chronology).

Salt affected soil was found in the environment of the hillock. The soil formation on the body of the hillock showed quite different traits, and it showed chernozem formation. This is also indicated by vegetation of the kurgan and its surroundings. For comparison also the coenological examinations was made.

The Hungarian heath-plant vegetation of loess is the most western appearance of the continental grass vegetation. In undisturbed state it’s extremely rich in living areas, and a suitable place to get food, for reproduction and rest for the living organisms, and it can be a reservoir area for them at the winter time. On the hillocks, which are in the best condition, we find a relatively weedless loessgrass, but it often has a limited species number. These living areas should play a great part in the biological “green passage system” or the restoring of the original vegetation to the area.

The kurgans in Hungary are under preservational protection from 1996. With further study of the circumstances of their formation, with the reconstruction and exploration of the paleoenvironment new information can be obtained also for the soil genetics of the hillocks, to the preservation of their values.

Keywords: kurgans, biodiversity, soil formation, palaeosoils, loess vegetation
Vetustols and Paleosols: natural versus man-induced environmental change in the Atlantic coastal region of Morocco

BRONGER A. (1) and SEDOV S.N. (2)

(1) Geographisches Institut der Universität Kiel, 24098 Kiel, Germany
(2) Department of Soil Science, Institute of Geology, UNAM, Mexico City, Mexico

The selected surfaces of Terrae Rossae, or Rhodoxeralfs, and a Terra Fusca (Petrocalcic Palexeralf) developed on mid-Quaternary calcarenites in the moister region of Rabat show a substantial degree of pedogenic formation of clay minerals, particularly of kaolinites, primarily in the fraction < 0.2 μm. For the most part, the pedogenic kaolinites show poor crystallinity of the fireclay type. The main sources of the pedogenic kaolinites are feldspars, probably also amphiboles and pyroxenes in the fractions > 2 μm, and smectites inherited from the calcarenite-residual loam in the coarse (2-0.2 μm) and fine clay fractions (< 0.2 μm). One Terra Rossa shows clear evidence that the soil formation was interrupted twice by deposition of eolian materials, hence it is regarded as a polycyclic pedocomplex. Eolian input was only of secondary importance during the pedogenesis of the other surface Terrae Rossae. On younger calcarenites (100 ka) near the coast, three Rendzinas, or Typic Calcixerolls, show only slight mineral weathering and pedogenic clay mineral formation, in spite of a varied spectrum of primary minerals. In one example kaolinites formation had just started. Probably the Calcixerolls were recalcified by the addition of eolian material either as a result of anthropogenous thinning of the vegetation and/or due to the vicinity to the coast. These results strongly suggest that, at least in this region, Terrae Rossae, or Rhodoxeralfs, were formed during much of the Brunhes epoch in a younger coastal area and over the greatest part of the Brunhes epoch in areas farther from the coast. Because the climatic fluctuation in the cycles of cold and warm periods were generally slight in this region, the direction of soil formation was the same. Therefore we regard the Rhodoxeralfs in the northern part of our study area as Vetustols, in accordance with the concept of M. Cremaschi (1987). According to our expanded definition, Vetustols are surface soils which underwent the same or very similar processes of soil formation under a similar or almost similar constellation of soil-forming factors, especially climate and with it vegetation, over a long period of time, including at least some part of the Pleistocene. Consequently today’s patchy distribution of Terrae Rossae is hardly a result of climatically induced periods of “geomorphological activity and stability,” but the result of the removal of earlier dense forest cover, followed by severe soil erosion. The human impact on the ecosystem is much more serious than climatic fluctuations. In the southwestern part of the study area, between El Jadida and Agadir, the soil moisture regime is dry xeric to aridic and Terrae Rossae occur only in small areas, mostly in depressions. However, two selected Rhodoxeralfs in the vicinity of Tamanar show substantial rates of pedogenic mineral weathering and clay mineral formation, though hardly any kaolinites. The strong weathering, including the process of clay illuviation, must have been preceded by decalcification, implying a distinctly moister climate here in the past. However, micromorphological features of recent recalcification are common in these Rhodoxeralfs, suggesting that they are not in equilibrium with the present climate and must therefore be regarded as nonburied paleosols or relict soils.

Keywords: Vetustols, Paleosols, micromorphology, clay mineralogy, landscape development
Physical, geochemical and mineralogical indicators of aging in quaternary soils of Central Italy

COSTANTINI Edoardo A.C. (1), ANGELONE Massimo (2) and DAMIANI Damiano (3)

(1) Experimental Institute for Soil Study and Conservation, P.za M. D'Azeglio, 30, 50121 Firenze, Italy
(2) ENEA, Tein-Chim, C.R.Casaccia, C.P.2400, 00100 Roma A.D., Italy
(3) Earth Sciences Department, University of Siena, Laterino, Siena, Italy

In this paper, a set of physical, geochemical and mineralogical indicators are proposed for the correlation of soil age. The parameters studied allowed the highlighting of trends in soil aging as well as the relating of these trends to specific soil forming processes. Soil aging was marked by a progressive increase in clay content and a decrease in the silt/clay ratio, a slight reduction in the CEC of clay and a striking increase in free iron content. Clay mineralogy transformation over time was marked by a progressive increase in kaolinite and vermiculite, as well as a decrease in illite and chlorite. The most outstanding pedological processes, i.e. crystalline free iron content increase, clay neo-genesis and illuviation, glossic horizon and fragipan formation, were all found to be related to kaolinite content. Element content, namely that of Fe, Cr, Pb, Zn, Ti and K increased from the Holocene to the Upper and Middle Pleistocene soil horizons and as far as Fe, Cr, Pb and Zn are concerned, up to those attributed to the Lower Pleistocene. Al and Ca content decreased along with time, especially in soils older than Holocene. The trends of silt/clay ratio, CEC of clay and free iron were linear, that is not influenced by changes of weathering conditions during Pleistocene, while vermiculite and kaolinite content, total iron, chromium and lead distinguished the stronger weathering environment occurring during Lower Pleistocene in Southern Europe. The tendencies of the remaining indicators revealed intermediate phases of mineral transformation or were influenced by rather fast processes. Besides soil age, the indicators resulted as being affected by clay impoverishment, which occurred within eluvial horizons and bleached streaks of fragipan, reducing and oxidizing conditions, and lithological and chronological discontinuities within profiles.

Keywords: soil physics, geochemistry, clay mineralogy, soil aging, Central Italy
Application of paleopedological research method for Holocene soils in study of archaeological relict (of the Siberian monuments)

DEMIDENKO Galina A.

Institute of Forest, Krasnoyarsk, Russia

Paleosoil - as a natural body - keeps many initial features of genesis. Paleopedological studies allow for the recovery of voluminous material, which can be used for solving paleogeographical problems in the analysis of the Holocene environment. Each of the time periods of the Holocene is characterized by soil cover succession.

The pre-boreal Holocene period: the soil cover succession beginning with the non-differentiated soils, cryogenic, tundra-ever frozen, gley and podzol gley soils in the Priangarie plateau to the soddy-taiga and podzol-ever frozen soils of the Chulym-Balakhta depression is possible.

The boreal Holocene period: within the present taiga the podzolic soils were formed, within subtaiga-forest steppe - different kinds of podzolized soils and further south - the grey forest, soddy-forest and Chernozem-like soils.

The Atlantic Holocene period: in the first half of the period the soil cover geography has changed from the soddy-forest, soddy-podzolic, soddy-gley northern areas to the soddy-forest, grey forest and Chernozem-like soils of the southern areas. The second half in the latitudinal extend is characterized by alternation of the soddy-forest, soddy-gley, meadow- Chernozem soils within the southern taiga by the chernozem-like (enleached, carbonated and ordinary Chernozems) and chestnut's soils of the steppe landscapes.

The subboreal Holocene period: the soil forming in the Priangarie plateau region resulted in the formation of soddy-forest, grey-podzolized, soddy-gley soils. Soil cover of the Chulym-Balakhta hollow was presented by the grey forest, soddy-forest, meadow-forest, meadow- chernozem and chernozem-like soils.

The Subatlantic period reflects the present soil cover development.

Keywords: evolution, paleosoil, Holocene
Paleosols and new approaches to paleoenvironment reconstruction

DERGACHEVA Maria

Institute of Soil Science and Agrochemistry, Sovetskaya st., 18, Novosibirsk, 630099, Russia

Nowadays the approaches to paleopedology objects learning are based on adoption from contiguous sciences: pedology, stratigraphy, and litology etc. The principles of interpretation have been carried out for Holocene, Pleistocene or Pliocene objects separately. Complexity of information extracting and its interpretation turned out to be more difficult and less understandable from Pre-Quaternary surface Paleosols to Pliocene and more ancient ones in connection with the decreasing of paleosols profile preservation degree. At the same time the approaches to the studying of paleopedology objects of any age and preservation and methods of their investigation should be common for all objects for the research data to be comparable.

That's why we have suggested a new method of paleopedogenesis and paleoenvironment diagnostics. The pedohumic method based on pedogenetic and geochemical properties of humus was theoretically grounded and tested on Pliocene–Holocene objects of Siberia, Eastern Europe, Mongolia and Kazakhstan. It allows us to diagnose the environment from Pliocene to Holocene on pedogenic features associated with humus using any paleopedology objects from the full well-preserved profile to pedosediments and pedorelicts. Its essence is based on the fact that humus possesses sensority and reflectority features in relation to the environment, and therefore it reflects and codes ecological conditions of its formation period and preserves them in diagenesis.

The following theoretical and experimental statements allow us to use the characteristics of humus for the diagnosis of Paleosols and paleoenvironment:

- the composition of humus substances and the structure of humic acids of modern soils reflect the climatic (thermodynamic) conditions during the time of their formation;
- the humic acids and fulvic acids are a single system in soils; the former as the accumulative component are in that place where they have been formed; the latter become incorporated into the complexes together with the humic acids and partially migrate deep into the pack of soil; the amount of fulvic acids, which can be bound by the humic acids into complexes, depends on their composition and the structure; in various bioclimatic conditions the system of humus substances displayed different composition and consequently it may serve as an indicator of the conditions under which both modern and ancient soils had been formed;
- this interaction is preserved through time, and the composition of humic acids in a paleosols corresponds to the natural conditions under which the macromolecules of humic acids, the same as the complexes of humic acids with the fulvic acids were formed.

Thus all the above mentioned statements allow us to consider humus as an indicator of features of paleoenvironment specific to any particular period.

New reconstruction of some Eurasian regions paleoenvironment will be presented in paper as an example.

Keywords: Paleosols, humus composition, humic acids, reconstruction of environment
According to geological and geomorphological data the volcanic Mátra Hills (1,014 m amsl) has been rising on the northern margin of the Pannonian Basin from the beginnings of the Quaternary. During this period the climate has been characterized alternately by cold, cool, dry and relatively warmer and wetter conditions.

Due to these factors various sedimentary environments, including soil formation, have developed on the pediment of the Mátra Hills.

The open cast lignite mine of the Mátra Power Station offers a good opportunity to study the past environmental changes in 3D. Observations are the following:

1. Paleotopography with 1-30 m deep valleys and hills identified within the area of the lignite mine;
2. Different sedimentary facies following each other from bottom to top:
   - late Pannonian lignite bearing alluvial (meandering river and flood plain) facies; including hydromorphic paleosoils
   - the proposed Quaternary soil-sedimentary complex including coarse, pedorelict bearing conglomerate which fills the bottom of the paleovalleys;
   - red clays redeposited and also subject to pedogenesis;
   - repeated intercalations of alluvial sediments with abundant evidence of soil erosion (such as debris of former red Paleosols, stratified layers of CaCO₃ concretions)
3. Mixture of pottery fragments of the Bronze- and Neolithic Ages in an unsorted layer which suggest occasional intense events of erosion and sedimentation
4. Frost features and soft sediment deformation in both paleo- and recent soils of the studied area.

We present field and laboratory evidence in support of the Pleistocene age of the emplacement of the red Paleosols in the Mátra Pediment.

**Keywords:** Quaternary, Paleosols, erosion, sedimentation, secondary CaCO₃
Loess-like deposits at Blayney, South-eastern Australia

HUMPHREYS Geoff S. (1), HESSE Paul P. (1), PETERSON Elizabeth K. (1,2), CAMPBELL James (1) and CONAGHAN Patrick J. (3)

(1) Dept. Physical Geography, Macquarie University, Sydney, Australia
(2) Presently: NSW Dept Land and Water Conservation, Parramatta, Australia
(3) Dept. Earth & Planetary Sciences, Macquarie University, Sydney, Australia

Loessic mantles are reported for the first time from Australia. Three sites, with known or suspected dust accumulations, were examined in detail near Blayney, which is positioned within a major south-easterly dust trajectory that extends from the centre of the Australian continent across the Tasman Sea to New Zealand and beyond. Particle sizing, using a Sedigraph-5100, shows that the mantles are dominated by silt with 40-60% of the <2 mm fraction between 10-50 μm with a mode mostly between 25-30 μm and clay content of mostly 15-25% and sometimes to >35%. XRD, XRF and petrological examinations indicate that this silt fraction is dominated by rounded to sub-rounded quartz with minor traces of rounded heavy minerals such as zircon and the <2 μm fraction is mostly quartz, kaolin and illite/mica. In none of the studied materials has silt or sand sized clay pellets been unequivocally recognised. Compositionally and texturally these mantles are quite distinct from underlying saprolites derived from basalt or phyllite. Nevertheless, the silty mantles are very similar to classic loess deposits especially those from Europe and North America, though calcite is absent. However, in comparison to other loess areas the mantles are relatively thin and do not contain multiple Paleosols. The thickest mantle, up to 3.65 m thick and with a date of 40 ka at 1.35 m, is positioned on the leeward side of a broad saddle where preservation potential is possibly enhanced especially as the lower 2 m consists of an indurated pan complex. In contrast the thinnest mantle, comprising a topsoil of 24 cm, occurs on a narrow ridge crest. The comparative thinness of the dust mantles may relate to a limited supply and/or to post-depositional erosion. Furthermore, the 40 ka OSL date also establishes that the major dust deposition began prior to the LGM, which is contrary to the common expectation that dust deposits date from the LGM.

Keywords: dust, micropedology, relict Paleosols, pedogenesis, Quaternary
Pedogenetic processes in loess sediments in Serbia and Milankovich's astronomic theory

PROTIC N.J. (1) and KOSTIC N.M. (2)

(1) Institute of soil science, Belgrade, FR Yugoslavia
(2) Faculty of Agriculture, Zemun, FR Yugoslavia

This paper deals with the relation of pedological parameters obtained by the analysis of several loess profiles in Serbia with the values of solar radiation received on Earth for the period of 600,000 years according Milankovich. The cyclic nature of sedimentological and pedogenetic processes in loess profiles was studied by the analysis of CaCO₃ content, particle-size composition and mineralogical analysis of silt and clay fractions.

The sequential analysis of data was conducted by Fourier's method and spectral analysis. This resulted in several data and curves, as a frame for the explanation of the relationship of pedogenetic processes and Milankovich's cycles. In the second method, the parameters of spectral analysis were reduced to the length of measured values of the Milankovich age (600 ka), which approximately corresponds to the length of the oldest soil formations in the loess profile of Batajnica, ~583 ka. This resulted in several data and curves, as a frame for the explanation of the relationship of pedogenetic processes and Milankovich's cycles.

Keywords: pedological parameters, solar radiation received on Earth, Milankovich, sequential analysis, spectral analysis, astronomic parameters
Pleistocene periglacial slope deposits influenced by geology and relief in the Rhenish Massif, Germany

SAUER Daniela (1), SCHOLTEN Thomas (1), SPIES Ernst-Dieter (2) and FELIX-HENNINGSEN Peter (1)

(1) Institute of soil science, University of Giessen, Heinrich-Buff-Ring 26-32, D-35392 Giessen, Germany
(2) Geological survey of Rheinland-Pfalz, Emy-Roeder-Str. 5, D-55129 Mainz, Germany

The Rhenish Massif like most other mountainous areas in Germany is largely covered by several Pleistocene periglacial slope deposits (PPSD) lying on top of each other. In a soil profile usually two or three layers are found in a vertical sequence. The German soil classification system distinguishes four types of PPSD:

• The basal layer (BL) lies immediately on top of the bedrock in almost every relief position. It consists of debris of the underlying rock and is free of loess. Its thickness varies in a wide range.
• The intermediate layer (IL) is rich in loess and only occurs in positions which favour loess accumulation and preservation. Its position is usually on top of the BL.
• The upper layer (UL) contains rock debris and loess. Where it has not been eroded, it covers the land surface with a thickness of about 50 ± 20 cm in all relief positions.
• The top layer (TL) covers only small areas in higher regions (mostly >700 – 800 m a.s.l.). It is predominantly composed of rock debris which lies on top of the UL.

In the mountainous areas in Germany the PPSD are of particular importance, because many soil characteristics, e.g. stone content, texture, field capacity, soil depth and rootability, are rather given by the properties of the PPSD than by soil formation. The pedogenic processes only modify these properties. Therefore, investigations on the distribution patterns and properties of the slope deposits were carried out in three different parts of the Rhenish Massif - the Eifel, Hunsrück and Westerwald areas. We found out that along the slope the soil depth increased from top to bottom, and that the main reason for this was the increase of the thickness of the BL. An IL occurred at most slopes with exposition NE to SE from the lower middle slope downwards which additionally increased the soil depth. At slopes with other expositions the IL was found less often. The increase of soil thickness downslope often was also supported by holocene erosion and accumulation due to former deforestation and agricultural use. One of the ecologically most important properties of the UL and IL is their loess content which was identified by heavy mineral composition, particle size distribution and trace element content. The stone content is extremely high in the BL and also high in the UL. In the IL it is distinctly lower. The BL is often very dense so that the rooting decreases abruptly in the upper centimeters of the BL and the water turns from vertical infiltration to lateral flow within the LB. This water path is of great importance for the water fluxes in many mountainous regions in Germany on the landscape scale.

Keywords: Pleistocene periglacial slope deposits, periglacial layers, Rhenish Massif
Relict soils as paleoclimatic indicators: examples from the Austrian Alps and the Central Andes

VEIT Heinz

University of Bern, Geographical Institute, Hallerstr. 12, CH-3012 Bern, Switzerland

Two examples of widespread relict soils in high mountains of different climatic environments are presented. In the European Alps above the timberline, Podzols are typical soils on silicatic rocks. The Podzols seem to be relicts of an Early Holocene climatic optimum, when the slopes of the alpine and lower subnival ecotone had been stabilized by high reaching alpine meadows, probably for a period of several thousand years. From 5000-6000 $^{14}$C y BP on, the Podzols were partly fossilized by solifluction lobes. Due to intensified periglacial processes as a consequence of climate change, the formation of Podzols has not been possible at these altitudes during the Upper Holocene. But in many places with a dense cover of alpine meadows, the Early Holocene Podzols are preserved until today. A similar situation can be recognized with well developed Cambic Calcaric Regosols on carbonate rocks, also pointing to a climatically more favorable Early Holocene.

In the semiarid and arid Central Andes of Chile and Argentina, relict Luvisols characterize great part of the landscape. On the Altiplano north of 27°S, Luvisols developed under the influence of tropical summer precipitation. South of it, humidity for soil formation is related to the westerlies. According to geomorphological aspects as well as to $^{14}$C- and OSL-dates, the Luvisols in the winter rainfall region were formed during the Upper Pleistocene, prior to 20,000-25,000 $^{14}$C y BP. The Luvisols on the northern Altiplano were formed during the lateglacial period around 15,000 $^{14}$C y BP. This discrepancy in the timing of the humidity maximum between the tropics and ekptropics is well documented in other paleoclimatic archives (e.g. glaciers, lakes) of the Central Andes, too. Due to a more arid climate since the Early Holocene (Altiplano: summer precipitation) or since the Last Glacial Maximum (westerlies: winter precipitation), the relict Luvisols have been severely eroded, which must not be confused with anthropogenically induced soil erosion since the arrival of the Spanish colonizers.

Keywords: Holocene Paleosols, Upper Pleistocene Paleosols, European Alps, Andes, paleoclimate
Symposium 50

Sustainable paddy soil ecosystem: a global challenge

Convenor: CONCEPCION Rogelio N.
Co-Convenor: SAENJAN Patcharee

Oral Session
Saturday 17 August 2002
8:30 - 11:50
Room: Meeting Room 3

Poster Session
Saturday 17 August 2002
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Eh, pH, soluble Fe and Zn, and available P variations in paddy soils of Iran, with and without rice crop

AKHGAR Abdorreza (1) and TOWFIGHI Hassan (2)

(1) Soil Sci. Department, College of Agriculture, Vali-E- Asr Univ. of Rafsanjan, Iran
(2) Soil Sci. Department, College of Agriculture, Tehran University, Iran

This study was conducted to investigate the trend and extent of variations in Eh, pH, iron and zinc concentrations under flooding conditions in two soils under uncultivated and rice-cultivated treatments. Each of soils was a composite paddy soil sample from either of Gilan or Mazandaran provinces. The experiment was performed in a set of specially fabricated cylindrical pots equipped with a perforated sampling tube installed in the root zone area. Soil solution samples were taken in the atmosphere of nitrogen gas and the Eh and pH were measured in the same atmosphere. Each treatment was done with four replicates and the duration of the experiment was two months. In a different experiment, changes in the sodium bicarbonate extractable P during a two months period of flooding were studied in 9 soils, four belong to Mazandaran and five from Gilan paddy soils. The redox potential (Eh) of the soil solutions sampled from the uncultivated soils decreased rapidly with flooding as was expected, but then increased slightly with the progression of time. The lowest values of Eh were 39.6 and 23.9 mv in Mazandaran and Gilan soils respectively. The pH of the soils which was alkaline at the beginning, were decreased gradually to final neutral pH values. The concentration of iron in both soils were increased initially and after a period of two weeks started to decrease gradually to a relatively constant value in the range of 20 to 30 mg kg\(^{-1}\). The concentration of zinc in both soils after a fluctuation in the initial period was decreased gradually but permanently until the end of the experiment. Results from the cultivated treatment indicate that except for the first few weeks, the electrochemical conditions in the root zone of the rice were mainly different from the conditions in the uncultivated soils at the same depth. In the root zone, Eh values were higher, pH values were lower and the concentration of iron was much lower in both soils. However, the concentration of zinc was the same in both treatments. In all nine soils, the sodium bicarbonate extractable P was increased with flooding, the concentration were almost doubled in less than two weeks.

Keywords: paddy soils, available P, soluble Fe and Zn
Methane emission from rice field as influenced by water management practices and nitrogen doses

SINGH Surendra, BHARADWAJ Venkatesh and JAIN M.C.

Department of Soil Science, College of Agriculture, G.B. Pant Univ. of Agri. and Technology Pantnagar (U.S. Nagar-263 145), India

The increased awareness in global climate change in terms of global warming has led to the identification of methane as one of the most important greenhouse gas. Thus a field experiment was conducted in split plot design to assess the effect of water management practices as main treatment and nitrogen doses as sub-treatment on methane emission from rice field growing Pusa-169, variety of rice. The measurements of pH, temperature and redox potential (Eh) were measured at the site under the field condition. Gas samples were collected by the closed chamber technique. Methane concentration in the gas sample was estimated by using a gas chromatography fitted with flame ionization detector (FID). The area under the peak was measured and area of methane peak was used for calculating methane concentration against the pre-calibrated air. The total methane emission over the 84 days of crop were 2.23, 1.99 and 1.82 g in continuous flooding (CF), intermittent irrigation (II) and alternate wetting and drying (AWD) of water management practices, respectively. Growth stages of rice also influenced the methane emission as highest flux (1.31 mg m⁻² h⁻¹) was observed during transplanting to tillering and lowest during heading to maturity (0.70 mg m⁻² h⁻¹). Among the water management practices, the maximum methane flux was recorded under continuous flooding than other water management practices at all growth stages of crop. Whereas, with nitrogen doses, the maximum methane flux was observed with an application of 120 kg N per hectare than other nitrogen doses at all growth stages of crop.

Keywords: methane emission, rice field, water management, nitrogen doses
Methane production and population dynamics of acetoclastic methanogens in relation to atmospheric methane in paddy field

CHAWANAKUL Sansanee (1), CHAIKRASERT Pawinee (2), KERDCHOECHUEN Orapin (2), TOWPRAYOON Srinthorntep (1) and TANTICHAREON Morakot (3)

(1) The Joint Graduate School of Energy and Environment, King Mongkut University of Thonburi, Thailand
(2) School of Bioresources and Technology, King Mongkut University of Thonburi, Thailand
(3) National Center of Genetic Engineering and Biotechnology (BIOTEC), Bangkok, Thailand

Methane productions from rice field are important contributors to increase the atmospheric methane concentrations. The anaerobic conditions after prolonged flooding phase as a result of the active oxygen reduction by methane-producing bacteria in planted paddy field supply to the sufficient nutrients on methanogenesis, accomplish to the acetoclastic methanogens. The methane production in laboratory scale and acetoclastic methanogens in term of the variation in population size using the MPN technique and specific methanogenic activity via serum vial procedure were determined in transplanted rice fields of rice cultivar: Supanburi, Supanburi province, Thailand. Methane productions are greater in planted (1.04 ± 0.27 mg gdw⁻¹ h⁻¹ at rooted zone and 0.72 ± 0.15 mg gdw⁻¹ h⁻¹ at non-rooted zone) than unplanted rice field (0.53 ± 0.04 mg gdw⁻¹ h⁻¹). After transplanting, the methane production is maximal particularly at day 56 (1.07 ± 0.55 ml gdw⁻¹ soil) over the rice-growing season (98 days). The concentration of atmospheric methane emitted shows positively correlated with the production at boosting stage (day 56-70). The changes in methanogenic population size are associated with methane production. However, population sizes of acetoclastic methanogens at day 56 (3.5 x 10⁵ cell gdw⁻¹ soil) are greatest at day 56, the methane production was highest according to the large methanogenic population size but not its specific activity. In addition, the specific methanogenic activity of acetoclastic methanogens at day 35 and day 56 were 1.12 and 0.03 ml methane produced 100 cell⁻¹, respectively. However, a smaller population sizes at day 35 than at day 56 was associated with higher specific methanogenic activity than day 56. These indicate that the size of acetoclastic methanogens population stimulated on the methane production. In addition, the activeness of methanogens possibly, the availability of substrates is likely to be significant factors on methane production in paddy field as well.

Keywords: methane production, rice field, acetoclastic methanogens, methanogenesis, specific methanogenic activity
Stable carbon isotope fractionation during methanogenesis in California paddy field

CHIDTHAISONG Amnat (1), McMILLAN Andrew L. (2) and TYLER Stanley C. (2)

(1) Department of Earth System Science, University of California, Irvine, CA92697, USA
(2) The Joint Graduate School of Energy and Environment, King Mongkut’s University of Technology Thonburi, Bangkok 10140, Thailand

To understand the processes leading to production and emission, and the stable carbon isotopic pattern of CH\textsubscript{4} in paddy fields, the study was carried out during the 1999-growing season in California rice paddy. Effects of straw treatments and planting (incorporation & burning, planted & unplanted) on acetate and CH\textsubscript{4} concentrations and their isotope biogeochemistry are reported. During the early flooding period, straw incorporated plots showed a higher acetate concentration (400-700 μM) than straw-burnt plots (<400 μM). However, when rice plants were well developed and reached the reproductive stage, acetate concentration was not significantly different between these two plots. CH\textsubscript{4} concentration in soil was higher in unplanted than planted plots, especially when straw was incorporated. The isotope ratios of soil organic carbon were not significantly different among plots, falling within the range of -26.4\% to -27.6\%. On the other hand, the average isotope ratios of methyl-C of acetate was -35.3±4.9\%. Variation in the isotope ratios of carboxyl-C of acetate was large, about 10\% over the growing season. The average isotope ratios of the whole molecule of acetate was -32.5±16.4\%. Thus, the δ13C value of the whole acetate molecule falls within the similar range as of organic carbon. Accordingly, only small isotope fractionation occurs during acetogenesis from soil organic carbon. The δ13C of CH\textsubscript{4}, on the other hand, was highly negative (-60\% to -72\%), indicating that there was large isotope fractionation during methanogenesis in paddy fields. With this information, we report the calculation results of the partitioning between methanogenic pathways (acetate fermentation vs CO\textsubscript{2} reduction). We also discussed the steps and the associated isotope fractionation during organic carbon mineralization to CO\textsubscript{2} and CH\textsubscript{4} over rice growing season.

Keywords: stable carbon isotope, acetate, methane, isotope fractionation, methanogenesis, California paddy
A field experiment was conducted during kharif 1996 in the farmers field at Kolar District representing the Eastern Dry Zone of Karnataka to assess the performance of different phosphate fertilizers on acid soils to rice and to know the effect of different organic manures on the release of P from different rock phosphates. The phosphatic fertilizers used were North Carolina rockphosphate and (NCRP) Tunisia rockphosphate (TURP 60 mesh), single superphosphates (SSP), were applied with certain adjuncts like farmyard manure (FYM), citycompost, green leaf manure (OLM) and phosphorus solubilizing fungi (Aspergillus awamori) (PSF). The salient findings of the study indicate a highly significant response was observed in crop yield, available P and improvement in soil P status due to the application of P irrespective of the sources. Water soluble P fertilizer are greatly fixed by the exchangeable iron and aluminum in acid soils and thus crop plants are likely to suffer for want of an adequate supply of available phosphorus in soils.

The performance of North Carolina rockphosphate, Tunisia rockphosphate (60 mesh) and SSP was found to be superior on crop yield. Some of the adjuncts like FYM citycompost, GLM and SSP were employed along with North Carolina rockphosphate, Tunisia rockphosphate and SSP in order to increase its relative efficiency and found that addition of these adjuncts showed better performance on its utility. Among the adjuncts tested, the performance of North Carolina rockphosphate with compost, GLM and FYM proved to be superior in respect of yield uptake and available P status in soils followed by Tunisia rockphosphate with compost, GLM with TLTRP, FLM with TLTRP and compost with SSP, GLM with SSP and FYM with SSP. The higher performance of compost with North Carolina rockphosphate may be attributed to the release of organic acids upon decomposition of compost which effectively chelates the active iron and aluminum thereby reducing the fixation of available P.

With regard to phosphorus use efficiency the maximum response was obtained in compost with NCRP compared to rest of the treatments in the following descending order, compost + NCRP (40.25) > GLM + NCRP (38.62) > FYM + NCRP (37.97) > compost + TURP (35.34) > GLM + TURP (34.08) > FYM + TURP (33.28) respectively.

With respect to economic utility, the North Carolina rockphosphate proved to be superior next to the Tunisia rockphosphate compared to the conventional source of P found to hold promise on acid soil in agriculture.

Keywords: phosphateterock, eastern dry zone, organic manure
Dispersion of soil fertility in a field where was consolidated 37 years ago and influence for rice yield

HISATOMI Yoko, OHNISHI Masao and WAKATSUKI Toshiyuki

Faculty of Life and Environment Science, Shimane University, Matsue 690-8504, Japan

Land consolidation of small parcel has been in Japan to increase work productivity. But land consolidation makes dispersion of soil environment, especially soil fertility, in a field. To increase soil and work productivity precise characterization of the dispersion of soil fertility is important. Research field was consolidated from 3 terraced fields into one large field 37 years ago. During leveling topsoil of the upper field was moved to the lower field. The soil movement made the field heterogeneous dispersion of soil fertility and hardness. Research field has 3 types of soil environments. Type 1 (T-1): top-soil was moved then sub-soil became to the present top-soil. Type 2 (T-2): top-soil had not move so much. Type 3 (T-3): additional top-soil was accepted from the upper field. Result of precise characterization of top soil heterogeneity and its influence to rice yield showed that (1) distribution of N, P, K and effective soil depth were T-1<T-2<T-3, (2) distribution of Mg and Na were T1->T-2>T-3, and (3) depth of soil which hardness is less than 15kg/m² were T1<T2<T3. Those results suggest that heterogeneous dispersion of soil fertility still exists on the field after the consolidation 37 years ago. Such heterogeneous dispersion of soil had influence on rice yield. N, P, K and effective soil depth of soil showed significant positive correlation with rice yield. After the land consolidation, significant heterogeneous dispersion of soil fertility was created even though small field like Japan. Precision Agriculture is necessary to increase total productivity and the some time to conserve environment.

Keywords: precision agriculture, top-soil heterogeneity, rice yield
Factors affecting methane emission from rice paddies in Taiwan

HUANG Shan-Ney (1), LIOU Rey-May (2), CHEN Shin-Hsiung (2) and LIN Chin-Wei (1)

(1) Tainan District Agricultural Improvement Station, Tainan, Taiwan, ROC
(2) Department of Environmental Engineering and Health, Chia-Nan University of Pharmacy and Science

Rice paddies are considered to be one of the major biogenic sources of atmospheric methane. Recently the importance of CH₄ as a greenhouse gas has been recognized and studied to assess its contribution to global warming. Changes in water management, nutrient management, cultural practices, and cultivars selection may have a potential to increase rice production and productivity and reduce CH₄ fluxes at the same time. Field studies from 1998 to 2000 in middle Taiwan showed that continuous flooding, addition of organic fertilizer and incorporation of rice straw are the sources for initial methane production. Accumulated methane emission in the continuous flooded area was about 1.5- to 9-fold higher than that in the intermittent irrigation in the whole crop season. Effects of four organic fertilizers (including chicken manure, rice bran, rape seed cake and soybean cake) on methane emissions were measured in 1999. The results showed that application of chicken manure had a stimulating effect on methane production. Methane emissions from fields amended with 140 kg N ha⁻¹ for NO₃⁻-N (potassium nitrate and calcium nitrate) and NH₄⁺-N (ammonium sulfate), methane emission rates from the NO₃⁻-plots were 1.5 to 3.7-fold as high as those from the NH₄⁺-plots throughout the growth period. Application of (NH₄)₂SO₄ would significantly inhibit the methane fluxes in the paddy soils. Methane emission rates from the Indica-plots were 1.3 to 2-fold as high as those from the Japonica-plots throughout the growth period. Selection of rice cultivars that emit smaller amounts of CH₄ may also be effective in mitigating CH₄ emission from paddy fields. Field experiments with the treatment of removing rice straw, burning the rice straw and incorporation of chopped rice root and straw were made to investigate in 2000. The seasonal methane emission in the first crop season with the treatment of removing rice straw, burning the rice straw and incorporation of chopped rice root and straw were 4.49, 3.84 and 3.84 g CH₄ m⁻², and 32, 34 and 72.3 g CH₄ m⁻² in the second crop season, respectively. It was shown that incorporation of plant residue should significantly enhance production and emission of methane in the second crop season. Water management, organic amendments, fertilization, cultural practices, and the selection of rice varieties are promising mitigation candidates in paddy soils.

Keywords: paddy fields, water management, organic amendment, nitrogen fertilizer, rice cultivars, methane emission
Determination of critical limit of sulphur in rice soils of Bangladesh

ISLAM M.R., HUDA M.N. and JAHIRUDDIN M.

Department of Soil Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

An investigation was undertaken on rice soils of Bangladesh to determine the critical level of soil sulphur for wetland rice. Some 22 soils from 0-15 cm depth were collected from different locations of Old Brahmaputra Floodplains of the country. Sulphur in the soils was extracted with four different extractants, MCP (500 mg kg \(^{-1}\) P), CaCl\(_2\) (0.15%), NH\(_4\)OAc (0.5M) and NaHCO\(_3\) (0.5M). Rice plants were grown in pots treated with and without S for eight weeks. At harvest dry matter of rice was recorded. The critical level of S was determined by both graphical and statistical methods. The extractable S of the soils varied considerably with the soils and the extractants used. The ability of the extractants to extract S followed the order: 0.5M NH\(_4\)OAc > 0.5M NaHCO\(_3\), > 0.15% CaCl\(_2\) > MCP. The MCP extractable S showed significant and positive correlation with organic matter, available P and exchangeable K contents but was significantly and negatively correlated with soil pH. The amount of extractable S by other methods did not show any significant correlation with soil properties. The extractable S by any pair of extractants viz. CaCl\(_2\) vs NH\(_4\)OAc, CaCl\(_2\) vs NaHCO\(_3\) and NH\(_4\)OAc vs NaHCO\(_3\) were significantly and positively correlated. The critical levels of MCP, CaCl\(_2\), NaHCO\(_3\) and NH\(_4\)OAc extractable S were 9.3, 9.7, 15.8 and 17.8 mg kg \(^{-1}\), respectively in both graphical and statistical methods for rice.

Keywords: critical limit, extractable sulphur, wetland rice
Vertical distribution of heavy metals in paddy soils near closed mines and their availability to rice

JUNGGoo-Bok (1), KIM Won-Il (1), KIM Kyung-Min (2), YUN Sun-Gang (1) and PARK Ro-Dong (3)

(1) National Institute of Agricultural Science and Technology (NIAST), RDA, Suwon 441-707, Korea
(2) Dept. of Environmental Engineering, Yonsei University, Wonju 220-710, Korea
(3) Chonnam National University, Kwangju, 500-757, Korea

To compare the relationships between the vertical distribution of heavy metals and their availability to rice plant in paddy fields near four abandoned metal mines, 40 paddy surface soils (0-15 cm) and 12 sites soil samples with soil depths (0-20, 20-40, 40-60, 60-80, 80-100 cm) were collected. Both total and extractable heavy metal contents in soils were analyzed after acid digestion ($\text{HNO}_3 : \text{HClO}_4 : \text{H}_2\text{SO}_4$) and 0.1N $\text{HCl}$ extraction, respectively.

The 0.1N $\text{HCl}$ availability ratio against total contents of Cd, Cu, Pb, and Zn were 57, 30, 23, and 19%, respectively. Vertical distribution of heavy metals varied considerably among the different mines. In Choil mine, there was no difference in the concentrations of all metals with soil layers. However, Cu and Pb contents in Gahak mine were high at 0-20 cm depth, and Zn was high at 0-40 cm depth. In Sinyemi mine, Cd and Cu contents were high at 0-40 cm depth. Cd, Cu and Pb contents in Okcheon mine were high through all soil profiles until 100 cm soil depth. The 0.1N-HCl availability ratio against total contents of heavy metals with soil layers were very high at 0-20 cm depth. As soil depth increased, availability ratio of heavy metals decreased at the high soil pH (Gahak, Sinyemi, and Choil mines). However, the ratios of Cd, Cu and Pb in Okcheon mine, having a relatively lower soil pH than other sites, were relatively similar through all soil profiles until 100 cm soil depth. Therefore, it was estimated that the mobility and availability of heavy metals in soils were affected by soil pH.

Heavy metal fractionation in paddy soils near closed mines was also analyzed by sequential extraction method. Soil Cd consisted of 25.1% exchangeable form, 32.9% oxide and carbonate form, 37.4% sulfide and residual form, and 4.6% organically bound form. All kinds of Cd fractionation in soils were highly positively correlated with Cd content in polished rice. However, there was no significant correlation between Cu fractionation and Cu content in rice.

Keywords: paddy soils, heavy metals, vertical distribution, rice, availability, fractionation
Effects of copper and magnesium fertilization on rice yield and nitrogen use efficiency: a $^{15}$N-tracer study

CHOU DHURY A.T.M.A. (1), KHANIF Y.M. (2), AMINUDDIN H. (2) and ZAKARIA W. (2)

(1) Department of Agricultural Chemistry & Soil Science, Ross Street Building A03, University of Sydney, NSW 2006, Australia
(2) Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor Darul Ehsan, Malaysia

Recent investigations showed that fertilizer nitrogen (N) use efficiency is lower in rice soils of Malaysia due to copper (Cu) and magnesium (Mg) deficiencies. It was assumed that the efficiency of fertilizer N could be increased through Cu and Mg fertilization. In this regard, research works were conducted at Universiti Putra Malaysia. Some salient findings of these research works are reviewed in this paper. Two greenhouse experiments, using $^{15}$N tracer technique, were conducted to evaluate the effects of Cu and Mg fertilization on rice yield and fertilizer N efficiency. It was found that Cu application increased rice yield and fertilizer N recovery slightly although the effect was not significant. Magnesium application increased rice yield and fertilizer N recovery significantly. In a succeeding field experiment, rice yield and agronomic efficiency of added N increased significantly due to both Cu and Mg fertilization. Highest grain yield and agronomic efficiency of added N were recorded in the plots those received both Cu and Mg fertilizers. The results of these experiments indicate that rice yield and fertilizer N use efficiency can be increased by Cu and Mg fertilization in soils deficient in Cu and Mg.

Keywords: rice, nitrogen efficiency, $^{15}$N tracer technique
Conservation tillage practices in corn production after rice: a case in San Jose, Mindoro Occidental, Philippines


(1) Farming Systems and Soil Resources Institute, University of the Philippines Los Baños, College, Laguna 4031, Philippines
(2) Office of the Provincial Agriculturist, San Jose, Mindoro Occidental, Philippines
(3) Monsanto Philippines, Inc. 7th F, Ayala Life FGU Center, Alabang, Muntinlupa City, Philippines

The potential of conservation tillage technology to improve yields while reducing production costs and conserving soil and water resources was tested through on-farm trials in Brgys. Mangarin and Mabini, San Jose, Mindoro Occidental from November 1999 to April 2000. Six farmer-partners cooperated in the conduct of the trial. Treatments include conventional tillage, zero tillage and farmers' tillage practices combined with two fertilizer levels (F1= 600 kg ha⁻¹ ammosul; F2= 300 kg ha⁻¹ ammosul + 1 kg ha⁻¹ BIO-N). Average production ranges from 4.60 to 5.44 t ha⁻¹ for yellow corn and 23855 to 29306 ears ha⁻¹ for green corn. The highest yield of yellow corn (Var C818) was obtained using zero tillage with the application of POWER™ herbicide compared to conventional and farmer's tillage practices. This resulted to higher net returns mainly due to lower production cost. Reducing the rate of fertilizer application to ½ recommended rate plus 1 kg ha⁻¹ BIO-N combined with zero tillage contributed to the increase in net income of the farmers compared to other treatments. Similar results were obtained with green corn (Var Glut # 2). Zero tillage technology, therefore, is a viable option for corn production after rice.

Keywords: conservation tillage, conventional tillage, zero tillage, farmers' tillage practices, POWER™ herbicide
Nitrogen and irrigation management for direct seeded rice in light soils in a rice-wheat cropping system


(1) CIMMYT, P.O. Box 6057, Gulshan Dhaka-1212, Bangladesh
(2) Wheat Research Centre, Bangladesh Agriculture Research Institute, Dinajpur, Bangladesh
(3) 917 Bradfield Hall, Cornell University Ithaca, NY 14853, USA
(4) Dept. of Plant Science, North Dakota State University, Fargo, ND 58105, USA

Direct seeded rice is becoming very prominent in Southeast Asia. However, the practice is not being adapted to South Asia in the same extent. In a sandy loam soil of NW Bangladesh, four years of experiments were conducted using a two-crop system per year, as is the practice in that area. However instead of transplanting the rice, the rice was direct seeded followed by winter wheat. The trial had 3 nitrogen rates (low, recommended and high), two rice tillage practices (puddled and direct seeded) followed by wheat with the same nitrogen rates, but the tillage was conventional versus a power operated 2-wheel tractor seeder. This seeder prepares a 5-cm seedbed, sows the seed and presses the soil to the seed in one pass. Results showed that the direct seeded rice was difficult to maintain under flooded conditions. In later years, it was irrigated as truly aerobic rice. Because of the amounts of irrigation percolating through the soil, the rice yields under puddled conditions with medium nitrogen rates equalled the yields of the non-puddled rice under 150% high nitrogen rates. Weeds remained a real constraint to maintaining direct seeded rice. Next to weeds, insect infestation was greater with direct seeding—in this study mealy bugs attacked the DSR plots. Only by using herbicides and constant hand weeding were weeds able to be controlled adequately. In the last year, two rice varieties were used in sub plots and distinct differences were found in their responses to direct seeding. One of the varieties has increased nutrient uptake efficiency under anaerobic conditions, possibly phosphorus. The soils are very low in phosphorus in Bangladesh. Flooding raises the pH and reduces iron, allowing the fixed phosphorus to become available. Direct seeded rice in lighter soils of Bangladesh, where P is less available may require genotypes efficient in nutrient extraction from anaerobic conditions compared with those lines which are selected under flooded conditions. Additionally, nitrogen and irrigation must be carefully managed to ensure less nitrogen leaching losses. There were no differences in wheat yields following either direct seeded rice or puddling. Since wheat is 90% irrigated in Bangladesh (and in this experiment), wheat roots were able to grow down through the weak plow pan established by puddling.

Keywords: nitrogen, irrigation, wheat, direct, seeded, rice
Chemical determination of microbially reducible manganese and iron in paddy soils and lake sediments

MURASE Jun (1,2), OKAJIMA Atsushi (1) and NAKAYAMA Eiichiro (1)

(1) School of Environmental Science, University of Shiga Prefecture, 2500 Hassaka, Hikone, 522-8533 Shiga, Japan
(2) Present address: Graduate School of Bioagricultural Sciences, Nagoya University, Chikusa, Nagoya 464-8601, Japan

Manganese and iron are important electron acceptors for controlling redox potentials of submerged paddy soils and sediments. Among the various forms of these metals, only fractions that are directly and indirectly reduced by anaerobic microbial metabolism should be concerned. For example, we observed that only 30% of total iron could be reduced and about 70% of total manganese existed in reduced forms in the sediment of Lake Biwa, the largest lake in Japan. Although several chemical methods have been proposed for the determination of different forms of the metals (e.g. crystalline, amorphous and free forms), availability of the metals for microbial reduction processes have been less studied. In the present study, extraction methods for manganese and iron were examined on the basis of availability for anaerobic microbial metabolism, and a new chemical method for simultaneous extraction of microbially reducible manganese and iron from paddy soils and lake sediments is proposed.

Paddy soils and freshwater sediments, which were collected from paddy fields in Japan and Lake Biwa were anaerobically incubated and the amounts of reduced manganese and iron were determined by atomic absorption spectrometry or ICP-AES after extraction. These values, which were defined as 'actual microbially reducible forms' in this study, were compared with the amounts that were extracted with various chemical extraction methods. The soil and sediment samples were extracted with different combinations of reductants and extractants. NH2OH-HNO3, NH2OH-HCl, oxalate buffer, and Na2S2O4-EDTA extracted nearly equal amounts of manganese to the actual microbially reducible manganese in the lake sediments. However, less amounts of iron than the incubation method were extracted with NH2OH solutions and more amounts of iron were extracted with Na2S2O4-EDTA. Oxalate buffer extracted mostly equal amounts of the actual microbially reducible iron in the lake sediments but surplus amounts of iron in paddy soils (140-265% of microbially reducible iron). The effects of Na2S2O4 and EDTA in Na2S2O4-EDTA solution were separately examined and the results demonstrated that the chelating agent (EDTA) singly extracted appreciable amounts of microbially reducible manganese and iron both in paddy soils and lake sediments. EDTA solution extracted 107-130% and 85-120% of microbially reducible manganese and iron from grey lowland soils, gley soil, and yellow soil. In contrast, the efficiency of extraction from volcanic ash soil was very low (20% and less than 10% of the actually reducible manganese and iron). Under the optimized conditions (sample: 0.04M EDTA = 50 mg: 10 ml, extraction for 3 h at 85°C), 93-101% of the actual microbially reducible manganese and iron in sediments was extracted. The results demonstrated that EDTA is an efficient extractant for microbially reducible manganese and iron from paddy soils and lake sediments except for volcanic ash soil.

Keywords: paddy soils, sediments, manganese, iron, microbial reduction, methodology
The role of organic matter quality in nitrogen cycling and yield trends in intensively cropped paddy soils

OLK D.C. (1) and CASSMAN K.G. (2)

(1) National Soil Tilth Laboratory, USDA/ARS, 2150 Pammel Drive, Ames, IA 50011, USA
(2) Department of Agronomy and Horticulture, 279 Plant Science, University of Nebraska, Lincoln, NE 68583, USA

The sustainability of intensive lowland rice (Oryza sativa, L.) cropping in tropical Asia has been evaluated in on-station field experiments of double- or triple-cropped rice that have run for up to 30+ years. In those experiments managed at initially high yield levels, availability of soil nitrogen (N) and grain yields declined across several years, despite maintained quantities of total soil N and availability of fertilizer N. To explain the decrease in soil N availability, we investigated the quality, or chemical nature, of soil N under intensive rice cropping. Chemical characterization of soil organic matter (SOM) fractions extracted from the long-running field experiments associated intensive rice cropping with accumulation of incompletely decomposed materials derived from crop residues, including phenolic compounds. Under controlled conditions phenols chemically stabilize N, suggesting a mechanism for the decreased availability of soil N. In order to further test this hypothesis under field mitigation options, in a new field experiment SOM quality and N cycling were compared for anaerobic decomposition of crop residues—the conventional practice in lowland rice cropping—versus aerobic decomposition. During four years, anaerobic decomposition led to the gradual enrichment of young SOM with phenolic compounds and decreased N mineralization from young SOM during the growing season, as compared to aerobic decomposition. In-season N mineralization from one SOM fraction was inhibited by anaerobic decomposition relative to aerobic decomposition by up to 22 kg N ha⁻¹. The inhibition became most pronounced in mid- to late-season. It was best correlated with phenol enrichment at high biomass of incorporated crop residues, and the correlation strengthened across consecutive years. ¹⁵N-labeled fertilizer was applied at different splits. By harvest, of the ¹⁵N that had been immobilized, little was remineralized following anaerobic decomposition, but 45% was remineralized following aerobic decomposition. The responses of crop N uptake and grain yield to residue management were in most years consistent with trends in soil N mineralization, but causality cannot be established in this experiment. Nitrogen fertilizer was applied in synchonization with crop N demand, which should have maintained an adequate N supply to the crop despite decreased availability of soil N. Also, a zinc deficiency affected crop growth in a pattern confounded with that of residue management. Although the duration of this experiment did not suffice to allow a definitive explanation for the decrease in grain yield and soil N availability of the long-running field experiments, observations from all experiments are consistent with the hypothesis that anaerobic decomposition of crop residues amended at high rates promotes an accumulation of phenols. These compounds may chemically stabilize soil N into forms that remain less available during the growing period, leading to late-season deficiency of soil N. Results suggest that aerobic decomposition of crop residues will over the long-term promote greater mineralization of soil N during the growing season and hence recovery by the crop. Aerobic decomposition could be accomplished by incorporating crop residues during the fallow season or by draining floodwaters during critical portions of the growing season.

Keywords: rice, nitrogen, phenols, organic matter, crop residues
Nutrient release from straw of three rice (*Oryza sativa* L.) varieties and the impact on the growth of rice

PANGGA Gina Villegas (1) and BLAIR Graeme J. (2)

(1) University Researcher III, Farming Systems and Soil Resources Institute, College of Agriculture, University of the Philippines, College, Laguna, 4031, Philippines

(2) Division of Agronomy and Soil Science, School of Rural Science, University of New England, Armidale, NSW 2350, Australia

Straw of rice varieties Soc Nau and IR-67962 collected from the field and straw of IR-30, collected from a glasshouse experiment, were incorporated to an Alfisol sandy loam soil at an application rate of 5 t ha$^{-1}$. A no-residue control was also included. The effects of soil water condition (flooded and non-flooded) and the rate of fertilisers (low and high) on the availability of nutrients were examined.

The results showed that straw dry matter and grain yield were higher under flooded than non-flooded conditions and the higher fertiliser rate produced higher yields. Each variety resulted in reduced yields at active tillering because of strong negative apparent recoveries of N and P. At maturity incorporation of Soc Nau and IR-67962 straw increased straw dry matter yield in the rice crop by 11% over the no-residue control. Grain yield was increased by 25, 18 and 12% in the IR-67962, Soc Nau and IR-30 treatments, respectively. Soc Nau straw had the highest N, P and S concentration, the highest straw quality index (SQI) and the narrowest C:N ratio among the straw. Straw of IR67962 had the highest K and lignin:N ratio and the lowest SQI. By contrast IR30 had deficient concentrations of S and K, the highest digestible organic matter (DOM) and the highest labile C. The anticipated decomposition effects were modified by the availability of nutrients from the straw and/or the amount of immobilisation of nutrients that took place.

**Keywords:** mineralisation, immobilisation, organic matter, nutrients, decomposition
Fertilizer appreciate use for paddy rice cultivation in Korea

PARK Yang-Ho, LEE Youn, KIM Seok-Cheol and PARK Moon-Hee

Plant Nutrition Division, National Institute of Agricultural Science and Technology, Rural Development Administration Suwon 441-707, Republic of Korea

In Korea, fertilization levels for rice were previously managed with N-P₂O₅-K₂O = 110-70-80 kg ha⁻¹ to get maximum yields, but it was recently controlled with N-P₂O₅-K₂O = 110-45-57 kg ha⁻¹ to minimize environmental pollution.

To make an optimum fertilization strategy for rice cultivation, we have managed long-term fertilizer application fields in the central and local agricultural Research Institutes. Here, rice has been fertilized differently by chemical fertilizers and soil amendments depending on the self-local condition like climate, soil characteristics and etc. Here, the effects of long-term fertilizer application of no fertilizer, PK, NK, NP and NPK were summarized as follows.

In the standard fertilization treatments managed with N-P₂O₅-K₂O = 110-70-80 kg ha⁻¹ for 15-30 years, average yield of milled rice was 4,510 kg ha⁻¹. Here, each rice yield of fertilizer treatment was compared with the yield of standard fertilization in control, they were 64% in non fertilization, 69% in non nitrogen (PK), 93% in non phosphate (NK), and 93% in non potassium (NP) treatments, respectively.

In the compost treatments in rates of 7,500, 10,000, 15,000, 22,500 and 30,000 kg ha⁻¹ combined with the standard fertilization treatment (N-P₂O₅-K₂O = 110-70-80 kg ha⁻¹), rice yields were increased with compost application. Yields were inclined to 11% (5,010 kg ha⁻¹) by amending 10,000 - 15,000 kg ha⁻¹ of compost in standard fertilization (NPK) more than that in standard fertilization. However, the effects of compost application on rice yields were not recognized significantly in over 10,000 - 15,000 kg ha⁻¹ of compost treatment.

In 0, 100, 150, 200, and 250 N kg ha⁻¹ in non organic matter, 5,000 kg ha⁻¹ of rice straw, and 10,000 kg ha⁻¹ of compost treatments, we got the correlation formula between N application rates and yields. Rice yields were 4,920 (109%) and 5,170 (115%) kg ha⁻¹ in Si+NPK and Si+compost 10,000 kg ha⁻¹+NPK, respectively.

In this study, we characterized nutrient uptake patterns together with nutrient contents of rice during the growing season. Finally, we analyzed three major elements efficiency and tried the strategy of nutrient management for sustainable farming.

Keywords: paddy rice, fertilizer and compost, nutrient management
Sustainability of rice-wheat production system—a case study across Indo-gangetic alluvial plains

PASRICHA Nanak S.
Potash Research Institute of India, Sector 19, Gurgaon-122001, Haryana, India

Among the rice-based cropping systems, rice-wheat is the most important production system followed on more than 12 million hectares of land in the South Asian countries of Pakistan, India, Nepal and Bangladesh across the Indo-gangetic alluvial plains (Latitude 30° 6' N-32° 5' N and longitude 73° 3' E-88° 5' E). With an assured water supply, the farmers in this region readily adopted modern fertilizer responsive high-yielding crop cultivars of rice and wheat. The system of Rice-Wheat contributed to an impressive increase in food-grain production from 1965-85. These gains in production have, however, stagnated in recent years. Rice yields generally declined over time while wheat yields remained stable.

The cost of intensive agriculture in this region has often been erosion in biological potential and depletion of underground water. The natural resource base devoted to rice-wheat production system is thus, being degraded. In order to have an economically viable farming system in the Indo-gangetic plains, it is necessary to sustain the rice-wheat production system, because any slowing-down of the annual yield increase of the rice-wheat system can gradually result in rural economic stagnation. Average growth rates of the rice decreased from 2.3% y⁻¹ during 1970-85 to 1.93 y⁻¹ during 1985-98. Control yields were generally higher at the beginning than at the end phase of several long-term experiments, consequently the yield response curves for initial and final phases of the experiments are well separated. Thus yield changes without nutrient inputs indicated a decline in the biological potential of the soil.

The estimated average recovery of N in grain was low at 21% for rice and 26% for wheat. However, little change in the agronomic efficiency of fertilizer N over time indicated that some factors other than NPK are responsible for declining rice yields. Yield increases obtained with organic inputs along with recommended levels of NPK were not simply due to concomitant increased N-additions but due to some other effect of organic materials. Less negative and/or more positive yearly yield change suggests that productivity was more sustainable with organic additions. About 25% of N and roughly 80% of K removed by rice and wheat are contained in the straw and that its return will have a positive impact on N availability and would help in overcoming the negative balance of K in soil. The level of organic-carbon increased with inputs of organic materials to soil including crop residues, green manures, and farmyard manures etc. At recommended levels of NPK, without addition of organic materials, the soil organic carbon (SOC) content declined with cropping over time especially at sites where initially the SOC was high (>0.7%). The objective of this paper is to highlight the analysis (Duxbury et al., 2000) of the data of several long-term experiments conducted across the Indo-gangetic plains. Some generalities have been derived which can suggest key areas for future research.

Keywords: rice-wheat system, sustainability, soil degradation, water use, soil fertility
Emission of methane and nitrous oxide from rice-wheat cropping system of Indo-Gangetic Plains

PATHAK H., SINGH S., PRASAD S., BHATIA A., RASTOGI M., JAIN M.C., KUMAR S. and MANDAL N.

Division of Environmental Sciences, Nuclear Research Laboratory Building, Indian Agricultural Research Institute, New Delhi 110 012, India

Methane (CH₄) and nitrous oxide (N₂O) account for 15% and 5% of the total greenhouse effect, respectively. Nitrous oxide is also responsible for the destruction of stratospheric ozone. Rice cultivation has been considered as one of the major sources of CH₄ while nitrification and denitrification processes in the soil are responsible for the major part of atmospheric N₂O emission. Rice-wheat cropping system occupying 10.5 million ha of productive land in the Indo-Gangetic Plains of South Asia could be a major source of CH₄ and N₂O. A field study was undertaken during 1999-2000 and 2000-2001 to estimate the emission of CH₄ and N₂O from the rice-wheat cropping system and to determine the effect of irrigation and N fertilizer management on the emissions. Effects of dicyandiamide (DCD), a nitrification inhibitor, and farm yard manure (FYM) on the emissions was also studied. The study included four fertilizer treatments, 1) urea (120 kg N ha⁻¹), 2) urea (60 kg N ha⁻¹) + FYM (60 kg N ha⁻¹), 3) urea (108 kg N ha⁻¹) + DCD (10% of urea N, added 12 kg N ha⁻¹), and 4) unfertilized (control); and two moisture regimes, 1) saturated soil condition in rice and 5 irrigations in wheat and 2) intermittent wetting and drying in rice and 3 irrigations in wheat. The gases were collected by closed chamber technique and analyzed using gas chromatograph equipped with FID for CH₄ and ECD for N₂O. Total CH₄ and N₂O-N emission from the rice-wheat system was 15.2 kg ha⁻¹ and 0.65 kg ha⁻¹ in unfertilized plots, respectively. While higher CH₄ (36.9 kg ha⁻¹) and N₂O-N (1.57 kg ha⁻¹) emissions were observed in urea treatments. Use of DCD reduced the emissions. Application of FYM with urea decreased N₂O emission but increased CH₄ emission in rice. Intermittent wetting and drying of soil in rice gave higher N₂O-N and lower CH₄ emission compared to saturated soil condition as intermittent aerobic and anaerobic cycles in soil are not conducive for CH₄ formation but favours denitrification through the additional supply of NO₃-N formed during nitrification in an aerobic cycle. In wheat, more supply of water through 5 irrigations led to more N₂O-N emission but had no effect on CH₄ emission. Conversely, CH₄ uptake was observed in wheat. As in rice, DCD reduced N₂O-N emission in wheat also. In the rice-wheat system, typical of a farmer’s field in the Indo-Gangetic plains, where 240 kg N is applied through urea, CH₄ and N₂O-N emissions are 20.8 kg ha⁻¹ and 1.57 kg ha⁻¹ (0.38% of applied N), respectively. Application of DCD can reduce the emission to 13.8 and 1.10 kg ha⁻¹, respectively.

Keywords: nitrous oxide, methane, rice-wheat cropping system, farm yard manure, moisture regime, nitrification inhibitor
Changes of some chemical properties, inorganic phosphate fractions and available P in some paddy soils in Thailand

POOROONGRUANG Samrit (1), CHANCHAREONSOOK Jongruk (2), SUWANNARAT Chairerk (2) and TUNGKANANURUK Nipon (3)

(1) Faculty of Science and Technology, Rajabhat Institute Chiangmai, Chiangmai, Thailand
(2) Faculty of Agriculture, Kasetsart University, Bangkok, Thailand
(3) Faculty of Science, Kasetsart University, Bangkok, Thailand

Two parts were conducted in this study. The first part consisted of determining inorganic phosphate fractions and P sorption capacity in the paddy soils as Rangsit very acid (Rsa), Rangsit (Rs), Manorom (Mn) and Banmi soil series (Bm). Results showed that inorganic phosphate fractions in Rsa and Rs, acid sulfate soils, were in the following order: Fe-P>Re-P>Al-P>Ca-P while in Mn, acid soil, were Fe-P>Al-P-Ca-P>Re-P and Bm, calcareous soil, were Ca-P>Fe-P>Al-P>Re-P. P sorption ability of the soils were in the following order: Rsa>Rs>Mn>Bm. The second part of the study investigated changes of soil pH, inorganic fractions and available P in the submerged soils. This experiment was done in pots as 4 replications. Rice, Khao Jao Haum Suphanburi variety, was grown in the soils receiving 0, 50, 150 and 300 mg P$_2$O$_5$ kg$^{-1}$. Soil and rice plant sampling was done at the transplanting (TP), panicle initiation (PI), flowering (FW) and harvesting (HV) stages. Results showed that soil pH in Rsa, Rs and Mn were increased from TP to HV stage while those in Bm were decreased. Extracted-P content in soils were in the following order: Bm>Rs>Mn>Rsa and those in soils at TP and PI stages were higher than those at FW and HV stages. Inorganic phosphate fractions content in the paddy soils were in the following order: Fe-P>Ca-P>Re-P. Correlation between extracted-P and P uptake by plant showed that soil P extracted with Bray II, Olsen and Mehlich III extractants were highly correlated with P uptake. Correlation between extracted-P with Bray II, Olsen and total grain weight were highly significant ($r = 0.64^{**}$ and $0.69^{**}$). Correlation between inorganic phosphate fractions and soil extracted P were in the following order: Fe-P>Re-P>Ca-P.

Keywords: inorganic phosphate fractions, available P, paddy soil, correlation, P sorption, P uptake
Methane emission from Thai farmers’ paddy fields as a basis for appropriate mitigation technologies

SAENJAN Patcharee (1), TULAPHITAK Duangsamorn (2), TULAPHITAK Thepparit (1), TANGCHUPONG Soupachai (3) and JEARAKONGMAN Suwat (3)

(1) Department of Land Resources and Environment, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand
(2) Center of Agricultural Research and Development, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand
(3) Khon Kaen Rice Experiment Station, Khon Kaen 40000, Thailand

Methane emission rates were directly measured from 4 rice seasons with variations in soils: Clayey Tropaquepts and Loamy Paleaquults, rice varieties: glutinous and indica rice, and cultivation methods: transplanting and broadcasting and to identify potential mitigation measures while sustaining high yield. In irrigated major rice 1999, total CH$_4$ emission from Tropaquepts ranged from 6.73-16.78 g m$^{-2}$; whereas those from Paleaquults with an extraordinary high dose of fresh aquatic weeds (mainly Impomoea aquatica) 113 ton fresh weight ha$^{-1}$ (20 ton dry weight ha$^{-1}$) ranged from 24.54-86.89 g m$^{-2}$ as a consequence of turning aquatic weed fields into paddy fields. Total CH$_4$ emissions from Tropaquepts in irrigated second rice 2000 ranged from 6.20 to 29.18 g m$^{-2}$ due to incorporation of rice residues prior to planting. Whereas Paleaquults in irrigated second rice 2000 and 2001 with burnt rice residues ranged from 10.01-24.34 g m$^{-2}$. Overflood in rainfed rice 2000 destroyed paddy areas on the flood plain of Tropaquepts, emitted CH$_4$ 8.96-14.72 g m$^{-2}$. Moderate amounts of total CH$_4$ emission from Paleaquults under rainfed ranged from 27.1-41.94 g m$^{-2}$.

A problem with low yield is obvious in this study. Management of organic matter remarkably dominated CH$_4$ emissions more than chemical fertilizers. Grain yield and total CH$_4$ emissions were positively vague correlated (R = 0.153, n = 20) for transplanted rice, while for broadcasted rice were negatively correlated (R = -0.456, n = 14). Moreover CH$_4$ emissions per unit grain yield were negatively correlated with grain yield as indicated R = -0.275 and -0.761 for transplanted (n=20) and broadcasted rice (n=14), respectively. Maybe broadcasted rice has some advantages over transplanted rice, and could be an alternative for mitigating CH$_4$. Suggestions for CH$_4$ mitigation with sustaining yield were concluded.

Keywords: paddy soil, rice yield, farmer, methane mitigation
A review of rainfed lowland rice-growing soils of Cambodia, Laos, and Northeast Thailand

BELL R.W. (1) and SENG V. (2)

(1) School of Environmental Science, Murdoch University, Western Australia
(2) Soil and Water Research Program, Cambodian Agricultural Research and Development Institute (CARDI), Phnom Penh, Cambodia

Regional reviews of the lowland rainfed rice ecosystems of Asia often lump Laos, Cambodia and northeast Thailand together on the basis of similarities in their agro-ecosystems. Significant overlap in soil characteristics may facilitate the exchange of research information among these countries to their mutual advantage especially in an environment where none can maintain an elaborate research programme for rainfed lowland rice. However, there has been little critical assessment of the similarities and differences amongst the lowland rainfed rice soils of Laos, Cambodia and northeast Thailand and their response to soil management technologies. The purpose of this paper will be to critically review the published literature on soil properties and their spatial distribution, the main soil related constraints identified for lowland rainfed rice in Laos, Cambodia and northeast Thailand, and the similarities and differences in soil management technologies found to be effective. Areas of common strategic interest for research on soil management technologies will be identified and discussed.

Keywords: Cambodia, fertiliser, Laos, rainfed lowlands, rice, soil fertility, Thailand
On-farm residue effects on rainfed lowland rice productivity in Laos

SENGXUA Pheng (1) and LINQUIST Bruce (2)

(1) Soil Survey and Land Classification Center, National Agriculture and Forestry Research Institute, Vientiane, Laos
(2) Lao-IRRI Project, P.O. Box 600, Luang Prabang, Laos

Rice is the most important crop in Laos, accounting for almost 70% of the total calorie supply. Low yields (typically 1.5 to 2.0 t ha\(^{-1}\)) and high risk (due to drought and/or flooding) characterize the rainfed lowland rice environment. Improving and sustaining rice yields on these coarse textured soils requires an increase in nutrient inputs. Currently, on-farm residues such as farmyard manure (FYM), rice straw and husks are poorly utilized. Two field experiments were initiated in 1999 to test effects of applying on-farm residues with commercial fertilizers on nutrient-use efficiency. The experiment was conducted for two years Saravane and three years in Champassak. The experiments were set up in a split plot design with minus and plus fertilizer (60, 13 and 18 kg ha\(^{-1}\) of N, P and K, respectively) as main plot treatments and residues (none or 2 t ha\(^{-1}\) dry weight of FYM, rice straw or rice husks) as sub-plot treatments. This rate of residue provided 40, 5 and 30 (FYM); 5, 1 and 6 (rice husks); and 14, 1 and 27 (straw) kg ha\(^{-1}\) of N, P and K, respectively.

Rice yields when neither fertilizers nor residues were applied ranged from 1.1 to 1.6 t ha\(^{-1}\) across sites and years. In response to fertilizer alone rice yields in Saravane increased on average by 2.0 t ha\(^{-1}\) (150%) in both years. In Champassak, yields increased by 1.5 t ha\(^{-1}\) (126%) in the first two years but only by 0.7 t ha\(^{-1}\) (43%) in the third year.

When residues were applied alone, yields increased by 0.6 t ha\(^{-1}\) (48%) in Champassak in the first two years and 1.2 t ha\(^{-1}\) (78%) in the third year. In Saravane, yields increased on average by 0.95 t ha\(^{-1}\) (68%) in both years. There was no difference in rice yield response to the different residues when they were applied alone, despite a large difference in N, P, and K concentration of the residues.

In the first two years, at both sites, there was little to no yield benefit of applying residues if commercial fertilizer was already applied. However, in the third year at the Champassak site, there was a response to residues when fertilizers were applied. This response been have been the result of a decline in soil fertility when only fertilizer was used. This is supported by the fact that in the fertilizer only treatment, both yield and response to fertilizer declined in the third year. This decline may be due to the depletion of micronutrients and carbon. While commercial fertilizers can maintain N, P and K balances, other nutrients, such as micronutrients may become depleted with continuous cropping and removal of residues. Recycling on-farm residues returns much of these nutrients back into the soil system, helping to maintain soil fertility. Based on these results, the most productive and sustainable practice is to apply residues with commercial fertilizers. Applying residues alone is sustainable but may not be as productive, however, more research is required to determine the long-term impacts of each practice.

**Keywords:** lowland rice, residue management, fertilizer management, nutrient-use efficiency
Improved agronomic practices for sustainable crop production in paddy-wheat cropping in Vertisols

SHARMA S.K., TOMER S.S. and SHRIVASTAVA S.P.

Department of Soil Science & Agricultural Chemistry, Jawaharlal Nehru Agricultural University, Jabalpur (Madhya Pradesh), India 482 004

There are extensive areas of Vertisols and associated soils in the central and eastern parts of India which are effectively used for the cultivation of paddy and wheat. At present there is a lack of information on such long term effects which reduce the yield of non-rice crops in these soils. Therefore, a long term field experiment was conducted at the Experimental Station, J.N. Agricultural University, Jabalpur, Madhya Pradesh, India from 1991 to 1999, considering various aspects of the paddy-wheat cropping sequence. The soil of the experimental site is deep, fine textured, montmorillonitic family of typic haplusterts. A split plot design consisting of three tillage treatments viz; T₀: zero tillage, T₁: cultivar + disc harrow, T₂: mould broad plough + disc harrow, sub plots consisting of the three methods of rice cultivation viz; M₀: direct seeded paddy, M₁: lehi system (half germinated seeds broad casted under semi puddled conditions) and M₂: puddled transplanted paddy and three phosphorus levels viz; P₀: no phosphorus, P₁: 40 kg P₂O₅ and P₂: 80 kg P₂O₅ ha⁻¹ or three nitrogen levels N₁: 40 kg, N₂: 80 kg and N₃: 120 kg/ha in various years. High yielding varieties of paddy (CV Ratna or Kranti) and wheat (CV Lok-1) were grown in different years.

Results revealed that in different years puddled plots had a higher bulk density and penetration force and lower hydraulic conductivity and basic and cumulative infiltration as compared to direct seeded plots. Creation of tillage by various implements in the paddy wheat cropping sequence significantly affected all the soil physical properties. Continuous use of zero tillage in direct seeded paddy followed by wheat for nine years had favourable soil physical properties as compared to puddled transplanted paddy. The mean weight diameter decreased significantly in Ti by 8% and T₂ by 13% as compared to plots. Puddled transplanted paddy had a significantly lower mean weight diameter as compared to M₀ plots.

Germination of wheat was significantly affected by tillage as well as by residual effect of puddling. The highest (64%) germination was observed in T₀ plots followed by T₂ (54%) plots. Direct seeded paddy plots had significantly higher germination (70%) than the M₁ (53%) M₂ (48%) plots. The grain yield of paddy was not significantly affected by the summer tillage treatment except in the 1995 and 1997 seasons. Transplanted puddled paddy plots produced significantly higher grain yield in five years out of nine years. In other years direct seeded paddy either produced significantly higher grain yield or were par with transplanted paddy. Grain yield of wheat was adversely affected due to rabi tillage and the residual effect of puddling. Zero till plots produced significantly higher grain yield of wheat till 1998 as compared to shallow till and deep till plots. After 1998 tillage created after paddy significantly increased the grain yield of wheat. Wheat grown after direct paddy produced significantly higher grain yield as compared to lehi and transplanted paddy in all the years. These results indicated that total productivity of rice-wheat cropping in Vertisols is higher under direct seeded paddy conditions followed by zero till wheat for consecutive eight years. Increasing levels of phosphorus or nitrogen significantly increased the grain yield of paddy and wheat in different years. Highest water use efficacy of wheat was observed when grown after direct seeded paddy in all the tillage treatment and minimum in wheat grown after puddled paddy. Direct seeded paddy followed by zero till wheat consumed less energy as compared to puddled transplanted paddy followed by shallow till or deep till wheat.

Keywords: no-tillage, Vertisols, cropping system, crop productivity
The effect of irrigation water quality on the accumulation of heavy metals in paddy soils and rice plant tissues

SHIRINFEKRA. (1) and KAVOOSI M. (2)

(1) Tea research and Services of Iran
(2) Rice Research Institute of Iran

Peerbazar rood is one of the most polluted rivers in the north of Iran, which discharges into Anzali lagoon. Due to the discharge of effluent and waste water from the industrial city of Rasht into the peerbazar rood, the concentration of heavy metals in this river is too high. Despite this the river has been used as an irrigation water source for rice crops since many years ago.

The main objective of our study was to determine the role of irrigation water quality on the accumulation of heavy metals (Zn, Cu, Cd, Pb and Ni) in paddy soils and rice plant tissues. A RCB design with 3 treatments and 10 replications was adopted to conduct this study. The treatments were the following sources of irrigation water as follows:

a) Peerbazar rood
b) Main drainage of paddy field irrigated by peerbazar rood
c) Other irrigation water source

Thirty soil and whole plant samples were obtained to measure the concentration of heavy metals in the soil and plant tissues. Concentration of heavy metals was measured by atomic absorption apparatus. The results showed that, except for Cd, there were no significant differences between heavy metals extracted by HNO₃ in different sites. But there were significant differences for Zn, Pb and Cd extracted by DTPA in different sites which were irrigated by different water sources. Zn, Cu and Pb concentration in plant tissues have shown significant differences between treatments. Concentration of heavy metals in soil and rice plant tissues have shown a decreasing trend from paddy fields of group I to group III. The correlation between concentration of heavy metals in rice tissue and available concentration of metals in soils except for Zn (r = 0.38* ) were not significant. But there were significant correlations between available concentration of metals and some soil physico-chemical parameters.

Keywords: Peerbazar rood, heavy metals, rice, paddy soils, pollution
Biofertilizer as a component of integrated nutrient management for rice-legume rice system in Assam, India

TALUKDAR N.C., THAKURIA D., CHAUDHURY A.M. and BORDOLOI L.J.

Soil Microbiology Laboratory, Department of Soil Science, AAU, Jorhat-785013, Assam, India

Biofertilizer is an important component of integrated nutrient management (INM) practices in multiple cropping systems and can increase crop production without affecting soil health. In a field experiment, the contribution of different components of INM treatments viz., inorganic fertilizer, organic manure and biofertilizer to grain yield and soil quality under kharif rice (July-Nov)-legumes (Nov-March)-summer rice (April-July) rotation was assessed during 1999-2001. The six treatment combinations tested were: 1) Control, 2) NPK, 3) Organic manure (OM), 4) OM + Azospirillum (Azo) + phosphate solubilizing bacteria (PSB) + Rock phosphate (RP) + Muriate of potash (MOP), 5. OM + Azo + SSP + MOP and 6) OM + N + PSB + RP + MOP. Azospirillum (A-10) and PSB (P5) were applied to rice crops as biofertilizer in sterilized compost carrier. French bean (Phaseolus vulgaris) and pea (Pisum sativum) were grown as grain legume in the rotation during 1999-2000 and 2000-2001 season, respectively. Specific Rhizobium isolates (AAU Rh2 and Gm Rh1) were applied as N2 fixers in case of the grain legumes. The population of Azospirillum, PSB and Rhizobium in the compost carrier were 3.5X10^9, 3.3X10^6 and 2.9X10^9 CFU g⁻¹. Five ton organic manure (air dry weight) was applied to the three crops in each year. Application of organic manure, Azospirillum, PSB, RP and MOP increased total grain yield of the sali rice-legume-a/w rice system by 35.8% over the yield of control treatment and 14.5% over NPK treatment. Application of OM + N + PSB + RP + K was also equally effective in increasing grain yield. However, soil quality parameters such as dehydrogenase activity, Azospirillum population, water stable soil aggregates, and earthworm castings were observed to increase only in OM + Azo + PSB + RP + K treatment. Plant and soil analysis data indicated that approximately 17 kg N ha⁻¹ was fixed during one year rotation in the OM + Azo + PSB + RP + K treatment. Acetylene reduction assay (ARA) carried out on rice roots of different treatments provided evidence of N fixation by Azospirillum. ARA was highest in roots of organic manure treated plots followed by that in Azospirillum added plots.

Cultivation of the three crops without manures, fertilizers and biofertilizers depleted total N, available P and K content of soil by 5%, 38.5% and 40.7% over their content in soil at the time of start of the experiment. In the NPK treated soil, the depletion was 2.5%, 13.7% and 40.7% and in OM + Azo + PSB + RP + K treatment, depletion of N, P and was 3.2%, 4.5% and 8.2%. The results of this study clearly indicate that yield can be improved and soil quality can be maintained in kharif rice-legumes-summer rice rotation by inclusion of Azo and PSB biofertilizer and organic manure component of INM practice.

Keywords: biofertilizer, integrated nutrient management, rice-legume-rice, soil quality.
Farming methods of rice (*Oryza sativa* L.) on environment conservation at college farm in reclaimed land

TASHIRO Takashi, CHIBA Kazuo, SATO Teruo, JINGUJI Hiroshi and KONDO Tadashi

Akita Prefectural College of Agriculture, Ogata 6, Ogatamura, Minamiakitagun, Akita Pref., 010-0451, Japan

Water pollution on rice farming is a serious environmental problem in reclaimed land. The objectives of this study were to evaluate the effects of rice farming on the environment. We conducted a survey research on the productivity of rice, growth of aquatic organism, physical properties of soil and water pollution among the different farming methods on paddy field at College Farm on reclaimed land.

The total area of the experimental paddy field was 12.5 ha. Paddy fields were divided into 4 plots. The, no-till transplanting plot (NT) was 2.00ha, no-paddling transplanting plot (NP) was 1.25ha, nursery box with total fertilizer application transplanting plot (NB) was 5.5 ha and conventional transplanting plot (CV) was 3.75. The fertilizer treatments using controlled release fertilizer (CAF) application were NT, NP, NB and conventional fertilizer using readily available fertilizer application was CV.

1) Grain yield (2000 yr.) per 10a among each plots was 618 kg, 605 kg, 577 kg, 560 kg in NP, NB, NT, CV, respectively. Grain yield showed the same tendency in 2 years (1999, 2000) to compare among each plot. The highest grain yield in NB had a reason why the air-drying effect on ammonification arose in soil. Grain yield was higher in NB than in CV for 2 years.

2) Number of a dragonfly per 10a in each plots was 12500, 48750, 4040 in NP, NT, CV, respectively. It was not good for the growth of a dragonfly to grade the paddy field with a plowing and a paddling.

3) Ground water level was -20cm—+5cm, -50cm—10cm, -3—6cm in NP, NT, CV for a flooding period, respectively. It seemed that the air permeability in the soil in NT and in NP was more suitable than in CV.

4) Load of emission in nitrogen from each plot was 10.4 kg ha$^{-1}$, -1.9 kg ha$^{-1}$, -1.9 kg ha$^{-1}$, 0.3 kg ha$^{-1}$ in NP, NB, NT, CV, respectively. Load of emission in phosphorus from each plot was 5.05 kg ha$^{-1}$, 0.56 kg ha$^{-1}$, 4.68 kg ha$^{-1}$, 2.06 kg ha$^{-1}$ in NP, NB, NT, CV, respectively. High load of emission in nitrogen, phosphorus in NP and NT resulted in the enlargement of leaching with the well drained paddy field. Therefore, we have to prevent the percolation of water in NP and NT.

There were few indications from this study that the no-till transplanting and no-paddling transplanting cultivation of rice (*Oryza sativa* L.) were very feasible not only for the growth of aquatic organism and grain yield but also for significantly improving the water quality and physical properties of soil compared with the conventional transplanting cultivation of rice. Therefore, we will continue to study this research for the long-term.

**Keywords:** environment, no-till, nursery box, paddy field, rice, water pollution
Spatial variability of soil properties and rice yield in paddies: is precision agriculture worth practicing?

YANAI Junta, LEE Choung Keun, UMEDA Mikio and KOSAKI Takashi

Graduate School of Agriculture, Kyoto University, Kitashirakawa Oiwake, Sakyo-ku, Kyoto 606-8502, Japan

To evaluate the possible benefit of precision agriculture in paddies, a series of experiments were carried out in a paddy field in Japan. (1) The spatial variability of soil properties and rice yield were analyzed and their relationship examined under homogeneous (conventional) land management in 1999. One hundred surface soil samples were collected from each of the 5 m×10 m plots in a 50m×100m field before basal fertilizer application, and the following soil properties measured: pH, EC, total C content, total N content, C/N ratio, contents of mineralizable N, inorganic N, available P, exchangeable Ca, Mg, K and Na. Grain yield was also measured for the same 100 plots. (2) The effect of site-specific management on rice yield was examined in 2000 by comparing a homogeneously managed area with one where N fertilizer application was related to measured plant N content, leading to a total N application 13% less than the conventional area. (3) The temporal stability of the spatial pattern of soil properties was evaluated using the data collected in 1999, 2000 and 2001, to estimate for how long soil data can be reliable.

In the first experiment, geostatistical analysis indicated a high to moderate spatial dependence for all soil properties except for inorganic N content. The ranges of spatial dependence were about 20-30 m for pH, EC, total C, total N and exchangeable Na, about 40 m for available P, mineralizable N, exchangeable Ca and Mg, and about 50-60 m for the C/N ratio and exchangeable K. Grain yield showed moderate spatial dependence with a range of about 50 m. Kriged maps of soil properties and yield indicated a distinct spatial pattern. Multivariate analysis in combination with geostatistics showed that soil properties were important yield determining factors and explained as much as 65% of the spatially structured or non-random variation of the yield. These results suggest the existence of considerable spatial variability of soil properties and yield and therefore possible benefits of precision agriculture in the paddy. The second experiment indicated that site-specific fertilizer management could reduce the spatial variability of yield and reduce fertilizer N usage without any reduction in yield. Advantages of site-specific management were, therefore, demonstrated from both agricultural and environmental points of view. In the third experiment, correlation analysis among the soil data from different years, in combination with geostatistical analysis, further showed that temporal stability differed among soil properties: e.g. total C content, total N content, available P, exchangeable Ca and Mg were relatively stable, whereas EC, inorganic N and mineralizable N were less stable. This suggests that different frequencies of field measurement could be used for some of the properties examined.

It was concluded that precision agriculture would be worth practicing for paddy rice production due to agricultural and environmental advantages.

Keywords: geostatistics, paddy field, precision agriculture, rice yield, soil properties, spatial variability
Symposium 51

Manufactured, amended, and intensively tilled soils and substrates

Convenor: KOOLEN Jos
Co-Convenor: KESAWAPITAK Prasat

Oral Session
Friday 16 August 2002
14:00-17:20
Room: Meeting Room 3

Poster Session
Friday 16 August 2002
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Influence of PE-films treated with parafin-wax on soil heat storage under greenhouse condition

AL-KAYSSI A.W.

Ministry of Agriculture, AL-Andulus Square, P.O. Box 5923, Baghdad, Iraq

One problem with polyethylene covering films of greenhouses has been drop condensation on the inside of the roof. Condensation of water in drop form considerably reduces light transmission as within the drops reflection of the light takes place. Condensation on the roof has not only an effect on light transmission but also on heat transfer and soil heat storage.

A parafin-wax emulsion was manufactured and sprayed on the inside of the roof of the greenhouse. The parafin-wax emulsion was white, cationic, easily diluted by water, with pH=6.5 and density $= 0.92 \text{ kg m}^{-3}$.

A field experiment was carried out to verify the validity of polyethylene films treated with parafin-wax emulsion for inhibition of water condensation in drop form on the inside of the roof of the greenhouse.

The result show that PE-film treated with parafin-wax increased the light transmission 9% more than the untreated one. Moreover the diurnal soil heat storage increased also. A difference of $+15.31 \text{ W m}^{-3}$ at a depth of 1-5 cm represents significant heat storage at 10 00 h between the treated and non-treated PE-films. While a significant difference of $-8.75 \text{ W m}^{-3}$ between treated and untreated PE-film referred to nocturnal losses of stored heat at 17 00 h for the same soil depth. Finally, plant growth rate and yield increased due to the modification of plant microclimate.

Keywords: soil temperature, soil heat storage, microclimate, parafin-wax, greenhouse, polyethylene
The use of natural deposits as an alternative for polymers on water management in arid calcareous sandy soils of Saudi Arabia

AL-OMRAN A.M. (1), FALATAH A.M. (1) and AL-HARBI A.R. (2)

(1) Department of Soil Science, College of Agriculture, P.O. Box 2460 King Saud University, Riyadh 11451, Saudi Arabia
(2) Department of Plant Production, College of Agriculture, P.O. Box 2460 King Saud University, Riyadh 11451, Saudi Arabia

Most cultivated soils in Saudi Arabia are calcareous sandy soils. These soils are characterized by low organic matter content, low specific surface area, low water holding capacity, high infiltration rate, excessive deep percolation losses and high cumulative evaporation, causing inefficient water use. Thus, the practices including the application of several synthetic polymers as soil conditioners were carried out in our laboratory and greenhouses, to improve some physical and chemical properties of arid calcareous sandy soils, and to increase their productivity. The results of these studies demonstrated that these polymers were effective in improving the physical properties of some soils. However, the results showed a significant increase in soil pH as a substantial increase in EC values, and inconsistent changes in available macro and micronutrients. The application of these polymers on a large scale could be unfeasible because of their high cost, insufficient longevity, reduction of water absorption capacity with salinity of irrigation water and not practicable under field conditions. As an alternative, utilization of natural deposits as a soil conditioner might be a good means to alleviate some of the above-mentioned soil constraints caused by the addition of synthetic polymers. The motivation of the present study was to gain information the effect of natural deposits produced locally on selected physical and chemical properties such as infiltration rate, relative swelling, EC and pH. The results of this study will be discussed in this paper.

Keywords: natural deposits, synthetic polymers, calcareous sandy soils, cumulative evaporation, infiltration rate
Use of microbial inoculants and mineral additives in composting lignocellulosic wastes

ANUSUYA D.

Department of Botany, Bangalore University, Bangalore-560056, India

Lignocellulosic Fungi, when used as inoculants in composting banana waste, accelerated the composting process. The waste has a high C/N ratio (338:16) and cannot be directly used as organic manure. Hence, experiments conducted for enrichment of compost have shown that inoculation of Trichoderma viride, Aspergillus awamori and Phanerochaete chrysosporium and the addition of rock phosphate improved the manurial value of compost as compared to the non-inoculated compost. The uptake of NPK and micronutrients from the inoculated compost by tomato crops increased significantly. Use of inoculated compost at 10 t ha$^{-1}$ containing 50% of the recommended fertilizer rate resulted in a tomato yields 30% greater than with the recommended full dose of fertilizers.

Keywords: compost, banana waste, Trichoderma, tomato, phosphate
Estimating generalized soil-water characteristics from particle size distribution organic matter content and bulk density

BASSIRANI Nasrollah (1) and GILL G.S. (2)

(1) Zabol University, Zabol, Iran
(2) Cas In Geology Panjab University, Chandigarh, India

Many problems in soil and water management require knowledge of the moisture retention curve and hydraulic conductivity of soils. Experimental determination of these parameters is expensive, difficult, and often impractical. For many purposes, general estimates based on more readily available information such as soil texture, organic matter content, and bulk density are sufficient. Recent studies have developed statistical correlation between soil texture, organic matter content, bulk density and selected soil potentials using a large data base, and also between selected soil textures, organic matter content, bulk density and hydraulic conductivity. The objective of this study was to extend these results by providing mathematical equations for continuous estimates over broad ranges of soil texture, organic matter content, bulk density, water potentials, and hydraulic conductivities. Predicted values were successfully compared with several independent measurements of soil-water potential.

Keywords: soil moisture, soil water, particle size, organic matter, bulk density, estimating
Gypsum: an economical amendment for amelioration of saline-sodic waters and soils and improving crop yields

GHAFOOR Abdul, QADIR Manzoor and MURTAZA Ghulam

Dept. Soil Science, Univ. Agri., Faisalabad, Pakistan

The agriculturally important area of Pakistan, the Indus Plains, is situated in arid to semi-arid climate where monsoon rains are erratic and mostly in the months of July, August and March, i.e. quite insufficient to grow even a single crop without artificial irrigation. Under this ambient agro-environment, there is a net work of surface irrigation canals handling 111.1 MAF water, > 0.2 million tube wells pumping about 48 MAF water and sewage irrigation around big cities. At present, 6.3 mha soils are salt-affected and 70-80 % of the pumped ground water is hazardous for irrigation. Competition among the agricultural and non-agricultural uses has decreased the sweet water availability for agriculture and consequently the brackish ground water is being pumped more and more to practice irrigated agriculture.

The water quality parameters are: EC for total soluble salts, SAR and RSC reflect the sodicity hazards. The ground water, drainage water and sewage become hazardous because of high EC ($\geq 1.0 \, \text{dS m}^{-1}$), SAR ($\geq 10.0$) and/or RSC ($\geq 2.5 \, \text{mmol L}^{-1}$). For lowering high EC of water, only dilution with low electrolyte water is the option but use of any amendment (gypsum, acids, acid formers) will increase it further without any beneficial effect. To lower high water SAR, gypsum is the most economical amendment, dilution will decrease it by the square root times of the dilution factor, while use of any acid (sulphurous acid or sulphuric acid) or acid former has to do nothing with high water SAR rather will be the wastage of funds as well as may deteriorate the soil health (physically and chemically) if acids or acid formers are used for longer periods. For high RSC, dilution with low $\text{CO}_3^{2-} + \text{HCO}_3^-$ water will decrease it proportionately to the dilution factor, Ca-salts will increase $\text{Ca}^{2+} + \text{Mg}^{2+}$ to affect a decrease in water RSC, while acids or acid formers will decrease water RSC through neutralizing the $\text{CO}_3^{2-} + \text{HCO}_3^-$. Among RSC treatment amendments, still the gypsum use is economical and safe, although acid could accomplish the same but at a much higher cost.

For reclaiming saline soils ($\text{EC}_e \geq 4.0 \, \text{dS m}^{-1}$, SAR $\leq 13.0$), no amendment is required rather simple leaching with all the types of water (canal, ground water, agricultural drainage) is useful at the beginning following a gradual shift toward sweet water application. For saline-sodic ($\text{EC}_e \geq 4.0 \, \text{dS m}^{-1}$, SAR $\geq 13.0$) and sodic ($\text{EC}_e \leq 4.0 \, \text{dS m}^{-1}$, SAR $\geq 13.0$) soils, Ca-carriers (gypsum, calcium chloride, calcium nitrate, phosphogypsum) are the most economical, acids (H$_2$SO$_4$, HCl, HNO$_3$) or acid formers (sulphur, calcium poly-sulphide, pyrite, ferrous sulphate) can reclaim such soils relatively at a faster rate but at 5-10 times higher cost. The most feasible cropping systems are: rice ($\text{Oryza sativa}$ L) - wheat ($\text{Triticum aestivum}$ L) in the upper Punjab (i.e. rice areas) and rice-berseem in the central and southern Punjab (mix cropping and cotton-wheat areas). Inclusion of junter ($\text{Sesbania aculeata}$) as fodder or green manure crop is helpful in soil reclamation and Kallar Grass ($\text{Leptochloa fusca}$) is also a good summer fodder crop for very high EC and SAR soils during the initial years even using very poor quality waters for irrigation.

Keywords: saline-sodic waters, saline-sodic soils, economic amendment, rice-wheat cropping system, gypsum
Relationships between mechanical properties, penetration resistance and bulk density in reconstituted Anthroposols

JEAN-PIERRE Rossignol and DEBAYLE Christophe

UMR SAGAH, Institut National d’Horticulture, 2 rue Le Nôtre, 49045 Angers, France

The soils of new green areas are made from the topsoil of agricultural arable farmland. These reconstructed soils undergo important constraints from earth excavation at the original site to placement in the new site. One can foresee negative constraints during the various procedures involved.

This work studies the relationship between soil mechanical properties and some physical properties such as bulk density and penetration resistance, with the objective of controlling earth placement quality and anticipating material reactions to external constraints. The earth used for the tests is a clayey loam from the Lyons region (France).

The tests were carried out in the laboratory in controlled conditions, by varying bulk density and moisture using the Proctor test and then measuring penetration resistance. Moreover, measures on reconstituted soils in green areas installed three years ago being carried out: penetration resistance (by Panda® penetrometer), bulk density (by gammadensitometer) and moisture.

This work allowed us to confirm that penetration resistance increases when moisture decreases with an exponential statistical relationship. The work also showed that bulk density controls the variations of penetration resistance, with exponential relationships when the physical state is considered: consistent state, plastic state and liquid state. For each of these soil physical states, a threshold value of bulk density was determined from which the penetration resistance increased greatly. For the used material, at consistent state, the penetration resistance increase greatly from a bulk density value of 1.55 (5 Mpa) to a superior value of 7 (30 Mpa) at which point the penetrometer could not enter; at the plastic state, the threshold is 1.7 (5 Mpa) to 1.85 (30 Mpa); at liquid state, this threshold is 1.85 (5 Mpa) to 1.95 – 2 (30 Mpa).

The use of the penetrometer can allow the control of soil compaction, given the material type and these physical states. The use of the thresholds allow us to link bulk densities and penetration resistance when the physical state (consistent, plastic or liquid) is known.

Keywords: reconstituted anthropic soils, penetrometer, bulk density, moisture, mechanical properties
Soil aeration under varying physical edaphic properties in relation to crop growth

KHAN A.R. (1), NANDA P. (2), CHANDRA D. (1) and SINGH S.R. (3)

(1) I.C.T.P. (UNESCO & IAEA), Trieste, Italy
(2) Water Technology Centre for Eastern Region (ICAR), Bhubaneswar, Orissa- 751 023, India
(3) Water Management Research, Indian Council of Agricultural Research (ICAR), Walmi Complex, P.O. – Phulwari Sharif PATNA, Bihar – 801 505, India

The process of soil aeration is one of the most important determining factors of soil productivity. In the process of respiration, crop roots absorb oxygen and release carbon di-oxide (CO₂). The CO₂ concentration of the atmosphere is about 0.03 per cent whereas in soil, it reaches 10 or 100 times higher. Adequate root respiration requires that the soil itself be aerated and gaseous exchanges take place between soil air and the atmosphere at such a rate as to prevent a deficiency of oxygen and excess of CO₂ from developing in the root zone. Soil microorganisms also respire and under restricted condition may compete with the roots of higher plants.

Restricted aeration due to water logging, poor drainage, crust formation or mechanical compaction of the soil can restrict crop growth. Restricted aeration also causes a decrease in the permeability of roots to water. Anaerobic conditions in the soil induce a series of reduction reactions, both chemical and biochemical. Oxygen concentration of air is normally about 20 per cent but due to an increase in CO₂ concentration in soil, oxygen concentration starts declining and many plants, which are sensitive to aeration (like sugar-beet etc.) start suffering due to an excessive concentration of CO₂ in both gaseous and aqueous phases. In more extreme cases of aeration restriction, the oxygen concentration can fall to near zero and prolonged anaerobic conditions can result in the development of a chemical environment characterized by reduction reactions such as denitrification, the evolution of such gases as hydrogen sulfide (H₂S), methane (CH₄) and ethylene and a reduction of mineral oxides like Fe and Mg.

The assessment of the importance of soil aeration for various plant characteristics and environmental conditions is necessary to evaluate the oxygen relations to the crops. The root environment as a solid-liquid matrix depends upon soil structure and moisture condition. Soil surface conditions can be altered by tillage, mulching, irrigation and mechanical compaction etc. They play a significant role in protecting/or restricting the plants against deficient aeration during critical periods of growth phases. Various experiments were conducted to study the influence of different farming practices like tillage, the manipulation of soil surface condition and irrigation on soil aeration in relation to crop growth.

Keywords: aeration, mulch, tillage, oxygen diffusion rate (ODR), peanut
Influence of type of organic material on strength of sport turfs

BOS O.F. (1), WOLLESWINKEL A.P. (2) and KOOLEN A.J. (1)

(1) Soil Technology Group, Wageningen University, Mansholtlaan 10, 6708PA Wageningen, The Netherlands
(2) Institute for Sports Accomodations, NOC*NSF, P.O. Box 302, 6800AH Arnhem, The Netherlands

In The Netherlands, quality of sport turfs is controlled by the National Olympic Committee/National Sports Federation (NOC*NSF). Soil profiles of current Dutch sport turfs include an installed, 15 cm thick, upper layer above an installed, 25cm thick, sublayer. These layers are laid on original soil, often after removal of an upper part of the original soil profile. Depending on the hydrology of the site, drainpipes are applied at the bottom of the sublayer. The installed sublayer is sand of a certain grading, which should promote quick rainwater drainage. The installed upper layer should allow growth and fuctionning of grass roots, and provide enough bearing capacity and stability for the players, also under wet conditions. It is made by mixing sand with a material that is rich in organic matter. According to prevailing standards, the weight ratio of that material and the sand should be such that the resulting mix (the upper layer) has an organic matter content of 4%. As material, rich in organic matter, several products are used. A.o.: compost made from biowaste (GFT); heath compost; highly decomposed peat that has been frozen (a black peat product); so-called superpeat compost (a mix of the black peat product with GFT). The upper layer may also be supplied from agricultural soils that have an organic matter content of 4%.

Experiments were carried out in order to answer the question whether the type of material, rich in organic matter, has an influence on the bearing capacity/stability of upper layers with an organic matter content of 4%. Bearing capacity/stability was measured by a pseudo-static penetration test with a steel wedge. Wedge dimensions, loading, and test conditions followed standards set by NOC*NSF, so that the test results could be interpreted in terms of the playability of turf and the risk of turf damage by playing. The range of tested upper layers could be ranked according to their measured bearing capacity/stability.

Keywords: turf, compost, peat, bearing capacity, stability
Development of a slow sand filter system for treatment of wastewater from hydroponics

LEE Hyun Haeng, KIM Kwon Rae, PARK Jae-Bok and KIM Kye-Hoon

Dept. of Environmental Horticulture, The University of Seoul, 90 Jeonnong-dong, Dongdaemun-gu, Seoul, 130-743, Korea

Despite many advantages of the hydroponics such as low production cost and high yield, the major disadvantage of the system is production of wastewater. Excess nutrient in wastewater can cause the problem of pollution of soil, stream and subterranean water nearby hydroponics system. The slow sand filtration is one of the most popular purification methods with low cost and high efficiency in the removal of bacteria. A slow sand filtration system was developed using sand and zeolite. In PVC pipes with 110 mm diameter, 350 mm of gravel (2–32 mm dia.) was put followed by 50-110 mm of pre-washed sand (0.15–2 mm) and zeolite mixture. Wastewater from hydroponic systems for various crops was filtered through the system by gravity. The pH and concentration of cations before and after the sand filtration were compared. The contents of NH₄, K, Ca, Zn and Mn in the wastewater after filtration decreased compared to those before filtration. The potential use of media used for the filtration system as high quality growing media was also examined. The percentage of germination, growth rate, and early growth rate of lettuces (Lactuca sativa L.) shown in the used filtering media are increased compared to those in the control (sand).

Keywords: sand filter, zeolite, cation
Usability of brown coal for improvement of physical and water properties of sandy soil

MACIEJEWSKA Alina and KWIATKOWSKA Jolanta

Department of Soil Science and Soil Conservation, Warsaw University of Technology, Warsaw, Poland

Very light soil is too porous and remains dry. This is a result of poor granulometric composition, in which sand is a dominant fraction whereas the content of silt and colloids does not exceed 10 per cent. Very light soil accounts for a considerable proportion of the arable land in Poland, therefore methods for improving their productivity have been searched for. One such method is agromelioration treatment with brown coal which has a positive effect on water soil properties. This result is due to such properties of brown coal like very strongly developed porosity structure and their capability in ions exchange. Doughty variety of brown coal has a high content of humodentrinite macerals which provide the earthy and porous texture and steaming moisture between 50% and 60%.

The aim of this paper was to analyse the changes of physical and water properties of very light soil after application of a preparation obtained from brown coal.

The long-term experiment was carried out on rusty soil formed from loose sand. Soil in the experiment had low retention of water, big permeability and porosity. The preparation containing 85% of brown coal, was applied into the soil in autumn 1987 in a dose of 80.0 t ha⁻¹ or 160.0 t ha⁻¹. Soil samples with non-disturbed structure into the measuring 100 cm³ cylinder were collected from Ap horizon layer (0-25 cm) every year after crop harvesting. Bulk density by the piknometr method were determined. Porosity total was counted on the base of bulk and specific density.

It was found that the preparation obtained from brown coal remarkably influenced the physical and water properties of very light soil. The treatment caused a decrease in bulk density of the arable layer of soil in the first year (1988) after applying this fertilizer and so on in the next years (1992, 1995) with the dose increased. Specific density was not changed under the influence of this preparation. The porosity total increased after agromelioration with the preparation obtained from brown coal to the same level in the experimental years (1988, 1992 and 1995). The increase in soil retention of water was observed also.

Thus, the results obtained are promising and further studies should be carried out with brown coal for soil cultivation and the improvement of water properties of very light soils.

Keywords: brown coal, soil properties, sandy soil
Characterisation of physico-chemical nature of sewage of Tamil Nadu

CHANDRA SEKARAN N., SARAVANAN A. and RAJKANNAN B.

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

A survey has been carried out in different districts and municipalities of Tamil Nadu on the raw sewage, primary and secondary treated sewage and a case of diluted sewage representing separately for urban and domestic areas were collected and appraised in the laboratory with particular weightage for assessing their agricultural value. Domestic raw sewage can undoubtedly be considered as an excellent source for agricultural use. The pH, EC and water quality parameters remained well within the normal limits of irrigation water quality. The heavy metal content was also low. Urban raw sewage suffered from poor water quality parameters and a relatively high content of heavy metals particularly Ni, Cr and Pb. However it carried considerable amounts of plant nutrients. The treated sewage effluent at both primary and secondary level with regard to domestic and urban effluent had certain beneficial effects. Reduction in suspended solids/BOD and COD/heavy metals and water quality parameters improvement was observed.

Keywords: sewage effluents, water quality appraisal, quality of irrigation water
Bioclogging of glass beads by bacteria and fungi

SEKI Katsutoshi, SUKO Takeshi and MIYAZAKI Tsuyoshi

Department of Biological and Environmental Engineering, Faculty of Agriculture, The University of Tokyo

We analyzed biological clogging of glass beads in laboratory column experiments. Glucose solution of 50 g cm\(^{-3}\) was percolated in columns packed with glass beads of 0.2-mm and 0.05-mm in diameters, and change in hydraulic conductivity was measured continuously for 30 days. The bioclogging at the inlet of solution proceeded rapidly in every column. When glass filter was placed on the top of the sample, the glass filter was clogged severely. To avoid filter clogging, we did the other column experiments without setting glass filter over the top of the sample. Hydraulic conductivity at the top layer of every column decreased in three orders of magnitude in 2 to 4 days, and stabilized with small tendency to decrease afterwards. The numbers of fungi as well as bacteria at clogged layers increased in every column. Therefore fungi are also important clogging material, although many researches so far have focused on bacterial clogging and neglected the effect of fungi. The thickness of the layer of clogged part depends on the particle size of the beads. In 0.2-mm beads, the thickness of the clogged layer was larger than 0.3 cm, while in 0.05-mm beads the thickness of the clogged layer was smaller than 0.3 cm. Shear stress of biomass at 0.2-mm beads is larger than the biomass at 0.05-mm beads because of larger flux at initial condition, and microbial cells moved downward by shear detachment force and the clogged layer became thicker. When deaerated distilled water was percolated, hydraulic conductivity changed in three stage, increase, decrease and increase, and finally two orders decrease in hydraulic conductivity was observed.

Keywords: clogging, bioclogging, bacteria, fungi, hydraulic conductivity, microbial effect
Effect of soil cooling on growth and development of freesia

RUAMRUNGSRI Soraya (1) and SENAWONG Suebsak (2)

(1) Department of Horticulture, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50202, Thailand
(2) Flower section, Royal Project Foundation, Chiang Mai, Thailand

Freesia is temperate cut flower crop which has the potential and possibility to be cultivated in the highlands of Thailand. Soil temperature is one of the main factors for flower initiation and flowering. The research was aimed at studying the effects of soil cooling on growth and flowering of freesias that are produced in Thailand. Four cultivars of freesia i.e. Diva, Michelle, Orangina and White Star were planted in two groups. In the first group, the four cultivars of freesia were planted in a bed, lined with cooling pipes (T1). The pipes were placed 20 cm deep in the soil. The distance between the pipes was about 10 cm and the temperature was lowered to about 1-2 °C. With the other group, of plants were cultivated in a bed without cooling pipes (T2) as a control. Results show that, by decreasing soil temperature by only 1 to 2 °C, the growth and development of freesias was affected. Plant height of 'Diva', 'Michelle' and 'White Star' treated by soil cooling was lower than those in the control group. The number of leaves per spike was also different between treatments. Soil cooling also affected the flowering date and flower quality of all cultivars.

Keywords: soil cooling, freesia
Active biomonitoring of the urban areas

UDUANSKAYA Elena Alekseevna
Belgorod State University, 12, Studencheskaya street, Belgorod 308007, Russia,

Changes in health of townspeople, certainly, is a parameter of an ecological condition of city, but such parameters which are more sensitive, necessary for its diagnostics human body and could warn of danger threats to health.

Condition of biota - the most important diagnostic attribute of intensity processes of destruction, reflection of the balance of receipt and decomposition of substances in the urbocosystem. At chemical pollution lichen flora reacts one of the first, becoming less various or disappearing altogether in an aura of dispersion pollution from sources of emissions. In such areas of a city it is difficult to find the trees covered with lichens on a surface of trunks. The principal cause of it is the absence of lichens of film -cuticle and apertures - stomata and, thereof, delays of exchange processes. Elements of a feed receive lichens basically from drains during rains, with a high rate of absorption the first concentrated deposits. This ability to promote the survival of deficiency of nutrients, in conditions of pollution appear pernicious. But due to this it is possible to receive good dependence between the contents phytotoxic gases, heavy metals and dust in a lichen and concentration of these substances in an environment. The received data suggest that the chemical compound of communities of lichens adjusted by type of sources of pollution. So it is revealed, that for the purposes of biomonitoring of a dust and the heavy metals present in air around cement and machine-building factories, it is the best way to use lichen Lecanora conisaeoides. Also Cladonia rungifera, Hypogymnia physodes, Pseudoevernia furfuracea, Usnea filipendula were used. Heavy particles of dust settle on lichens and their substrata, forming on them a white film. In such conditions lichens perish. Sedimentation is weak or an alkaline dust will neutralize sour substrata, for example, the bark of trees. Such kinds of lichens as Physcia and Xanthoria, living on the basic bark, can appear on trees, usual which acidity of the bark was neutralized by a dust therefore has increased pH a bark.

Thus, the regular description of communities of lichens in connection with chemical processes is necessary for understanding physiological stability for the following reasons:

1. These plants are excellent receptors and stores of toxic gases, heavy metals and a dust and allow diagnostics and to anticipate their harmful influence on an organism of the person;
2. All set forth above substances getting in plants and penetrating into them, it is possible to subject to the physical-chemical analysis
3. Lichens selectively absorb these substances; therefore the certain kinds of lichens are indicators determined pollution.
4. Plants can be used for definition of a site of a source of emissions in an atmosphere of toxic gases, heavy metals and dust, and also their distribution and sedimentation.

Keywords: chemical pollution, biomonitoring, lichen flora, urban areas, health
Changes in the grassland-forest boundary at LTER site using stable isotope ratios of soil organic matter

CHIANG Bor Nan and WANG Ming Kuang

Department of Agricultural Chemistry, National Taiwan University, Taipei, Taiwan

The $\delta^{13}C$ values of organic samples can be useful as a research tool in ecological sciences because they are unique, and each value carries an imprint of the plant source and origin of a sample. The changes in the vegetation community of alpine forest at Ta-Ta-Chia long-term ecological research (LTER) site was not well studied. The objective of this study was to investigate the plant changes along the grassland-forest boundary in the alpine forest LTER site in central Taiwan. Four pedons of grassland areas ($Miscanthus$, pedons 1 and 2), a transition zone between grassland and forest ($Tsuga$ and $Yushania$, pedon 3), and forest zone ($Tsuga$ and $Yushania$, pedon 4) were investigated. The $\delta^{13}C$ values of the grassland areas ranged from -19.4‰ to -24.1‰ and decreased with increasing soil depth. This suggests that $C_4$ plants ($Miscanthus$) replaced $C_3$ plants of $Tsuga$ and $Yushania$. SOM $\delta^{13}C$ values in the upper soil horizon were similar to $\delta^{13}C$ values of overlaying vegetation types and did not suggest a movement of the boundary between these plant communities during the last decades. However, $\delta^{13}C$ values obtained from deeper soil layers of grassland soils indicated that the vegetation community has changed. However, the $\delta^{13}C$ values of the $Tsuga$ forest area (pedon 4) showed only a slight change with soil depth, indicating that the $C_3$ plants have remained the major species in the forest. The $\delta^{13}C$ values are in the range of -27.0‰ and -23.5‰. Further investigations in grassland-forest boundaries within this region using $^{14}C$ dating analysis of both SOM and charcoals will be necessary in the future to confirm these results.

Keywords: forest, grassland, LTER site
Symposium 52

Remote sensing for data fusion and GIS as tools in land evaluation and degradation studies

Convenor: ESCADAFAL Richard
Co-Convenor: POPAN Apisak

Oral Session
Saturday 17 August 2002
8:30 - 11:50
Room: Meeting Room 4

Poster Session
Saturday 17 August 2002
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Development of three-dimensional maps of eroded soil with data from a profile cone penetrometer

ARRIAGA Francisco J., REINERT Dalvan J., LOWERY Birl and McSWEENEY Kevin

Department of Soil Science, University of Wisconsin-Madison, Madison, Wis., USA

Erosion of the productive surface soil from a landscape reduces crop production and alters chemical and physical properties of the soil, especially the thickness of the effective rooting depth and surface horizon thickness. Fast and reliable tools are needed to detect and map the thickness of soil horizons of eroded landscapes to allow for proper management of eroded soil for optimum agricultural production and environmental protection. A truck-mounted, constant rate profile cone penetrometer was used to determine horizon thickness and thus, map the distribution of various erosion levels of an eroded Dubuque silt loam soil, in Southwest Wisconsin, USA. The penetrometer was pushed into the ground with the hydraulic cylinder of a soil probe mounted on a large truck, to a depth of approximately 1.3 m. Data were collected continuously with a datalogger connected to a load cell and a string potentiometer depth gauge. The 30° tip of the penetrometer was constructed following the American Society of Agricultural Engineers guidelines. Data collected with the penetrometer correlate well with previously constructed maps of soil erosion distribution for the study site, where depth to clay residuum (2Bt2 horizon) was used to determine erosion severity. Depth to clay residuum averaged 0.95, 0.74, and 0.45 m for the slight, moderate, and severe erosion levels, respectively. Of the total study area, approximately 44, 31, and 25% consisted of slight, moderate, and severe erosion levels, respectively. Three-dimensional (3-D) maps of the site were developed using data from the penetrometer. Development of limited invasive tools and methods for mapping eroded soil, such as the one described here, provide some useful tools that can aid in land management.

Keywords: erosion, cone penetrometer, three-dimensional soil map
Land suitability evaluation for mulberry plantation: a remote sensing and GIS based approach

BERA A.K., PATHAK Suparn and SHARMA J.R.

RRSSC, ISRO/Dept. of Space, Govt. of India, CAZRI Campus, Jodhpur – 342 003, India

Site specific farming has the potential to maintain agricultural sustainability. Sericulture can be the largest cottage industry in Rajasthan because of its vast potential for employment generation. The cultivated silk worms which live solely on mulberry leaves produce the finest lustrous fibres, known as real silk fibre. The objective of this study was to identify suitable sites for mulberry plantations. The study area was Rajasthan state of India lying between 69°29' to 78°17' E longitude and 23°30' to 30°11' N latitude and covering an area of about 341,556 km². The methodology adopted involved integration of remotely sensed data with conventional data in GIS environment. A soil resource map was evaluated based on properties like soil depth, texture, drainage, moisture holding capacity and pH. A slope map was studied to identify areas having 0° to 30° slope. A hydrogeomorphological map, prepared from LANDSAT TM FCC, was evaluated to identify moderate or above ground water potential areas which could meet the water requirement of mulberry plantation. A landuse/landcover map, prepared from supervised classification of multi-seasons IRS-1C WiFS sensor data using EASI/PACE (version 6.2) software, was studied to identify areas under crop lands, fallow and scrub lands where mulberry plantations can be grown. After matching optimal physical requirements of mulberry plantations with characteristics of various land units, suitable sites were identified using ARC/INFO GIS (version 7.2.1) software. The thematic map on soil revealed that about 63,387.62 km² area were suitable because the soils of these areas have favourable characteristics like deep to moderately deep, well drained, clay loam to loam texture and good moisture holding capacity as required for mulberry plantations. A slope map showed that within suitable soil area about 761.58 km² area has 0-1% slope followed by 47,222.73 sq. km², 15,356.37 km² and 46.95 km² areas under 1-3%, 3-8% and 8-15% slopes, respectively. From the hydrogeomorphological map, it was found that about 191,353.10 km² area had suitable ground water potential. Moderate ground water potential covers 89,893.29 km² area followed by 46,893.49 km², 16,509.52 km² and 38,056.81 km² areas under moderate to good, good and good to excellent categories, respectively as evident from predominant geomorphic units. The landuse/landcover map showed that about 230,675.55 km² area had favourable kinds of landuse. Out of it 108,609.49 km² area was under crop followed by 47,182.33 km² and 74,883.83 km² areas under scrub and fallow land categories, respectively. The suitable site map represented the spatial extent of each site. As a whole about 32,921.57 km² area had optimum conditions for mulberry plantation. Out of it 12.79% areas were highly suitable where soil, slope, hydrogeomorphology and landuse/landcover were most favourable. Moderately and marginally suitable categories cover 60.23% and 26.98% of suitable areas, respectively. Thus, land suitability evaluation for any crop through integration of remotely sensed data with conventional data in GIS environment can be a reliable, cost and time effective solution.

Keywords: GIS, land evaluation
Continental-scale spatial modelling of soil properties

BUI Elisabeth (1), HENDERSON Brent (2), MORAN Chris (1) and JOHNSTON Robyn (3)

(1) CSIRO Land and Water, GPO Box 1666, Canberra, ACT 2601, Australia
(2) CSIRO Mathematical and Information Sciences, GPO Box 664, Canberra, ACT 2601, Australia
(3) Land and Water Sciences, Bureau of Rural Sciences, PO Box E11, Kingston, ACT 2604, Australia

Maps of soil properties such as pH, organic carbon, total nitrogen, total phosphorus, texture, thickness, % clay, in surface and sub-surface horizons, for the more intensively used agricultural regions of Australia, some 2.7 million km$^2$, were produced for the National Land and Water Audit 2000. In addition, interpretations for soil erodibility and acidification risk were made.

The database consisted of some 135,000 point observations of varying completeness across the properties of interest. The point density for any property shows sparsely and intensively sampled areas. The data came from many sources over many years: some from model-based surveys, some collected for specific purposes and other samples obviously dictated by convenience.

Attributes for which soil profile data were limited were estimated using map-based interpretations, where the dominant soil classes in each map unit were identified, and values for specific properties assigned to each map unit on the basis of the range observed for those soil types. Spatial regression and classification models using environmental variables as predictors of chemical soil properties were developed. The environmental variables considered include 19 climatic variables, 4 bands of MSS, lithology, land-use, a 9" digital elevation model, and a large number of derived variables from the DEM and the drainage network designed to capture the landscape and transport characteristics, e.g. distances to ridges or rivers, path lengths of erosion and deposition, measures of transport power, hillslope lengths, relative elevation and relief. The DEM was gridded to 250 m and all datasets were co-registered. Because the environmental variables cover the entire spatial extent, any models built from the point data can be used to extend predictions to the entire region of interest. At a pixel resolution of 250 metres the spatial prediction of soil properties presented a considerable challenge.

The spatial models were derived using the data mining package Cubist (www.rulequest.com) which builds piecewise linear models or C5.0 which builds classification trees. Both are flexible, data-driven, computationally fast, automatically handles interactions between predictors, and is widely recognised for its performance. All models were internally validated by separating the data set into a training and test set. Performance was also assessed through cross-validation on the full data set.

The models showed strong predictive ability for most properties: topsoil pH had an $R^2$ of approximately 70%. While there is a sizable portion of unexplained variability this was considered to be a reasonable model given the sources of variation in the data for which we can make no account, e.g. differences due to sampling strategies, methods or laboratories. The resolution was also deemed an important contributing factor given the expected variation in soil properties within any 250 m pixel. Climate variables were often found to be the more important predictors, especially for pH, organic carbon, nitrogen and phosphorus. Models built from point data were turned into maps by applying them over the whole extent. Pedotransfer functions for soil erodibility and pH buffering capacity were implemented using the mapped models for soil properties.

**Keywords:** Australia, continental-scale, spatial modelling, spatial prediction, soil property maps
Multi-scale agroecological characterization for natural resources management in dryland areas

DE PAUW Eddy (1), COOLS Nathalie (2) and CELIS David (1)

(1) ICARDA, P.O.Box 5466, Aleppo, Syria
(2) Laboratory for Soil and Water, Katholieke Universiteit, B-3000 Leuven, Belgium

The multi-scale nature of agroecosystem diversity is a major challenge for natural resources management. It limits the ability to transfer agricultural research results from one site to another and to develop land use plans that are fine-tuned to the potentials and constraints of specific areas. Agroecological characterization addresses the issue of agroecosystem diversity through multi-scale agroecological frameworks. The principle is that large areas, e.g. whole countries, are characterized at a general level, whereas the detailed characterizations needed for more detailed planning objectives are only undertaken for small areas. The complementary and simultaneous use of all levels is affordable and allows a speed up of the process of land resource assessment, land use planning and agrotechnology transfer. The main challenge in agroecological characterization is related to developing methods that are applicable at different scales and allow linking the scales.

To explore the feasibility of multi-scale approaches a case study covering the dryland areas of West Asia is presented. The approach used relies on the differentiation of agroecological entities at different scales. 4 broad levels are proposed, the agroecoregion, the agroecological zone, the agroecological unit and the agroecological niche at micro-scale. Delineation of well-documented agroecoregions allows detection over large areas of hot spots of specified resource management problems, such as drought stress or human-induced salinization, using highly aggregated datasets. At a more detailed level agroecological zones are defined through a step-wise integration procedure, in which a large number of basic thematic layers are reduced to a limited number of independent thematic frameworks. Through GIS procedures the new entities are fully characterized in terms of component attributes. Delineation of agroecological zones at the national level is useful for agricultural planning and policy management. At the level of the agroecological unit and niche, land quality is assessed in conjunction with farmers through specific participatory techniques. The feedback obtained from farmers is incorporated into conventional resource mapping and land evaluation procedures. The characterization of agroecological units results into site-specific land use recommendations, which take full account of indigenous knowledge.

At each scale level different data sets and models for integrating the thematic information need to be used. Data sets and models have to be well matched in accuracy and resolution and the conclusions for resource management recommendations adapted to the scale limitations. At all scales remote sensing is becoming increasingly important as a complement and even substitute for field surveys. In order to upscale site-specific research findings a classification system is needed for scaling the components of natural resources management.

Keywords: agroecological characterization, GIS, remote sensing, drylands, land degradation
Remote sensing and modeling of topsoil properties, a clue for assessing land degradation

FARIFTEH Jamshid and FARSHAD Abbas

International Institute for Geoinformation Science and Earth Observation (ITC) P.O. Box 6, 7500 AA Enschede, The Netherlands

Semi-arid regions are under high pressure to supply the required food for their rapidly-increasing populations. This, together with the harsh climatic conditions and changes in land use accelerates land degradation processes, which eventually leads to yield reduction. Conventional sensor systems provide data in only a few spectral bands, which can be, to a given extent, used to model the reflectance of some of the soil components. With the development of scanner systems, that acquire data in many narrow-wavelength bands, almost continuous reflectance data become obtainable, which have considerably enriched all studies of the Earth’s surface. In order to examine the capability of the narrow absorption bands three different study levels, namely spot, local and regional can be planned. At the spot level, soil properties are determined in soil profiles and in laboratory. The key narrow bands, which highly correlate with any of the soil properties, are measured in laboratory and in field. The results should give room to develop a model to predict each property from its spectral signature. The data obtained at this stage might be used to model soil structure and the affect of salinization on it. At the local level, high-resolution air-borne data together with ground-based reflected measurements and laboratory data, from previous phase, are used to determine the spectral reflectance of the salt-affected soils. Ancillary data such as spatial distribution and surface conditions of the salt-affected areas are to be correlated with reflectance data. At the regional level, multi-spectral and multi-spatial resolution spaceborne data and the data from previous phases are used to delineate salt-affected areas.

Keywords: soil degradation, salinization, soil structure, remote sensing, hyperspectral, modeling
Prediction of the soil organic carbon content at micro-, meso- and macroscales by digital terrain modelling

FLORINSKY Igor V. (1,2) and EILERS Robert G. (3)

(1) Department of Soil Science, University of Manitoba, 362 Ellis Bldg, Winnipeg, Manitoba, R3T 2N2, Canada
(2) Institute of Mathematical Problems of Biology, Russian Academy of Sciences, Pushchino, Moscow Region, 142292, Russia
(3) Land Resource Unit, Agriculture and Agri-Food Canada, 360 Ellis Bldg, University of Manitoba, Winnipeg, Manitoba, R3T 2N2, Canada

Estimation of the carbon sink capacity of soils for different scales of assessment is an urgent problem. Since the spatial distribution of the Soil Organic Carbon (SOC) is affected by topography, it is logical to utilise Digital Terrain Modelling (DTM) to predict a spatial distribution of current levels of the SOC content and thereby assess the potential capacity of soils to sequester additional carbon. A DTM-based concept of accumulation, transit and dissipation zones of the landsurface can be applied to provide this prediction, and to upscale systematically the prediction from micro- (field) to meso- (regional) to macro- (national) scales. The objective of this work was to develop a DTM-based method for the prediction of the spatial distribution of the SOC at micro-, meso- and macroscales. Three areas within the Black Soils Zone of the Canadian prairies were selected for the study: (1) the Miniota Precision Agriculture Research Site (microscale), (2) a part of the southern Manitoba (mesoscale), and (3) the provinces of Alberta, Saskatchewan and Manitoba (macroscale). Digital Elevation Models (DEMs) of these areas and selected soil information were used as initial data. We derived digital models of horizontal and vertical curvatures from the DEMs. Then, maps of accumulation, transit and dissipation zones were obtained by a combination of data on horizontal and vertical curvatures. Relationships between the SOC content of the A horizon and accumulation, transit and dissipation zones were found for the Miniota site. To carry out the scaling-up procedure, the microscale relations between the SOC content of the A horizon and microtopography were extrapolated to meso- and macrotopography of broader ecological districts with similar soils, parent materials and landforms. Then, we used maps of accumulation, transit and dissipation zones to produce predictive maps of the SOC content of the A horizon at three different scales. The method developed can provide an objective and replicable prediction for the SOC content at different scales, and may be linked with models for prediction of the soil carbon sink, dynamics of the soil organic matter, and the soil inorganic carbon.

Keywords: digital terrain modelling, soil organic carbon, prediction, upscaling
Mapping paddy fields in Northeast Thailand using remotely sensed data

KATAWATIN Roengsak (1) and SUKCHAN Somsak (2)

(1) Department of Land Resources and Environment, Faculty of Agriculture, Khon Kaen University 40002, Thailand
(2) Soil Survey and Classification Division, Land Development Department, Bangkok 10900, Thailand

Information on the areal extent of paddy fields is always essential for agricultural land use planning in NE Thailand. In this study, an attempt was made to investigate the feasibility of using LANDSAT-5 TM data with some common supervised classification methods, to generate information on the spatial distribution of different paddy types. To explore the extent to which various paddy types can be distinguished, four classification schemes of different levels of detail for paddy classification were developed. Various statistics including histogram analysis, KAPPA analysis and Z-statistic, overall accuracy, producer’s accuracy and user’s accuracy were employed as the basis for this investigation. Although, the use of data from all TM bands with the Maximum Likelihood method appeared to be most appropriate, mapping of paddy based on this technique was found fairly satisfactory only when all paddy types were considered as one single class, i.e., "paddy". Distinguishing different paddy types could not be done successfully.

Keywords: mapping, paddy fields, remotely sensed data, LANDSAT-5 TM, Thailand
GIS and Hevea growth model for production potential map on land quality in Chanthha Buri Province, Thailand

PRATUMMINTRA Somjate (1), VAN RANST Eric (2), VERPLANCKE Hubert (2), KUNGPHISDARN Nuchanart (1) and KESAWAPITAK Prasat (1),

(1) Rubber Research Institute of Thailand, Chatuchak, Bangkok 10900, Thailand
(2) Ghent University, Krijgslaan 281, Ghent 9000, Belgium

Chanthha Buri province is one of the south eastern coast provinces of Thailand, which covers an area of 636,271 ha. It is classified as a traditional rubber planting area existing of about 50,000 ha of rubber plantations. The preliminary surveyed showed that more than 75% of the plantations have been exploited, with the girth being lower than that of the standard. The study aimed to evaluate rubber production potential and to carry out a suitable package of technology, and promote the increasing of the actual yield up to the maximum potential.

Ninety-nine rubber plantations were selected based on the digital data of LANDSAT TM5 image (7 Bands, full scene), interpreting was by the ENVI ver. 4.0 and ARCVIEW ver.3.1. The land characteristics were studied to determine the land index (LI) by using a parametric approach together with comparing the characteristics with the crop requirement tables. The average girth of 80 trees measured at 170 cm from each plantation together with production and cultural practice data were used to validate the growth model.

This growth model was modified using a variable factor such as rubber age, planting density and LI to evaluate rubber tree growth, and the total girth as the sum of an increment of annual girth. The fertilizer index (Fl) was added to the model for improving tree growth from using fertilizer. The Fl, 38% increase in the tree growth rate, was linked to LI for the adjustment index in the model was the clonal index. This obtained the value of 1 for the RRIM 600 clone, for the other clone the value of 0.6-1.8 applied to the model. The production potential as an annual yield, with a minimum expectation of 950 kg ha⁻¹, was then calculated using the LI and girth of rubber trees.

The growth model together with the GIS program (ARCVIEW ver 3.1) yielded the maximum production potential map of a district scale such as, Kaenghangmaew, Khlung, Koahitchkut, Lamsing, Makham, Muang, Nayaiarm, Pongnamron, Soidoa and Thamai. Moreover, in each district, the problem soils can be mapped, and can be solved by using a suitable package of technology.

Keywords: GIS, data fusion, land evaluation, soil quality, land management, MIS
A soil survey of the Grand Staircase-Escalante National Monument (GSENM), located in southern Utah, USA, has been in progress since the fall of 1997. The vastness (700,000 ha) and inaccessibility of the GSENM has led to the exploration of Geographical Information Systems (GIS) as a landscape analysis tool for soil mapping. The Circle Cliffs study area is located in the north-eastern corner of the GSENM. The Moenkopi Formation covers 57% of the Circle Cliffs area. The Moenkopi soil map units were initially separated according to color, red or brown, and the degree of dissection, low or high. Quantitatively defining and validating these map unit concepts would allow them to be applied to other areas of the GSENM that contain the Moenkopi Formation. The purpose of this project was to test a method that employs GIS as a landscape analysis tool for validating map unit concepts. Average slope and slope distribution were used as a proxy for the degree of dissection. This method assumes that high average slope and broad slope distribution correspond to the high degree of dissection, and the opposite for the low degree of dissection. Average slope and slope distribution were calculated for each Moenkopi map unit, 5107, 5108, 5109, 5110, and 5111, using ArcView GIS. These data were examined to determine low or high degree of dissection for each map unit. The results were compared to the initial designation of degree of dissection made during analysis of aerial photography. An average slope value for a threshold between low and high degrees of dissection was determined. This analysis shows that map units 5107 and 5111 have narrow slope distributions, and low average slopes. Map units 5108, 5109, and 5111 have broad slope distributions, and high average slopes. The results of this analysis lead to the conclusion that map units 5107 and 5111 have a low degree of dissection, and map units 5108, 5109, and 5110 have a high degree of dissection. These results are consistent with the results from the initial analysis of aerial photography. The average slopes for 5107 and 5111 are less than 45%, and the average slopes for 5108, 5109, and 5110 are greater than 45%. Therefore, the average slope value of 45% was designated as a threshold value between low and high degrees of dissection for Moenkopi map units. This analysis proved to be useful for validating Moenkopi soil map unit concepts. Average slope and slope distribution were shown to be a valid proxy for degrees of dissection. This project demonstrates that GIS is a useful landscape analysis tool for quantifying and validating soil map unit concepts. The implementation of GIS for landscape analysis in vast and inaccessible soil survey areas may be the key to maintaining efficiency, accuracy, and accountability within the soil survey.

Keywords: arid soils, soil survey, landscape analysis, GIS
Integrating biophysical and economic data using GIS/DSS to assess irrigation suitability for specific crops


(1) Bureau of Rural Sciences, P.O. Box E11, Kingston ACT 2604, Australia
(2) Bureau of Rural Sciences, currently at CSIRO Land and Water, GPO Box 1666, Canberra ACT 2601, Australia
(3) Bureau of Rural Sciences, currently at the Mekong River Commission, P.O. Box 1112, 364 M.V. Preah Monivong Boulevard, Phnom Penh, Cambodia
(4) CSIRO Land and Water, GPO Box 1666, Canberra ACT 2601, Australia

Economic and environmental sustainability are of great importance in the planning and development of new irrigation schemes in order to underpin their long-term viability. In San Luis Province, Argentina, a novel approach has been used to produce irrigation suitability maps for specific crops using the combination of two decision support systems (DSS) with a geographic information system (GIS) in order to select areas suitable for irrigation development using groundwater. This approach has enabled spatial data on soils, groundwater and climate to be integrated with crop agronomic data and economic analysis to produce maps of physical and economic suitability for specific crops. The methodology initially involved land suitability classification based on FAO methodology and hydrogeological mapping of depth to groundwater, potential yield and groundwater quality (salinity and toxic trace elements). These datasets were analysed within the ASSESS (A System for SEIecting Suitable Sites) decision support system using both the Law of the Minimum and Addition methodologies to exclude areas and to rank the remainder with potential for irrigation suitability. More detailed investigations were undertaken using the ALES (Automated Land Evaluation System) decision support system that provided the framework for the integration of biophysical data with crop suitability and economics. This facilitated the comparison of alternative crops in terms of biophysical and economic feasibility. Specifically, a modelled long-term annual rainfall surface was combined in the GIS with the soil and groundwater data as the basis for estimating soil-crop-water relations within the ALES land map units. Crop water requirements and potential yields were modelled based on field and laboratory data. This information was used to define land utilisation types, which were combined within ALES with the land characteristics of each land map unit and economic data to determine physical suitability and economic returns in terms of internal rates of return, gross margins and net present value. Definitions of the sustainable aquifer yield further refined the model allowing for the estimation of the potential irrigable area for any given combination of crop types. The results provide a spatial context for the sustainable development of groundwater based irrigation areas in San Luis Province, together with an economic basis for the selection of alternative cropping systems, and a methodology which has great potential for use elsewhere.

Keywords: irrigation suitability, ALES, ASSESS, GIS, San Luis Province Argentina
A soil geographical database for multi-source data integration to improve user access to soil information

KROL Bart

International Institute for Geo-Information Science and Earth Observation (ITC), P.O. Box 6, 7500 AA Enschede, The Netherlands

Adequate information on soil resources plays an important role in support of planning and decision making for natural resources management. Soil information, however, varies widely in quality, quantity and form. Often it is difficult to access and mobilise. To improve user access to soil information Soil Information Systems (SIS) are increasingly being used to store and interpret basic soil data and to generate soil information on, amongst others, selected soil properties, soil erosion and land degradation hazards, and soil suitability for land use alternatives. A Soil Geographical Database (SGDB), an important component of any SIS, represents the spatial distribution and variability of soil properties and soil-landscape relationships that have been studied in the field.

During several years in the period from 1985 until 1999 different groups of participants to ITC's Soil Survey courses have been conducting field surveys in the Antequera area in southern Spain. Apart from insights gained in soil-landscape relationships occurring in the Antequera area a wealth of field data, numerous semi-detailed soil interpretation maps and accompanying reports of selected study areas have been produced. This data set provides a good example of multiple-source soil information in different analogue and digital formats being difficult to access for further soil interpretation.

The project introduced in this paper attempts to integrate the multiple-source, multiple-category soil data in a soil geographical database. Project activities focus on the design of a proto-type database for data storage and management, and for multi-purpose soil data interpretation. Emphasis is on soil information for regional to local level planning and management.

Available data include soil profile descriptions and analytical data, multiple semi-detailed physiographic and geomorphic soil maps, topographical maps, DEM, geological maps, and remote sensing data.

The soil geographical database is designed applying a hybrid GIS database structure: non-spatial data are organised in a relational database; the spatial database component is managed using the ILWIS GIS software. Spatial-non spatial data integration is realised at the level of data analysis and modelling. Design issues considered include data upscaling/downscaling, meta data documentation and user interfacing.

A proto-type of the database will be used in various user applications, such as: detailed analysis of spatial distribution of soil salinity, soil salinity hazard mapping using remote sensing and field data, and the assessment of soil loss by water erosion.

The results of this project include a semi-detailed soil map for the Antequera area as information output from the Antequera SGDB. Furthermore, the soil database is used by the ITC Soil Science Division in training on 'Soil Information for Sustainable Land Management' and in the further development of training and advisory services dealing with the design and use of Soil Information Systems.

Links with other soil database initiatives include the SOTER database, which emphasises data management at global/continental to national level (small scale maps), and SDBM Plus that facilitates the handling of field description and laboratory data. In Spain, the Instituto de Recursos Naturales y Agrobiologicas de Sevilla (IRNAS) has developed MICROLeis, an integrated system for land data transfer and agro-ecological land evaluation.

Keywords: soil information system, database, data integration, GIS, remote sensing, terrain analysis

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SoLIM: an approach to soil survey using GIS, artificial intelligence and fuzzy logic

ZHOU A-Xing (1), KUNICKIS Sheryl H. (2), BURT James E. (3), HUDSON Berman (4) and SIMONSON Duane (5)

(1) Department of Geography, University of Wisconsin-Madison, Madison, Wisconsin, 53706, USA
(2) USDA-NRCS Soil Survey Division, Room 4250 South Building, 14th & Independence Ave, SW, Washington, DC 20250, USA
(3) Department of Geography, University of Wisconsin-Madison, Madison, Wisconsin, 53706, USA
(4) Soil Survey Interpretations, Natural Resources Conservation Service, 100 Centennial Mall North, Lincoln, NE 68508, USA
(5) Natural Resources Conservation Service, USDA, 1850 Bohmann Drive, Suite C, Richland Center, Wisconsin 53581, USA

The conventional soil survey method faces three major challenges: the limitation of the polygon-based model, the tedious/time-consuming manual mapping process, and the lack of formal documentation of field soil mappers' knowledge. A GIS/expert knowledge-based fuzzy soil inference scheme (SoLIM, Soil-Land Inference Model) was developed to overcome these challenges and to improve the quality and efficiency of soil surveys. The scheme is based on the soil factor equation and the soil-landscape model. The soil-landscape concept contends that if one knows the relationships between each soil and its environment for an area, then one is able to infer what soil might be at each location on the landscape by assessing the environmental conditions at that point. Under the SoLIM scheme the soil landscape is considered as a continuum and represented by a fuzzy logic-based similarity model which overcomes the limitation of the polygon-based model used in conventional soil mapping. The relationships between soils and their formative environmental conditions are explicitly extracted and documented through a set of artificial intelligence techniques, which overcomes the knowledge documentation problem in conventional soil surveys. Soil environmental conditions over an area are characterized using GIS/remote sensing techniques. The characterized environmental conditions are then combined with the extracted relationships to derive a similarity representation of soils over an area through a set of inference techniques, which overcomes the problems associated with the conventional manual mapping process. It is demonstrated through two case studies that the SoLIM scheme for soil survey has many advantages over the conventional soil survey approach. Soil information products derived through the SoLIM approach are of high quality in terms of both level of spatial detail and degree of attribute accuracy. In addition, the scheme shows promise for improving the efficiency of soil surveys and subsequent updates through reducing time and costs of conducting a survey. However, the degree of success of the SoLIM approach highly depends on the availability and quality of environmental data and the quality of knowledge on soil-environmental relationships over the study area.

Keywords: GIS, soil mapping, soil survey, fuzzy logic, SoLIM, artificial intelligence
GIS: an effective tool for delineating soil constraints and quality of water in sugarcane growing soils

KUPPAYEVALASU MALAYAPPAN Sellamuthu, SUBRAMANIAM Natarajan, KARTHIKEYAN Sivakumar and RAMASAMY Sivasamy

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-641003, India

A soil and water resources study was carried in sugarcane growing areas of Kancheepuram district, Tamil Nadu state, India. The study area covering 52,508 hectares of lands are distributed in 131 revenue villages. The lands cultivated with sugarcane in each revenue village is not contiguous. Therefore, the lands cultivated to sugarcane were only chosen for the current studies. Thematic maps were prepared to delineate the distribution of soil related constraints and quality of irrigation water. In Kancheepuram district, well drained to excessively drained class (21.40%), very deep-deep class (36.02 %), sandy loam - sandy clay loam textural class (22.66 %), neutral – neutral class (42.43%) and slightly alkaline – slightly alkaline class (33.34%) were the dominant drainage, textural and reaction classes.

In Kancheepuram district, Low N – Medium P – Medium K class (45.65%) was the predominant major nutrient status class and zinc deficiency occurred in most part of the area (92.45%). High salinity (59.77 %) and low sodium hazard (84.32 %) were the limitations of irrigation water quality in Kancheepuram district.

Keywords: GIS, sugarcane areas, soil and water qualities
A detailed study on GIS aided (soil) “environmental” capacity of Farsala District in Larissa, Greece

LELENTJIS Telemachus (1) and FOTOPOULOS Christos (2)

(1) National Agricultural Research Foundation/Institute of Soil Classification and Mapping, Theophrastou 1, 41335 Larissa, Greece
(2) University of Ioannina, Agrinio School of Natural Resources and Enterprises Management, Department of Agribusiness Management, Seferis 2, 301000, Agrinio, Greece

The area is situated in the south-east part of the so-called region of Thessaly. It is the valley of the Enipeus River, an area of about 85,000 ha. According to the USDA Soil Taxonomy five main orders have been found: Entisols, Inceptisols, Alfisols, Vertisols and Mollisols. The whole area is agricultural and for this purpose is cultivated with cereals (mainly wheat and corn), cotton, and etc.

The aim of the work is to point out the procedures of the inventory and monitoring of the soil and land resources of the area. Also to risk prediction of the possible work out of the agricultural population of this typical agricultural zone of Greece by reason of the structural changes of the global economy and desertification

The soil survey consists of: 1) inventories of the soil and land resources, 2) evaluation of the land resources for agriculture, 3) data processing and publication of results in local scale. The end product is a mosaic of polygons (map units), each containing a classification symbol. The polygon mosaic is produced by ground surveys and by reference to 1:5,000 contour maps, with areas labelled with a particular classification scheme. The end product is edited in scale 1:20,000.

The soil database includes a computerized system for storage and displaying the large scale soil map together with the body of related data like soil profiles and other additional geographical data as topographical and geology maps.

The Land Information System (LIS) is described by a sophisticated GIS, using the Intergraph’s Modular GIS Environment System Nucleus (MGE/SX) cooperated by the Intergraph’s Geomedia™ Professional. MGE and Geomedia™ support the RDBMS ORACLE in our system. The survey is analyzed from the outputs: Soil map with a lateral present land use, a Soil-Phases map, Irrigability map, Infiltration map and Cultivated groups map.

Keywords: soil taxonomy, LIS, GIS, MGE/SX, RDBMS
Application of HARSD for landscape evaluation and salinity risk management, little river, NSW, Australia

DAVIES S.W. and MILNE-HOME W.A.

National Centre for Groundwater Management, University of Technology, Sydney, P.O. Box 123 Broadway NSW 2007, Australia

The HARSD method (Hydrogeomorphic Analysis of Regional Spatial Data) has been applied to the Little River Catchment, Macquarie Valley, NSW, Australia. HARSD is a suite of procedures designed by CSIRO, Australia to provide hydrogeological inferences for catchments using parameters developed from spatial GIS data sets to model landuse scenarios aimed at controlling salinity. The approach maintains that the shape of the landscape is a function of climate and geology, resulting in slopes which, together with geology, control the movement of groundwater through their mutual influence on transmissivity and hydraulic gradient.

HARSD and conventional GIS techniques were combined within Arcview (Ver. 3.2a) to perform automated terrain classification of the 1,075 km$^2$ catchment to generate objective and reproducible Hydrogeomorphic Units (HGU's) with similar aquifer properties and hydraulic response. A 25 m resolution DEM was used to derive topographic attributes (slope, break of slope and curvature), whose statistical distributions were examined in combination with map overlays for soil, lithology and landuse. Four main HGU's were defined on the basis of elevation and further subdivided to eight units using the mean slope.

HARSD and GIS methods were used to predict the Hydraulic Head Surface (HHS) for the identification of potential discharge sites and input to Flownet, a steady-state groundwater model used to derive groundwater and salt fluxes. The HHS was estimated using linear regression between 'bore water level elevation' and 'surface elevation' for eight minimum slope categories (avg. $r^2 = 0.97$). The more definitive regression, 'depth to bore water level' v's 'surface elevation', provided poor results due to inadequate bore density and distribution and the extended time frame over which it was necessary to include observations.

GIS techniques were used to 'cookie-cut' topographic attributes with salt-site polygons to examine spatial relationships with mapped salinity. This is based on the assumption that saline sites represent areas where groundwater is effectively in contact with the surface. Conditions including minimum break of slope $< 1.0^\circ$ and profile curvature $> -0.5^\circ$ were combined with negative values from the calculated 'depth to HHS' grid to constrain the definition of potential discharge sites. These sites compared well with mapped salinity in the southern part of the catchment, but not as well in central and northern parts of the catchment. An inaccurate HHS is less critical during flux estimation in Flownet as it is the derived gradient that matters, not the absolute HHS level. The results remain useful in that they can still provide a relative basis for prioritising areas for remediation.

SPOT (10 m resolution) and Landsat-7 TM (12.5 m resolution) imagery are routinely fused with other spatial data sets within ER Mapper and visually enhanced using 3-D capability.

Despite sparse borehole data, HARSD has been able to provide a satisfactory HHS for input to regional scale Flownet studies. The application of Flownet results and the incorporation of landuse scenarios for salinity management and remediation at Little River is the focus of current investigation.

Keywords: HARSD, GIS, DEM, remote sensing, landscape evaluation, salinity
Improvements of regional soil and landscape mapping in drylands with recent low resolution satellite data

MOUGENOT Bernard (1), DUCHEMIN Benoît (1), CALMELS Stéphanie (1), WISPELAERE Gérard De (2) and HIERNAX Pierre (3)

(1) CESBIO (UPS-CNRS-CNES-IRD), 18 Avenue Edouard Belin, 31401 Toulouse Cedex 4, France
(2) CIRAD, GEOTROP/AMIS, Maison de la Télédétection, 500 Rue J.F. Breton, 34093 Montpellier Cedex 5, France
(3) IRI, ICRISAT Center, BP 12404 Niamey, Niger

Drylands cover 40 percent of the earth’s surface. Soil surface is most of time apparent for remote sensing system, which can be used to help landscape mapping and soil inventory. This study focuses on the interest of low resolution satellite data to map agro-ecological zones at a regional scale, and to put them in relation with soils and their surface dynamics. The scale of available maps ranges between 1:5,000,000 and 1:500,000 such as the Soil map of the world of the FAO or other regional maps. At this level, soils are interesting for global studies. Existing maps and ground data particularly in developing countries can limit regional soil inventory. New needs concern a detailed soils inventory with surface characteristics and land cover types. The rationales are to assess land degradation monitoring or to provide inputs for an ecological model (erosion, plant growth, soil-vegetation-atmosphere transfer). Different international programs tend to improve these soils maps and derived properties at the regional and global level.

This study has focused on the sahelian region in West Africa. We used daily satellite data at 1 km resolution, delivered by the VEGETATION instrument onboard SPOT-4 since April 1998. Two spectral bands in visible spectrum and two in near and mid-infrared spectrums allow us to produce indices both for soils surface (visible bands) and vegetation. New algorithms give “top of soil” reflectances, corrected from atmospheric and directional effects. During the dry season, we extracted colour indices in relationship with ferric/ferrous iron content, simplified texture (clay or sand) and organic matter. During the rainy season, we analysed the vegetation dynamics from the Normalised Difference Vegetation Index (NDVI). The maximum annual biomass production derived from NDVI from 1998 to 2000 removed a great part of rain variability and produced an indicator of soil potentialities. It was balanced against the soil surface characteristics previously extracted. We tested and validated these relationships in a GIS on two pastoral sahelian regions in Mali and Niger for which we used local morpho-pedological maps (1:50,000 to 1:200,000).

Results combining satellite and ecological data showed possibilities to improve mapping of landscapes, associated soils and derived soil properties. This approach could be applied at a regional scale and contributed to characterise and monitor soil surface processes, such as erosion by wind and water, crusting, the loss of nutrients or organic matter. Applications for vegetation and hydrological modelling using soil information such as texture and surface structure are reviewed.

Keywords: surface features, soils, landscape, drylands, remote sensing, Sahel
3-D soil model of modern Syr-Darya delta and adjoining part of Aral Sea dried bottom

PACHIKIN Konstantin (1), MORIMOTO Yukihiro (2) and KRIVENKO Vladimir (3)

(1) Institute of Soil Science, Academgorodok, 480060, Almaty, Kazakhstan
(2) Kyoto University, Graduate School of Agriculture, Lab Landscape Architecture, Kitasirakawa-Oiwake-cho, Sakyo-ku, Kyoto, Japan 606-8502
(3) Association "Isotope", 26, Dalnyaya str., 480050, Almaty, Kazakhstan

On the basis of joint researches of the Kazakhstan and Japanese scientists the soil map of the modern delta of Syr-Darya River and a part of the dried bottom of the Aral Sea is made. The map was made with use of SPOT space image and the field data of 1999-2000. The computer variant of the map is created on Mapinfo 5.5 basis.

The map has a database containing the basic types, subtypes and genera of soils, their combinations (maximum of 3 components), percent of the area of each component in a contour, and also granulometric texture of soils.

Besides the layer of soils, a layer with isogyps and points with known altitude was created on the basis of a topographical map. Further, the uniform grid of 3D model of relief was constructed using a method of regressive analysis. Distance between nodes is 100 m. Each node has values on X, Y, Z coordinates, and also contain data on soils. A final stage of creating a 3D soil model was the combination of the soil map and a model of the relief.

The soil map reflects the basic laws of soil formation as a result of the drying up of the Syr-Darya delta and Aral Sea level decrease. The following sequence of soil types, reflecting different stages of the Aral Sea drying, are observed on the dried bottom: march solonchaks → seaside solonchaks → ordinary solonchaks → takyric solonchaks → takyr-like soils. Seaside primitive soils are formed on the heightened relief elements of the sand bottom deposits. With the time these soils are fluttered and replaced by aeolian forms of relief with desert sandy soils.

Processes of desertification and drying of hydromorphic soils - marsh, meadow-marsh, and alluvial-meadow - are observed in the modern delta. In connection with the reduction of the areas of cultivation of agricultural crops, especially rice, secondary salinisation of irrigated lands is occurring resulting in secondary solonchaks formation.

Keywords: Aral Sea, soil, GIS, desertification
Using satellite imagery and electromagnetic induction to assess soil salinity, drainage problems and crop yield

PULIDO-Madrigal Leonardo (1), GONZALEZ-Meraz Jorge (1) and SANTANA-Lopez Jorge (2)

(1) Instituto Mexicano de Tecnología del Agua. Paseo Cuauhnahuac 8532, Progreso 62550, Jiutepec, Morelos, Mexico
(2) Comisión Nacional del Agua, Distrito de Riego 075 Río Fuerte, Los Mochis, Sinaloa, México

Surveying of soil salinity and drainage deficient areas surveying, as well as yield estimation, in the Río Fuerte Irrigation District, Northwest Mexico, were carried out by applying satellite imagery, a portable electromagnetic-type sensor, and a GPS unit. Soil and plant samples were obtained in selected salt-affected fields grown with wheat (Triticum aestivium), cotton (Gossypium hirsutum), sorghum (Sorghum bicolor) and maize (Zea mays), which were considered as the reference crops, since they all together covered most of the cropped area of the irrigation district. Spectral values (TM2, TM3 and TM4 bands) were extracted from Landsat TM images. The images were obtained during the flowering stage of each crop. Salinity and spectral data were analyzed, and multiple regression models were obtained to estimate the salinity status of the cropped areas, together with its correspondent crop yield. Salinity and yield maps for each crop were digitized and classified on the Landsat image using the regression models. The non-referenced area of the district (fields planted with any other crops, non cropped, fallowed, or abandoned) was mapped in-situ using an EM-38 electromagnetic sensor, along with a GPS unit to locate the geographic coordinates of each of the sites. Both Landsat- and EM38-based salinity maps were joined, and a final map covering all the ID area was obtained. The total mapped area was 319,976 ha, and a salt-affected area of 138,345 ha (43%, EC > 4 dSm⁻¹) was estimated. Poorly drained areas were also obtained based on water table monitoring for the most critical period of the year. This information was also added to the salinity map previously obtained, so salt-affected areas with shallow water tables were determined for reclamation and planning purposes. Yield maps were also combined with the salinity map to analyze the effect of the various existing salinity levels on crop yield. An economical analysis was performed, and we concluded this method is highly cost and time effective, compared to the traditional one (extensive soil sampling and laboratory analysis).

Keywords: satellite imagery, salinity, drainage, yield, regression model, electromagnetic sensor
About new principles of detail soil mapping

SAVIN I. (1) and PYAGAY E. (2)

(1) V.V.Dokuchaev Soil Science Institute, Pyzhevsky per., 7, 109017 Moscow, Russia
(2) EOM KI-CHEOL, National Institute of Agricultural Science and Technology, Suwon 441-707, Republic of Korea

The purpose of detail soil mapping is the delineation of elementary soil units (ESU) or their combinations. Practically, it implements mainly on the basis of the field description of soils, and ESU border is delineated in most cases in an expert way, based on the analysis of soil forming factors. Such approaches are not dispossessed of lacks, limiting the practical value of soil maps. ESU is legibly fastened to a position of soil in applied classification. It means, that at usage of the miscellaneous classifications it is possible to receive miscellaneous soil maps. Therefore, the soil map contains data only about soil properties, which are significant within soil classification. But, for land evaluation there can be a necessity of the analysis of spatial variations of a lot of soil properties, which cannot be obtained by simple grouping of ESUs. So, the information of the traditional soil maps in many cases is insufficient for land evaluation. A similar lack of detail soil maps was disputed in the scientific literature at the beginning of the 20th century (Levitsky, 1907; Nefedov, 1914). G.F. Nefedov offered to inventory soils by separate layers of soil properties mapping. As a result of a controversy his approach was recognized as an error and the priority has resulted in the approach of professor V.V. Dokuchaev’s school.

It is offered on a qualitatively new level of researches a return to the ideas of G.F. Nefedov and, based on them, to execute a transition from conventional soil mapping to a computer based inventory of soils. It is offered to apply creation of digital database (DB) with a specially designed structure as a basis for detailed soil mapping. At first, DB should contain the information on spatial variations of soil forming factors. The structure of the given part of DB can be nonconstant and depends on natural conditions, but the basic layers of the information are esteemed DEM, microclimatic and geological data, land cover and land use information, and also RS data. Secondly, DB should contain the data about soil properties obtained during fieldwork with precise binding on location. Ideally, the set of properties of soils should actuate all properties indispensable for soil resources analysis. Basically, for data retrieval about each property the network of points should be gobed up. Quantity of points and their allocation should be determined beforehand, and should be sufficient for spatial interpolation of the dot observations data. As the main methods of interpolation the geostatistical approaches can be used.

Usage of proposed approaches is illustrated in the report on concrete examples.

The application of tendered approaches in practice will allow to permit a problem of poor information of traditionally compounded soil maps. A problem of delineation of ESU practically is eliminated from discussion: ESU will be possible to generate on the basis of DB GIS, outgoing from needs of a concrete problem of soil resources analysis.

Keywords: soil mapping, remote sensing, GIS
Spectral unmixing versus spectral angle mapper for land degradation assessment: a case study in Southern Spain

SHRESTHA D.P. (1), MARGATE D.E. (2), ANH H.V. (3) and Van DER MEER F. (1)

(1) International Institute for Aerospace Survey and Earth Sciences (ITC), P.O. Box 6, 7500 AA Enschede, The Netherlands
(2) Bureau of Soils and Water Management, Quezon City, Philippines
(3) Forest Science Institute, Hanoi, Vietnam

Unlike conventional sensor systems such as Landsat-TM, Spot-MX or IRS-LISS, which acquire data in only a few spectral bands, the development of scanner systems that acquire data in many narrow-wavelength bands allows the use of almost continuous reflectance data in studies of the Earth’s surface. This not only produces laboratory-like reflectance spectra with absorption bands specific to object properties, but also helps increase accuracy of mapping surface features. Classification by means of spectral matching thus becomes more feasible. With so much information, the well-known problem of mixed pixels can be solved by a mixture model, which is commonly assumed to occur in a linear fashion.

In this study, we compared linear unmixing and spectral angle matching techniques to assess the classification performance for identifying and mapping ‘desert like’ surface features in southern Spain. These features include desert pavements, calcareous, gypsiferous and saline surface soils. Although spectral unmixing helps to assign a pixel to a dominant class, the data is affected by illumination variations caused by topography, so that selection of end member can be biased. By comparison, the spectral angle matching technique compares only the angle between known and unknown spectra, which uses only the direction and not the length of the spectral vector. It is therefore insensitive to the gain factor caused by surface illumination conditions and thus more suitable in areas with high illumination differences. On the other hand, linear unmixing calculates, for each pixel, the abundance of pixel components. This present study shows that linear unmixing seems to provide more realistic results for mapping “desert like” surface features as compared to a spectral angle mapper.

Keywords: hyperspectral, linear unmixing, spectral matching, spectral angle ‘desert like’ surface features
Quantitative pedogenic approach on soilscape by relief analysis, geophysics and remote sensing

SOMMER Michael, WEHRHAN Marc, ZIPPRICH Matthias, ZU CASTELL Wolfgang and WELLER Ulrich

GSF–National Research Center for Environment and Health, Institute of Biomathematics and Biometrics, Ingolstädter Landstr. 1, 85764 Neuherberg, Germany

We analysed a highly complex soilscape of fluvial sediments by a hierarchical expert system. Using (i) inquiries, (ii) relief analysis on a basis of a DEM 5, and (iii) soils apparent electrical conductivity (EM38). As a data base we first defined zones of identical pedogenic context. Next, multitemporal remote sensing data of winterwheat were obtained by an airborne multispectral scanner (Daedalus-ATM), which gives radiometric information with a geometric (ground) resolution of 1 m² (pixel size). Vegetation parameters, like LAI and aboveground biomass, were semi-physically modelled using three relevant spectral channels (red, green, NIR). Further, the resulting spatial patterns of vegetation parameters were processed by image analysis methods, i.e. an opening - closing procedure using a circular element with a radius of 5 m. These coarser patterns of LAI and biomass, respectively, were interpreted as patterns of site quality within each zone of pedogenic context. By our multitemporal approach we were able to distinguish between stationary and time-variant patterns. Combined with point calibration on a basis of a 50 m raster we identified available water capacity (AWC) and O₂ deficiency due to stagnant water as the most important soil properties constituting site quality for plant growth. Our results will be used for precision agriculture practices in the future.

Keywords: soilscape analysis, remote sensing, relief analysis, EM38, hierarchical expert systems, precision agriculture
Maize crop yield prediction through satellite images and mathematical models

SORIA-RUIZ Jesús (1) and FERNANDEZ-ORDÓÑEZ Yolanda (2)

(1) Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP)
Vial A. López Mateos Km. 4.5, Zinacantepec, Estado de México, México
(2) Colegio de Postgraduados. Carr. Mexico-Texcoco Km. 35.5, Montecillo, Estado de Mexico, Mexico

Crop yield and harvested volume prediction are topics of interest in Mexico for farmers and government officers responsible of managing the agricultural national policies, since they represent an important step towards precision agriculture of the 21st century. Digital data from satellite images jointly analyzed with crop modeling parameters provide information that enables crop yield prediction. The objective of this study was the prediction of yield and total volume of maize production through the use of Landsat - TM satellite images and mathematical models, previous to crop harvesting. The work was realized in the 2000 and 2001 spring - summer cycles 2001 in the northwestern region of the State of Mexico. The methodological procedure consisted of: a) location of polygons and sampling sites in maize fields through GPS; b) quantification of spatial sowing distribution by NDVI from satellite images bands 2, 3 and 4; c) sampling calculation of the leaf area index (LAI) with high-precision equipment (ACUPAR) and d) application of crop yield prediction models generated in the previous year. These models were the following: a) yield (Y) as a function of LAI and b) yield as a function of NDVI. To determine the efficiency degree of the calculated predictions at the flowering stage of maize, yield sampling was realized in the physiological maturity stage in pilot plots. The average yield obtained was 5.22 t ha⁻¹. Percentages of under and overestimation were obtained comparing the average yield with the calculated predictions, according to each model under consideration. The estimated sowing surface by the NDVI method of Landsat – ETM+ was of 141,726 ha. Comparing this value with the historical value data reported by the Agriculture Department (SAGARPA) of 164,400, an underestimation of 14.8% was found. Regarding yield prediction in the flowering stage, the models LAI = f (NDVI) and Y = f (LAI) reported a value of 5.96 t ha⁻¹. Using the model Y = f (NDVI) a value of 5.04 t ha⁻¹ was obtained. These data represent 114% and 97% respectively of the true yield obtained on the field.

Keywords: crops, yield prediction, maize, remote sensing
Mapping salt affected areas in Northeast Thailand using LANDSAT-5 TM data

SUKCHAN Somsak (1), KATAWATIN Roengsak (2), JANTHOTHAI Kraingsak (2) and WICHAIDIT Pichai (1)

(1) Soil Survey and Classification Division, Land Development Department, MOAC, Thailand
(2) Department of Land Resources Faculty of Agriculture, Khon Kaen University, Thailand

The study was conducted in a 45 x 45 km² area at 1760000-1783000 N and 233000-258000 E (grid zone 48P in Universal Transverse Mercator), covering some parts of Ban Phai, Chonnabot, Waeng Yai and Munchakiri districts, in Khon Kaen province. The LANDSAT-5 TM data acquired on March 7, 1995 were used. In this mapping, 4 classes of salt affected areas were mapped based on the Land Development Department criteria. These included (1) areas with salt crust >50%, (2) salt crust 10-50%, (3) salt crust 1-10%, and (4) salt crust <1%.

This study was conducted with two major objectives. First, to compare the accuracy of the maps generated using 3 techniques i.e., (1) Visual interpretation of false color composite bands 5, 3, 1 (red, green, blue) image, 2) Digital image classification of data in bands 1, 4, 7, and 3) Digital image classification of data in bands 1, 4, 7 together with other relevant spatial data on geology, underground water quality and soil. The false color composite image of bands 5, 3, 1 were previously found promising for visual interpretation of salt affected areas. The image data bands 1, 4, 7 were selected as a result of a band selection process. The techniques #2 and #3 were undertaken using Supervised Classification with Maximum Likelihood classifier. The second objective was to determine appropriate technique(s) for mapping salt affected areas in northeast Thailand.

Accuracies of the maps generated using these three techniques were compared based on statistics i.e., overall accuracy, omission errors and commission errors calculated in the error matrix tables. Results have shown that the overall accuracy, omission errors and commission errors were (1) 73.37%, 11-54% and 5-60%, respectively, for the maps generated based on visual interpretation, (2) 60.41%, 24-99% and 17-98%, respectively, for the maps generated using digital image classification alone, and (3) 82.22%, 13-45% and 1-51% for the maps generated using digital image classification together with other relevant spatial data. This means that, technique #3 has appeared to be most promising for mapping salt affected areas in northeast Thailand.

Keywords: salt affected areas, LANDSAT-5 TM, supervised classification, overall accuracy
Data processing of sensed apparent electrical conductivity to support soil mapping under non-saline conditions

MEUL Marijke and VAN MEIRVENNE Marc

Dept. Soil Management and Soil Care, Ghent University, Coupure 653, 9000 Gent, Belgium

Electromagnetic induction allows sensing above the soil surface the apparent electrical conductivity (ECa) over a certain soil depth (about 1.5 m). This is similar to the more conventional remotely sensed signals from aerial or spatial platforms. This ECa can be related to different soil properties like salinity, soil water content, and concentration of soil colloids (clay, organic matter). Mostly this technique has been applied to map soil salinity, but under non-saline conditions it was much less often used, partly because it is less clear which are the most influencing soil properties.

In Belgium, non saline conditions prevail, but there is a need for detailed soil information, triggered by increasing environmental regulations on land use. Since classical soil sampling and laboratory analysis prevents large sampling densities, we used a large number of sensed signals of ECa in combination with a limited number of soil samples. Therefore we used an EM38-DD, which has a dual configuration allowing it to be measured simultaneously in two different soil profiles. By comparing both profiles information was obtained about the homogeneity/heterogeneity of the soil profile. This information was used to guide soil sampling and soil investigation.

The paper describes the geostatistical soil data analyses we used to improve the usefulness of the sensed EMI measurements as an exhaustive secondary information source in combination with a limited number of direct soil observations on soil texture and soil chemical properties. As a case study an agricultural field in Belgium was used and we sensed the ECa at several moments throughout the growing season. It was found that the use of EMI in combination with spatial statistics largely improved our ability to map and understand the field soil variability.

Keywords: electromagnetic induction, geostatistics, EM38, soil mapping, within-field variability
Remote sensing for soil resource mapping in watershed

VENUGOPAL Arunkumar, SUBRAMANIAM Natarajan, RAMASAMY Sivasamy and MAHARAJAN Elayarajan

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, India

Timely and reliable information on soils with respect to their nature, extent, spatial distribution, potentials and limitations is very crucial for optimal utilization of available agricultural resources on a sustained basis. Remote sensing has proved to be the most efficient, economical and reliable technique to prepare a comprehensive inventory of the natural soil resources and land use pattern of an area.

A study was carried out to characterise the soils of the Palar-Manimuthar Watershed in Tamil Nadu, India through satellite remote sensing. The extent of the study area is about 3,22,457 hectares and lies between 9°43'55" and 10°26'57" N latitude and between 78°07'15" and 79°07'37" E longitude. IRS - 1B LISS II Geocoded False Colour Composite (FCC) satellite imageries on 1:50,000 scale acquired from National Remote Sensing Agency (NRSA), Hyderabad, India were visually interpreted based on image interpretation elements such as tone, texture, size, shape, pattern, elements and association. Different interpretation units and keys for the study area were then developed. Sample strips for ground truth collection, profile studies and field traverse were chosen for each imagery interpretation unit.

Detailed soil investigation was carried out in each sample strip and soil composition in terms of soil series/soil association were identified. Random checks were done to confirm the soil composition in unsampled strips with the sample units. A total of 140 profiles were examined for detailed morphological characteristics. Fifty two soil series were established. Horizonwise soil samples were collected from representative profiles and analysed for the physical and chemical properties of the soils.

Based on the morphological, physical and chemical properties, the soil series were classified up to family level under the USDA system of soil classification (Soil Survey Staff, 1996). The soils series were classified in the orders of Entisols, Inceptisols, Alfisols and Vertisols. The final soil map was prepared by transferring the details of the field map to the base map of 1:50,000 scale. The soil map consisted of 51 mapping units. The soils were interpreted based on the climate, site and inherent characteristics for a) Land capability classification, b) Land irrigability classification c) Soil suitability rating and d) Horticulture development and thematic maps were prepared by using GIS techniques.

Keywords: remote sensing, soil mapping, agricultural planning
Studying the efficiency of Landsat ETM+ bands for differentiating soil playa margin
(case study: Semnan Playa, Iran)

ZEHTABIAN Gholam Reza (1), ALAVI PANAH Seyed Kazem (2) and EHSANI Amir Hushang (3)

(1) Faculty of Natural Resources, University of Tehran, Iran
(2) Iran Desert Research Center, Tehran University, Iran
(3) Desert Research Center, University of Tehran, Iran

Despite vast areas of arid regions in Iran, a few studies have been done in these areas using remotely sensed data. In this study, in order to detect and to differentiate between soil types in the playa margin, digital data of Landsat 7 (ETM+) were used. The study area is located in North Eastern Iran in Semnan province with longitude of 54°10' to 54°55' E and latitude of 35°45' to 36°5' N. The most recent available Landsat satellite data, dated 20 July 2000 were used. In this study based on the image interpretation of FCC and image processing approach such as principal component analysis (PCA), Intensity - Hue - Saturation (IHS). 19 training areas were selected and with field observation and GPS sampling, the condition of each unit has been determined and defined. Then based on the separated units and feature space analysis and other information, a maximum likelihood image classification was performed. In the classification four approaches were used and results have shown that in separating some classes, each band has a key role in enhancing accuracy.

Keywords: playa margin, ETM+, maximum likelihood, image processing, soil surface