Using GIS approach to map soil fertility in Hyderabad district of Pakistan

Naheed Akhter[A], Manfred Denich[A] and Heiner Goldbach[B]

[A]University of Bonn, Center for Development Research (ZEF), Germany, Email nakther@uni-bonn.de
[B]University of Bonn, Institute of Crop Science and Resource Conservation (INRES), Germany.

Abstract
A study was conducted in district Hyderabad of Pakistan to map the soil fertility using GIS software under different agricultural practices. Cotton, wheat and sugarcane are the major crops cultivated in the region. Due to arid climate, irrigated agriculture in the region depends largely on water withdrawal from Indus River while some farmers use tube-wells. Key characteristics of the region are intensive cropping, imbalanced use of fertilizers, unreliable and poor quality of the irrigation water which resulted in less fertile soils. However, there is yet no detailed spatial information with respect to the status of the micro and macro nutrients in the soils. The objective of this study was thus to prepare detailed maps using GIS for the soil fertility of the region and to link the status of fertility with agricultural practices. The soil samples were taken from 80 spatially distributed locations from a depth of 0-60 cm. Soil samples were analyzed for texture, electrical conductivity, pH, total nitrogen, available phosphorus, potassium and micro nutrients (Zn, Cu, Fe, Mn and B). The data regarding fertilizer application, cropping pattern, crop rotation and irrigation practices were also collected from the farmers. The interpolated maps for the status of micro and macro nutrients show a clear deficiency of nutrients across the district. Nitrogen is deficient in 96 %, potassium and phosphorus are below the critical levels in 95 and 76 % of the soils of the irrigated area, respectively. Organic matter is below recommended levels in 95 % of the cropping area. More than 50 % of the area has sandy loam to sandy clay loam soil texture. The cotton-wheat rotation does not provide any time for soil recovery and therefore intensive cropping followed by mismanaged heavy irrigation and insufficient and unbalanced fertilization caused nutrient deficiencies in the soils of this region.

Key Words
Soil Fertility, cropping pattern, Hyderabad.

Introduction
Until 2025, food production must grow by at least 40% to meet the needs of a 33% increase in population and to satisfy the trends for improved nutrition (Bos *et al.* 2005). To meet these targets of food production for an affluent population, the increase in food grain and hence the improvement in agriculture sector is inevitable. As land is finite, increased food production from the limited land resources is one of the tasks for the coming decades. Moreover, farmers apply fertilizers without having knowledge of the status of the nutrients in their soils. Agriculture, being the backbone of Pakistan's economy, contributes approximately one-fourth of the country's gross domestic product (GDP) and employs almost half of its labor force. Due to intensive cropping systems, imbalanced use of fertilizer, unreliable and poor quality of irrigation water, the soils of the study region are reported as less fertile (than what?) (NFDC-FAO 2006a; Rashid and Ryan 2004; Rashid *et al.* 2006). Due to lack of knowledge and institutional incapability to implement the developed norms, farmers apply heavy fertilizer doses without considering the current nutrient status of their soils. Therefore, farmers need to be aware of the nature and severity of the nutrient problems in order to arrive at a prudent decision regarding the kind and dose of fertilizer to be applied (Rashid and Rafique 1998; Rashid and Ryan 2004). The district of Hyderabad is one of the leading agricultural production regions of Pakistan. Cotton-wheat is a dominant cropping pattern with intensive irrigation to meet the cropping requirements in an arid climate. Large farms mainly produce mono crops (e.g. mango), whereas the medium and small farms are intercropping wheat with sugarcane besides the wheat-cotton in rotation. Cultivation of wheat with onion is also a common practice within the region.

Despite the importance of the region in the agricultural sector, there is still no detailed spatial information showing the nutrient status of soils. The objective of the study was thus not only to prepare detailed maps of soil fertility of the region but also to link the status of fertility with agricultural practices and the nutrient status of crops by DRIS and critical level (CL) approaches to identify the most important nutrient constraints for a sustainable production (DRIS and CL will be published elsewhere).

Materials and Methods

This study was conducted during the 2007-08 vegetation season in the district of Hyderabad, located at 25.367°N latitude and 68.367°E longitude with an elevation of 13 m from mean sea level. The soils of the study area are light to medium and some parts of the region are heavy in texture. Composite soil samples from eighty locations distributed randomly across the whole of the district were collected at the depth of 0-60 cm. The soil samples were air-dried and ground to pass a 2 mm sieve for the analysis of soil pH, OM and macronutrients (N, P and K) and micronutrients (Cu, Zn, Fe, Mn and B).

Soil pH was determined with a pH electrode at a soil to water ratio of 1:2.5 (w/v) (Lu 1999). Soil OM was analyzed using the Walkley–Black method (Walkley and Black, 1934). Because the soil was calcareous, available Zn, Cu, Mn, and Fe were extracted by the DTPA procedure developed for calcareous soils (Lindsay and Norvell 1978), extracting 10 g soil (<2 mm) with 20 mL of 0.005 M DTPA + 0.01 M $CaCl2$ + 0.1 M TEA (triethanolamine) solution. After 2 h continuous shaking at room temperature, the soil suspension was centrifuged and filtered through Whatman No.5 filter paper. Aliquots were analyzed by atomic absorption spectrophotometer to determine the amounts of available Cu, Zn, Mn, and Fe. The way points on the global positioning system (GPS) device were marked during the field work from the all eighty locations and imported to Arc GIS software. The geographical information system software Arc GIS was used to interpolate the results from the point data to the entire region. Kriging interpolation (Cressie 1992) was used for the estimation of the spatial distribution of nutrients.

Results and Discussion

The results of the spatially interpolated maps show that the distribution of macro and micro nutrients is generally low but varies across the district. Nitrogen is deficient in 96 % of the irrigated area, whereas potassium and phosphorus are below the critical levels in 95 and 76 % of the soils of the irrigated area, respectively. The low fertility of soils caused by low amounts of available nutrients can be due to several reasons. Aulakh and Singh (1997) reported that the low nutrients in the soils can be due to the low organic matter and coarse soil texture and therefore only adequate supply of nutrients can improve the productivity of soil. In the study area, more than 50 % of the irrigated area has a coarse soil texture and 95 % of the cropped area is low in organic matter. Although the low OM with coarse soil texture resulted in nutrient deficiency in the area, there are further important factors such as cropping history. The survey during the data collection revealed that farmers are using cotton-wheat rotation in more than 70 % of the area for a long time. Dwivedi *et al.* (2001), S.Fujisaka *et al.* (1994) and Singh and Singh (1995) documented that continuous cropping for longer periods with low system diversity, and often with poor crop management practices, resulted in loss of soil fertility due to emergence of multiple nutrient deficiencies due to nutrient mining, especially if not compensated for by addition of proper fertilizer amounts in the required ratios.

Conclusion

The maps suggested that there are overall multi-nutrient deficiencies in the region. The reasons for low fertility are the intensive cropping system, imbalanced use of fertilizer and thus nutrient mining, possibly of minor elements such as Zn. The cotton-wheat rotation is intensively being used in the area and is causing the low fertility of soils when nutrient and OM supply are not compensating for the losses. One of the solutions could be the introduction of leguminous species into the cotton-wheat rotation either by intercropping with the leguminous crops or growing leguminous crops in between the season. The benefits of legume crops have been reported repeatedly (Buresh and Datta 1991; Singh *et al.* 2002; Timsina and Connor 2001). Balanced fertilizer use and complementary use of organic nutrient inputs with fertilizers are the possible agro-techniques to sustain yield, increase fertilizer use efficiency and to restore soil fertility under intensive cropping (Dwivedi *et al.* 2003; Timsina and Connor 2001; Yadav *et al.* 1998a).

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