Mapping ‘unsuitability’ for de-rocking in Northwestern Syria

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Abstract
As part of an ecogeographical survey in the Jebel Wastani and Jebel Zawia hilly lands of NW Syria, a rapid appraisal was conducted to assess potential for de-rocking in currently marginal rocky areas. The study was conducted using a newly developed land use/land cover map and limited field work, which did not include a systematic soil survey. On the basis of these information sources and other secondary data integrated in a GIS system, it was possible to disqualify 85% of the study area as having no potential for de-rocking. The criteria used were existing agricultural use, forest cover, excessive rockiness or slopes, nearby presence of historical and cultural sites, quarries, and potential to serve as a conservation area. The strongest predictor of potential for de-rocking was the land use class ‘rangelands’ on nummulithic limestones.

Key Words
Syria, land suitability, land use, remote sensing, lithology.

Introduction
Under an agreement with the Syrian Ministry of Agriculture and Agrarian Reform (MAAR), a botanical and ecogeographical survey was undertaken in 2007 in Jebel Wastani and Jebel Zawia in Idleb Governorate, as part of a large Syria Government poverty alleviation project, the “Idleb Rural Development Project” (IRDP). The project is located in Idleb Governorate, in the extreme north-west corner of the country, focusing initially on two major upland areas, Jebel Wastani and Jebel Zawia (Figure 1). A number of poverty and farming systems studies (e.g. IFAD 2001; Szonyi *et al.* 2005; Wattenbach 2005; Keyzer *et al.* 2006) have identified this area as one of the main rural poverty hotspots in Syria.

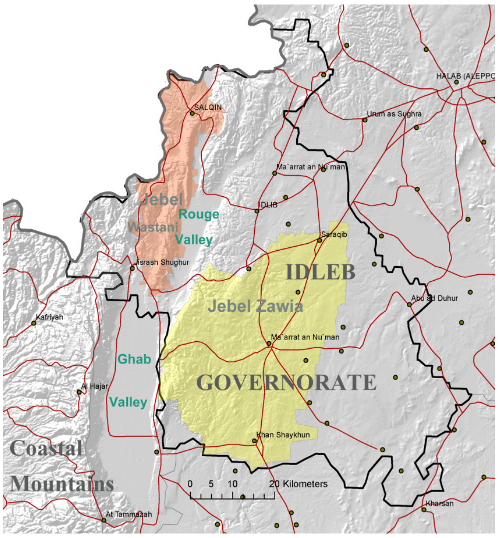

Figure 1. Location of the study area.

Study area
Jebel Wastani and Jebel Zawia are upland areas, with higher elevation than the surrounding areas, with a total surface area of about 2,200 km^2.The range in elevation is quite high, especially in Jebel Wastani, with a difference between the lowest (82 m) and highest point (841 m) of 759 m over a horizontal distance of a few kilometers only. Jebel Zawia rises less dramatically, although in absolute terms, its highest point (939 m) surpasses Jebel Wastani. Whereas Jebel Wastani has a more rugged, hilly topography, Jebel Zawia is more plain-like in character. The study area has a semi-arid Mediterranean climate characterized by hot, dry summers and mild and rainy winters. Nearly all of the rainfall occurs in the winter and spring. The mean annual precipitation drops from about 700 mm in the west of the study area to 450 mm in the east, but with considerable variation from year to year, as is typical for Mediterranean climates. Despite such variability, the minimum to be expected is sufficiently high to make the growth of most field crops possible, especially

climatically adapted cereals and food legumes, as well as olive and fruit trees. Except at high elevation, there is no serious temperature constraint for agriculture in the project area. The number of days with frost is very low, hence the growing period is, under rainfed conditions, essentially limited only by the precipitation regime.

Despite a favourable rainfall, the lack of land with adequate soils for agricultural use, combined with a high population density, creates conditions of low per-capita income from agriculture and high reliance on off-farm income, obtained through either seasonal farm labour in other farming systems or external labour markets (Wattenbach, 2005). Agroecological characterization and farming systems research thus lead to the same conclusion that the main physical constraints for agriculture are shallow soils and steep slopes.

The main strategy of Government of Syria (GOS) to tackle poverty in the project area and to increase food production in the country, has been by removing the key constraint, lack of suitable land, through an extensive program of land development involving reclamation of rocky areas by rock removal ('de-rocking'). While de-rocking marginal land has directly brought many benefits to tens of thousands of small farmer households, there is some evidence that, if unmitigated, this intervention could induce some undesirable environmental impacts. In addition to the apparent reduction in the diversity of the natural vegetation, including the land races of common food crops, a major concern was that heavy earth-moving equipment, as used in the de-rocking operations, could disturb archaeological, historical and cultural sites. Moreover, there was an important economic aspect: to ensure that the rock removal process would not lead to excessive wear-and-tear to the machinery or yield too little soil and result in heavy costs for soil mining and transport. For this reason an activity related to suitability for de-rocking was included in the botanical and eco-geographical surveys.

Materials and methods

A two-stage approach to mapping suitability for de-rocking was followed. The first step was a rapid screening process resulting in the identification of areas that are definitely unsuitable (mapping 'unsuitability'), to be followed later by a second phase of actual suitability mapping, confined to the areas that could not be excluded on the basis of the criteria used during the first mapping phase, and involving detailed and targeted soil characterization. In this paper we discuss mainly the methods and results from this first assessment phase.

Secondary data were compiled on climate, geology, soils, land use and farming systems in the project area. On the basis of these and field observations a detailed characterization of the agricultural environment was undertaken in Jebel Zawia and Jebel Wastani. This agroecological characterization of the project area was summarized in a set of raster maps covering climatic themes (precipitation, temperature, length of growing period, frost), topography (elevation, slopes, aspect, drainage, wetness index, watersheds), and geology, all of which were integrated into a map of agroecological units. The geological materials existing in the project area were obtained from the 1:200,000 geological map sheets Hama and Lattakia (Technoexport, 1963). The 17 mapping units of the geological map sheets covering the project area were reclassified into 4 major lithological groups:

- Quaternary soft materials, soils and sediments (group A materials)
- Pliocene and Upper Miocene basalts (group B materials)
- Soft and easily crushed limestones and other calcareous sediments of various ages from Cretaceous to Pliocene (group C materials)
- Hard 'nummulithic' limestones of the Middle Eocene (group D materials)

In order to guide all field operations and as a background to all thematic mapping, a base map at 1:50,000 scale was compiled from existing 1:50,000 topographical maps, combined with information from satellite imagery (Landsat ETM+, March 2003, and the Quickbird images in Google Earth) and GPS measurements of sites and roads. Areas with slopes exceeding 25% were considered unfeasible for de-rocking by the IRDP. In view of the outdated information on the 1:50,000 topographical maps, it was considered essential to conduct a new assessment of land use/land cover. The land use/land cover survey was undertaken through image classification procedures using relatively recent (23 March 2003) Landsat ETM+ imagery and ENVI software, and covered the entire Idleb Governorate. Ground truthing was obtained during field trips between March and May 2007. Using Google Earth the areas covered with QuickBird images (spatial resolution 1m) were directly used as ground truth data for training area selection, verification and validation of the land use/land cover map. The mapping process included the following steps:

- Field investigations using a GPS to obtain a broad understanding of the main land use/cover types and their geographical locations in the study area;
- Radiometric calibration, geometric correction and resolving displacements with topographical maps
- Selection of training areas, covering a total of 5.4% (297 km^2) of the Idleb Governorate: 18 classes were provisionally differentiated.
- Separability analysis using the Jeffrey-Matusita Distance measure (Richard and Jia, 1999)
- Supervised classification using the Maximum Likelihood classifier
- Selection of final classes by aggregation of classes difficult to separate, and reduction of fragmentation by generalization to a minimum mapping unit size of .81 ha (9 original pixels)
- Verification using 265 field points yielded a field observation accuracy of nearly 93%.

Combining the information from the base map and the maps of slopes, lithological materials, land use/land cover, and potential conservation areas, it was now possible to differentiate areas where de-rocking was unfeasible for the following reasons, either individually or in combination:

- Too many rocks: land cover type is 'bare rocks'
- Too steep slopes: > 25%
- Presence of quarries
- Presence of historical ruins within a 100 m buffer zone
- Built-up areas and villages
- Already under crops (fallow, irrigated crops, orchards, terraces)
- Forest cover
- Potential to serve as conservation area

These areas were delineated in ArcGIS using simple built-in overlay and reclassification functions.

Results and discussion

Eight final land use/land cover classes were differentiated in the study area: Forests (2.4%), Built-up areas (1.7%), Water bodies and temporary flooding zones (0.7%), Irrigated crops (17.2%), Tree crops and orchards (51.3%), Fallow (4.8%), Bare rocks (2.4%), and Rangelands (19.2%). Settled cropland (73.3%) thus dominates the study area, especially in Jebel Zawia (77.3%), and to a lesser extent in Jebel Wastani (60.7%), indicating that the potential for further de-rocking is limited by the existing land use. From the land use perspective, the only remaining land resources for creating new agricultural land through de-rocking are the rangelands, covering 19.2% of the study area, more in Jebel Wastani (26.4%) and less in Jebel Zawia (16.9%). Within the rangelands another 28% is unsuitable for de-rocking due to additional constraints, mainly related to slopes exceeding 25% (16% of the rangelands), reforestation areas (6.6%), and proposed conservation areas (2.5%), and the remainder due to proposed 100 m buffer zones around historical sites, and the presence of quarries, terraced land, and built-up areas that were not detected from the Landsat imagery but were present on the 1:50,000 topographical maps. On the basis of the criteria presented earlier, in total 85% of the project area could be excluded as unsuitable for de-rocking, and only 15% may have a potential for de-rocking, requiring further investigations.

A strong relationship was observed between the different lithological groups and the feasibility (or necessity) for rock removal. The A-materials are located in valleys and almost entirely under agricultural use. B and C materials are also mostly taken into cultivation, because de-rocking has been relatively easy and worthwhile, since the rocks are fairly soft or easy to detach, and have a reasonable reservoir of agricultural soil in between. Materials of lithological groups A and B contribute less than 5% to the area with potential for de-rocking, whereas C-materials may contribute up to 27%. The nummulithic limestones (D-materials) are the largest reserve for soil mining in the area with potential for de-rocking (68%). At the same time they are the hardest materials and bare surfaces with little or no soil (and agricultural use) are common on these materials. On the other hand, here and there pockets of good agricultural soil exist between and even below the rocks. The soils are characterized by reddish or reddish brown colors, clayey texture, strong structure and extremely variable soil depth, depending on the position in the landscape and the erosion that took place in a particular location. In landscape positions where accumulation took place, mostly as a result of erosion uphill, the soil profile is deep, whereas in others the nummulithic limestone emerges and the soil is confined to patches between the rocks. Despite their differences in depth, these soils are fairly homogenous in their physical properties. Once de-rocking has taken place, the soil depth can be increased either by homogenizing the soil from the surface layer, or eventually deeper layers, or by importing soil from an area with deeper soil. Hence, depending on slope and rock area coverage, the nummulithic limestones are the most relevant geological material to assess the feasibility of de-rocking, since these are within the project area the main remaining free resource for creating new agricultural land.

Conclusions

Using the rapid-screening procedure outlined earlier, it was possible to disqualify 85% of the project area as unsuitable for de-rocking. As current land use is the main predictor of de-rocking potential in most of the study area, the new land use/land cover map has been instrumental in avoiding lengthy and expensive soil surveys. Within the remaining 15% (330 km^2) with potential for de-rocking, a second-phase assessment, targeting the rangelands and limestone areas, is currently undertaken to evaluate the feasibility of in-situ soil collection. Detailed soil survey focusing on depth properties and soil/rock ratios associated with differences in the lithological materials are major components of the study.

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