SOIL SURVEY AS A BASIS FOR LAND EVALUATION

Deckers J.
Institute for Land and Water Management, Catholic University Leuven (KUL), Belgium

Spaargaren O.
International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands

Dondeyne S.
Institute for Land and Water Management, Catholic University Leuven (KUL), Belgium

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Contents

Summary

The objective of this paper is to elaborate on soil surveys in view of land evaluation, with emphasis on how soil surveys can meet the information demand for land evaluation. The paper starts by explaining what soil survey and land evaluation is about. Elements of soil survey and land evaluation relating to scale and purpose are discussed. The main focus will be on the linkage between soil survey, soil survey interpretation and physical land evaluation.

Soil classification is a key component of soil surveys. The International Union of Soil Sciences (IUSS)-endorsed soil classification system “World Reference Base for Soil

Resources” is briefly elaborated upon as a means to summarize the wealth of information from soil profiles for the purpose of land evaluation. The different steps from soil parameters, to land characteristics and land qualities for use in land evaluation are explained. The theory is illustrated by a worked example: land evaluation for irrigated rice in the West-African Sahel, wherein the Fertility Capability Classification (FCC) system is used to make the bridge between soil and land information.

1. Soil Surveying

1.2. History and Scope of Soil Surveys

Soil surveys provide information needed for land use management and land use planning. The selection of good land for farming is as old as agricultural land use. The fact that during early Holocene, some 8000 years ago the first farmers in Europe were cultivating the relatively rich löss soils and alluvial plains shows that these people were aware of major differences in fertility between major land units, and that they were able to judge which soil was more productive than others.

Gong (1994) stated that the oldest historical record of soil survey and land classification is most likely the Chinese book “Yugong” in which soils of China were classified into three categories and nine classes, based on soil color, texture and hydrological features. Also now, farmers have a vast knowledge on soil and land resources which ought to be taken into account during soil surveys. However, one of the limitations is that this information is rather location-specific and not transferable as such. Unless brought together under a common denominator, indigenous knowledge will seldom lead to a synthesis of land resources for land planning and management.

According to Simson (1990), soil survey started with the systematic assessment of agricultural land in the United States in the late 1890s. Europe soon followed suit in the early 1900s. A peak in soil survey activity was reached during the 1950s, 1960s and 1970s, particularly with surveys for development projects in Africa, Asia and Latin America.

Soil surveys are meant:

- to investigate the geographical distribution of soils that occur in a given area;
- to determine the most important characteristics of the soils;
- to delineate map units and describe them in a logical legend in terms of dominant, associated and inclusion soil units, including classification of soils. Soil surveys ultimately lead to evaluation of the quality of the different map units for specific types of land use.

The latter point is most crucial. Soil surveys are always conducted with a certain purpose in mind which will be reflected upon in the map legend and in the explanatory notes. Soil data are only part of the information which is needed for land evaluation. Additional data should be supplemented on climate, water resources, landforms, land use and the people in their socio-economic setting.

1.2. Intensity and Scale Considerations of Soil Surveys

The data requirement during field surveys is related to the specific objectives of the study and types of land use under consideration. The scale and intensity of soil surveys are set in function of the objectives of the evaluation and time/money available. An overview of types of soil surveys, scale, purpose and methods used is given in Table 1.

Exploratory **Scale:** 1:500,000 - 1:1,000,000 **Purpose:** establish major soil regions **Methods:** • Deductions from other maps, geological surveys, vegetation records • Remote sensing and ground verification
Reconnaissance **Scale:** 1:100,000 – 1:250,000 **Purpose:** Systematic land resources inventory **Methods:** • Aerial photo interpretation • Comprehensive field surveys and land system analysis • Profile description + analyses
Semi-detailed **Scales:** 1:20,000 – 1:50,000 **Purpose:** • Project feasibility studies • Land use development **Methods:** • Aerial photo interpretation • Intensive field observations • Profile descriptions and analysis
Detailed **Scales:** 1:10,000 and larger **Purpose:** farm planning **Methods:** • Very intensive soil augering • Laboratory analysis

Table 1: Types of soil surveys versus scale, purpose and methods used (after Dent and Young, 1981)

Rate of progress of soil surveys depends on scale of the survey and sampling requirement as illustrated in Table 2.

Survey type	Scale	1 cm on the map = field surface	Observation density	Progress rate per 20 days
Very high intensive	1:5,000 1:10,000	0.25 ha 1.00 ha	1/0.5 ha 1/2.5 ha	500 ha 800 ha
High intensive	1:20,000 1:25,000	4.0 ha 6.25 ha	1/8 ha 1/12.5 ha	1250 ha 1500 ha
Medium intensity	1:50,000	25 ha	1/50 ha	75 km^2
Low intensity	1:100,000	1 km^2	1/km^2	200 km^2

Table 2: Soil survey intensity versus sampling density and progress rate of mapping activities
(after Dent and Young, 1981)

1.3. Soil Survey Methodology

Soil surveying usually comprises five essential steps: (1) background study; (2) ground-truthing of collected geo-referenced information such as aerial or remote sensing data; (3) in-depth soil profile study and soil sampling; (4) extrapolation and boundary verification; (5) laboratory analysis; (6) data crunching, map production, interpretation and reporting.

(1) During the *background study* all relevant data on the target area are compiled, including former studies and existing maps; most important are aerial photographs. If available, time series of aerial photographs are of particular value for reconstructing land use history. Stereoscopic interpretation of the aerial photographs allows in-door investigation of the geomorphology of the area and its relationship with soils and vegetation patterns. The scale at which the maps are published is usually twice as small as the scale with which the aerial photo interpretation of the terrain was done, for example when the area is studied with 1/20,000 scale aerial photos, the resulting soil maps will be published at 1/40,000 scale.

Other relevant background information which needs to be compiled concerns hydrology, geology and lithology, geomorphology, land use history, phytosociology, and past and present land use.

(2) Aerial photographs glued together as a full-cover mosaic may serve as a base for *ground truth* of stereoscopic interpretations. Assessment of soil variability can be done in different ways. In hilly areas Gobin et al. (2000) introduced the concept of integrated *transect walks.* Soils are mapped from hilltops to valleys along transects which ideally have been set out on the aerial photographs during stereoscopic analysis. In the best case these walks are done by a multidisciplinary team and in the presence of local inhabitants (e.g. farmers, pastoralists). On flat terrain the link between soils and landscape is less clear and soil profiles are sampled according to a systematic grid. Soil variability is assessed by auger down to 120cm depth or deeper. An auger register is established by logging readily observable soil characteristics such as soil colour, texture, soil depth, stoniness, drainage, parent rock and so on. At each observation point due attention is paid to other relevant features such as signs of erosion/deposition, status of the vegetation (species composition and cover), micro-topography, aspect, presence of fauna (e.g. ants, termites, moles etc).

(3) After having established the dominant soil regions during the transect walks, representative sites are located for *in-depth soil profile studies.* From each site general information is recorded such as its coordinates (by GPS-logging), land system data (geological formation, parent material, physiography, altitude, land use/vegetation, micro-climate). Soil profiles are dug 2 metres deep, 2.5 metres long and 1 metre wide, leaving steps opposite to the description side for easy access. Vertical variability of the soil horizons in the profile pit is assessed by carefully investigating differences in colour

patterns, texture variations, resistance to penetration by knife, consistency, structure, humus accumulations, presence of clay coatings, inclusions, salts, manganese, cementation, rooting patterns and so on. De Pauw (1985) prepared a handy reference data sheet given in Table 3. This template was based on the FAO Guidelines for Soil Profile Description. Though detailed profile description conventionally stops at 2 metres depth it is usually warranted to assess the deeper layers by soil auger, with particular attention to depth of parent rock, hardpans, groundwater table, and presence of salinity or alkalinity.

On the stairs of the profile pit, horizontal horizon sections are studied with special attention for vertical porosity (worm galleries, small burrows etc.) and polygonal cracking patterns. Soil sampling of selected representative profiles is done at this stage. For the purpose of chemical soil analysis, a disturbed sample (±1 kg) is taken from each horizon. For physical analysis undisturbed core samples are needed. For that purpose 100 cc *copecky rings* are taken in two or three replicates per horizon. Important to note is that for a proper physical analysis it is necessary that the soil profile is moist (at field capacity). Time permitting hydrological conductivity is measured on-site by an infiltrometer to assess the intake rate, and by auger hole method to investigate sub-soil permeability.

(4) *Extrapolation and borderline identification* is done by linking the information from the auger register to soil profile descriptions. After field classification of the soil profiles, all auger observations can be correlated to the soil profiles and all observation points are plotted on the base map (usually a topographic map or an aerial photo composite) along with the landscape features. At that stage a conceptual model emerges, linking the distribution of soils to landscape features. Three-dimensional terrain models produced by GIS technology have proven to be invaluable at this stage to guide extrapolation from transect to full land coverage. Depending on the scale of the survey and terrain complexity, it will then be necessary to verify the mapped boundary lines in the field by augering and by small soil profile pits (micro pits) along additional transect walks.

(5) The purpose of *laboratory analyses* is to provide hard data on land characteristics which are necessary for soil classification and for calculations in land evaluation models. The type of analysis required depends on the purpose of the survey. A sample list of routine analysis done for the purpose of soil classification for physical land evaluation is depicted in Table 3. This comprises for each horizon: the particle-size distribution, pH, electrical conductivity (EC), organic carbon (OC) and nitrogen contents, cation exchange capacity (CEC), exchangeable bases, phosphorus content, soil moisture retention capacity and saturated hydraulic conductivity. For specific analytical data requirements to classify certain soils as Andosols, Podzols and Alisols, reference is made to the FAO World Soil Resources Report Nr. 84.

(6) Once the laboratory data are on file, field classification of the soil profile pits can be verified and the soil map can be finalized. The legend of the map is constructed in such a way that it serves its purpose to a maximum extent. From the original soil map thematic maps are produced which translate the selected information from the soil maps into qualities for a certain land utilization type for example irrigated agriculture.

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Biographical Sketches

Prof. J. Deckers lectures on Soil Geography, Tropical Soils and Land Evaluation at the University of Leuven, Belgium. After ten years of fieldwork as land resources expert for FAO in Eastern Africa, he is now promoter of land resources research projects in South America, Sub-Saharan Africa and in Southeast Asia. He is chairman of the IUSS Working Group WRB and secretary of the IUSS Working Group "Soils and Geo-medicine".

Dr. O.C. Spaargaren graduated from the University of Amsterdam, The Netherlands, in Physical Geography with specialization in Soil Science. In 1979 he obtained his Ph.D. degree in Mathematics and Sciences. He spent 14 years working in Nigeria, Sri Lanka, Nepal, Zambia, Thailand and Ivory Coast, carrying out soil surveys, soil correlation, soil management and irrigation projects. In 1993 he joined the International Soil Reference and Information Centre (ISRIC) in Wageningen, where he is currently responsible for the documentation and information services, the relations with the World Data Centres of the International Council for Science (ICSU), and the implementation of ISRIC's ICT projects.

S. Dondeyne graduated in 1989 in soil science at the Catholic University of Leuven, Belgium. He was involved in soil surveys and irrigation projects in tropical Africa, including South-East Tanzania for the last seven years. He has a main interest in ecology, land evaluation and land management. He is currently finalizing a Ph.D. study on participatory research in land use management.