Selection and use of soil characteristics in digital soil mapping in Tanzania

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Abstract
A study of soil characteristics was conducted in three different agro-ecological zones representing the humid, sub humid and semi-arid-sub humid zones in East Africa. The selected sites correspond to high potential medium and near-marginal areas for the production of maize. Emphasis was put on the topsoil characteristics which largely influence the performance of soils in terms of crop production in the inter-tropical African region. Topsoil depth, available water capacity, organic carbon content, pH, and bulk density, cation exchange capacity are among the key characteristics that influence the functioning of the studied soils. In certain cases, a few key characteristics determine the soils behaviour while in others the same do not. The selection of which ones are critical for a given soil requires detailed analysis supported by field evidence such as experimental data. Spatial heterogeneity in magnitude of individual soil characteristics was common in all sites. In the future digital soil mapping should provide room for subsequent upgrading of the soil information as more data become available. A digital soil map should be prepared such that it provides a possibility to extract information at various resolutions according to needs.

Key Words
Soil characterisatiation, digital soil map.

Introduction
The publication of the soil map of the World in 1981 paved the way for classifying soils using a widely accepted harmonised criteria and nomenclature at the global scale. The World soil map has contributed a lot in understanding of the distribution of global soil resources, but its usefulness remains limited for land management due to its low resolution. Recent advances in remote sensing, invention of Global Positioning System (GPS), Geographical Information Systems (GIS), and spatial and modelling techniques have made it possible to collect, analyse and interpret land resources information at varying spatial and temporal resolutions. These developments are the basis for the revolution in land resources mapping including soils.

Precise and accurate soil or land resources information is vital for properly understanding and predicting the attributes that affect its functions. While the availability of accurate and high resolution soil information is basic for appropriate land use and management, only about 31% of the global land resources have been mapped at a scale of 1:1000, 000 or larger, most of the poorly known soil resources being in Africa. This provides an explanation as to why soil-based problems such as land degradation, low productivity and severity of climate change are inadequately addressed, particularly in the developing world.

The GlobalSoilMap.net (GSM) Digital soil map of the World project is looked upon as a platform for facilitating the accessibility of geo-referenced soil information to a wide range of stakeholders including land users and policy makers. According to GSM, products of digital soil mapping will be tailored to specific needs of end users. It may vary from 30-m resolution (approximately 1:30000) for small holder farmers to 90-m resolution for commercial farmers. Existing databases in Sub Sahara Africa are weakly developed, with scanty and outdated soil characteristic information. Use of such legacy data would not suffice to provide the details needed at the intended resolution. The digital soil map of Africa has to rely on the existence of detailed, accurate and transferable soil information data sets. This study was conducted with an objective of determining the spatial distribution of selected soil properties under maize and legume crops fields in three Agro-ecological zones in Tanzania as a contribution to the development of digital mapping of soils in the Inter-tropical zone of Africa.

The study specifically aimed at determining within small areas equivalent to those owned by small farmers in the inter-tropical zone in Africa, how soil properties vary spatially, which soil characteristics are most relevant, and the relationships among selected properties and their influence in yield. The study was conducted on sites with deep soils, however because on the enormous importance of the status of topsoil on the productivity of annual crops in the tropics, the study was restricted to the topsoil.

Methods
A study was conducted in three different agro-ecological zones representing the humid, sub humid and semi-arid-sub humid zones in East Africa. The study sites were located as follows: two in Hai District in Kilimanjaro region, two in Muheza District in Tanga region and three in Morogoro District in Morogoro in Tanzania. The selected sites correspond to high potential medium and near-marginal areas for the production of maize. The soil at both sites in the Hai district were classified as Nitisols, those in Muheza district as Lixisols and Ferralsols while in Morogoro district, these were Cambisols, Luvisols and Alfisols. An area of 2 hectare within a uniform mapping unit defined at a scale of 1:25000 and representative of the larger landscape was delineated for the study. Both surface (topsoil) and subsurface soil characteristics were determined for classifying the soils. Emphasis was put on the topsoil characteristics which largely influence the performance of soils in terms of crop production in the inter-tropical African region. Topsoil thickness based on soil morphological characteristics, particle size distribution, available water capacity, bulk density, easily dispersible clay, CEC, organic carbon, pH and total nitrogen were determined in the topsoil at grid points 5 metres apart. A maize crop was grown to evaluate soil performance within the delineated study plot at each site. The magnitude of each of the physical and chemical parameters was correlated with both topsoil depth and maize yield. Runoff, erosion studies and infiltration measurements were carried out only on selected sites.

Results
Spatial heterogeneity in magnitude of individual soil characteristics was common in all sites. Topsoil thickness varied largely in the studied districts from 10 to 40cm. The magnitude of both soil physical and chemical characteristics varied spatially and with soil type. Good correlation existed among certain soil properties, giving an opportunity for deciding key characteristics to consider for further testing for their suitability for mapping tropical soils. Topsoil organic carbon correlated well with topsoil thickness in all soils. Relationships between other soil properties and soil depth varied widely with soil types. Maize grain yield was well correlated with topsoil thickness and the soil organic carbon content nearly in all soils. Other soil characteristics showed marked differences among the soils studied, with variation from negative to positive correlation coefficient implying the complexity of the influence of soil properties to crop performance. Up to 73% of maize grain yield was explained by a combination of topsoil depth, bulk density, clay content, and soil organic carbon content. Topsoil depth, available water capacity, organic carbon content, pH, and bulk density, cation exchange capacity are among the key characteristics that influence the functioning of the studied soils. In the well micro-aggregated Nitosols, eroded sites had substantially reduced soil nutrients, in particular nitrogen, compared to sites that only experienced nutrient loss through seepage and leaching. Definition of mapping units could not be achieved without defining the range of heterogeneity in each unit.

Conclusion
It is concluded that the behaviour and hence potential of a given soil depends on the combination of a number of characteristics. In certain cases, a few key characteristics determine the soils behaviour while in others the same do not. The selection of which ones are critical for a given soil requires detailed analysis supported by field evidence such as experimental data. In the future digital soil mapping should provide room for subsequent upgrading of the soil information as more data become available. A digital soil map should be prepared such that it provides a possibility to extract information at various resolutions according to needs. In view of the fact that soil information that will meet the land users' needs is largely inadequate for the production of the envisaged digital map at a 90-m resolution or finer, investment is needed in field and laboratory data acquisition and management, and in infrastructural and human capacity building. Simple and quick means of measuring soil characteristics should be envisaged.

There is a need to study soil properties over a wide range of environmental conditions in order to understanding the behavior of tropical African soils. Activity of the clay fraction is crucial, it ought to be determined or predicted with accuracy. The soil properties that will be included in the digital soil map should reflect the status of soil genesis and its impact to land use. Hence, there is a need to include soil properties of both pedological and of edaphological interest. The need for sharp soil property limits in defining certain horizons as currently used in existing classification systems, such as the limit of clay for defining the argic B horizon or the CEC for the ferralic horizon ought to be justified in terms of functioning of the soil in question. Digital soil mapping should simplify the language used in soil classification to create comfort to end users of mapping products