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Classifying soils at the ultimate stage of weathering: A continuing challenge for sustainable agromanagement practices in the 21st Century

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Abstract
Oxisols cover approximately 23% of the land surface in the tropics and are utilized extensively for agricultural purposes in the tropical countries. Under the variable input types of agricultural systems practiced locally, some of these soils still appear to have problems in terms of proper soil classification and subsequently, hinder attempts to implement sustainable agro-management protocols. Therefore, the objective of this study is to examine the properties of some Oxisols and closely related soils in order to evaluate the classification of these soils.

Soils from several countries in the tropics used in this study. Field observations, water retention differences, apparent CEC of the subsurface horizons, extractable Fe-oxides and external specific surface areas of the clay fractions showed that many kandic horizons have surface properties that are similar to the oxic horizons. Micromorphology indicated that the genetic transition from the argillic to the oxic involves a diminishing expression of the argillic.

It is proposed that the Oxisols be keyed out based only on the presence of an oxic horizon. The proposal provides a better basis for the classification of Malaysian soils and the development of meaningful soil management groups for plantations.

Introduction

Oxisols are known to occupy close to 23% of the land surface in the tropics (Eswaran *et al.*, 1993). Other estimates indicate that these soils occupy approximately 46% (Thomas & Ayarza, 1999), or 38% (Lehane, 2000), if taken into account with the closely related Ultisols. Since the advent of Soil Taxonomy (Soil Survey Staff, 1975), several revisions to the classification of Oxisols had been proposed. However, the classification of transitional soils continued to pose serious problems in many parts of Africa as well as other parts of the tropics. As such, the objective of this study is to reexamine the properties of some Oxisols and closely related soils in order to evaluate the classification of these soils.

Materials and Methods

Soils were selected from Brazil, several countries in Africa and Malaysia for this study (Table 1). The soils were described according to Soil Survey Manual (Soil Survey Staff, 1993). Soils were classified according the Soil Survey Staff (1994). The cation exchange capacity (CEC, pH 7 NH_4OAc method), organic carbon (OC), water retention difference (WRD) and particle-size distribution were carried out according to Soil Survey Laboratory Staff (1992). The data for WRD and CEC of the argillic and cambic horizons were taken from Soil Taxonomy (Soil Survey Staff, 1975). Field descriptions were carried out using the Soil Survey Manual (Soil Survey Staff, 1993) and soil classification according to Keys to Soil Taxonomy (Soil Survey Staff, 1994).

Clay separation was carried out according to Jackson (1969). Mineralogical composition was determined by X-ray diffraction (XRD) technique on oriented specimens using a Phillips diffractometer with an Fe tube. Total elemental analyses on the clay fractions were done according to Jackson (1969). Sequential extraction of the various forms of Fe-oxides was carried out following the recommendation of McKeague *et al.* (1971). External specific surface areas (S.S.A.) were estimated by the N_2-BET method using an Autosorb 1 (Quantachrome Corp., NY). Thin sections of undisturbed soil samples were made according to Jongerius and Heintzberger (1975) and described according to Bullock *et al.* (1985) and Brewer (1964).

General Properties

Many of the soils studied have finer-textured subsurface horizons (Table 1).

Table 1. The location, classification, texture, soil moisture regime (SMR) and soil temperature regime (STR) of selected soils used in this study.

Soil	Location	Classification	Texture	SMR	STR
		(Soil Survey Staff, 1994)	‡		
P1	Brazil	Typic Eutrustox	c	ustic	isohyperthermic
P2	Zambia	Acrustox	c	ustic	isohyperthermic
P3	Uganda	Kandiudalfic Eutrudox	c	udic	isohyperthermic
P4	Kenya	Typic Kandiustalf	c	ustic	isohyperthermic
P5	Mali	Plinthic Kandiustalf	l	ustic	isohyperthermic
P6	Brazil	Plinthustalf	sl	ustic	isohyperthermic
P7	Zambia	Typic Kandiustult	c	ustic	isohyperthermic
P8	Congo-Kinshasha	Psammentic Paleudult	ls	udic	isohyperthermic
P9	Burundi	Orthoxic Kanhapludult	cl	udic	isothermic
P10	Brazil	Rhodustult	sl	udic	isohyperthermic
P11	Malaysia	Kandiudult	c	udic	isohyperthermic

‡ c=clay, l=loam, scl=sandy clay loam, cl=clay loam, sl=sandy loam, ls=loamy sand.

Many of these soils show a clay increase with depth but do not always have the necessary clay skins on peds faces to support the idea of clay illuviation. The water retention differences expressed on a clay basis and the apparent cation exchange capacities (CEC) of these soils indicate that many of the presently classified kandi-Ultisols and Alfisols are closer to Oxisols, than the true Ultisols or Alfisols.

Mineralo-Chemistry

The X-ray diffraction of clay fractions indicate that the kandic and oxic horizons have similar mineralogical assemblage (Table 2). The similarities of the CEC and external specific surface areas (SSA), and the ratios of the various extractable Fe-oxides also point to the same conclusion.

Table 2 Mineral composition of the oxic and kandic subsurface horizons (from XRD analyses). XRD peak intensity: X=weak, XX=moderate intensity, XXX=intense.

MINERAL	ARGILLIC	KANDIC	OXIC
2:1 phyllosilicates	XXX	---	---
1:1 phyllosilicates	XX	XXX	XXX
Quartz	X	XXX	XXX
Hematite	X	XXX	XXX
Goethite	XXX	X	X
Gibbsite	X	X	X
Short-range order oxides	XXX	X	X
Others	XXX	X	X

Micromorphology

There are highly weathered soils with good evidence of moved clay which have CEC as well as other physical and chemical properties that are closer to the properties of Oxisols than Ultisols or Alfisols. There is a diminishing expression of the argillic horizon as soil formation approaches the oxic stage.

Proposed Classification Criteria for Oxisols

It is proposed that the new definition for Oxisols should read as follows,

D. *Other soils that have an oxic horizon and an iso- soil temperature regime*
Oxisols

The oxic horizon does not have andic soil properties and has all of the following characteristics:

1. A thickness of 30 cm or more, and
2. A particle size of sandy loam or finer in the fine earth fraction, and
3. Less than 10 percent weatherable minerals in the 50- to 200- micrometer fraction, and
4. Rock structure in less than 5 percent of its volume, or sesquioxide coatings on lithorelicts containing weatherable minerals, and
5. A CEC of 16 cmol(+) or less per kg clay (by 1N NH_4OAc pH 7) and an ECEC of 12 cmol(+) or less per kg clay (sum of bases extracted with 1N NH_4OAc pH 7 plus 1N KCl-extractable Al)

Conclusion

As a result of the changes proposed to Soil Taxonomy (Soil Survey Staff, 1999), the Oxisols will now be exclusive to the intertropical belt with an iso- soil temperature regime. The geographic extent of Oxisols in the tropics will increase and conversely, that of kandi- Alfisols and Ultisols will decrease. Testing of the proposed classification on some Malaysian soils showed that the new definition for Oxisols provides a better basis for the classification of the local soils. It is believed that the proposed changes to the Keys to Soil Taxonomy will contribute to a better differentiation of the landscape units in the field as well as permit better interpretations for landuse purposes.

References

Andriesse JP (1972) Memoir 1. The soils of west-Sarawak (East-Malaysia). Vol. 1. Dept. of Agric. - Sarawak, East Malaysia. Gov. Print. Office, Kuching, Sarawak. 415p.

Brewer R (1964) Fabric and mineral analysis of soils. John Wiley and Sons. New York.

Bullock P, Fedoroff N, Jongerius A, Stoops G, Tursina T, Babel U (1985) Handbook for Soil Thin Section Description. Waine Research Publ. 152p.

Buol SW, Eswaran H (1988) International Committee on Oxisols (ICOMOX): Final Report. Tech. Mono. No.17. Soil Management Support Services and North Carolina State University, Washington, DC and Raleigh, N.C.

Eswaran H, Van Den Berg E, Reich P (1993) Organic carbon in soils of the world. *Soil Sci. Soc. Am. J.* **75**, 192-194.

Jackson ML (1969) Soil chemical analysis - Advanced course. 2nd. Edition, 8th. printing, 1973. Published by M.L. Jackson. Dept. of Soil Science, Univ. of Wisconsin, Madison, WI.

Jongerius A, Heintzberger G (1975) Methods in soil micromorphology. A technique for the preparation of large thin sections. Soil Survey Institute, Wageningen, The Netherlands.

Lehane R (2000) Higher Yields from Upland Soils. Partners in Research for Development. AGIAR, Australia No.13, May 2000. p. 2-9.

McKeague JA, Brydon JE, Miles NM (1971) Differentiation of forms of extractable iron and aluminium in soils. *Soil Sci. Soc. Am. Proc.* **35**, 33-38.

Moorman FR (1985) Excerpts from the circular letters of the International Committee on Low Activity Clay (ICOMLAC). Tech. Mono. No.8, Soil Management Support Services. 228p.

Soil Survey Laboratory Staff (1992) Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42. Version 2.0. USDA-SCS, National Soil Survey Centre, Lincoln, NE.

Soil Survey Staff (1975) Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys. SCS. USDA. Agriculture Handbook No. 436.

Soil Survey Staff (1990) Keys to Soil Taxonomy. Soil Management Support Services Tech. Mono. No. 6. 4th. Edition. Blacksburg, Virginia.

Soil Survey Staff (1993) Soil Survey Manual. U.S. Dept. Agri. Handbook No. 18. 437p. Washington D.C.

Soil Survey Staff (1994) Keys to Soil Taxonomy. USDA-SCS. 6th Edition. Washington, D.C.

Soil Survey Staff (1999) Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Second Edition. NRCS. USDA. Agriculture Handbook No. 436. 869p.

Thomas R, Ayarza MA (Ed.) (1999) Sustainable Land Management for the Oxisols of the Latin American Savannas: Dynamics of Soil Organic Matter and Indicators of Soil Quality. Cali, Colombia: Centro Internacional de Agriculture Tropical. CIAT Publ. N. 312. 231p.

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Common ground between soil scientists and geotechnical engineers

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Abstract
There is an emerging lack in Australia of science graduates with significant studies in soil science. Traditionally the rolls of soil scientist and geotechnical engineer have been kept separate in the work place. However, as graduate soil scientists become fewer (there are no soil science degrees available in Australia), there is a need to encourage geotechnical engineers, geologists and environmental scientists towards the more traditional soil science areas. There is increased demand for a range of studies, including acid sulfate soils, carbon sequestration initiatives, soil contamination, salinity impacts etc., with a focus on sustainability and environmental responsibility, as well as the more traditional engineering properties. There is high demand in all areas of soil science to address sustainable and environmentally defendable development, as well as investigation of basic soil properties. Incorporation of as many aspects of soil/land characterisation into investigations for projects covering large areas and varied soil landscapes (such as corridor studies, mining leases etc.) and some on the job training becomes logical and cost effective. This presentation aims to compare requirements for soils and engineering investigations and highlight options for educating and training of staff.

Key Words
Chemistry – Training – Stratigraphy – Characterisation – Sampling – Groundwater.

Introduction
As a point of clarification, this paper is not ‘technical’ in nature, it does not present the findings of any specific research, rather observations made in a professional environment over the past 15-20 years. As a senior scientist and engineer in a large engineering consultancy, I and many others in my field, both geotechnical engineers and soil scientists, currently lament the lack of graduates from soil science based university courses as the demands for environmental soils investigations increase.

The Problem
In fact, other than one or two agricultural science degrees and a single diploma level soils technology/science course, there are no soil science degrees being run by universities in Australia. In addition, many engineering courses have dropped soil units from their syllabuses; the argument over the past decade being that high school graduates have lacked the maths and science basics to handle too many science units, and so these are kept to the bare minimum (unfortunately in our field a sound knowledge of soils is ‘the bare minimum’). As a result of fewer soils course options there has been a considerable lack of new soil scientists joining the work force over the last 10-15 years. This has occurred at the same time as a reduction in the number of people in allied fields with sound soils knowledge, due to retirements in an aging participating workforce and some redundancies in government agencies. The average age of soil Australian scientists has been estimated at over 55 years of age. This combined with the re-emergent economy, a boom in infrastructure, and increased demand on agriculture is resulting in a higher than ever demand in all areas of soil science. However, there are fewer qualified people available to do the work, including Government employees (i.e. regulators). Additionally, people in positions to pass on some of the key soils knowledge (private and Government sectors) are busier than ever, so on the job training by these people is problematic.

Similarities (and Differences) Between Engineering, Environmental and Agricultural Soil Studies
Engineers have been studying soil properties and it’s interaction with structures for as long as soil scientists and agronomists have been studying soil chemistry and biology and the interaction between soil, groundwater, plants and the receiving environment.

There is a lot of common ground with what scientists and engineers need to know about soils and how to use the knowledge. Summarised in Table 1 are areas of soil investigation and assessment, relevant to both soils scientists and geotechnical engineers.

Table 1. Similarities and Differences in the Soils Field Investigations

Area of Interest	Relevance to Engineers	Relevance to Soil Scientists
Origins of soils and their eventual fate	2	3
Ways of “classifying” soils, to allow common interpretation	3	3
Mapping / Displaying soil type and data	2	2
Moisture state and it’s relationship to soil properties	3	2
Soil chemistry – effecting soil behaviour	2	2
Soil chemistry – effecting agriculture/vegetation	1	3
Environmental Impact – caused by disturbing soil/water system	2	3
Erosion Control in Agriculture and/or Construction	2	3
Influence of contaminates soils – costs, constraints	3	2
Use/Disposal of soils in engineering, mining and construction	2	1
Total	22	24

Note: Where ‘3’ is most important (note this is based on observation and is somewhat subjective)

It is easy to see that scientists and engineers often have similar information priorities in most of their requirements for soils knowledge. So it seems very reasonable to pool what resources are available when undertaking soil assessments and where possible to create accessible soils databases. The latter has become more easily achievable with the advent of powerful, inexpensive data storages and high speed and portable internet connections. Sometimes clients and planners fail to recognise commonalities in the various investigation programs that are commissioned for projects, particularly as more varied high level assessments become mandatory for development. This is particularly so [in Australia] where different government agencies are responsible for different aspects of the approvals process.

In practice, many scientific investigations tend to target one or more specific areas and may be undertaken as part of data gathering or mapping exercises such as, mapping Acid Sulfate Soils, Dry Land Salinity, Good Quality Agricultural Land, Soil landscapes etc. However, a good deal of the data gathered for each of these discrete exercises can be of use to the others. For example, cations and anions (and associated ratios such as CEC and ESP), pH, EC, soil moisture and particle size are common to many investigations, and screening for metals, common nutrients and organic matter (organic carbon) are also useful in several circumstances. Some aspects of contaminated land, agricultural and geotechnical investigations are more specific, but can still be assessed from the same boreholes or test pits.

The origin of soils, whether they are imported fill (unknown origin), alluvial, colluvial or formed *insitu* as weathering products of underlying parent geology can be of great importance. Assessing soil chemistry and how the soils may act if disturbed (i.e. whether are they are acid forming, potentially dispersive, saline, potentially contaminated etc.) and interaction with groundwater through watertable influences and water quality impacts should be undertaken using an holistic approach. The data accumulated can then be used for a number of related purposes.

Typically scientific investigations specify undisturbed soil samples or a continuous ‘core’ to be recovered for both logging and sampling purposes, while geotechnical investigations require *insitu* strength tests, typically at set intervals down the borehole with recovery of both disturbed and undisturbed samples from locations between the strength testing locations. For most applications, a selection of representative disturbed and undisturbed samples will suffice for chemical testing even where physical tests may need to be undertaken on the same samples, as only small representative sub-samples are required for most soil chemistry analyses. Even geotechnical programs utilising ‘wash boring’ techniques which do not recover soil between the intermittent sampling intervals can be used for preliminary and indicative assessments of soil chemistry where only a single sample from each soil horizon is sufficient.

Some investigations, such as those for Acid Sulfate Soils require continuous sampling in order to capture accurately the stratigraphy present in an alluvial sequence, however, this becomes less important when sampling from disturbed soil profiles. Sampling for contaminants, is generally focused on the source of contamination and may focus on the fill materials, surface soils, former natural surface, alluvial channels where present or perhaps the interface with shallow parent rock. Soil sampling from disturbed or homogenous sources (e.g. stockpiles) should be random and based on an adopted frequency such as one sample/50m^3.

Characterising large areas is often undertaken by sampling on an area basis (e.g. 1 location / 4ha) or may target individual land forms such as ridges or depressions, or along the banks of waterways; or within specific soil landscapes.

Sample collection and preservation is important. Samples for chemical or biological analysis usually require collects in clean jars, sometimes with preservatives added, and require being kept refrigerated and dispatched promptly to laboratories within relatively short holding times. Engineering samples generally requires less attention, but some need to be undisturbed so are taken as block samples sealed in wax, or using thin walled metal tubes of common diameters (U50, U75 etc.) which need to be sealed at both ends to preserve moisture state for testing. Regardless, all samples need to be clearly identified, dated and documented on borelog records and laboratory chain of custody documents. This is common to all soils investigations. Marking, either physically with stakes and tags, or using a coordinate system, usually both is also very important, as data that cannot be attributed to specific locations is often useless. All of these techniques and processes form a vital part of the fieldwork for both scientists and engineers, and adequate training must be provided.

A Way Forward

A way to rectify the situation, at least in the short to medium term is to encourage cross learning and skilling among geotechnical engineers and environmental science graduates. This could be achieved by the inclusion of soil science subjects in core and elective streams of engineering, and a stronger focus on soils properties and chemistry and groundwater interaction, in environmental science courses. While geotechnical engineers typically take four or more soil and rock mechanics subjects as well as basic geology, there is typically only a single core 'environmental' subject, which broadly covers aspects of soil, water, air, flora and fauna.

There would be great benefit from including a specific soil chemistry subject dealing with the importance of soil chemistry and highlighting the interrelationship with engineering soil properties and the way that engineers and scientists classify and log soils. A better understanding of soil and groundwater interaction is also needed to allow soil assessments to predict changes in the groundwater system and potential impacts.

A brief introductory syllabus covering the basics of sodic/ dispersive soils, acid forming soils, contaminated soils, soil salinity and soil nutrients and properties that benefit agriculture would be very useful. Similarly, a better understanding of soil chemistry and how this interacts with physical properties (i.e. erosion and stability, expansive clay soils, aggression to built structures and the potential to cause environmental impacts), would greatly improve the engineering graduates knowledge base.

In-house training within the major engineering firms based around technical presentations and workshops and on the job where environmentalists and engineers present case studies and investigation methods to each other can benefit all. Particularly when flexibility within the workforce is such an axiom of the modern approach to staffing.

It is important to 'think outside of the square' when preparing proposals and planning site investigations. The pairing of experienced engineers with graduate environmental scientists for investigation programs that are predominantly engineering in nature, and the reverse for soil science studies and environmental programs with limited engineering requirements, would allow good governance while promoting learning across the disciplines. Training of engineers in basics of soils science and utilising flexible sampling and data gathering methods makes it is possible to obtain a wider range of environmental and geotechnical information from one sampling program. This needs to be considered when preparing proposals for large scale investigations such as 'broad brush' area and corridor investigations for feasibility studies and Environmental Impact Statements, where a range of developmental constraints need to be considered.

A summary of proposed lecture topics/course content that could form the basis of possible soils subjects aimed at combining environmental, agricultural and engineering input is given in Table 2.

Table 2. Suggested inclusions in a ‘Soils & Engineering’ subject suitable for either syllabus

Suggested 2 Hour Sessions	Composition
Origins of Soils their fate.	Basic geology Lithology Transport mechanisms.
Classifying Soils to Allow Common Description and Understanding	Classification (Australian Soils Classification Vs USC Systems) Soil profile descriptions (horizons, strata, weathering fronts etc.) Practical aspects of soil logging (texture, colour, moisture etc.) What else is needed on a soil log ? location, date, co-ordinates description of samples recovered, refusal on rock etc.
Mapping and Describing Soils & Landscapes	Soil distribution / landscapes Use of GIS systems Availability of published data (maps, test data and web-sites) Types of assessment – ASS, Erosion Potential, GQAL, Salinity
Moisture Related Soil Properties of Clays, Silts, Sands and Gravels	Moisture state and retention (practical) Soil consistency (practical) Influence on insitu strength Compaction characteristics of soils Permeability and void saturation state Clay shrink/swell characteristics.
Hydrogeology and Soils	Micro Vs macro permeability The water table / deep drainage influences Effluent disposal / irrigation practises Salinity migration Catchment hydrogeology/groundwater.
Chemistry Influencing Soil Behaviour	Soil sodicity and salinity Soil Nutrients Acid Sulfate Soils Contaminated soils
Soil Science for Agriculture	Nutrient retention and loss Soil biology (biota) Impacts of pesticides Maximising crop yield
Erosion and Soil Conservation	Erosion and Sediment Control (ESC) assessment Erosion measures for agriculture ESC Plans for construction and infrastructure Dispersive soils – use of lime and gypsum and geotextile
Use of Soils in Mining and Construction	Managing mine tailings Open cut planning Construction of temporary roads Rehabilitation planning measures.
Soils for Cropping and Farm Maintenance.	Aeration and mechanical impedance Maximising crop yield Topsoil retention Draining of Acid Sulfate Soils (impacts).

Conclusions

A number of short courses have been conducted by ASSSI (in Queensland) over the past two decades, and while these have been well attended and very successful and are to be applauded, it is not enough and the private sector must try to assist wherever possible. Private sector engineering firms, can act to provide some course presenters and ‘one off’ or periodic workshops outside of the formal education system. Consideration should also be given to running a mentoring program for junior scientists and engineers by allied organisations like ASSSI and Engineers Australia, possibly utilising retired persons who retain a wealth of knowledge, some of which will otherwise disappear as it has failed to cross the void into cyber space.

In closing, it is hoped that this paper has summarised the many commonalities between the needs of soil scientists and engineers (and clients and other stakeholders); and highlighted some of the short falls of the current tertiary education system and workplace training in Australia. It is hoped that this may focus some in the industry who are best placed to assist in promoting the spread of soil science education and practise.

Land suitability survey and different planting dates for farming of burley 21 tobacco in Marivan

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Abstract

In the present study and research work, an experiment land suitability evaluation for tobacco burley 21 was performed in 13200 ha total area in the Marivan plain and near Zaribar Lake. Marivan is located 130 km of west of Sanandaj, the capital of Kurdistan province. The present research fulfilled in pedology at a semi-detailed study level using climatological information. Tobacco edaphic and climate requirements have been taken from Sys Tables (1993). After necessary calculations with the Simple Limitation Method (SLM), the Limitation Method regarding Number and Intensity (LMNI) and the Parametric Method (PM) such as Storie and Square-root methods, a qualitative classification has been prepared for production and maps have been drawn. Also, land suitability evaluation calibration and determination of suitable dates for cultivation, tobacco sampling has been examined at the zone level at 24 farms and acquired outputs have been compared. According to this calibration, proportional output of sampling zones has been compared to results of land suitability theoretical classification. The present research has shown that the study zone is suitable from climate point of view and determination of suitability final class depends on land, type of cultivation, and management of production for cultivation of tobacco. Land classes in the zone with the Simple Limitation Method for cultivation of tobacco are included as moderately suitable (S_2) and marginally suitable (S_3) and Storie and Square root methods non-suitable (N) and marginally suitable (S_3) respectively. Also suitability classification maps have been prepared for cultivation of tobacco in the study zone. According to these, 25 % of the land is moderately suitable (S_2) and 75 % marginally suitable (S_3).

Key Words

Suitability, climate, planting date, Marivan plain, parametric method, tobacco.

Introduction

Soil is as one of the most important factors of production in agriculture and its exploitation in a manner that it does not damage it for future usages in addition to reaching to the maximum of production is required type. Land suitability evaluation for common crops of a zone is one of the methods for achieving this purpose (Ayoobi 2006). If soil and climate limiting factors and product special limitations are observed and each land type will be exploited according to its ability and each climate according to its potenial and as a result we will have the most production with highest quality. Land suitability studies have been done according to the FAO method using land characteristics and their comparison with a plant requirements table which has been adapted from Sys tables. In this research, the Marivan Plain zone with an area of 13200 has been studied for qualitative evaluation of land suitability for the determination of the most suitable land for cultivation of tobacco according to the land characteristics which have been acquired by soil climatic studies and topography, related to the plans and determination of suitable cultivation dates.

Methods

Marivan zone lies between 45°59' and 46°16' latitudes and between 35°27' and 35°41 longitudes. The altitude of the region is about 1287 m above sea level. The average annual total rainfall is 700 mm and it is more in winter. The minimum and maximum temperatures are 2°C on January and 28°C in July respectively. The slope varies between 1% and 4%. The comprehensive information and reliable data from climatic and agricultural condition has been acquired by reference to State Water and Soil Institution and State Meteorology Organization (Marivan synoptic meteorological station). Also the study zone has soil units and land units in pedology maps and by usage of GPS. Soil samples of soil unit have been examined. Collected soil samples have been examined in laboratory by physical and chemical tests according to the Water and Soil Research Institute common methods. By consideration of geomorphology and physiographic status of the zone and also soil characteristics, 5 soil series have been distinguished which are included as: Zaribar Soil, Veleh Zhir Soil, Marivan Soil, Ghezelsu Soil and Lanjabad Soil.

24 farms with equal condition and similar agricultural operation have been evaluated for cultivation dates. Row spaces are 1 m and plant spaces on the rows have been considered 50 cm. The date of cultivation was three different times, Mar.10, Mar. 24, April 8.

Equations

The parametric land evaluation consists in numerical rating of different limitation levels of land characteristics according to a numerical scale between the maximum (normalised as 100%) and the minimum value. Finally, the climatic index, as well as the land index, is calculated from these individual ratings. In our case, the indices were calculated following two alternative procedures, The Storie method (Storie 1976) and Square-root method (Khiddir 1986). The index was taken as a product of individual ratings:

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \ldots \quad (1)$$

I – index (%)

A, b, C etc. – ratings (%)

$$I = R_{min} \times \sqrt{\frac{A}{100} \times \frac{B}{100} \times \ldots} \quad (2)$$

I – index (%)

R_{min} – minimum rating (%)

A, b, C etc. – remaining ratings (%)

Results

Characteristics of land units are in Table1.

Table1. Index characteristics amounts in existence land units

Land Units	Slope (%)	Text. Class	Depth	Gravel (%)	pH	$CaCO_3$ (%)	ECe (dS/m)
1	1 1	SICL	>100	15	7.33	1.68	0.51
2	2 1	SICL	>100	34	7.18	1.98	0.49
3	1 1	C	>100	15	7.03	1.5	0.66
4	2 1	CL	>100	15	6.5	1.66	1.36
5	3 2	CL	>100	15	7.08	4.2	0.49

Land units located at Zaribar, Veleh Zhir, Marivan were indentified by the simple limitation method, the, Square root method identified a marginally suitable class (S_3) its limitations are related to acidity (pH), texture and structure of soil. Separate unit No. 4 located at Gezelsu in the SLM and LMNI was moderately suitable (S_2) and PM belongs to the marginally suitable class (S_3) and had acidity limitation (pH). Separate unit No. 5 located at Lanjabad is marginally suitable (S_3) and had acidity and $CaCO_3$ limitations.

Table 2. Results of evaluation by different methods of land units for tobacco

Land units	SLM	LMNI	PM	
			Storie	Square Root
1	S_{3f}	S_{3f}	S_{3f}	S_{3f}
2	S_{3f}	S_{3f}	N_f	S_{3f}
3	S_{3f}	S_{3f}	N_f	S_{3f}
4	S_{2fc}	S_{2fc}	S_{3f}	S_{3f}
5	S_{3f}	S_{3f}	N_f	S_{3f}

Three date of cultivation associated with growth period have been identified. For tobacco, cultivation of tobacco should be done near to Mar. 18 in the reservoir region. Generally, land suitability tables for utilization in different zones need a suitable classification. Varieties may have special ecological needs. As a result it is necessary to evaluate production for different zones with different climates and at least for a common variety in relation to climate status and other factors. For modification of pH limitation, addition of acid and sulfur fertilizers is necessary.

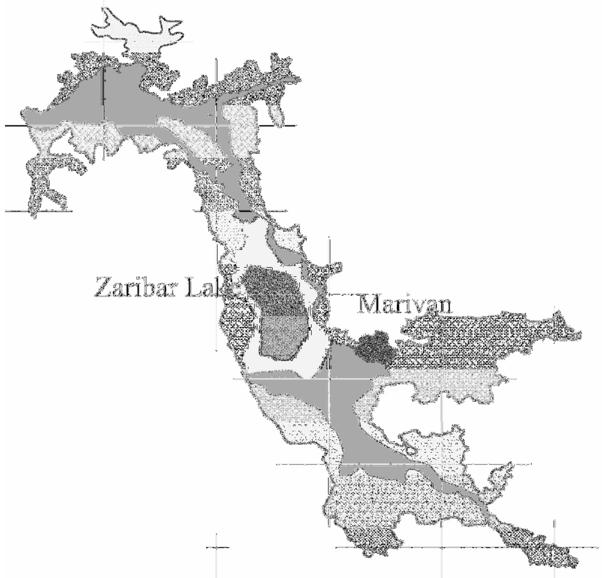

Figure 1. Marivan plain in the current experiment and the parametric methods shows that is belong to the marginally suitable class, (▦) and to the other areas non-suitable classes.

Conclusion

In general, the area is highly suitable from the climatic point of view for tobacco. However, the soil fertility characteristics make the lands in the area marginally suitable. Based on these results (especially on those obtained with the parametric square-root method, which seems to be the best), the cultivation of tobacco burley can be recommended for suitable soils in the area.

References

Akbas F (2000) Land suitability classification of Tokat-Kazova Agricultural Farm using two different land evaluation methods. *Turkish Journal of Agriculture and Forestry* **24,** 551-560.

Ayoobi SH (2006) 'Land evaluation for agricultural and natural sources utilizations'. (Esfahan industrial University publication).

Azimi R (2006) Land suitability evaluation of wheat, sugar beet and potato in Kheirabad plain in Arak. M.Sc. Thesis, Islamic Azad University.

Breen TH (1985) 'Tobacco Culture'. (Prenseton University Press).

Ebrahimi KSMR (2003) An investigation of land suitability evaluation for irrigated crop, using remote sensing and geographical information system techniques in parts of Varamin plain. *Iranian Journal of Agricultural Sciences* **34,** 899-912.

Jafarzadeh AA (2008) Land suitability evaluation of Bilverdy Research Station for wheat, barley, alfalfa, maize and safflower. *Soil and Water Research* **1,** 81-88.

Khiddir SM (1986) A statistical approach in the use of parametric systems applied to the FAO framework for land evaluation. Ph.D. Thesis, State University Ghent.

Rahim IS (2006) Land suitability assessment of wheat in the Nile Delta using NationalSOTER Database. *Research Journal of Agriculture and Biological Sciences* **2,** 38-43.

Need for interpreted soil information for policy making

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Abstract

There is a wealth of soil data being collected at all scales: local, national, regional and global. Most of these data turn out to be of little use for the increasing need by policy makers for updated soil information. New emerging policy areas are demanding detailed, updated and policy relevant soil information that can underpin the decision making process. These needs are not only present at local and national level, but are increasingly present at global scales. Global multilateral environmental agreements, like the climate change convention, the biodiversity convention and the desertification convention, are increasingly putting soils at the centre of their negotiations. Therefore policy relevant global soil information becomes increasingly demanded and is still largely based on obsolete data collected more then 50 years ago. New digital soil mapping technologies allow now developing a completely new high-resolution soil database for the globe that will form the basis for future global soil protection strategies and policymaking.

Key Words

Digital soil mapping, soil information, policymaking, sustainable development, climate change.

Introduction

Over the past 100 years a major shift in policy priorities related to soil science has been observed: From an early phase of exclusive focus of soil protection policies on the agricultural function of soils, there has been a rapid change in recent years towards a more comprehensive approach to soil related policies addressing the full multi-functionality of the natural soil cover. This old mono-functional view on soils was as well reflected in the early days of soil science (agro-geology), with a nearly exclusive focus on soils as agricultural substrate.

In recent years soil policies are more and more addressing aspects related to climate change, environmental protection, health and food security/safety, civil protection, renewable energies, raw materials, cultural heritage, biodiversity and spatial planning. This dramatic shift in policy relevance of soils has not been followed by an equivalent re-adjustment of the research priorities by the soil science community, with a growing gap between the academic soil science community and the policy making process. Bridging this gap between soil science and soil related policies will be one of the major challenges for the next years.

Emerging priority topics, like the role of soils within climate change, will need a focused research effort in order to provide the urgently needed scientific background to the next phase of the climate change convention. Other important policy areas will as well require extended scientific data and information for their development. Policy relevant soil data and information are needed at all scales, from local to global, and should to be easily interpretable by policy makers for decision making in relation to soils.

Currently available soil data are often obsolete, not documented by proper metadata and largely totally irrelevant for the needs of the policy makers. There is therefore the urgent need to collect and interpret policy relevant soil data from new soil surveys and soil monitoring exercises.

Current needs of soil information for policy making

There are a large number of policy areas that require soil information:

- Climate change
- Agriculture and food security
- Food quality and food safety
- Bio-energies including Biofuel
- Nature protection and biodiversity
- Water
- Waste (bio-waste)
- Desertification

These are just few of the major policy areas of current interest, but there are certainly more, given the crosscutting nature of soils as the interface between the atmosphere, hydrosphere, lithosphere and biosphere, recently termed the “critical zone”.

Climate change

Climate change is certainly the area of environmental policymaking which is attracting the wast majority of the political attention (and the funding) at the moment. Soils have played a relatively minor role during the early phases of the United Nations Framework Convention for Climate Change (UNFCCC) negotiations. The role of land use and land use change was essentially not considered of relevance compared to the urgent need of reducing emissions from industrial sources. Only forestry made it up on the negotiation agenda in a pretty early phase with the early introduction in negotiation documents of the term "Land Use, Land Use Change and Forestry (LULUCF)". Only recently the full recognition of the role of soils as the main terrestrial carbon sink has gained attention by negotiators. This increased interest unfortunately has not been underpinned with an increase of reliable data and information on this large terrestrial carbon pool. Not even the precise amount of the currently available carbon in soils at global scale can be determined, due to the lack of updated and reliable data. Some estimates are reported in table 1.

Table 1. Recent estimates of global soil organic carbon (SOC) stocks

Source	Total SOC (0-100 cm)	Total SOC (0-30 cm)
HWSD	1,208 Pg	473 Pg[2]
NRCS	1,376 Pg	
IGBP	1,494 Pg	
FAO DSMW	1,455 Pg	554 Pg[2]
IPCC[1]	1,500 Pg	697 Pg[3]

[1] Global estimate from 4th IPCC Assessment Report

[2] Equivalent spatial coverage to IPCC

[3] Estimate from default reference values for mineral soils under native vegetation

Sources of data:

HWSD: Harmonized World Soil Database (http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/)

NRCS: Natural Resources Conservation Service (http://soils.usda.gov/use/worldsoils/mapindex/soc.html)

IGBP: International Geosphere-Biosphere Programme (http://daac.ornl.gov/SOILS/guides/igbp-surfaces.html)

FAO DSMW: Food and Agriculture Organization Digital Soil Map of the World (http://www.fao.org/nr/land/soils/en/)

IPCC: Intergovernmental Panel on Climate Change (http://www.ipcc.ch/index.htm)

Agriculture and Food security

Human population is still constantly rising, with estimates predicting more the 9 billion of humans on earth by 2050. Can the available soil resources of the planet earth provide the necessary food for this growing population? What are the available soil resources for food production today, and what could be the available soil resources in 50 years, taking into account climate change as well as land use changes? What is the extent of soil degradation today? Still most of these estimates are based on data collected in the 1950's and need urgent updated information. Soil degradation is still reported at global scale on the basis of the Global Soil Degradation (GLASOD) project of 1990.

Bio-energy and Biofuel production

Expansion of bio-energy crops is claimed to be not in competition with food production since it will expand on degraded and marginal soils. Is this assumption based on hard data and facts? Do we have the data about the degraded soils in the world in order to make any statement on this issue?

Nature protection and biodiversity

Soils are the host of a large pool of biodiversity. Still a large part of this soil biodiversity pool is not sufficiently characterized and may be lost before we will be able to classify all organisms present in the soils of the world. Land use changes as well as soil contamination are rapidly changing the flora and fauna in the soils of the world. Rare species maybe already lost and more will be lost in the future without a rapid action on the full characterization of soil biodiversity in the world. The problem has been well recognized by the Convention on Biological Diversity (CBD) that has launched a specific initiative on soil biodiversity. Still we are far away from a coherent global approach to soil biodiversity characterization. The European Commission has taken up the challenge of increasing the knowledge and awareness about the importance of soil biodiversity and will release in 2010 as a contribution to the International Year of Biodiversity a Soil Biodiversity Atlas.

Waste
Waste policy is closely linked with soils, given the fact that most wastes are still disposed in landfills and therefore end up in the soils. Changing the perception of soils as a waste dumping site will take a long time and will require a major educational effort. It is of crucial importance to reverse the current approach towards a vision of recycling treated wastes in soils. Of great interest is to the policy maker the potential use of soils for the disposal of organic wastes, thus increasing the soil organic carbon content and the fertility of depleted soils. Creating a partnership between urban and rural populations would allow closing the cycle of precious waste materials that could return to the soils for their benefit. Still insufficient data on health effects and long term stability of these materials in soils exist in order to take any final decision in this matter.

Water and desertification
Soils play a crucial role in the hydrological cycle. Still updated and detailed information on available water capacity of soils at global scale is missing. Water and soils are at the core of the negotiations of the desertification convention (UNCCD). A solid scientific basis for this convention is still missing, also due to the lack of global data about the extent and severity of desertification processes. A new Global Atlas of Desertification is in preparation under the coordination of the European Commission and may provide in the near future new updated information on desertification processes in the world.

The way forward
Policy makers usually cannot take any decisions on the basis of raw data. Traditional soil maps reporting soil names are not a basis for decisions by policy makers. There is the need to provide interpreted soil information that usually is only available after a complex process of data collection, integration of ancillary data, integration of models and scenarios, assessment and final reporting. The full process has been described by Dobos *et al*. and is illustrated in Figure 1. Modern digital soil mapping techniques can provide relevant soil data on properties that can be of use for the on-going policy making processes.

A new generation of soil data and information is needed, not anymore responding to the needs of a limited scientific community, but opening up to a wider horizon of users and stakeholders. Traditional ways of soil data collection, based on soil profile descriptions, can not respond anymore to the needs of a modern society requiring data responding to stringent QA/QC requirements and allowing for informed decision making in soil related matters. The starting point of any soil information system will remain the point observations based on sampling at different depth and measurements of chemical, physical and biological properties. But new technologies will allow improving the spatial extrapolation of the point observations, giving maps with quantified uncertainties associated with each mapping unit and value reported. Field observations will remain at the core of soil information systems, but will have to be extended to cover the actual priorities set by policy makers. The traditional vision of soils for their single function as agricultural substrate will have to be abandoned towards a much more holistic and multidisciplinary vision of soils having multiple functions for humans, as formally identified in the EU Thematic Strategy for Soil Protection: Storage, filtering and buffering of chemicals; archive of cultural heritage; stock of biodiversity; pool of atmospheric carbon; source of raw materials; surface for housing and infrastructure; substrate for biomass production.

Future soil classification systems will have to respond to this expanded vision on soils. This will require introducing new concepts in soil classification, reflecting not only physical and chemical properties, but also biological properties. It will also require a re-definition of the actual object to be classified, not anymore restricted to the pedogenetic horizons, but classifying the full unconsolidated material from the surface to the bed rock.

Given the increasingly global dimension of all policy relevant assessments related to soils, there is the need for developing such a new paradigm for soil classification and soil data collection at global scales.

Conclusion
There is a growing need for interpreted soil information for policy making. The soil science community has still to adapt to these needs by providing the relevant scientific data and background information on the various emerging topics. Soil science alone will not be sufficient for assessing all aspects of soil policy. Integrated approaches incorporating also other scientific disciplines will be needed, particularly for addressing the socio-economic aspects of soil protection and sustainable soil management. The new initiatives (Sanchez *et al*. 2009) towards the compilation of high resolution digital soil maps of the world are certainly very promising and will provide the needed interpreted soil information for global policy making in the near future

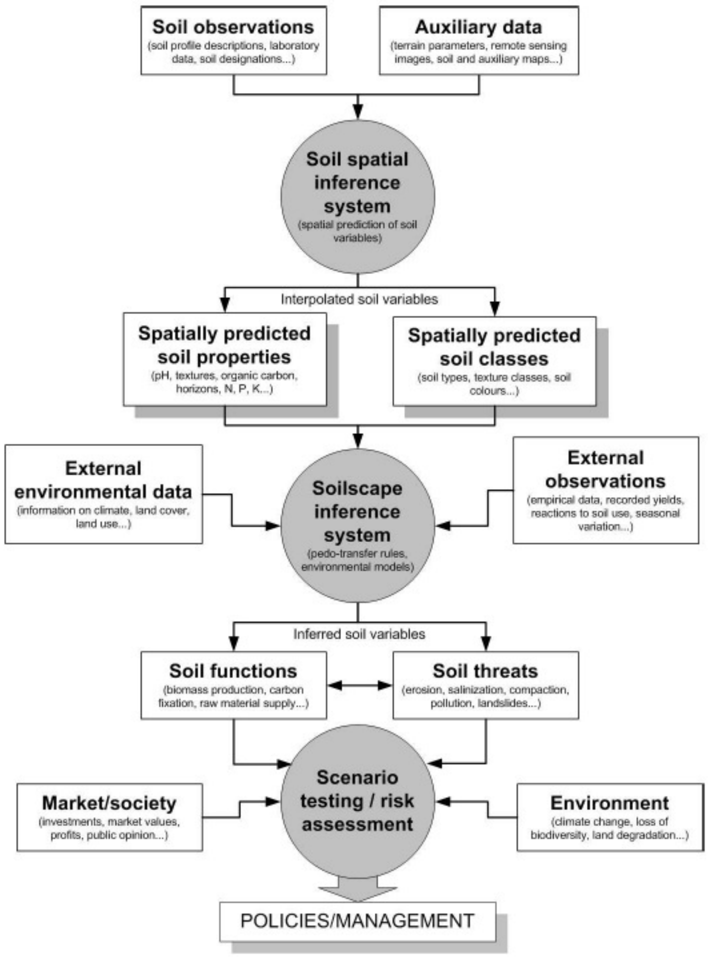

Figure 1. Digital Soil Mapping steps for decision-making and policies management (from Dobos *et al*. 2006).

References

Dobos E, Carré F, Hengl T, Reuter HI, Tóth G (2006) Digital Soil Mapping as a support to production of functional maps. EUR 22123 EN, 68 pp. Office for Official Publications of the European Communities, Luxemburg.Hill KD (1989)

Sanchez PA, Ahamed S, Carré F, Hartemink AE, Hempel J, Huising J, Lagacherie P, McBratney AB, McKenzie NJ, Mendonça-Santos M de L, Minasny B, Montanarella L, Okoth P, Palm CA, Sachs JD, Shepherd KD, Vågen T.-G, Vanlauwe B, Walsh MG, Winowiecki LA, Zhang G-L (2009) Digital Soil Map of the World. *Science* **325** (5941), 680.

Numerical soil classification: A missed, but not a lost, opportunity

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Abstract
The history of numerical soil classification from its advent in the 1960s is reviewed. The current and future possibilities for a numerical approach are explored in the light of available large soil databases and prior soil classificatory knowledge.

Key Words
World Reference Base for Soil Resources (WRB), numerical taxonomy, Soil Taxonomy, pedometrics, numerical soil classification.

Introduction
The idea of numerical classification comes from the 1770s – the so-called Adansonian approach (Michel Adanson, French botanist, 1727-1806). This notion came into reality in the 1950's and 1960's with the advent of digital computers and numerical analysis. This movement was largely led by biologists.

History
Soil scientists were involved in the early stages of numerical taxonomy and many experiments with numerical soil classification were completed. However these were generally local studies of limited scope.
The jump to national and international studies was not made, largely, we believe, because of the lack of good national and global soil databases in the 1970's and '80's.

Discussion
Today, we have good national and international databases, much faster computers, and better pedometric methods such as continuous classification (with fuzzy k-means with extragrades), so the possibility of global numerical classification is good. But, is it too late? Many would argue that the era of soil classification is past. We believe that there is still a great need for improved and new ways of ordering soil information. There are some choices to be made however. Do we create classes of soil horizons and/or profiles? Do we use all soil properties to define and allocate soil classes? Do we create such classes *ab initio* or do we start with centroids of pre-defined classes (e.g., WRB diagnostic horizons or Soil Taxonomy suborders) with the aim of improving them? Do we use new technologies such as NIR and MIR reflectance spectra to generate data for classification? It is clear however that at least the concept of taxonomic distance is essential for the improvement of all conventional national and international soil classification systems.

Conclusion
The time for numerical soil classification based on large global datasets has arrived.

Sampling Intensity Required to Adequately Describe Soil Variations at Three Danish Ecosystems: Heather, Oak and Spruce

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Abstract
The objective of this study was to determine the effect of spatial variability on basic soil properties and the necessary number of samples to describe this adequately in the laboratory. This was done at a Danish heathland site, Hjelm Hede, where all soil forming factors except vegetation are comparable. Surface soil (0-10 cm) underneath Heather (*Calluna Vulgaris*), Oak (*Quercus robur*) and Spruce (*Picea* sp.) were sampled in a simple random sampling procedure to obtain 10 subsamples at each ecosystem. Physical and chemical analyses included bulk density, pH, total organic C, organic N, and measurement by Near Infrared (VIS/NIR) spectrophotometer of organic N and C were included to compare different analytical techniques and the soil variability. Presuming that all samples were derived from normal distributions, 10 samples from each ecosystem yielded an error on the determined means of 30-40 % at a 95% confidence level. For an error on the determined mean of 10 % and a 95% confidence level generally 120 to 170 samples would be needed from each sampling unit. Bulk density and pH required least samples, while chemical determinations of C and N and VIS/NIR predictions of C and N required a comparable number of samples for the same level of precision. The main conclusions for the three ecosystems are that the needed number of samples to describe soil property means depend on the property being examined. A precision of 40 % allowable error of the means obtained by approximately 10 subsamples from each ecosystem is nevertheless considered acceptable when resource allocation for soil sampling is included as a parameter.

Key Words
Soil variability, soil sampling, VIS/NIR spectroscopy, replicates.

Introduction
Variability of soil properties is a well known constrain on proper interpretation of soil test results, and quantification of soil spatial variability across multiple scales is thus highly important in many different aspects of soil science. Especially when information on average soil properties are required soil variability associated with micro-scale heterogeneity can be addressed with spatially sampling designs and appropriate sample volumes or replicated samples (Stein and Ettema 2003). Numerous previous studies has hence investigated the variability of e.g., soil map units and soil properties at multiple scales, and recently geostatistics has been presented as a useful tool for quantifying soil variation and for interpreting spatial soil patterns (e.g., Beckett and Burrough 1971; Webster and Oliver 2001). Site assessment describing soils at any level always rely on properties which especially are known to vary in space. Especially some soil properties and soil ecosystems require more intensive sampling and often have less predictive value for site assessment purposes, e.g. shallow soils (e.g., Hitz *et al.* 2002). The number of samples required to achieve a desired level of precision for estimation of soil properties within a sampling unit has since the 1980s often been obtained by variograms from geostatistical analysis. However, such approaches designed for soil mapping typically require >100 analysis of a soil property. A more simple practice to assess if a soil mapping unit is good or badly defined is that the within-class variance which should be lower than the total variance (e.g., Webster and Oliver, 2001). Variance of soil properties within a soil unit should hence be smaller than their variability in the landscape at large. Several parameters have been used for estimating the uniformity of soil properties within mapping units (e.g., Beckett and Burrough 1971), while the number of samples necessary to obtain the mean value of a property within a soil mapping unit with a specified allowable error rarely have been assessed (e.g., Amponsah *et al.* 2000).

The aim of the present study was thus to investigate consequences of soil in-homogeneity on soil sampling intensity by specifically examining differences in variances of soil physical and chemical properties when no information on spatial dependency is known from geostatistics.

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Materials and methods

Study area and soil sampling design

The study area Hjelm Hede in NW Jutland, Denmark (56^{O} 24' N; 8^{O} 54' E) is a unique site where sampling from three different vegetation types in the same parent material and climate is possible. The type of vegetation was heather (*Calluna Vulgaris*) since at least 2,000 years. However, over the past 50-70 years unmanaged parts of the area has turned into oak (*Quercus robur*) woodland, and parts have been planted with spruce (*Picea abies or P. sitchensis*). These vegetation shifts in parts of the area has resulted in major changes to the organic layers and soils chemistry (e.g., Madsen and Nørnberg, 1995). Ten representative composite soil samples were randomly collected from each of the three ecosystems at 0- to 10-cm depth, using a 10x10x10 cm sharpened steel box.

Laboratory methods

Fresh vegetation was removed and soil samples were subsequently air-dried at 50°C. Prior to analysis, all samples were put through a grinding and homogenizing machine to pass <2 mm and split by a rotary divider. Analysis of bulk density, C, N, pH, and Visible Near Infrared spectrophotometry (VIS/NIR) was performed on all samples. The pH was determined with a glass-calomel electrode in 1:2.5 soil:water suspensions (w/w). Total organic C was determined by dry combustion. Total nitrogen was determined by the Kjeldahl method. VIS/NIR measurements were acquired using a shank based spectrophotometer system (Veris Technologies, USA). The system includes two spectrometers measuring soil reflectance in the VIS/NIR regions (350-1000 and 1100-2200 nm). A calibration process involved the correlation of total organic C and N of the 30 samples with their spectral data, and calibration equations were calculated using the raw spectral data (log 1/R). Calibrations from spectral data were developed using the segmented cross-validation method on centred data. Prior to calibrations soil spectra were pre-processed. To improve the model spectra were reduced to eliminate the noise near the edges of each spectrum, and Savitzky-Golay smoothing averaging algorithms and the first derivative were calculated on spectral data.

Statistical analysis

Statistical treatment of the 30 subsamples from the three ecosystems included calculations of mean, SD, CV, and maximum and minimum values for each property. To determine the number of samples necessary to obtain the mean value of a property within a specified allowable error and confidence level, an iterative procedure using the calculated CVs of the properties and the number of samples required for allowable error of 10% at 95% confidence level was used (see e.g., Amponsah *et al.* 2000). Due to the low number of samples, data was not transformed to normality prior to analysis, even that this may bias interpretation of the pH which is on a logarithmic scale. The calculation was performed using eq. 1:

Eq. 1: $N = \frac{CV^2 \times t(\frac{\alpha}{2}, n-1)}{AE^2}$

N is the number of sample units needed to estimate the mean with a specific allowable error and probability, $t(_{\alpha/2, n-1})$ is the value of the student's t-distribution with n-1 degrees of freedom, CV is the coefficient of variation (%) and AE is the allowable sampling error expressed as a percentage of the mean. Student's t-test was used to reveal significant differences between the three ecosystems.

To test whether the chosen sampling units, i.e. ecosystems, gives more precise statements on soil properties than without them, an inter-class correlation coefficient has been calculated according to Beckett and Burrough (1971) using eq. 2:

Eq. 2: $RV = \frac{pooled\ within\text{-}unit\ variance}{total\ variance}$

Where the 'pooled' is intra-sampling unit variance and 'total' is the variance for the total dataset.

Results and discussion

The analyzed properties from the three ecosystems reflect major changes in topsoil properties after heather was replaces by either oak woodland or spruce plantation since *c.* 50-70 years (Table 1 and 2). Especially the oak trees resulted in significant increases in soil pH relative to the original heathland (Table 1). Bulk densities are significantly different between the three ecosystems with topsoil below oak having the densest surface soil (mean of 0.88 g/cm^3) and spruce the least dense (mean of 0.38 g/cm^3). This is probably a result of organic layer thickness, which is thickest under spruce and very thin under oak (Madsen and Nørnberg 1995).

The organic matter properties (C, N, and C/N ratio) underneath the spruce generally is comparable with the original heather vegetation (Table 2), as also found in previous studies on soil chemistry between these two ecosystems (e.g., Mossin *et al.* 2001). Mean content of total organic C increases from oak to heather to spruce as a response of both increasing content of C in A-horizons and thicker organic layers. Nitrogen contents increases in the same way but heather and spruce have comparable C/N ratios (Table 1) reflecting that soil organic matter in the oak ecosystem is more decomposed.

Table 1. Significant differences (Student's t-test) of soil (0-10 cm) under heather, oak and spruce in Denmark (n=10 for all).

	Bulk Density	Organic Carbon	Organic Nitrogen	C/N ratio	pH (1:2.5 in H_2O)
Heather vs. spruce$	***	*	*	n.s.	n.s.
Heather vs. oak	**	**	n.s.	***	***
Spruce vs. oak	***	**	**	**	***

***, ** * is significant differences at the 0.001, 0.01 and 0.05 significance level respectively; n.s. not significant.

Comparison of means and standard deviations of C and N determined by chemical methods and by VIS/NIR are in good agreement (Table 2). This is probably a partial result of the chemical data being used for calibration of the VIS/NIR method. However, underneath oak the VIS/NIR predicted N and C means (and standard deviation) deviates from the measured total organic carbon content probably as a response of the lower absolute contents underneath oak. For the two other ecosystems the VIS/NIR predicted C and N contents had lower standard deviations relative to the measured total organic C.

Table 2. Soil physical and chemical properties and estimated number of sample units to estimate the means with a specific allowable error (in % of the mean) using the calculated coefficients of correlations (CV). Soil samples (0-10 cm) under heather, oak and spruce in Denmark (n=10 for all).

Ecosystem/	Summary statistics			Required no. of samples (95% confidence)			
Parameter	Mean	Standard deviation	CV (%)	mean ± 10%	mean ± 20%	mean ± 30%	mean ± 40%
Oak							
Bulk Dens. (g/cm^3)	0.88	0.22	25	123	31	14	8
Carbon (g/kg)	45	23	52	153	38	17	10
Predicted C (g/kg)	32	51	160	370	92	41	23
Nitrogen (g/kg)	2.02	0.86	42	141	35	16	9
Predicted N (g/kg)	1.49	1.63	109	243	61	27	15
pH (1:2.5 in H_2O)	4.42	1.28	29	127	32	14	8
Heather							
Bulk Dens. (g/cm^3)	0.68	0.19	28	125	31	14	8
Carbon (g/kg)	109	53	48	148	37	16	9
Predicted C (g/kg)	116	44	38	136	34	15	9
Nitrogen (g/kg)	3.1	1.34	43	142	36	16	9
Predicted N (g/kg)	3.38	0.71	21	119	30	13	7
pH (1:2.5 in H_2O)	3.98	1.14	29	126	32	14	8
Spruce							
Bulk Dens. (g/cm^3)	0.3	0.18	59	161	40	18	10
Carbon (g/kg)	267	173	65	170	42	19	11
Predicted C (g/kg)	273	129	47	147	37	16	9
Nitrogen (g/kg)	7.94	5.07	64	169	42	19	11
Predicted N (g/kg)	8.17	3.28	40	139	35	15	9
pH (1:2.5 in H_2O)	3.86	1.11	29	126	32	14	8

The statistical estimate of required number of samples to adequately describe the soil variation with some allowable error and confidence interval showed some general aspects of soil properties in the three ecosystems. In all cases, it was presuming that all samples were derived from normal distributions and a 95 % confidence interval (two-tailed) as this often is considered acceptable in laboratory studies. Within the 95 % confidence interval the 10, 20, 30 and 40 % allowable error are shown in Table 2. For an allowable error on the determined mean of 10 % and a 95% confidence interval generally 120 to 170 subsamples would be needed from each ecosystem. However, if an error on 40 % of the soil property's mean derived from the field sampling was allowed between 7 and 11 subsamples were needed. Only two VIS/NIR predicted contents below oak was above this estimate. The Bulk density generally required the least number of samples for an adequately determination, while both chemical determinations and VIS/NIR predictions of C and N required a comparable number of samples for the same level of allowable error.

Table 3. Relative variance (RV) expressing the within-class correlation between the three sampling units and the total variance, calculated according to Beckett and Burgess (1971). Soil samples (0-10 cm) under heather, oak and spruce in Denmark (n=10 for all).

Relative variance	Spruce	Heather	Oak
Carbon	1.55	0.13	0.03
pH	0.40	0.32	0.56
Bulk density	0.42	0.25	0.18
Nitrogen	1.67	0.13	0.05
Predicted Carbon	0.74	0.05	0.19
Predicted Nitrogen	0.73	0.04	0.24

Table 3 reveals that the heather and oak sampling units are well defined as they have lower within class variance than total variance in all cases (Beckett and Burrough 1971). The measured C and N contents in the spruce ecosystem have, however, higher variance than the total dataset reflecting that the sampling unit is less well-defined or more spatial variable than the general area. Conclusions on soil sampling intensity under spruce are thus likely less well supported than under oak and heather.

Conclusion

The required soil sampling intensity in the three ecosystems is here evaluated without taking spatial effects into consideration which an initial use of a variogram could have revealed. However, most national guidelines on e.g. soil pollution sampling does not request such an initial geostatitical investigation (Theocharopolus *et al.* 2001). The present study thus yield basic knowledge on the number of field samples needed for an adequately determination within some well-defined sampling units (Danish vegetation types) when no information on soil spatial variation is know in advance. In order to yield reasonable results with a moderate field precision (here <40 % analytical error at 95 % confidence level) a larger number of replicates (7-11) are required. Considering analytical costs careful bulking of 10 or more soil subsamples after sampling is thus recommendable, and should prior to analysis be followed by representative diving into subsamples suitable for analysis.

References

Amponsah GI, Meyer WL, Murchison HG (2000) Soil sampling size estimates for soils under teak (*Tectona grandis* Linn. F) plantations and natural forests in Ashanti Region, Ghana. *Canadian Journal of Soil Science* **80**, 327-336.

Beckett PHT, Burrough PA (1971) The relation between cost and utility of soil surveys: IV: comparison of the utilities of soil mapds produced by different survey procedures, and at different scales. *Journal of Soil Science* **22**, 465-480.

Hitz C, Egli M, Fitze P (2002) Determination of sampling volumes needed for representative analysis of alpine soils. *Journal of Plant Nutrition and Soil Science* **165**, 326-331.

Madsen HB, Nørnberg P (1995) Mineralogy of four sandy soils developed under heather, oak, spruce and grass in the same fluvioglacial deposit in Denmark. *Geoderma* **64**, 233-256.

Mossin L, Jensen TB, Nørnberg P (2001) Altered Podzolization Resulting from Replacing Heather with Sitka Spruce. *Soil Science Society of America Journal* **65**, 1455-1462.

Stein A, Ettema C (2003) An overview of spatial sampling procedures and experimental design of spatial studies for ecosystem comparisons. *Agriculture Ecosystems and Environment* **94,** 31–47.

Theocharopoulos SP, Wagner G, Sprengart J, Mohr ME, Desaules A, Muntau H., Christou M, Quevauviller P (2001) European soil sampling guidelines for soil pollution studies. *The Science of the Total Environment* **264**, 51-66.

Webster R, Oliver MA (2001) 'Geostatistics for Environmental Scientists'. (John Wiley and Sons, Ltd.: England).

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

Classifying sodic soils: A comparison of the World Reference Base for Soil Resources and Australian Soil Classification systems

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Abstract
In this preliminary study, the World Reference Base (WRB) soil classification system is compared with the Australian Soil Classification (ASC) in order to establish the applicability of the former to Australian soils. Various differences in the structure of the two schemes using sodium-affected soils which cover much of Victoria indicate variation in profile classification and concomitant implications for mapping. Potential modifications to enhance both systems and facilitate the translation of data for mapping are suggested.

Key Words
Soil sodicity, Soil types, Sodosol, Solonetz, Planosol.

Introduction
The World Reference Base for Soil Resources (IUSS Working Group WRB 2007) is considered to be the international standard for describing soil types. Australian soils have been classified according to a number of schemes with the latest being the Australian Soil Classification (ASC) (Isbell 2002). The aim of this preliminary comparison is to gain an understanding as to how readily the world standard can be applied in Australia using sodium-affected soils as a case study. Sodic soils cover a substantial area of the continent with all states and territories being affected (Figure 1), and are frequently found in dryland environments (≤ 500 mm average annual rainfall). Generally speaking, the properties of these soils (e.g. low fertility and clay dispersion) make them difficult to manage, especially with constraints to plant growth and susceptibility to various forms of water erosion. Sodic soils cover approximately 59 % of Victoria (Figure 2) and at least 73 % of the State's agricultural land (Ford *et al*. 1993).

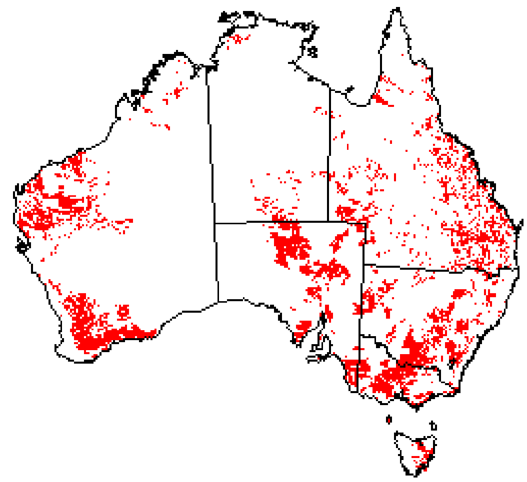

Figure 1. Generalised distribution of Sodosols in Australia (Isbell 2002).

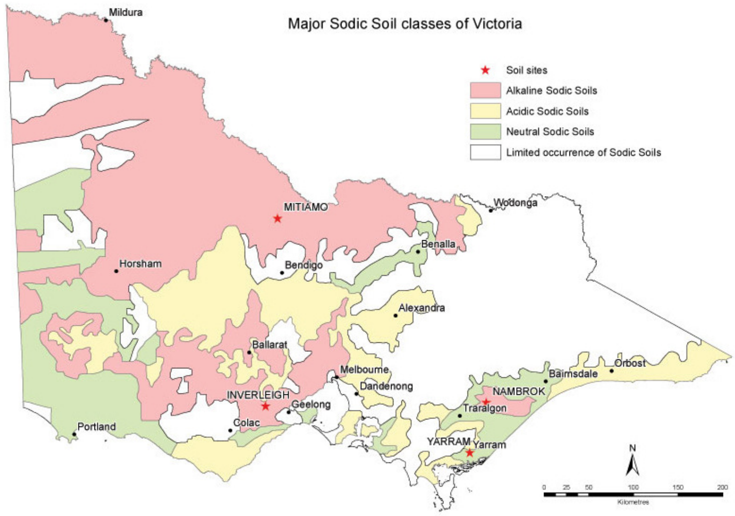

Figure 2. Major sodic soil classes of Victoria (after Ford *et al.* 1993).

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Methods

A comparison of each scheme as it applies to soil sodicity was made in relation to the following factors:

1. Purpose

The ASC was designed to cater for Australia's diversity of soil types while the WRB was intended to be a soil classification framework in which national classifications would fit and, by necessity, has a wide range of criteria to account for international diversity.

2. Structure of the systems

Sodic soils are dominated by a specific Soil Order in each classification; Sodosols in the ASC and Solonetz in the WRB, and the genesis of both terms relating to Australian sodic soils was summarised by Isbell (1995). The term 'Solonetz' has been used in earlier Australian schemes with a specific reference to texture contrast soils comprising columnar-structured clay subsoils (Isbell 1995), although the Order has been defined in broader terms in the WRB. The importance of sodium-affected soils in each classification is indicated by the fact that there are nine Soil Orders in the WRB and seven in the ASC which have a sodic component (Table 1). In the decision matrix, the Solonetz is encountered considerably earlier (indicating a higher relative importance) than Sodosols in the ASC.

Table 1. World Reference Base (WRB) and nominal relationships with the ASC for soils with sodic attributes.

WRB No.	WRB Order	Rationale	ASC No.	ASC Order
6	Vertisol	Water; wet/dry, shrink swell	4	Vertosol (VE)
8	Solonetz	Alkaline	7, 8	Sodosols (SO), Chromosols (CH)
9	Solonchaks	Salty after evaporation	7	Sodosols
10	Gleysols	Groundwater affected	5	Hydrosols (HY)
16	Planosols	Stagnant water, texture contrast	8, 7	Chromosols, Sodosols
17	Stagnosols	Stagnant water, structural or moderate textual discontinuity	7	non-Red Sodosols
23	Calcisols	Accumulation of calcium carbonate	9	Calcarosols (CA)
27	Luvisols	Clay subsoil; high base status, high activity clays	8, 7, 11, 12	Chromosols, Sodosols, Dermosols (DE), Kandosols (KA)
28	Lixisols	Clay subsoil, high base status, low activity clays	8, 7, 11, 12	Chromosols, Sodosols, Dermosols, Kandosols

3. Definition and levels of ESP

In the ASC, the Exchangeable Sodium Percentage (ESP) is defined as

$$\frac{\text{Exchangeable Na.100}}{\text{Effective Cation Exchange Capacity (ECEC)}} \quad (1)$$

In the WRB, ESP is defined as

$$\frac{\text{Exchangeable Na.100}}{\text{Cation Exchange Capacity (CEC at pH 7)}} \quad (2)$$

$$\text{or Na + Mg> (Ca+H+Al) @ pH 8.2} \quad (3)$$

The use of ECEC as a denominator is particularly relevant to Sodosols in Victoria where subsoils are neutral or slightly acidic, thereby reducing the relative concentration of sodium. This is because ESP is often calculated with a denominator of the exchangeable bases (i.e. Σ Ca+Mg+K+Na) (e.g. Rengasamy and Churchman 1999). This would be similar with denominators of ECEC or CEC where soils are alkaline, but not where pH is lower owing to higher levels of exchangeable H and Al. The definitions of soil sodicity used in Australia have included ranges of ESP (Northcote and Skene 1972) and the Sodium Adsorption Ratio (e.g. Rengasamy *et al.* 1984). In the ASC sodic soils are defined as ESP $\geq$ 6, with values between 6 and 15 termed 'subnatric', 15-25 'mesonatric' and greater than 25 'hypernatric'. On the other hand, whilst the lower sodicity limit in the WRB scheme is 15 ('natric'), the only subcategory for an ESP qualifier lies in the range of 6-15 ('hyposodic').

4. Role of other factors

The significant criteria used in identifying and diagnosing sodicity for the two classification systems are presented in Table 2. The effects of pH on sodic soil classification have been considered elsewhere (Figure 2, Rengasamy and Olsson (1991) and the values of samples tested at $pH_{1:2.5}$ are likely to be lower than for $pH_{1:5}$ (P Rengasamy pers. comm.).

Table 2. Comparative criteria for Sodosols (ASC) and Solonetz (WRB).

Factor	Sodosol (ASC)	Solonetz (WRB)
Texture	Texture contrast profile. Diagnostic Subsoil Horizon (DSH) has ≥20% clay than the overlying surface soil	n.a.[1]
	n.a.[1]	Natric horizon is loamy sand or heavier or >8% clay content
	n.a.[1]	Less clay in horizon above natric horizon, >1.2 times clay % of material above natric horizon
	n.a.[1]	COLE> 0.04
	n.a.[1]	Clay illuviation
Abrupt texture change	5 cm	7.5 cm
Subplasticity	Not strongly subplastic	n.a.[1]
ESP	≥6	ESP≥15, or Na + Mg> (Ca+H+Al) @ pH8.2
Soil depth	DSH thickness criteria > 0.2 m	Natric horizon thickness criteria
	n.a.[1]	Natric horizon must start within upper 1 m of soil surface
pH	Not strongly acid (pH≥ 5.5) $pH_{1:5}$	n.a.[1] $pH_{1:2.5}$
Structure	n.a.[1]	Structure (i.e. prismatic, columnar)

n.a.[1] not applicable

Results

A comparison of the two classifications and the compatibility between the primary sodic Soil Orders of the ASC (Sodosols) and WRB (Solonetz) was undertaken using four soil profiles (Figure 2) from different regions of Victoria with varying ESP ranges. While the number of soil profiles is limited, they are indicative of varying characteristics and comprise Brown Sodosols [(Nambrok West and Yarram, in south-eastern Victoria and Inverleigh (western Victoria)] as well as a Red Sodosol (Mitiamo, northernVictoria) (Table 3).

Table 3. Comparison of characteristics for the four selected Sodosols (ASC) in Victoria.

Site	$pH_{1:5}$ surface horizon (A1)	$pH_{1:5}$ upper subsoil (B21)	Exch. Bases upper subsoil	ECEC upper subsoil	ESP upper subsoil	ESP lower subsoil	WRB
Nambrok West	5.7	7.3	12.1	12.1	16.5	23.6	Solonetz
Inverleigh	5.8	5.7	16.0	29.0	6.2	22.0	Solonetz
Yarram	5.5	6.3	15.0	29.0	6.2	9.6	Planosol
Mitiamo	5.9	8.1	19.2	n.a.	17.0	32.3	Solonetz

The WRB scheme states that a natric horizon starting within the upper metre of a soil profile defines a Solonetz, but for the ASC the upper subsoil is the diagnostic horizon where the upper subsoil is seen as the major 'throttle' on the water and gas movement within the profile. There is no saline Soil Order in the ASC as exists in the WRB (i.e. 'Solonchak') and the combination of sodicity and salinity in the ASC and WRB is not prominent in either system. As mentioned earlier, the ESP in the upper and/or lower subsoil is a critical measure in both systems. The Nambrok West profile classification is both a Sodosol and Solonetz due to the high ESP (>15) occurring in the upper and lower subsoil. The soil profile from Inverleigh is also a Sodosol with an ESP between 6 and 15 (identified as Subnatric in the ASC) and also equates to a Solonetz due to greater sodicity (ESP of 22) in the deeper subsoil. The Yarram Sodosol is also classed as a Subnatric Suborder, to a depth of at least one metre and is therefore not a Solontez but a Planosol.

Conclusion

This paper indicates that there is a general alignment between these classifications in terms of a physical concentration of sodium in a soil profile and lighter material overlying a Natric horizon in the WRB scheme as compared with a distinct texture contrast in the ASC. However, significant differences include the definition and measurement of sodicity (i.e. ESP) and its position in the soil profile. More criteria need to be considered for determination of a Solonetz than a Sodosol and this reflects the international aspect of the WRB to accommodate world-wide variability. Accordingly there may be cost considerations in the application of the WRB in particular. However, there are more levels (Order, Suborder, Great Group, Subgroup and Family) in the ASC than the WRB (Order, prefix qualifier and suffix qualifier) allowing greater refinement.

The ASC has undergone progressive refinement since it was introduced in 1996 and the WRB scheme is also being modified. It is considered that ASC data should be extended to a depth of one metre in order to facilitate a direct comparison with WRB and potential extrapolation to the Global Soil Map Initiative. In addition, the colour of Sodosols is a significant characteristic which is not matched to the same degree in the WRB. In this regard, Red Sodosols are a prominent ASC Suborder occurring across the northern riverine plains of Victoria. Although they behave differently to other Sodosols in terms of drainage and waterlogging potential, this soil function information is lost in translation to the Solonetz WRB classification. The addition of a 'Chromic' qualifier to the WRB Solonetz Soil Order to account for the redder subsoil variants would address this issue. Further study is required top establish the relationships between the classifications, for sodium affected soils and extrapolate to other Soil Orders. In terms of sodic texture contrast soils**,** the ASC permits finer categorisation for mapping purposes compared with the WRB. Care is required to facilitate translation between ASC and WRB for publication to an international audience.
It is suggested that a measure of field behaviour reflecting clay dispersion be introduced to both schemes as Electrical Conductivity and other parameters that can exert a strong influence on Exchangeable Na are not taken into account. Options include a test of soil aggregate stability (Emerson 2002) or the measurement of spontaneous and mechanical clay dispersion (Rengasamy 2002).

References

Emerson WW (2002). Emerson Dispersion Test. In 'Soil physical measurement and interpretation for land evaluation'. (Eds. N McKenzie, K Coughlan, H Cresswell) pp. 190-199. (CSIRO Publishing: Collingwood)

Ford GW, Martin JJ, Rengasamy P, Boucher SC, Ellington A (1993). Soil sodicity in Victoria. *Australian Journal of Soil Research* **31**, 869-909.

Isbell RF (1995). The use of sodicity in Australian soil classification schemes. In 'Australian sodic soils: Distribution, properties and management'. (Eds. R Naidu, ME Sumner, P Rengasamy) pp. 41-45. (CSIRO Australia: East Melbourne)

Isbell RF (2002). Australian Soil Classification. Revised Edition. (CSIRO Publishing: Melbourne)

IUSS Working Group WRB (2007). World Reference Base for Soil Resources 2006, first update 2007. World Soil resources reports No. **103**. FAO: Rome.

Northcote KH, Skene JKM (1972). Australian soils with saline and sodic properties. CSIRO Australia, Division of Soils Soil Publication No. **27**.

Rengasamy P (2002). Clay dispersion. In 'Soil physical measurement and interpretation for land evaluation'. (Eds. N McKenzie, K Coughlan, H Cresswell) pp. 200-210. (CSIRO Publishing: Collingwood)

Rengasamy P, Churchman GJ (1999). Cation Exchange Capacity, Exchangeable Cations and Sodicity. In 'Soil Analysis an Interpretation Manual'. (Eds. KI Peverill, LA Sparrow, DJ Reuter) pp. 147-157. (CSIRO Publishing: Melbourne)

Rengasamy P, Greene RSB, Ford GW, Mehanni AH (1984). Identification of dispersive behaviour and the management of red-brown earths. *Australian Journal of Soil Research* **22**, 413-431.

Rengasamy P, Olsson KA (1991). Sodicity and soil structure. *Australian Journal of Soil Research* **29**, 935-952.

Soil moisture regime classification of Soil Taxonomy through physically based soil water balance modelling.

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Abstract
Soil Taxonomy classification differs from other systems as it includes estimation of the soil moisture regime (SMR). Currently, its estimation is obtained through simple calculation schemes, such as the Newhall and Billaux models (standard approaches) or the EPIC model.

The aim of this work was to use a physically based model SWAP for evaluating Soil Taxonomy – SMR in eight Italian sites with different pedoclimatic conditions. The SMRs obtained were compared to those applying Newhall and Billaux models, as well as the ICOMMOTR proposals.

In general, the standard approaches showed unrealistic results. They overestimated the dry conditions in the soil moisture control section (SMCS) during the year but allows the separation of different pedoclimatic settings. In contrast, the physically-based approach showed realistic results but it was not able to differentiate various pedoclimatic settings (almost all sites as Udic). Simulation modelling was then used to evaluate the sensitivity of the model output, namely SMR, by varying model inputs such as the dry limits values (-1500 kPa) for SMCS. Finally, a tentative proposal was designed that enlarged the SMR classification to include some information on the dynamic behavior of the soil-climate system so that the system may better perform in current environmental challenges.

Key Words
Soil moisture regimes, Newhall, SWAP, Soil Taxonomy.

Introduction
Climate is one of the most important soil forming factors affecting soil processes, soil properties and in turn the use of soils. Soil Taxonomy (Soil Survey Staff, 2006 uses climate information to classify soils by means of the soil moisture regime (SMR). SMR is typically calculated through the use of well known models such as Newhall (Newhall 1972; Van Wambeke 2000), Billaux (Billaux 1978), and more recently EPIC (Costantini *et al.* 2002). These models estimate the SMR through simple calculation schemes, based on the precipitation-evapotranspiration balance that frequently produce incorrect soil water flow predictions because are not based on physical laws. The arising question is whether they properly classify SMR and define soil moisture control section (SMCS). This work addressed these problems by evaluating, through the use of a calibrated and validated physically based water balance simulation models (SWAP, van Dam *et al.* 1997), the appropriateness of Soil Taxonomy criteria and also the International Committee on Soil Moisture and Temperature Regimes (ICOMMOTR) proposals (ICOMMOTR 1991) on selected Italian soils.

Methods
Criteria of SMR classification in Soil Taxonomy and ICOMMOTR
SMR classification was done according to Soil Taxonomy and the ICOMMOTR proposal.

Model applied to classify SMR
The Newhall and Billaux models (standard approach) which calculate itself the potential evapotranspiration through the Thornthwaite formula (Thornthwaite 1948).
The physically based model SWAP.

SMR Elaborator
In order to classify the SMR with the output of the physically-based model SWAP, a routine in Visual Basic for Excel called “SMR Elaborator” was developed, and is available upon request.

Sites

The eight soils studied were distributed in northern (six) and southern (two) Italy. They included very diverse Inceptisols, Alfisols, and a Vertisol. The SWAP model was calibrated and validated in the eight soils. The field and laboratory measurements and procedures to calibrate and validate the model were done as previously described (Bonfante *et al.* 2009; ERSAF 2007; Basile and Terribile 2008). The sites have been calibrated and validated in different years.

The daily climatic data applied for each site and year are: (i) air temperature (min and max), (ii) rain, and (iii) reference evapotranspiration estimated through the Penman-Monteith equation (Monteith 1965).

Results

The classification of SMR was conducted by two different methods: a standard approach based on two widely applied classification models (Newhall and Billaux), and a physically-based approach based on the hydrological model SWAP, to determine SMCS and the soil water potential over time (Figure 1).
In order to determine the boundaries of the SMCS, according to the Soil Taxonomy definition, the physically-based SWAP model was applied to the eight sites simulating the deepening of the wetting front.
The results (Figure 2) shows that: (i) the SMCSs thickness estimated by SWAP were close to those reported in Soil Taxonomy (Keys to Soil Taxonomy, pp.26, Soil Survey Staff 2006) for different soil texture classes but quite different from those obtained using the Newhall and Billaux models; (ii) the control section applied by the Newhall and Billaux models were in many cases unrealistic (e.g. Mantova, Ghisalba, Eboli); and (iii) in some cases the Newhall and Billaux models largely overestimated the lower boundary of the SMCS with an unrealistic estimation (e.g. Ghisalba site -118 cm).

Table 1 shows the SMR obtained by several approaches: (i) applying the SWAP model using the crop and lower boundary condition (presence/absence of water table) as measured in the running year, (ii) applying the SWAP model without using the crop and water table in order to emphasize the role of soil, (iii) applying the Newhall model and (iv) the Billaux model. Apparently, the three models give the same result for five sites (Udic moisture regime). However, further detailed analysis showed that the Newhall and Billaux approaches produced dry conditions in the SMCS (in some or in all parts) for several days during the year (e.g. the Mantova site in 2003 has 80 dry days using the Newhall model and 127 days using the Billaux model) while using SWAP the SMCS was always moist (in some or in all parts).
To further investigate the comparison between the physically-based and standard approaches, SMR classification with the Newhall and Billaux models using the same Et0 applied in SWAP was performed (Table 1, columns with §). The standard approaches showed unrealistic results with very high dryness values.

The classification using ICOMMOTR methodology fit that obtained with SWAP among those applied using Soil Taxonomy. The results suggested that the ICOMMOTR classification was similar to the classification after using the physically based approach, despite its simpler structure. Nevertheless, this approach required water potential measurements or estimates from calibrated hydrological models.

Based on the results obtained, we have attempted to produce some possible Soil Taxonomy methodology improvements, at least for the range of the investigated soils, with a sensitivity analysis of the dry limit values (-1500 kPa) on the SMR classification. The results of this sensitivity analysis showed that the Udic SMR comprised most of the dry limit range, producing a clear overestimation in respect to the other classes, almost irrespectively of the soil and climate conditions. In detail, in 50% of cases the transition between the Udic and Ustic regimes classification occurred below -40 kPa, and the transition between moisture regime classes occurred at -13 and -200 kPa. Indeed, these values physically correspond to wet soil conditions.

A new proposal was formulated for further implementation of the SMR classification to provide additional information on the soil-climate behavior using a physically based hydrological model. In detail, the classification proposed (Soil Driven Moisture Regimes Classification – SDMRC) was obtained through the use of two functional indices obtained from the simulation outputs with SWAP with bare soil in one year of analysis (normal year). The first index (I_{dr}) considered the exchanges of water at the bottom boundary of the soil system, and it consisted of the ratio between the annual drainage (estimated by the model) and the annual water inputs applied to the soil system (rain). The second index (I_{ev}) considered the exchange of water at the soil upper boundary, namely between the soil system and the atmosphere, and it was defined as the ratio between actual annual soil evaporation (estimated by the model) and potential annual soil evaporation. Both indices were expressed as a percentage and their combination enabled the estimation of the SMR in accordance with Soil Taxonomy criteria.

Table 1. Classification of SMR with Soil Taxonomy and ICOMMOTR methodologies.

Sites	Year	Soil Taxonomy Moisture regime						ICOMMOTR Moisture regime
						Penman-Monteith ET_0		
		SWAP†	SWAP††	Newhall	Billaux	Newhall§	Billaux§	
Mantova	2002	Udic	Udic	Udic	Udic	Ustic	Aridic	Udic Ustic
	2003	Udic	Udic	Xeric	Xeric	Xeric	Aridic	Udic Ustic
	2004	Udic	Udic	Udic	Udic	Ustic	Xeric	Udic Ustic
Caviaga	2002	Udic	Udic	Udic	Udic	Udic	Xeric	Perudic
	2003	Udic	Udic	n.a.	Xeric	n.a.	Aridic	Typic Udic
Carpaneta	2005	Udic	Udic	Udic	Udic	n.a.	Xeric	Typic Udic
Ghisalba	2005	Udic	Udic	Udic	Udic	Udic	Udic	Perudic
Landriano	2005	Udic	Udic	Udic	Udic	n.a.	Xeric	Typic Udic
Luignano	2005	Udic	Aquic	Udic	Udic	n.a.	Udic	Perudic
Scafati	2005	Udic	Udic	Xeric	Udic	n.a.	Udic	Typic Udic
Eboli	2004	Udic	Udic	Ustic	Udic	Xeric	Xeric	Typic Udic
	2005	Udic	Udic	Xeric	Udic	Xeric	Xeric	Perudic

§ Models were performed applying the Penman-Monteith equation to calculate reference evapotranspiration (Et_0) as in the SWAP model.
† Real management condition
††Without water table and plant growth
n.a.: Not available

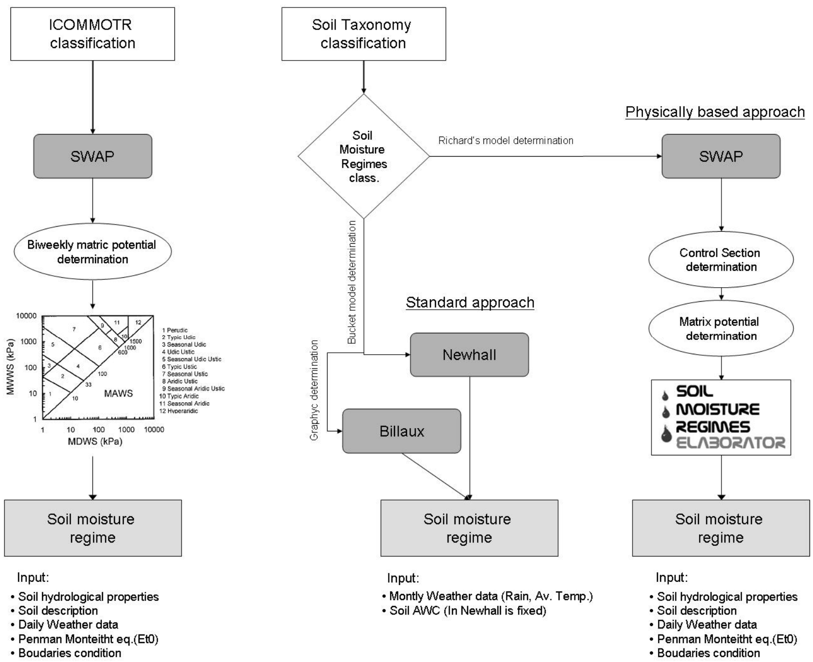

Figure 1. Schematic diagram of the procedures adopted for SMR classification.

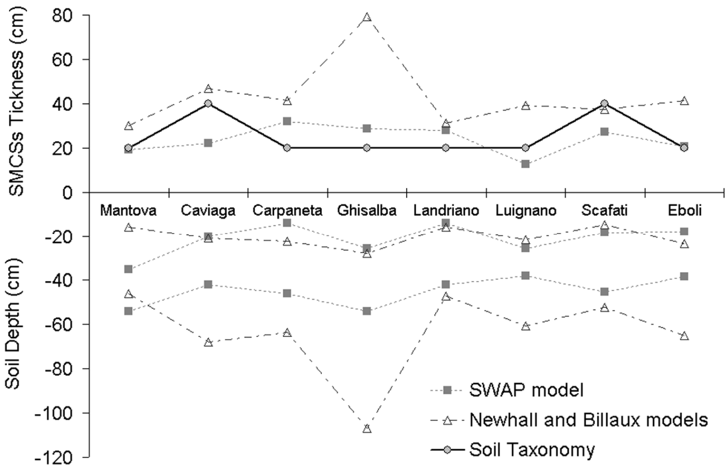

Figure 2. Upper: SMCS thickness of the eight soil samples according to SWAP (square), Newhall and Billaux (triangle) models, and Soil Taxonomy (circle). Lower: upper and lower boundaries of the SMCS determined using the SWAP model (square) and the Newhall and Billaux models (triangle).

Conclusion

The use of a physically-based approach showed that indeed some problems exist in the application of the SMR classification method proposed by Soil Taxonomy, at least for the studied sites. In our case studies, the use of standard approaches to classify SMR according to the Soil Taxonomy scheme showed unrealistic results but enabled the separation of different pedoclimatic settings. In contrast, the application of a calibrated and validated (in the eight study sites) physically-based approach, as expected, showed realistic results but was not able to distinguish different pedoclimatic settings. These findings suggest that if physical laws are applied, the strict scheme and criteria of SMR classification in Soil Taxomomy do not distinguish the different pedoclimatic settings ranging from Southern to Northern Italy. A tentative proposal was also provided for a SMR classification aiming to enlarge this procedure in order to meet new environmental issues, which often require the dynamic hydrological behavior of the soil-climate system to be addressed.

References

Basile A, Terribile F (2008) La ricerca sull'inquinamento da nitrati nei suoli campani: un approccio modellistico nella gestione agro-ambientale. Regione Campania , Assessorato all'Agricoltura ed alle Attività Produttive, SeSIRCA, Napoli 2008. ISBN: 978-88-95230-07-8.

Billaux P (1978) Estimation du "regime hydrique" des sols au moyen des données climatiques. Le method graphique: son utilization dans le cadre de la Taxonomie Americaine des sols. (In French, with English abstract.) (Eds de L'Orstom), *Ser. Pedol.* **3,** 317-318

Bonfante A, Basile A, Acutis M, De Mascellis R, Manna P, Perego A, Terribile F (2009) SWAP, CropSyst and MACRO comparison in two constraing soil cropped with maize in northern Italy. Submitted to *Agricultural Water Management* Jun 09. AGWAT2428.

Costantini EAC, Castelli F, Raimondi S, Lorenzoni P (2002) Assessing Soil Moisture Regimes with Tranditional and New Methods. *Soil Sci. Soc. Am. J.* **66,** 1889-1896.

ERSAF (2007) Modellizzazione della dinamica dell'acqua e dell'azoto nei suoli agricoli lombardi. Quaderni della ricerca. Regione Lombardia Coltivare il Futuro. N. 65

ICOMMOTR (1991) Circular letter no. 2. USDA-SCS, Lincoln, NE.

Soil Survey Staff (2006) Keys to Soil taxonomy: Tenth ed. USDA-NRCS. Washington.

Thornthwaite CW (1948) An approach towards a rational classification of climate. *Geographical Review* **38**, 55

van Dam JC, Huygen J, Wesseling JG, Feddes RA, Kabat P, van Walsum P, Groenendijk P, van Diepen CA (1997). Simulation of water flow, solute transport and plant growht in the Soil-Atmosphere-Plant environment. Theory of SWAP 2.0. Technical Document 45 DLO-SC, 168.

Van Wambeke AR (2000). The Newhall Simulation Model for estimating soil moisture & temperature regimes. (Department of Crop and Soil Sciences, Cornell University, Ithaca, NY USA).

Soil moisture-temperature correlation and classification model

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Abstract
Traditionally, soils that do not display evidence of wetness (i.e. redoximorphic features) are regionally defined regarding soil moisture classification. Likewise, soil temperature classification has been closely tied to mean annual air temperature recorded at nearby weather stations. Early models to aid soil scientists determine soil moisture classification regarded soil as a reservoir with a fixed capacity (Newhall 1980). Water was added through precipitation with the excess being lost to deep leaching or runoff. Stored water was removed through evapotranspiration. Later models included a formulation to account for rainfall intensity and the amount of energy required to remove moisture from layers of soil (Newhall and Berdanier 1996). Site specific variables or factors which affect soil moisture and temperature, including the interrelationship of percent slope, aspect, albedo, changes in elevation or latitude, and soil moisture handling characteristics, are quite complex and have not been consistently evaluated or used in determining these classifications.

The soil moisture-temperature model goes beyond regional determinations for moisture and temperature. It predicts site specific effects that elevation, latitude, slope, aspect, vegetation, soil depth, water holding capacity, and albedo have on soil moisture and temperature at both horizontal and vertical distances from the weather station.

Key Words
MCS, perudic, udic, ustic, xeric, aridic (torric).

Introduction
Soil moisture and temperature classification is a foundation for many modern international soil classification systems. It is recognized at virtually all levels of Soil Taxonomy (Soil Survey Staff 1999). Soil moisture and soil temperature properties influence soil-plant relationships and serve as a determinant of the chemical, mechanical, and biological processes that occur in the soil.

It has been conventional to recognize three soil moisture states or classes: saturated (wet), moist, and dry (Soil Survey Staff 1999; Soil Survey Division Staff 1993). Saturated occurs when water is not held by the soil and flows freely through soil pores, usually associated with a water table; moist occurs when water is held by the soil at tensions greater than 0 to less than 1500 kPa, where water moves down to a saturated substratum and can cause leaching of clay, carbonates, etc.; and dry occurs when water is held at tensions greater than or equal to 1500 kPa. In a dry state, water in soil is not available to keep most mesophytic plants alive (Greulach 1973; Soil Survey Division Staff 1993). With the possible exception of those saturated soils which have a permanent water table, soil will become alternately moist and dry during the growing season as rainfall enters the soil at the surface and moves downward. Eventually the water will be extracted by evaporation, evapotranspiration (plants), or passed through as deep percolation. It is these periods of saturated versus moist versus dry, and the amount of time during the growing season each of these conditions are present, that influences the type of native vegetation grown in the soil (Smith *et al*. 1964). Realizing this, soil scientists have identified and characterized six soil moisture regimes that occur world-wide: aquic, aridic (torric), ustic, xeric, udic, and perudic (Soil Survey Staff 1999).

The aquic moisture regime indicates that a soil is or has been saturated for extended periods of time. The saturated zone is virtually free of dissolved oxygen. In this state, iron in the soil undergoes reduction causing the soil to become gray and mottled in color. Since this moisture regime is readily identifiable in the field through visual or simple chemical testing, it is not the focus of this paper.

To aid in the classification of soil moisture regimes other than aquic, the concept of a soil moisture control section (MCS) was developed (Smith *et al*. 1964; Soil Survey Staff 1999). For standardization the top of the moisture control section was defined as being the depth to where 25 mm of water will moisten in 24 hours after being added to a soil surface with soil-water tension being at 1500 kPa. The bottom of the soil-moisture control section is determined by the depth 75 mm of water will moisten in 48 hours after being added to the soil surface

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with soil-water tension being 1500 kPa. The depths of the MCS from one soil to the next can vary widely depending on soil texture and water holding capacity. For instance, a clayey soil may have a MCS from 15 to 35 cm and a sandy soil may have a MCS that extends from 45 to 125 cm. If the soil contains a root limiting layer above the point where 75mm of water moistens, that point becomes the bottom of the MCS (Soil Survey Staff 1999).

Classification of the aridic (torric), ustic, xeric, udic, and perudic soil moisture regimes is determined by a statistical function of how many days the soil MCS is moist or dry when the soil is above critical soil temperatures that affect germination and active plant growth. Also factored in are when these periods of time occur during the year.

Nine soil temperature regimes are recognized: cryic, frigid, mesic, thermic, hyperthermic, isofrigid, isomesic, isothermic, and isohyperthermic (Soil Survey Staff 2006). The depth chosen to sample soil temperature is 50 cm or at a densic, lithic, or paralithic contact, whichever is shallower. That depth was chosen because it is deep enough to not be susceptible to daily temperature fluctuations, yet is shallow enough to excavate and collect a temperature reading without a lot of expense or effort (Smith *et al.* 1964). The average annual temperature at this depth is used for classification purposes. In the U. S., soil scientists have typically added 1 degree C. to the mean annual air temperature to approximate the soil temperature. U. S. soil scientists will quickly acknowledge that this method does not take into account temperature differences caused by slope and aspect, soil drainage, elevation and latitude changes over short distances, and shade or lack thereof from vegetation (Soil Survey Staff 1999).

Presently, soil classification and mapping throughout most of the U.S. is conducted by individual soil scientists with varying degrees of training, skill, ability, and experience. Soil moisture classification of soil containing redoximorphic features is usually straightforward (Soil Survey Division Staff 1993; Soil Survey Staff 1999); however, in the absence of these features, soil moisture classification tends to become more subjective. This is especially the case in areas that are intermediate or intergrade to perudic, udic, ustic, xeric, or aridic (torric). Ordinarily, soil moisture and temperature estimates are based on local meteorological data. Field soil scientists project these estimates by various means to the site by incorporating elevation or some regional or vegetative boundary as a guide in assessing the soil’s moisture and temperature classification. The position of the soil on the landscape, or the soil’s moisture handling characteristics, is typically not part of this process. In general, calculating soil moisture and temperature over large areas, (based on the interrelationships of soil, climate, physiography, and vegetation) is too complex for a consistent prediction by field soil scientists.

Factors influencing soil moisture and temperature at any given point on the landscape are: percent slope, aspect, albedo, vegetative cover (type and amount), relative humidity, runoff, soil depth, soil texture, soil mineralogy, soil bulk density, elevation, latitude, percent possible sunshine, daylength, wind speed, temperature, and precipitation. These interrelationships are commonly not considered when assessing soil temperature and moisture. Since current soil climate models are regional in nature, this has often resulted in erroneous soil moisture and temperature classifications, especially in areas of the country with high relief (Newhall and Berdanier 1996). In addition, soil scientists typically are unable to quantify or predict with a consistent degree of confidence how soil moisture or temperature would be affected if the landscape were altered. Consider the following situations and the effects each could have on soil moisture and temperature: forest fire, revegetating a barren area, overgrazing, severe erosion, desertification, and global climate change.

Gathering site or soil specific data with regard to moisture and temperature would be costly and time consuming since the data required is both seasonal and long-term. Although there is a very large body of common knowledge about soil moisture and temperature variation over time, there are very few long-term records and fewer still relating to the energy concept of soil moisture and temperature. Meteorological records, most of which are long-term, are available over many parts of the country and the world. A number of methods have been devised to relate meteorological records to soil moisture and temperature. These methods are typically based on average values of precipitation, temperature, and potential evapotranspiration. They tended to give an oversimplified picture of soil moisture and temperature and did not address the soil's chemical and physical properties, the soil's relative position to a weather station, or the position of the soil on the landscape (Soil Survey Staff 1999).

Modeling moisture accretion/depletion and soil temperature to regions or areas of the country using climatological data has been done by Thornthwaite (1948); Thorthwaite and Mather (1955); Palmer and Havens

(1958); Smith *et al*. (1964); Newhall (1980); and Newhall and Berdanier (1996), to assist soil scientists in classifying soil. Predicted results were projected over large areas and often a rather wide range in latitude and elevation. Newhall and Berdanier (1996) improved on earlier models by accounting for a reduction in potential evapotranspiration as the soil dried. Even with these improvements, none of these earlier models accounted for variations in climatic conditions that occur as elevation and latitude changes, even over short distances. In addition, none of these earlier models considered the relational effects that physiography, vegetation, or soil properties have on soil moisture and temperature (Soil Survey Staff 1990).

Methods and Discussion

A five-part relational model was developed to help soil scientists calculate soil moisture, temperature, and taxonomic classification virtually anywhere on the earth's surface with readily available data. The five-part model includes: (1) Climate data: nine climatic variables, including elevation and location of the weather station, are user-entered (Sellers and Hill 1974). (2) Soil data: due to the complexity of the model, seventy-seven critical soil variables, including the soil's elevation and location, are required to run the model. An additional fourteen optional variables are used in certain instances to refine classification. A complete soil description usually suffices for the information necessary. (3) Soil moisture calculator: a model that calculates the limits of the soil moisture control section (Baumer 1983). (4) Water balance calculator: a set of calculations which incorporates Thornthwaite and Mather's (1955) premises and equations along with other physiographic and vegetative computations and serves as the primary calculation engine for the model (Anderson 1976; Greulach 1973; and Palmer and Havens 1958). (5) Classification: an output which displays soil moisture, temperature, and taxonomic classification along with graphs depicting calculated monthly soil moisture, precipitation, and runoff at the sample site. Typically, climate data is entered only once for a survey area unless the area is large enough to have more than one weather station within or near the survey area.

Meteorological variables such as percent possible sunshine, relative humidity, precipitation, temperature, wind speed, and the number of storm events are entered into the (1) climate data section. Data from nearby weather stations is extrapolated in the model to sites being correlated. This provides consistency and standardization to estimated local climate. Soil property variables from pedon descriptions such as soil horizons or layers, depth, texture, consistence, chemical properties, color, clay activity, density, and hydrologic group are entered into the (2) soil data section along with vegetation variables and physiographical property variables such as aspect and percent slope. The (3) soil moisture calculator uses data from the (2) soil data section including layer depth, texture, bulk density, clay activity, and percent organic matter to calculate wilting point and MCS limits. The (4) water balance calculator uses data and calculations from (1), (2), and (3) to estimate soil moisture and temperature conditions. The (5) classification output displays results of the calculations made in the (4) water balance calculator to predict the soil taxonomic classification to the "Great Group" and, in some instances, the "Sub Group" level of Soil Taxonomy (Anderson 1976; Soil Survey Staff 1999). Where soil surveys are available, this data could be provided in a GIS format in order to classify or reclassify large areas.

The model was tested by comparing calculated output with data from soil moisture/temperature monitoring sites that are part of the USDA Soil Climate Analysis Network (SCAN). Ten sites representing five temperature and four moisture regimes located around the United States were evaluated. Calculated vs. measured classifications were in agreement at eight of the sites. Of the two sites that differed, one had a measured frigid soil temperature regime vs. a predicted cryic regime the other had a measured ustic soil moisture regime vs. a predicted ustic aridic regime. Soil temperature at the first site averaged 2.8 degrees C warmer than air temperature compared with the model's 1 degree C pre-adjusted default which was discussed above. The moisture discrepancy on the second site can be attributed to the way the model uses a water holding capacity average for each soil texture. A large deviation from this average can cause the model to overstate or understate the number of days the MCS is moist which may affect classification of the soil moisture regime.

Conclusion

The Soil Moisture-Temperature Correlation and Classification Model correlates site specific soil, vegetative, and physiographical variables with extrapolated climatological data. The relational aspects of the model can demonstrate how a change in any single variable can affect all the other factors of soil moisture, temperature, runoff, classification, etc. "What If ?" scenarios can be quantitatively assessed. Predictions of soil moisture, temperature, and classification are documented for testing, evaluation, or validation for every point on the landscape.

The model will never replace the need for good field descriptions of soil and vegetative characteristics; these descriptions fuel the model. In addition, the model does not replace the need for monitoring soil moisture and temperature in diverse areas. This data is crucial for validation and improvement of the model.

Further study of the model is needed including: a statistical evaluation of soil moisture and temperature calculations in various regions of the country, testing the runoff formula in various rainfall regions, developing a user manual, and scripting for GIS inputs and outputs.

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References

Anderson S (1976) 'The Solar Home Book: heating, cooling, and designing with the sun.' (Brick House Publishing Co., Inc.: Harrisville, NH)

Baumer OW (1983) Calculating available soil moisture from laboratory data. FORTRAN computer program. Unpublished.

Greulach VA (1973) 'Plant Function and Structure.' (The Macmillan Company: New York, NY)

Newhall F (1980) Calculation of Soil Moisture Regimes from the Climatic Record. Technical Paper, rev. 7, USDA-Soil Conservation Service.

Newhall F, Berdanier CR (1996) Calculation of Soil Moisture Regimes from the Climatic Record. SSIR·46. USDA-Natural Resources Conservation Service.

Palmer WC, Havens AV (1958) A Graphical Technique for Determining Evapotranspiration by the Thornthwaite Method. *Monthly Weather Review* **86,** 123-128.

Sellers WD, Hill RH (1974) 'Arizona Climate: 1931·1972.' (The University of Arizona Press: Tucson, AZ)

Smith GD, Newhall F, et. al. (1964) Soil Temperature Regimes-their characteristics and predictability. SCS·TP·144. USDA-Soil Conservation Service.

Soil Survey Division Staff (1993) 'Soil Survey Manual.' Agricultural Handbook No. 18. USDA-Soil Conservation Service. (U. S. Government Printing Office: Washington, D. C.)

Soil Survey Staff (1990) International Committee on Soil Moisture and Temperature Regimes. Circular Letter no. 1. (USDA-National Soil Survey Center: Soil Conservation Service: Lincoln, NE)

Soil Survey Staff (1999) 'Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys.' Second Edition. USDA-Soil Conservation Service. (U. S. Government Printing Office: Washington, D. C.)

Soil Survey Staff (2010) 'Keys to Soil Taxonomy.' Eleventh Edition. USDA-Natural Resources Conservation Service. ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Taxonomy/keys/2010_Keys_to_Soil_Taxonomy.pdf. 26/03/2010.

Thornthwaite CW (1948) An Approach Toward a Rational Classification of Climate. *Geographical Review* **38,** 55·94.

Thornthwaite CW, Mather JR (1955) 'The Water Balance.' *Publications in Climatology.* **8**, (Drexel Institute of Technology, Laboratory of Climatology: Centerton, NJ)

Soil properties of Hwaong reclaimed polder soil and its management

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Abstract
This soil survey was performed to produce basic data for developing techniques of environment-friendly agriculture utilization system for soil resources on the Hwaong reclaimed polder soil (HRPS, 4,380ha) that is located between Hwasung and Ansan in Kyeonggi province. Eight soil series were classified on the HRPS – Munpo, Bogcheon, Yeosu, Buyong, Yeompo, Mangyeong, Pori, Taean. The Munpo series was the largest among them at 1,616ha. The sequence of soil type distribution were salty paddy field 1,887ha > normal paddy field 1,309ha > ill-drained paddy field 1,018ha > sandy paddy field 86ha. The sequence of land suitability classification were fourth grade 1,935ha > first grade 1,390ha > second grade 970ha > third grade 86ha. pH, EC, Ex.K, Mg, Na of soil in HRPS were high but OM, Av.P_2O_5, Ex.Ca were low. Meanwhile, to extend agricultural use of HRPS, a soil salinity map was plotted using a Geonics EM38 instrument.

Key Words
Reclaimed land, soil series, soil chemical properties.

Introduction
There are 1,641 reclaimed areas in South Korea including Seosan, Hwaong, Siwha, Yeongsangang, Saemangeum and the total size is 135,100ha. Among them Hwaong reclaimed polder soil (HRPS) has been constructed since 1990 and its total size is 6,212ha. Some early developed parts of HRPS are used as paddy field because of high percentage of clay, silt loam and bad vertical drainage due to high watertable. For general use of reclaimed land, it is developed into upland that is more economical. So to determine environment-friendly upland agriculture in HRPS, a detailed soil survey and classification were conducted, and soil salinity maps were plotted.

Methods
Detail soil survey, soil classification and analysis of soil physio-chemical properties of HRPS were conducted using 1:25,000 topographic maps and aerial photographs. The survey followed the Korea RDA (Rural Development Administration) soil survey handbook and recorded soil texture and drainage grade. The soil chemical properties pH, EC, OM, Av.P_2O_5. Ex. K, Ca, Mg, Na – were analysed by the Korea RDA standard analysis method and the soil salinity map was made by using a Geonics EM38 instrument.

Results
The sequence of eight soil series in HRPS were Munpo > Bogcheon > Yeosu > Buyong > Yeompo > Mangyeong > Pori > Taean. The size of main soil series were Munpo 1,616ha> Bogcheon 978ha > Yeosu 970ha, respectively. The Munpo Series, the most largest series in HRPS, was fine silt loam with no soil structure containing low soil organic matter, available phosphorus, exchangeable calcium. To use this soil as upland, control of subsurface drainage, increase of organic matter and addition of lime should be considered firstly. As the sequence of soil type distributions were salty paddy field 1,887ha > normal paddy field 1,390ha > ill-drained paddy field 1,018ha > sandy paddy field 86ha, HRPS is more adaptable for using lowland than upland agriculture. Suitability grade four in HRPS is 1,935 ha that should need particular soil management. Physical properties of surface soil are sand 71.8%, silt 20.7%, clay 7.5%. Due to large portion of sand and silt, early desalination is thought to be easy. Soil chemical properties like pH, EC, Ex.K, Mg, Na are high but contents of OM, Av.P_2O_5, Ex.Ca are low. To extend the agricultural use of HRPS, a soil salinity map was plotted.

Table 1. Size of soil series in the Hwaong reclaimed polder soil.

Soil series	Munpo	Bogcheon	Yeosu	Buyong	Yeompo	Mankyoeng	Pori	Taean	sum
size(ha)	1,616	978	970	326	271	86	85	48	4382

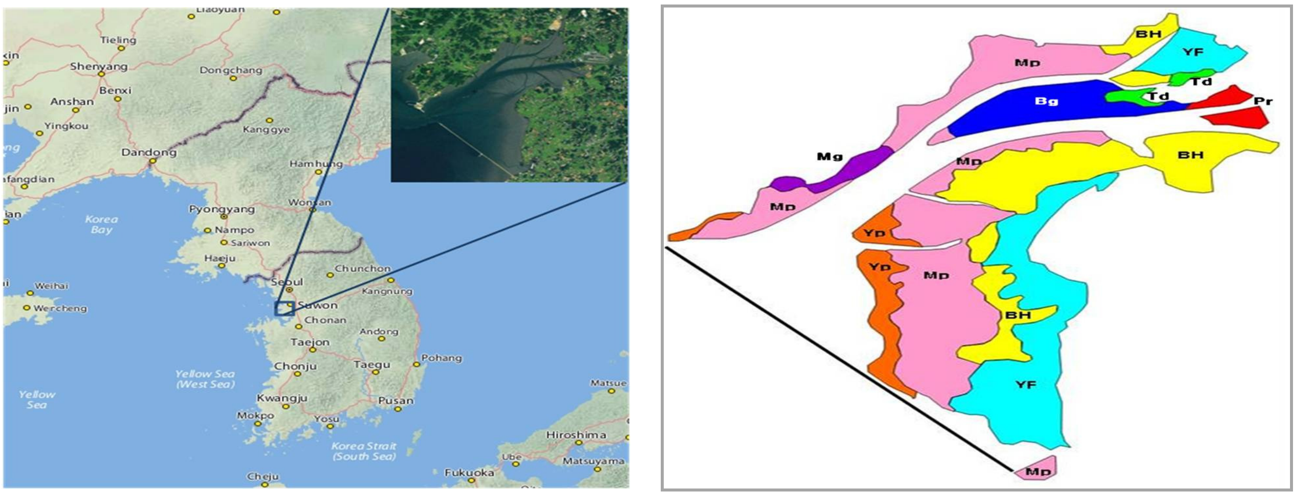

Figure 1. Location and soil series of the Hwaong reclaimed polder land.

Table 2. Classification of Hwaong reclaimed polder soils by paddy soil type.

Classification	Normal paddy field	Salt affected paddy field	Sandy paddy field	Ill-drained paddy field	sum
size(ha)	1,390	1,887	86	1,018	4,382
Soil series	Buyong, Pori, Bogcheon	Munpo, Yeompo	Mankyeong	Yeosu, Taean	

Table 3. Physical and chemical properties of soils of the Hwaong reclaimed polder land.

Soil texture	Bulk density	pH	EC	OM	Av.P_2O_5	Ex. Cations($cmol_c$/kg)			
	(Mg/m^3)	(1:5)	(dS/m)	(g/kg)	(mg/kg)	K	Ca	Mg	Na
Fi/SL	1.60	8.4	16.7	6.3	53	1.66	2.8	6.5	18.3

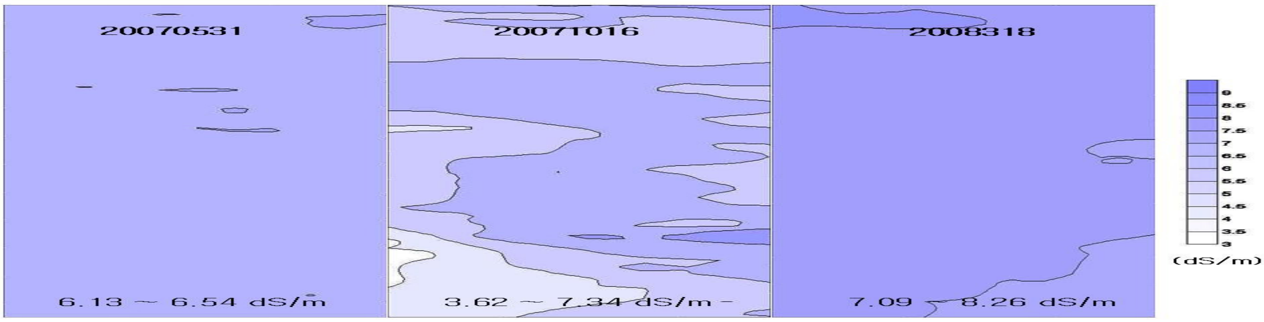

Figure 2. Soil salinity map of the Hwaong reclaimed polder soil.

Table 4. Problems and managements of the Hwaong reclaimed polder land.

Problem of Soil management	Soil series	Soil management recommendation
Salt affected soil	Munpo, Yeompo	groundwater level below 1m by subsurface drain, tube well, drainage canal
Weak foundation soil	Munpo, bogcheon, Yeosu, Yeompo,	permeability increase by gypsum, organic matter application
Sandy soil	Mankyeong, Taean, Munpo, Yeompo	Soil texture amelioration by soil dressing

Conclusion

Eight soil series were classified in the Hwaong reclaimed polder land, the largest soil series was the Munpo at 1,616 ha. Soil texture was sandy loam soil, soil bulk density was 1.60Mg/m^3. Due to the large percentage of silt in soil, early desalination was expected as rapid. Soil amelioration was thought to be difficult because of bad soil structure and high groundwater level.

References

Ja-Woong Koo (1998) Soil Properties of Reclaimed Tidal Lands and Tidelands of Western Sea Coast in Korea. *Korean Journal of Soil Science and Fertilizer* **31,** 122.

Sung Hwan Kim (2005) A Study on the Relationship between the Physio-chemical Properties of Soil and the Distribution of Vegetation on Reclaimed Daeho Tidal Flat. *The geographical Journal of Korea* **39,** 340.

Soil resource assessment of Kumaon Himalayan Mountains of India

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Abstract
A study was undertaken to identify the different physiographies and soil resources and to assess the soil organic carbon (SOC) stock in Kumaon Himalayan Mountains of India. Main physiographies are summits/ridge tops, side/reposed slopes, river valleys and piedmont plains. Soils of summits/ridge tops and side/reposed slopes are mainly shallow to medium deep, coarse textured, underdeveloped/partially developed having A-C horizons (Entisols) followed by deep, fine textured and comparatively developed soils (Inceptisols). Soils of river valleys and piedmont plains are mainly medium deep to deep, loam to clay loam with structural B horizon and belong to Inceptisols followed by Entisols. Soils of summits/ridge tops contain more SOC stock in comparison to other physiographies. The same trend was seen in higher elevations as in lower ones.

Key Words
Western Himalayas, physiographic units, remote sensing, landform, soil organic carbon.

Introduction

The main problems of mountains are their peculiar geographical conditions and the resultant physical and human constraints. Himalayas represent one of the most fragile mountain ecosystems of the world. For the past few decades, a sequence of changes has emerged in the traditional resource use due to population pressure and increasing demand for food, fodder, fuel wood, grazing areas, etc. in the region. Thus, management of natural resources, especially soils has become urgent though their study has been very difficult as most of the areas are inaccessible to humana. A New generation of remote sensing satellites has opened up possibilities for this type of study (Ahuja *et al.* 1992; Saxena *et al.* 2000). Soil organic carbon (SOC) is an important component for agro-ecosystem as it influences various soil properties (Batjes and Sombroek 1997; van Keulen 2001). Thus, the present research work has been undertaken to assessthe soil resources of Kumaon hills of India using remote sensing techniques.

Materials and Methods

The study area belongs to Almora district of Uttarakhand state, spread over 29^o 26’ to 30^o 20’ N latitudes and 79^o 3.5’ to 80^o 11’ E longitudes covering 3083 sq. km. geographical area. The area is under warm humid lesser Himalayan agro-ecoregion. The altitude ranges from 600 to 3000 m msl. Data from IRS, ID, LISS III, FCC generated from bands 2, 3, 4 on 1:50,000 scale was used for visual interpretation. Base maps were prepared by using Survey of India topographical sheets at the same scale. Landforms identified were further divided into physiograpic units based on their elemental characteristics and slope functions of landform. Soil survey was conducted using this physiographic map. Soil sampling was done in all the physiographic units by studying mini-pits and master profiles. Soil samples were collected from each diagnostic horizon of representative pedon for physiochemical analysis. Different soil series identified in different physiographic units were classified using Soil Taxonomy (Soil Survey Staff 2003).

Results and Discussion

On the basis of image data interpretations and field check different physiographic units viz. steeply, moderately steeply and moderately sloping summits/ridge tops, very steeply, steeply and moderately steeply sloping side/reposed slopes, river valleys and piedmont plains have been identified in the study area (Figure 1).

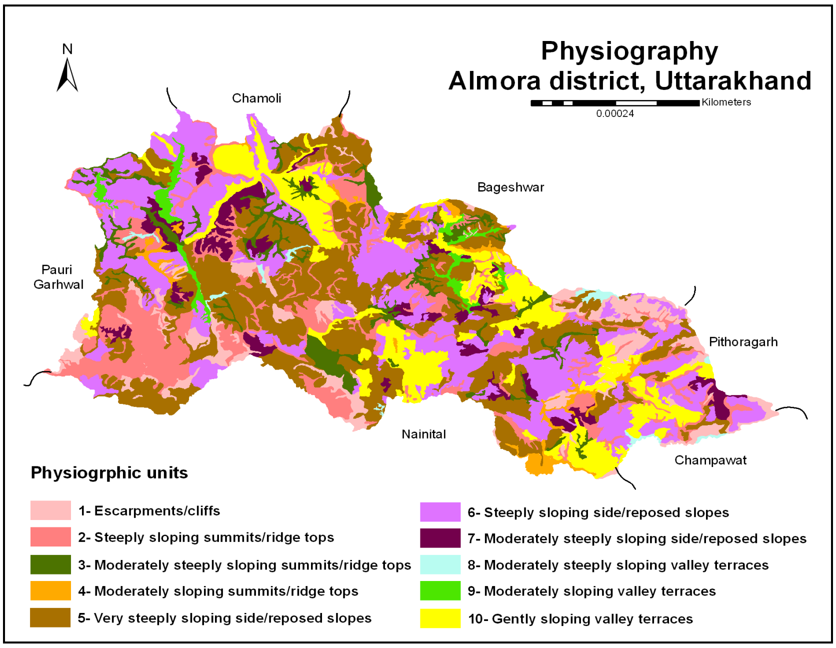

Figure 1. Physiography

After correlation of different soils observed in the area fifteen different soils have been identified. Soils of moderately steep to steeply sloping summits/ridge tops are very shallow to moderately deep(Figure 2), coarse textured, underdeveloped/partially developed having only A-C horizons and belong to Entisols (Lithic and Typic Ustorthents) whereas on moderate slopes of summits, soils are fine textured, comparatively well developed having structural B (cambic) horizons and belong to Inceptisols (Typic Dystrudepts). They are covered with forest, rock outcrops and cultivation on terraces. Main problems are low to medium available water capacity (AWC) and nutrient retention capacity, severe to very severe erosion and stoniness. Soils of side/reposed slopes are shallow to medium deep, excessively drained, sandy loam, moderately acidic and belong to mainly Entisols (Lithic and Typic Udorthents) followed by Inceptisols (Typic Dystrudepts). They are low in water holding capacity and fertility status and have low productivity potential. Other constraints are limited depth, stoniness and severe erosion.

Soils of river valleys occur on gentle, moderate and moderately steep slopes and are deep, somewhat excessively drained, sand with low AWC and nutrient retention capacity and developed on colluvium/alluvium originated from sandstone (Typic Ustipsamments) along with loam to clay loam, with medium AWC and nutrient retention capacity and developed on colluvium/alluvium of mica/quartzite (Typic Dystrudepts). They are cultivated with agricultural crops like wheat, mustard, millet and paddy.
Soils of piedmont plains occur on gentle to moderate slopes and are deep to very deep, well to somewhat excessively drained, clay loam to silty clay loam, brown with medium AWC and nutrient retention capacity (Typic Dystrudepts).

The organic carbon stock in the soils of major landforms has been assessed. The data reveals that in general, all the soils are rich in organic matter in surface layers and decreased with depth, as also obtained by earlier workers (Sehgal 1973 and Mahapatra *et al.* 2000). It has been observed that the immature soils and forest soils, developed on steep slopes, have high percentage of SOC stock though the soils are shallow in depth. Soils of summits and ridge

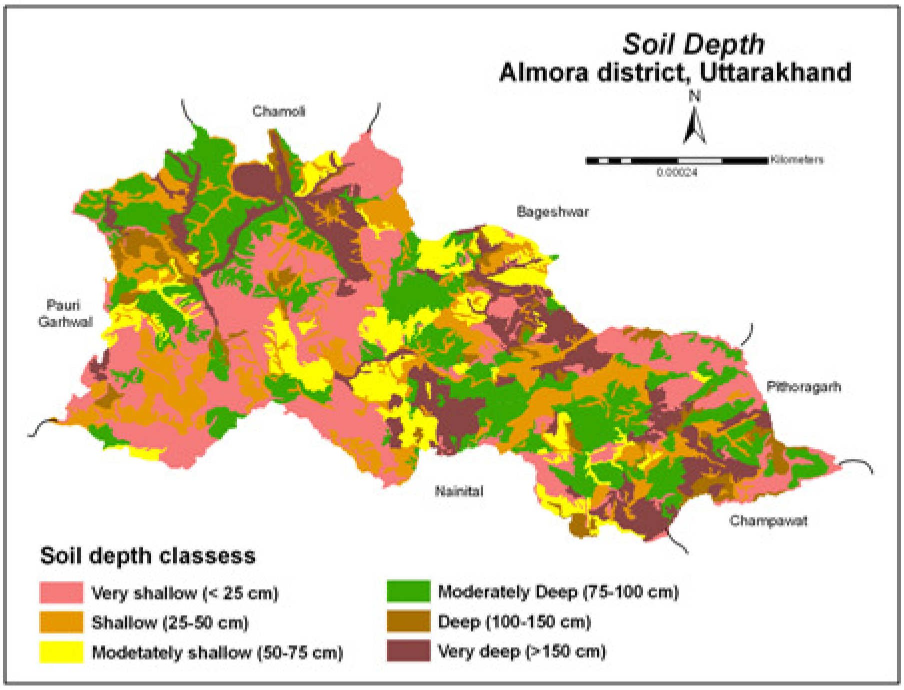

Figure 2. Soil Depth

tops are found to have more SOC stock in comparison to the soils occurring on other physiographic units. Besides, soils at higher altitudes contain more SOC than those at lower elevations. In deeper soils, although soils have less carbon in lower horizons, the total carbon stocks are sufficient. Hence, it is observed that physiographic position, land use and elevation play important roles in the status of SOC stocks, which is thus a key factor for sustainable land use planning in such a mountainous area.

References

Ahuja RL, Manchanda ML, Sangwan BS, Goyal VP, Agarwal RP (1992) Utilization of remotely sensed data for soil resource mapping and its interpretation for land use planning of Bhiwani district, Haryana. *Journal of the Indian Society of Remote Sensing*. **20**(2-3), 105-120.

Batjes NH, Sombroek WG (1997) Possibilities for carbon sequestration in tropical and subtropical soils. *Global Change Biology* **3**(2), 161-173.

Mahapatra SK, Walia CS, Sidhu GS, Rana KPC, Tarsem Lal (2000) Characterization and classification of the soils of different physiographic units in the subhumid eco-system of Kashmir region. *Journal of the Indian Society of Soil Science* **48**, 572-577.

Saxena RK, Verma KS, Chari GK, Srivastava R, Bhartawal AK (2000) RS IC data application in watershed characterization and management. *International Journal Remote Sensing* **21**(7), 3179-3208.

Sehgal JL (1973) Pedogenic calcite accumulation in acid and semiarid region of the Indo-Gangetic alluvial plains of erstwhile Punjab ((India)–Their morphology and origin. *Geoderma* **8**, 59.

Soil Survey Staff (1998) *Keys to Soil Taxonomy*, NRCS, Washington D.C., USA.

van Keulen H.(2001) Tropical soil organic matter modelling: problems and prospects. *Nutrient Cycling in Agroecosystems* **61**(1-2), 33-39.

The next steps in soil classification OR How to kill 3 birds with 1 stone: pedons, landscapes, functions

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Abstract
The next steps in soil classification are outlined starting from the present situation: Two worldwide-applicable systems exist, the US Soil Taxonomy (ST) and the World Reference Base for Soil Resources (WRB). ST has as a strong hierarchy with six categoric levels and WRB a flat hierarchy with two levels. For classification of an individual pedon, the flat hierarchy of WRB has two major advantages: All relevant characteristics of the pedon are reflected in the classification, and the technical key is thinner and easier to overlook. On the other hand, creating basic soil maps is nearly impossible in WRB except on very small scales. To make WRB suitable for mapping also at intermediate scales, Guidelines for constructing map legends were established recently and are now in a testing phase. A remodelled WRB system based on these Guidelines could be able to serve equally the needs of classification and mapping. The third task, to provide civil society's demand to predict the reaction of soils to human impacts is implicitly already fulfilled by both systems. The problem is that this information appears somewhat hidden for the non-soil science public, and we have the task to make it visible. A purely utilitarian classification system reflecting only soil functions, which is suggested by some soil scientists, would disregard soil dynamics and fail the objective to provide society with the relevant knowledge about soils behaviour. Recent discussions on developing a Universal Soil Classification are an interesting concept to overcome the lack of a single and worldwide-accepted soil classification system.

Key Words
Soil Taxonomy, World Reference Base for Soil Resources, hierarchy, flexibility, soil maps. soil dynamics.

Main text
Classification and Mapping
Two soil classification systems are applicable worldwide: The Soil Taxonomy (ST), edited by the United States Department of Agriculture (Soil Survey Staff 1999 and 2006), and the World Reference Base for Soil Resources (WRB), edited by a Working Group of the International Union of Soil Sciences (IUSS Working Group WRB 2007) and adopted by the IUSS as the officially recommended terminology to name and classify soils.

One purpose of both systems is to allocate an individual pedon within the system and give it the respective name. This procedure is (although not entirely correct) traditionally called the classification of a soil. ST has a strong hierarchy with six categoric levels. WRB has a flat hierarchy with only two categoric levels. The

In WRB, the upper level comprises 32 Reference Soil Groups (RSG). At the lower level, a soil name is constructed by adding qualifiers to the name of the RSG. All applying qualifiers have to be added, and the number of qualifiers, which a soil has, depends on the soil's properties. The qualifiers are defined in a common alphabetical list. For every RSG, the possible qualifiers are provided, and they are split up into two groups, prefix qualifiers and suffix qualifiers. The qualifiers of both groups are listed in a certain sequence, which must be followed when classifying a soil. But the position of a qualifier in the list is not related to its importance, i.e. the sequence is without any hierarchical order. The flat hierarchy of WRB has two major advantages: First, the open number of qualifiers for every pedon assures that all relevant characteristics of this pedon are reflected in its classification. Second, the definition of the qualifiers in a common list makes the technical key thinner and easier to overlook.

Besides classification of individual pedons, ST serves well for making soil maps at different scales. The strong hierarchy of ST helps to make that possible. In WRB, maps are only possible on the RSG level, which only makes sense at very small scales. For larger scales, qualifiers would have to be added, which is impeded by the fact that all qualifiers have the same rank, and up till now there is no rule, which ones have to be selected.
To make WRB suitable for mapping at intermediate scales (1 : 250 000 and smaller), the WRB Working Group developed Guidelines for constructing map legends (IUSS Working Group WRB 2010). Here, for every RSG, the qualifiers are subdivided into "main map unit qualifiers" and "optional map unit qualifiers". Whereas the

optional ones are listed alphabetically, the main ones are ranked in an order of priority. With increasing scale, the first, the first two and the first three applying main qualifiers have to be added to the RSG name. They stand before the RSG name with the first qualifier closest to the name of the RSG, i.e. from right to left. At every scale, additional qualifiers of the main list or qualifiers of the optional list may be used in brackets behind the RSG name, according to the purpose of the map.

This creates a new problem: WRB will have different sequences of qualifiers for the classification of individual soils and for mapping. The suggestion is now to use the mapping sequence also for the classification of pedons, just with the difference that in this case all applying qualifiers have to be used.

Soil Functions
The family level of ST and the qualifiers of WRB provide exhausting information about soil functions. Civil society's demand on soil science is to receive exactly that kind of information: soil functions and the threats to soil functions. The problem is that for non-soil scientists this information is somewhat hidden. Our task is to make it obvious. For WRB this may include to redefine some qualifiers in a way that they can serve better the demands of civil society.

In some discussions it had been argued that the needs of society could be better satisfied by inventing a new and more utilitarian classification system to be used in addition to the more scientific ones. The scientific classification systems then, in turn, would have the purpose to reflect the state-of-the-art of soil science and to serve as a tool to bring forward its development. This approach bares a risk: The utilitarian system would be based on the current values of certain parameters. It would regard soils and soil functions as something static and neglect their dynamics and the processes going on in them. Such a system would fail the principle needs of society: to predict the behaviour of soils. Therefore, any information provided for the decision-makers has to be based on a profound understanding of soils. And the practical advantage is, that there is less to teach and to learn, if all the purposes can be served by one system.

Universal Soil Classification
During the year 2009, a discussion became more intensive that it would be desirable to have one single worldwide-accepted soil classification system. In September 2009, a group of soil scientists, came together in Budapest, Hungary, to celebrate the 100th anniversary of the first international soil science conference and approved a resolution on that topic. None of the two existing worldwide-applicable systems is used worldwide. The reasons seem to be different for ST and WRB. ST is regarded to be complicated and has some deficits in classification of individual soils due to its strong hierarchy. WRB is less well-known outside the pure scientific community and has (or with the Guidelines for constructing Map Legends: had) severe deficits in creating soil maps due to its flat hierarchy. Bringing together the knowledge of soil science and soil survey, learning from the experiences of existing soil classifications systems (worldwide and local systems) and serving the demands of society, under the umbrella of the IUSS a worldwide-accepted system could be designed.

Conclusion

1. The two worldwide-applicable soil classifications systems, the US Soil Taxonomy and the WRB, have different architectures and consequently different points of strength and weakness: WRB stronger in classification, ST in mapping. A reform of the second categoric level of WRB, based on the recently established Guidelines for constructing small-scale map legends, may overcome the weak point of WRB.
2. A good soil classification allows deriving sufficient information on soil functions and threats to soil functions. Both, ST and WRB have the potential for that. Contrary to that approach, a purely utilitarian system, based only on soil functional parameters, would disregard the dynamics of soils and would therefore be unable to predict soil behaviour.
3. Recent discussions focus on the elaboration of a soil classification system that has a better worldwide acceptance than ST and WRB.

References

IUSS Working Group WRB (2007) World Reference for Soil Resources 2006, first update 2007. *World Soil Resources Reports* **103,** FAO, Rome. http://www.fao.org/ag/agl/agll/wrb/doc/wrb2007_corr.pdf.

IUSS Working Group WRB (2010) Guidelines for constructing small-scale map legends using the World Reference Base for Soil Resources. Addendum to the World Reference Base for Soil Resources. FAO, Rome. http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/WRB_Legend.pdf.

Soil Survey Staff (1999) Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys, 2nd edition. *Agric. Handbook* **436,** Natural Resources Conservation Service, United States Department of Agriculture, Washington, DC, USA.

Soil Survey Staff (2006) Keys to Soil Taxonomy, 10th edition. Natural Resources Conservation Service, United States Department of Agriculture, Washington, DC, USA. http://soils.usda.gov/technical/classification/tax_keys/.

The results of soil survey of rapidly changed city of soil information data in South Korea

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Abstract
By decreasing arable land rapidly and increasing urbanized and intensively developed areas, previous soil information should be changed to reflect present conditions. In order to revise old soil information to new ones, utilizing satellite image is easy and quick. This result was obtained as followed results. Yongin and Namyangju city have very abruptly changed soil information because of increasing urbanized. We examined soil of those areas. We made maps (paddy, upland, orchard and green house) of landuse in Yongin city. The results were similar to agricultural and forestry statistical yearbook k (2007). This method could be used the agricultural and forestry statistical yearbook in the future. Soil was resurveyed in Yongin municipality in Gyenggi province in 2007. The numbers of soil series were increased from 65 to 71. And the numbers of soil phases in Yongin increased from 159 to 170. The drainage classes were changed by readjustment of agricultural land and arable land that have changed to factory, house and road etc. The area of arable land (paddy, upland, orchard etc.) was much decreased compared to the super-detailed soil survey of upland in Namyangju. It had decreased by 439 ha of paddy, 317ha of upland and 717ha of orchard. The area of Jinjeob meon and Jingeon eup were mainly changed into areas of green house. The type of agricultural Anthrosols was mainly cumulated soil dressing. A new soil series was called the Jijeb soil series. The classification of Soil Taxonomy was coarse loamy, mesic family of Streptic Udorthents. Paddy has changed into urbanized area, cultivation of green house and fallowing as revealed by soil surveying in Namyangju. Moreover, the drainage classes of soil have changed to even worse conditions because of interception of flowing water owing to road construction etc.

Key Words
Yongin-city, Namyangju-city, soil survey, landuse.

Introduction
A soil map is a very important thing for managing soil resources properly. The Republic of Korea continued to soil survey from 1964 to now but because of rapidly decreasing arable land and increasing urbanized and intensifying developing areas, soil information has changed to present. The sample cities were Yongin and Namyangju which were very abruptly changed with respect to soil information because of the increasing urbanized area. We examined soils of those areas. We made maps (paddy, upland, orchard and green house) of landuse in Yongin city. In order to relate old soil information to new ones, satellite images provided an, easy and quick procedure.

Materials and methods
In order to revise and update old soil information data, especially arable land turned into urban and development areas, we should revise soil information data. The investigated areas were Yongin and Namyangju city which were abruptly changed recently. Base maps were aerial image and topographical map(1:5,000 scale). The main investigated items were landuse and area of past and present, soil information especially current paddy soil. We analyzed topography, soil drainage classes, soil texture, etc. Anthrosols were examined by methods used for soil and plant analysis (NIAST 2000)

Results and discussion
Table 1 shows the changing area of land classification according to year in Yongin city. The area of paddy had decreased but others(urbanized area, etc) had increased.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Table 1. The changing areas of land classifications according to year in Yongin city (Unit. ha).

Division	Paddy	Upland	Forest	Others	Whole
1990 (Soil interpretation map)[A]	10,484(17.3)	7,834(12.9)	37,257(61.6)	4,939(8.2)	60,514(100)
1999 (Statistical yearbook)	5,229(8.8)	8,668(14.7)	34,721(58.7)	10,521(17.8)	59,162(100)
2005(Statistical yearbook)	4,812(8.1)	8,140(13.8)	33,461(56.6)	12,732(21.5)	59,145(100)

[A]This area was classified by soil interpretation map of 1999 in Youngin city.

Table 2 shows soil types according to investigation year. The soil series increased from 65 to 71, soil types from 81 to 87, and soil phase from 159 to 170 comparing with 1997 to 2008.

Table 2. Soil types according to investigation year.

Year	Series	Types	Phases	Remarks
1977	39	56	58	Detailed soil survey. Not surveyed Mt. soils
1999	65	81	159	Highly detailed soil, survey of upland
Present('08)	71	87	170	Resurvey of paddy in 2000[A]

[A]Results of soil survey (11,000ha, Paddy soil mainly) : Ogcheon, Cheongweon, Hwasu, Baeggu, Daegu, Shinbul series(New series in Yongin citys)

Table 3 shows soil information of a resurvey in Yongin city and changing area of landuse. Change from paddy to others affected drainage classes (64.1%) and landuse (63.3). Reasons include better irrigation system construction and factory, road construction.

Table 3. Soil information of resurvey in Yongin city and changing area of landuse.

Division	Number of changing soil information polygon (Total 256)						
Soil properties	Topography	Texture	Drainage classes	Av. soil depth	Gravel	Slopeness	Landuse
Numbers	44	40	164	44	7	83	162
Ratio	17.2	15.6	64.1	17.2	2.7	32.4	63.3

※ After readjustment of arable land and construction of water facilities for irrigation, soil drainage classes are better than in the past landuse
of other soils has changed to urban, factory, road, etc.

Table 4 shows the changed soil information for soil resurvey results of paddy in Yongin city. As an example of Seogcheon series (this was paddy soil), changed to other soil series because of enlargement scaled (from 25,000 to 1:5,000) and landuse changed from paddy to urban or greenhouse.

Table 4. The changed soil information by soil resurvey results of paddy in Yongin city.

Topography	Soil series of old data (paddy)	No. Polygon	New soil series of resurvey and landuse
Alluvial plain	Seogcheon(SEP)	16	Cheongweon, Docheon, Eungog, Jungdong, Jisan, Jigog, Maegog, Noegog, Sachon, Shingheung, Yongji, /paddy, urban, upland, greenhouse
	Cheongweon(CwP)	2	Sangju, Shinhueung/upland, paddy
	Geumcheon(GMP)	8	Seogcheon, Gangseo, Hwabong, Jungdong, Sachon, Shindab/paddy, upland, urban, reservior
	Gacheon(GqP)	2	Deogcheon/urban, greenhouse
	Gangseo(GtP)	5	Seogcheon, Jungdong, Docheon, Noegog/paddy, upland, greenhouse
	Gocheon(GzP)	1	Jigog/upland
	Hoegog(HEBP, HECP)	21	Hoegog, Jigog, Maegog, Noegog, Osan, Yecheon, Samgag, Weolgog/urban, paddy, upland, barren, reservior, grassland
	Shinheung(ShP)	2	Gacheon/greenhouse
	Shindab(SnP)	9	Seogcheon, Docheon, Geumcheon, Hwabong, Hamchang, Hwasu, Noegog, Shinheung/paddy, upland, urban, greenhouse
	Subug(SpBP)	3	Hoegog, Maegog, Sacheon/paddy
	Hamchang(HhP)	6	Geumcheon, Docheon, Sangju, Seogcheon, Shinheung/paddy, urban, greenhouse
Diluvium	Hwadong(HjBP)	3	Gopyeong/orchard, greenhouse, urban
Fan	Haggog(HYBP)	1	Seogcheon/paddy
Mt. Footslope	Yeongog(YcBP)	2	Pungcheon, Sachon/urban, paddy

Conclusion

The number of soil series in Yongin city increased from 65 to 71. And the numbers of soil phases in Yongin increased from 159 to 170. The drainage classes were changed by readjustment of agricultural land and some arable land has changed to factory, house and road. The area of arable land (paddy, upland, orchard, etc.) was much decreased based on the super-detailed soil survey of upland in Namyangju. The decrease was 439ha of paddy, 317ha of upland and 717ha of orchard. The area of Jinjeob meon and Jingeon eup was mainly changed from paddy into areas of green house. The type of agricultural Anthrosols is mainly due to cumulated soil dressing. A new soil series the Jijeb soil series was established Its classification in Soil Taxonomy is coarse loamy, mesic family of Streptic Udorthents.

References

National Institute of Agricultural Science and Technology (2000) 'The method of soil and plant analysis'

Rural Development Administration (1973) 'Soil Survey Manual'. The material of soil survey No.1

Jung SJ, Sonn YK, Hyun BK, Shin DW, Song KC (2004) 'Super detailed soil survey of intensive developed areas'. Annual Res.Report of National Institute of Agricultural Science and Technology. pp.197-208.

Jung YT, Yun ES, Jung KY (1996) 'The Properties and Classification of Anthrosols'. Annual Research Report of Yeoungnam Agricultural Research Institute. pp. 692-696.

Jung YT, Yun ES, Kang UG (1998) Classification of Anthrosols in Korea and Anthrosols Classification Systems of Other Countries. RDA. *J. Agro. Envion. Sci.* **40**, 1- 6.

ICOMANTH (2004) Circular letter. No 5.

Song KC, Hyun BK, Sonn YK, Jung SJ (2006) 'Classification of Anthrosols in Korea. Annual Research'. Report of National Institute of Agricultural Science and Technology. pp. 149-166.

USDA (1951) 'Soil Survey Manual'.

The use of pedometric measurements to enhance and improve the presentation of soil information from soil maps

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Abstract
Several simple pedometric measures are used to compare the effectiveness of different map legends. These were the normalized soil properties and the pedological distance between different map units and the colour distance between different map units from published maps. The conclusions from the pedometric measurements were checked against a questionnaire of users of soil information. The measures do indicate which legends are more effective in presenting soil information but as always much depends on the requirements of the end user. The normalized soil values were also shown to be a potentially useful tool for presenting soil information in reports.

Key Words
Soil map legends, pedometric distance, soil information.

Introduction
The presentation of soil maps requires the development of map legends, the choice of soil colours for soil mapping units and the presentation of complex information and data. The presentation of soils information in soil maps and reports is often the interface between soil scientists and the clients or audience to which the soil information is directed. The success of communicating the soil information can depend on the types of legends, colour scheme and style of reports developed. There is scope to use the measurement and methodologies developed within pedometrics to provide some objectives measures of the efficiency and effectiveness of the legends, colour schemes and data and information presentation styles used in soil mapping. There is also scope to apply pedometrics to the traditional soil mapping methodologies. This paper explores briefly some of these possibilities.

Some pedometric measures of different legend and colour schemes for soil maps
The Nyngan and Forbes 1:250 000 Soil Landscape Maps from Central West New South Wales are depicted using two legend - colour schemes. Both these systems have been used to present soil map information to the community. These are:

a. The soil mapping units are coloured according to their recent and current landforming processes or conditions (eg residual, erosional, transferral, colluvial, alluvial, stagnant alluvial, estuarine). This is essentially a one dimensional system in which the geomorphological processes influencing the soil parent material are considered. These range from in-situ, through colluvial to alluvial and then any special geomophological proceses such as aeolian, estuarine or swamp processes are included. This was termed the Processes System
b. The major soil types based on parent material (geological structure, granites, basalts, riverine – alluvium, metasediments etc). This is a two dimensional system in which the geomorphological processes above are considered, but also the nature of the parent material is also taken into account. Essentially the key factor considered for the nature of the parent material is the silicon and ferromagnesium mineral content (basic – siliceous spectrum). This is not explicitly identified, but is inherently taken into account in the use of the geological structure and geological formations associated with the soil map units. This was termed the GeoGroup System.

The following steps were then taken.

1. The mathematical distance between the colours depicting the soil map units on the map sheet were then calculated using the Colosol Program (Viscarra Rossel 2006).
2. The similarity distance between the map units based on the pedological distance as calculated using the methodology outlined in (Carre and Jacobson 2008). This calculates the distance based on the normalised soil properties of the soils in the map units.
3. These were then plotted on a graph using the values for the above parameters. For convenience this was termed the map colour space (MCS).
4. An independent evaluation was undertaken of the usability and value of the two maps was made by soils and

land management advisory officers of the two sets of coloured maps.
The results for this study were reported in Murphy *et al.* (2009)

Conclusion
The use of pedometric measures has enabled some objective assessments of the types of legends and colour schemes soil mapping. This is a very important aspect of presenting soil information as this is often the entry point for many users of soil information. The form of the legend and the colours of the mapping units on soil maps have a large influence on the potential utility and the capacity of targeted users to gain useful information. An important conclusion may be that a series of soil maps should be made available in PDF format to cater for different levels of experience, knowledge and very importantly the problem of those who are colour blind.

Presenting summaries of soil data
One option to enhance the presentation of data is to use normalized soil values across arrange of soil landscapes. This enables soil data from a range of soil properties to be presented on the one graph. As can be seen in Figure 1, whether soil landscapes have high or low values for particular soil properties becomes immediately obvious. This is often lost in the more complex presentation of large quantities of soil data that accompanies the presentation of soil data in general reports. For example, in this case the low pH values of the surface soils of the sand dunes (KKdun), the high lime content and pH of the gilgai unit (BBgpu) and the high sodicity of the of the Bulbodney flow line unit (BBflo) are clearly evident. Such analyses and graphic can be used at the broader scale.

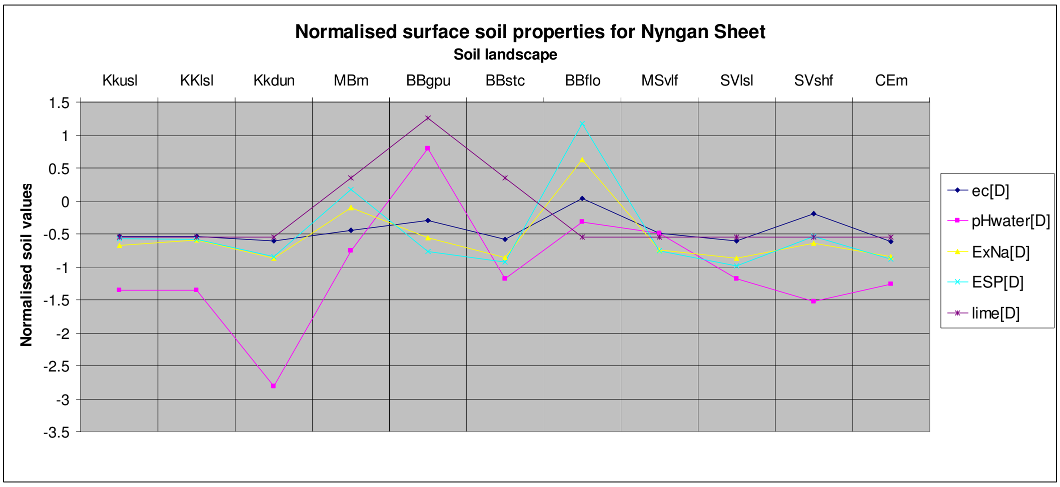

Figure 1. Normalised values for some soil properties in the Nyngan Soil Landscape Map.

Conclusion
The use of pedometric methods and measures can be used to enhance the presentation of soil information in maps and reports. Critically it can be used to make objective measurements of the effectiveness of different legends and mapping systems. It can also be used to develop improved and better methods for presenting complex soil data to make it more easily interpreted by users of soil information. However, there is a danger that pedometric methods can also make presentation of data more complex and difficult to understand.

References

Carre F, Jacobson M (2008) Numerical classification of soil profile data using distance metrics. *Geoderma* **148**, 336 -45.

Duncan D, Murphy BW, Welch A, Wooldridge A, Grant S (2008) 'Soil Landscapes of the Nyngan 1:250 000 Sheet'. (NSW Department of Environment and Climate Change, Central West Catchment Management Authority and Sustainable Soil Management: Australia).

King D (1998) 'Soil Landscapes of the Forbes 1:250 000 Sheet'. (NSW Department of land and Water Conservation: Australia).

Murphy BW, Koen T, Grant S (2009) 'A quantitative evaluation of the the effectivnesss of colours to convey information in the the presentation of maps'. In 'Pedometrics 2009 Conference. Beijing, China'.

Viscarra RA, Minasny B, Roudier P, Mcbratney AB (2006) Colour space models for soil science. *Geoderma* **133**, 320 – 337.

Time for a Universal Soil Classification System

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For thogh we slepe or wake, or rome, or ryde, Ay fleeth the tyme; it nil no man abyde.
[*c* 1390 Chaucer *Clerk's Tale* l. 118]
(Time and tide wait for no man)

Abstract
Soil science, unlike many other scientific disciplines, does not have a universally accepted classification system. Many countries have developed systems to classify their soils, but the results often do not translate well between taxonomic systems. Attempts have been made through efforts such as the *FAO Legend for the Soil Map of the World*, the *World Reference Base for Soil Resources*, and *Soil Taxonomy* to address the need for a globally accepted soil classification system. But so far, this goal has not been achieved. We believe the time is right to form a working group under the auspices of the International Union of Soil Sciences to explore the development of a universal soil classification system.

Background
Most natural sciences struggle for a common classification system such as botany, anthropology and astronomy. Natural classification systems should be accepted and used globally. Soil science and soil classification are viewed as National Systems yet none have received full international acceptance. Common reasons given for universal systems are pleas from a discipline to work together towards a common understanding and to provide a common language for communication.

Currently when we look at soil classification around the world we have what might be called an ‘adobe tower of Babel’ (see the variety of systems in Krasilnikov *et al*. 2009). The international politics that hampered global collaboration in soil science in the last Century has slowly mellowed towards a movement for more harmony and to develop an internationally acceptable nomenclature and methodology. This process was not merely to standardize terminology but required evaluation and changes in the whole process including methods of soil analysis and choice of criteria. The time is ripe for acceptance of standard soil terminology, concepts and rationale in elaborating the system and for linkages with current systems.

A group of international soil scientists while attending “Bridging the Centuries Conference in Gödöllő, Hungary, in 2009 agreed that we should submit the following declaration to the International Union of Soil Sciences:

The “Bridging the Centuries 1909–2009” events were organized to celebrate the 100th anniversary of the 1st International Conference of Agrogeology and to overview the last 100 years of advances in soil sciences:

The purpose of the 1st conference was to discuss the different approaches to field and laboratory methods, soil descriptions soil classification and soil mapping. An important objective was to gain a common understanding of methods and language, and to develop common soil classification and mapping schemes.

Although much has been achieved in the subsequent 100 years, the participants of the 2009 Centenary Conference concluded that soil science community is still lacking commonly accepted and used field and laboratory standards in soil characterization and classification, making communication and data exchange difficult within soil science and other disciplines.

Therefore the participants of the "Bridging the Centuries: 1909–2009" conference, declared that there is a need to develop a "Universal Soil Classification" (USC) system for the effective transfer of soil information.

It was recommended that a proposal for the development of such a system be addressed to the International Union of Soil Sciences (IUSS) Council at the 2010 World Soil Congress in Brisbane, Australia. The system would be developed under the scientific auspices of the IUSS in the form of a working group which would effectively be composed of representatives from countries from all continents, and representatives from key international and national agencies.

It was further recommend that the USC should be based on the experiences of existing broadly used national classification systems and to build on the experiences of the World Reference Base for Soil Resources (WRB), the correlation system of IUSS, as well as on accumulated soil information and state-of-the-art observation and data processing tools.

History

Many countries developed a national soil classification system, among others, Argentina, Australia, Brazil, Canada, China, France, Germany, Russia, Scotland, South Africa, and the United States and many of them have a long history.

A first international approach was the FAO Legend for the Soil Map of the World. This map had three levels, which was very apt for the scale of the map (1:5,000,000). Some countries have used the same legend for national mapping and encountered many difficulties. The scale of the potential use has to be reflected together with the detail of the categoric level that is selected. For classification purposes, the FAO Legend is meanwhile replaced by the World Reference Base for Soil Resources (WRB) that is maintained by a Working Group of the IUSS. WRB is a flexible system with a flat hierarchy and two categoric levels, the first level using a key, the second level using independent combinations of characteristics. The original purpose was to serve as a tool for correlation of national systems and help international communication. Some countries however adopted it also for mapping purposes. Lacking a common guideline however, the results were not satisfactory. In 2009, mapping guidelines have been established which allow using WRB for constructing small-scale map legends (1:250,000 and smaller) if the relevant soil data are available.

The Example of the United States

Standards are very important to have in all systems. There is need for a common and consistent way of describing, collecting and measuring soils. We should build upon existing systems. Moving away from an accepted system presents problems including psychological ones. The viable process that will enable change is to build upon existing systems and not to make dramatic changes that alarms users. For example, in the US we minimized the disruption to the Soil Survey Program when we replaced the 1938 system of soil classification with *Soil Taxonomy* by, in so far as was possible, accommodating the soil series that were established at that time as the lowest level of the new classification system.

One of the reasons for the success and acceptance of *Soil Taxonomy* was that there was ownership and an institutional guardian, the USDA Soil Conservation Service, and users were invited to contribute to developing the system. There are examples of individuals in countries who have tried to propose systems of their own; apart from being academic contributions, these quickly faded away in pedological history. A second important reason becomes evident and that is "for making and interpreting soil surveys". Just making an inventory of the soils with lines is not enough. By strongly linking the inventory with data to a system of making interpretations is the real strength of soil surveys. In the US soil interpretations became the important tool of soil survey and soil classification was only the vehicle. In countries where soil classification was a theoretical academic exercise, the system fell into disuse very quickly. A third reason that *Soil Taxonom*y is successful is that because it uses the properties of the soil itself for defining taxa, and not theories of the soil's genesis, any competent soil scientist, whether a junior or senior member of the soil survey program, can classify the soil accurately and consistently. These are important considerations when considering a global system.

Soil Taxonomy was developed to accommodate all soils, not just those known in the United States. There have been eleven International Committees formed over the years to improve *Soil Taxonomy*. Six committees were devoted to improving the system at the Order level (Andisols Aridisols Gelisols Oxisols, Spodosols, and

Vertisols.). Five other international committees were established to improve *Soil Taxonomy* with regard to specific characteristics including low activity clays, the aquic moisture regime, family-level classes, moisture and temperature regimes, and anthropogenic soils. The intent of these committees has been to continue to strive to achieve the eighth stated attribute of the system which is "*to provide for all known soils, wherever they may be*."

Towards a Universal Soil Classification System

We should consider adopting the most modern systems that have been inherited with a conceptual diagnostic approach, with established terminology, and existing structural elements.

We need to look for a starting point for a USC that is the most documented existing system. It should have the highest amount and most accurate data collected to support the science. We should share existing documents and documentation that represents the starting point for standards that will support our USC System. We also need an accepted approach by the IUSS in developing the new system, one that is fair and based on the best science of today one that is decided by a group of experts and political leaders and one that is accepted internationally.

We should however be cognizant of new developments. We see no reason why the numerical concepts that have been developed over the last 30 years cannot be investigated and if found fit for purpose, incorporated into the new system. These include the concepts of pedotaxonomic distance, numerical polythetic allocation and where appropriate, continuous classes. Existing taxa could be used as the starting point for such approaches.

Of crucial importance for the success of any global soil classification system is that there must be a solid and long-term support from an institution or group of institutions assuring the necessary resources for the development, maintenance and implementation of the USC worldwide. One of the main reasons for the failure of previous attempts was the lack of such an operational support. Any future global system will have to have behind its establishment one, or a group of, solid and committed institutions willing to mobilize the needed resources (staff and financial means) to maintain such a system on a long term.

The USC system must be dynamic and innovative. It must be continuously used and continuously tested and numerical approaches facilitate this. The classification should not be viewed as being just a name. The relevance and implications of the name and the kinds of accessory information incorporated in the name makes the system more powerful.

The detail in information required would depend on the kind of use and the scale of observations. During the processes of developing the system, an agreement on the number of categories is necessary. The system may use a Key that enables the selection of taxa, and the classification may consist of categories where the user can navigate with the aid of the Key. Standards for Terminology and Definitions (common data dictionary) are needed. Components of any system and users must adhere to the agreed terms and definitions to use the system accurately and reproducibly. This includes common methods of characterization of soil analysis and common methods for soil descriptions. Scale of mapping, 1:12,000 to 1:250,000 must be agreed upon also the way we make observations e.g., field morphology versus micromorphology.

Soil Scientists from around the world have expressed the desire and need to develop a common USC System. But, even more important, we need a global soil classification system that will be adopted by the major National soil survey and mapping agencies currently actively engaged in operational soil survey activities. The future USC should not be solely an academic exercise, but should be developed together with the major agencies supporting soil survey and mapping in the world.

Finally, an important consideration is the practicality of the process. A core group will be responsible for binding decisions into the USC System but they must be supported by a number of specialized groups that provide inputs for the different components. An advantage of the proposed effort is that many classification systems exist, each have been tested and enhanced and deficiencies are known by the authors or users. Inputs by these experts can merge the different systems into a universally acceptable system.

A focus on use and management from the system should be the ultimate goal. Linkages to existing national soil survey programs are very important. It is important for us to achieve "Buy In" into a system that is active and established such as the US “National Cooperative Soil Survey” or the Mexican “Instituto Nacional de Estadística y Geografía”, which are by far the most developed and extended operational soil survey programs in the world.

With the experience and enthusiasm that exists today, a USC System is feasible and will have international acceptance. The generation that developed the current systems is leaving the scene through retirement. Today the opportunity arises for the current generation to collaborate and realize the dream of one Universal Soil Classification System.

Thank you for your attention.

Reference

Krasilnikov P, Ibanez Marti J-J, Arnold R, Shoba S (2009). A Handbook of Soil Terminology, Correlation and Classification, Earthscan, London. 440pp.