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Ad hoc Working Group Soil in Germany

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Abstract
To coordinate soil information in Germany, a network of soil specialists of the respective authorities of the 16 federal state agencies and the Federal Institute for Geosciences and Natural Resources (BGR) was formed. This network, the "Ad-hoc-AG Boden" mainly synchronizes methods of soil description and other relevant data structures and data collections among the 16 federal states; resulting in proper soil information (e.g. data sets, soil maps) across Germany.

Key Words
Soil information system, Germany, soil map, mapping guide, network.

Introduction
The Ad hoc Working Group Soil of Germany, commonly known as "Ad-hoc-AG Boden" is a scientific and communication network of the heads of the soil surveys of the 16 federal states in Germany and the Federal Institute for Geosciences and Natural Resources (BGR). It coordinates soil related tasks of the respective federal state agencies, which generally are responsible for soil mapping and their federal state soil information systems. One of the members of this working group from the beginning was the later president of the German Soil Science Society Prof. Dr. Eduard Mückenhausen.

A report on the status of soil information in Germany in the European context has been published in 2005 (ECKELMANN 2005). Updates are given on the occasion of the annual meetings of the German Soil Science Society. The most recent report (ECKELMANN *et al.* 2009) was at the same time the first joint presentation of the Ad hoc Working Group Soil of Germany, given at the annual meeting 2009 at Bonn..

The formal establishment of the "Ad-hoc-AG Boden" by the Conference of the German Ministries of Economics is reported as from 1984, but earlier papers document similar activities and responsibilities from 1946 on. Though the formal name of the group has been changed several times, mainly for political reasons, the continuous work of this group is documented for the timespan before 1984.

Activities
Soil mapping guides
From the beginning, the "Ad-hoc-AG Boden" was aiming at using a common soil mapping guide by all 16 federal states agencies. After a long period of drafting and field testing, the first version of a German soil mapping guide was issued in 1965 (AG Boden 1965). Taking close contacts to scientists of the German soil science society; this first version was updated several times, resulting at least in the 5th version (KA 5; Ad-hoc-AG Boden 2005). This version is the first German soil mapping guide, offering links to the World Reference Base for Soil Resources (WRB, IUSS 2007).

To meet the needs of local soil protection authorities, it was decided to reduce and condense the contents of the 2005 soil mapping guide to a short version, which is using the same standards in all formal aspects, tables and coding, as they have been described in the traditional version (Ad-hoc-AG Boden 2009). This assures a common basis and comparable results for the user.

With respect to international soil description and to facilitate access to the World Reference Base for Soil Resources for German speaking scientists and staff, the BGR coordinated the preparation of a German version of the WRB. It is available as download from www.bgr.bund.de/boden (IUSS 2007).

Soil map at scale 1:200,000

Starting with the reunification of the western and eastern parts of Germany in 1990 the now larger “Ad-hoc-AG Boden” developed a mutual basis for a common German soil map at scale 1:200,000. This map became the first German soil map under the new standards. It is available at BGR and the cooperating 16 federal state agencies as well. The common standards ensure comparable outputs at federal and national levels (HARTWICH *et al.* 2007).

One of the most important steps in preparing a mapping manual for the 1:200,000 scales was the definition of a soil regions concept, which was later enlarged to the area of the European Union in close cooperation with the members of the European Soil Bureau Network (ESBN; HARTWICH *et al.* 2006). This regional concept has turned out to be one of the most crucial prerequisites for the compilation of a harmonized soil map system for the different regional authorities.

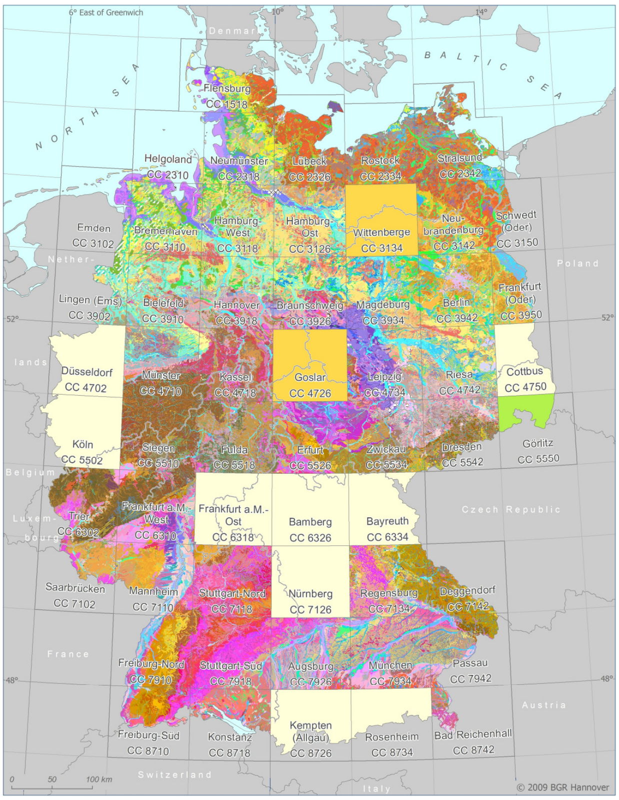

Figure 1. The spatial distribution of printed sheets of the German soil map at scale 1:200,000. granulometry (MÜLLER *et al.* 2009).

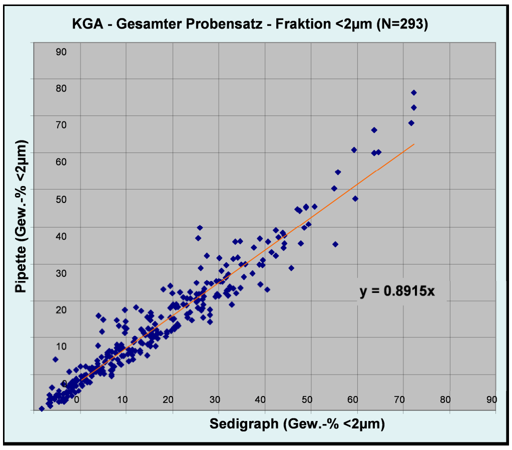

Figure 2. Comparing two different methods for particle-size analysis, KÖHN pipette and X-raywww.bgr.bund.de/boden.

By the end of 2009, 42 of the 54 map sheets needed to cover Germany have been printed (Figure 1), the last map shall be printed in 2014. For each soil map unit, comprehensive soil property information from representative soil profiles as well as the respective land use had to be documented. To enable easy scientific and administrative use of all data across political regions, it was decided to put the relevant data into a single data base covering all 16 federal state agencies. This procedure seems to be singular for such a political structure.

Laboratory work and quality standards, applications

Aiming at high standard and reliable soil information at federal state and national levels, the “Ad-hoc-AG Boden” initializes and coordinates comparisons of analytical methods of field or laboratory scale. Recent studies e.g. were comparing extraction methods for heavy metals (e.g. aqua regia; UTERMANN *et al.* 2005) or particle-size analysis. The comparison of two methods for particle-size analysis in soils has stated a better suitability of the KÖHN pipette method in this respect (MÜLLER *et al.* 2009; Figure 2).
A later consecutive round robin test including all the coordinating federal state laboratories has confirmed that the “Ad-hoc-AG Boden” can rely on a high data quality within this frame of the federal state agencies and their contributions to the common databases.

The “Ad-hoc-AG Boden” has published a comprehensive collection of methods, parameter lists and flow sheet diagrams offering the consistent use of soil data for scientific, administrative and political applications (www.bgr.bund.de/boden). As a member of the “Ad-hoc-AG Boden” and the European Soil Bureau Network (ESBN) as well, BGR is in the position to support activities at the European scale (ECKELMANN *et al.* 2006). Extensive information is available at:
http://www.bgr.bund.de/cln_101/nn_334066/DE/Themen/Boden/Zusammenarbeit/Adhocag/adhocag__node.html?__nnn=true

Conclusions

The “Ad-hoc-AG Boden” is the German network for the coordination of soil information for scientific, administrative and political needs. This close cooperation between the 16 federal state agencies and the Federal Institute for Geosciences and Natural Resources (BGR) – also in its role as a member of the European Soil Bureau - as well as further scientific partners exhibits the crucial position of such networks for high quality standards for soil information and long term data availability on the national and supranational level.

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Are global soil information systems adequate in forecasting impacts of global change?

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Abstract
For large areas in the world, Africa, Latin America and Asia, global soil information systems like the Harmonized World Soil Database do not present adequate information to forecast impacts of global change. Analytical methods used in determining soil attributes are not standardized. Also, soil characteristics that are subject to vary under global change, like organic carbon, are based on observations over a range of time while current figures are missing. New data collection campaigns combined with digital soil mapping techniques might improve the information systems. A capacity building effort is needed to ascertain the use of these techniques.

Key Words
Global Soil Information Systems, global change, Harmonized World Soil Database, e-SOTER, GlobalSoilMap.net.

Global soil information systems

Soil Map of the World and SOTER

During the past decades the only available global soil geography database was the FAO-Unesco Soil Map of the World - SMW (1971-1981) at scale 1:5 million which is based on survey data collected in the nineteen sixties. FAO recognized that a rapid update of the Soil Map of the World would be a feasible option if the original map scale of 1:5 M was retained, and started, together with the United Nations Environment Programme (UNEP) and ISRIC, to fund national updates at 1:5 M scale of soil maps in Latin America following the standardized SOTER approach (FAO *et al.* 1998b). During the following years central, north eastern and southern Africa, Eastern Europe and Northern and Central Eurasia were covered, partly at scales 1:1 million (FAO and IIASA 1999; FAO and ISRIC 2000, 2003; FAO *et al.* 1998a; FAO *et al.* 2007).

Basic to the SOTER approach is the mapping of tracts of land (SOTER units) with a distinctive, often repetitive, pattern of landform, soil parent material, surface form, slope and soil (van Engelen and Wen 1995). Each SOTER unit represents a unique combination of terrain and soil characteristics; Figure 1 shows how the terrain and soils are represented by a SOTER unit in the database.

Soil analytical data held in comprehensive SOTER database have been analysed according to a range of methods and in various laboratories, and these are documented in the various data sets. Generally, however, there are many gaps in the measured soil analytical data stored in primary SOTER databases — typically, not all the attributes that can be handled in SOTER have been collected during the ground surveys that provided the legacy profile data. Such gaps in the attribute data will often preclude the direct use of primary SOTER databases for modelling; gaps are typically filled using consistent taxo-transfer procedures (Batjes *et al.* 2007)

An update of the SOTER methodology started in 2008 within e-SOTER, an EU Seventh Framework Program financed research project with 14 partners from Europe, Morocco and China (e-SOTER 2008). The project addresses four major barriers to a comprehensive soil observing system:

- Morphometric descriptions - enabling quantitative mapping of landforms (Dobos *et al.* 2005) as opposed to crude slope categories as well as newly developed DEM analysis using natural breaks;
- Soil parent material characterization and pattern recognition by remote sensing and using legacy data will enable a separation of soil processes within the landscape and will generate a parent material classification relevant for soil development;
- Soil pattern recognition by remote sensing will generate additional predictors of soil properties;
- Standardization of methods and measures of soil attributes to convert legacy data already held in the European Geographical Soil Database and various national databases to a common standard - so that they may be applied, e.g. in predictive and descriptive models of soil behaviour.

Harmonized World Soil Database
Recognizing the urgent need for improved soil information worldwide and its immediate requirement for the Global Agro-ecological Assessment study, the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA) took the initiative of combining the recently collected regional and national updates of soil information with the information already contained within the Digital Soil Map of the World (FAO-Unesco 1995, 2003), into a new comprehensive Harmonized World Soil Database (HWSD, see FAO *et al.* 2009).

HWSD incorporates:

- The European Soil Database extended with information of the Northern Circumpolar soil map at 1:1 million scale
- The new Soil Map of China at scale 1:1 million produced by the Chinese Academy of Sciences.
- SOTER-derived databases for Eastern, Central and Southern Africa, South America and the Caribbean and parts of Asia
- For the areas not covered by the above mainly West Africa, North America, South Asia, and Australia, the "old" Soil Map of the World is still used.

GlobalSoilMap.net
A global consortium of scientific institutes and universities initiated in 2006 a program to use the latest satellite technology and global information layers, such as the Shuttle Radar Topography Mission 3 arc seconds (about 90 m) digital elevation model, to compile a new digital soil map of the world using state-of-the-art and emerging technologies for soil mapping and predicting soil properties at fine resolution (GlobalSoilMap.net 2009). Field sampling in the test areas stratified and is used to determine the spatial distribution of soil properties in order to develop reflectance spectral libraries for characterization of soil properties (Shepherd and Walsh 2002). The acquired soil properties are then used to predict soil properties in areas not sampled, making use of information reflecting state factors of soil formation; see for example (Hartemink *et al.* 2008; Lagacherie *et al.* 2006; McBratney *et al.* 2003) The GlobalSoilMap.net approach consists of several steps of which the first three concern the compilation of a digital soil map.

Data input is the first step and consists of the production of base maps of co-variates reflecting state factors of soil formation like topography, climatic information, land cover and geological variables relating to soil parent materials. Existing geo-referenced soil data, also known as soil legacy data, are also used (Carré *et al.* 2007). The second step involves the estimation of soil properties that are estimated using soil probability functions that express the probabilities of occurrence of a certain predictor value. Finally, during the third step, spatially inferred soil properties are used to predict more difficult to measure soil functions such as available soil water storage, carbon density and phosphorus fixation. This is achieved using pedo-transfer functions. An innovative element of the approach is that the overall uncertainty of the prediction will be determined by combining uncertainties of the input data, spatial inference model, and soil functions used.

The digital soil mapping theories that underlie GlobalSoilMap.net are now being tested in various pilots in Africa and Australia of which the latter is probably the most advanced. The test results will progressively lead towards consensus. Nevertheless, as with any new methodology, a number of scientific and operational challenges still need to be resolved; these have been discussed in detail by various authors (see Hartemink *et al.* 2008; Lagacherie *et al.* 2006).

The role of Global Soil Information Systems in the forecasting of impacts of global change
Ideally GSIS should be able to forecast the effects of soils in a changing climate and the vice versa. Forecasts on the changes in soil properties and behaviour related to climate change are mainly focussed on the soil carbon cycle: how will the temperature rise affect the soil carbon content and how can the rising atmospheric CO_2 be mitigated by increased storage in the soil? Growing emissions of greenhouse gasses (CO_2 and methane) from melting permafrost soils are other impacts. Change in rainfall intensities in combination with desertification processes will have an impact on soil erosion. Changes in land use and management due to climate change will also have an impact on the underlying soils.

It is clear that information on the soil, in particular the current status, is needed if the soil science community wants to address these global issues. However, GSIS in their current form do not comprise this information on soil attributes that will vary under changing conditions. GSIS data were collected over a range of years and reflect passed situations. It is therefore imperative that new GSIS contain up-to-date values of attributes that have a direct relation with changing climatic conditions. New hyper-spectral sensors will allow to map some of the essential soil attributes in real-time. Regionally, such efforts are underway and it is expected that projects as GlobalSoilMap.net will make use of it in the near future.

What are the hindrances to development of improved soil geographic databases globally?
Large tracts of land in Africa, Latin America and Asia lack sufficient soil data critical in forecasting agricultural impacts, particularly food shortages. Various constraints limit easy solutions. Data collection campaigns and laboratories are costly although new analytical methods (diffuse reflectance spectroscopy) will lower the costs of analysis. Survey staff in many countries has been reduced to the minimum or is non-existent. New digital soil mapping techniques can compensate for some of the lack of survey data but not completely, but without capacity building these technologies will only flourish in countries with high-tech environments.

Conclusions
Current GSIS have a low predictive value many parts of the world, in particular Africa, South America and Asia. Available information is based on data collected in the past and doesn't necessarily reflect the status of some of the soil attributes that might be affected by climate change, like organic carbon and nitrogen. New data collection campaigns, in combination with new analytical techniques could contribute to fill the gaps in soil geographic databases.

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Balanced micronutrient management for wheat using GIS techniques

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Abstract
The present paper includes the works done in Golestan province during the year 2005 - 2009 on a research project entitled "Establishing digital spatial pattern map of micronutrients in soils under rain-fed wheat in Golestan Province". The studied areas were under rain-fed wheat cultivation and the total surface area was about 300,000 hectares. Using base maps with a scale of 1:50,000, the area was divided into 3000 grid cells, each of them having one kilometer square area. Using a Global Positioning System (GPS) instrument a composite soil sample was taken from the center of grids and was analyzed for micronutrients namely; Iron, Zinc, Copper, Manganese and Chlorine. After obtaining the laboratory results, for the above stated data set, an electronic layer was created and after performing the interpolation, the layers were vectorized into polygons. Anisotropy of the data sets in different directions was evaluated by the help of variogram surface operation. Then spatial correlation of each data set was calculated. Doing variogram analysis, spatial variation of the data sets was studied and a suitable model was selected finally through point interpolation by the statistical, kriging technique, the digital map of each micronutrient was established.

Key Words
Kriging, spatial correlation, micronutrients, variogram analysis.

Introduction
A GIS (Geographic Information System) is a computer-based technology which manipulates spatial data from various sources. GIS is currently being used in many countries in Asia, to help farmers manage their soil resources more efficiently. The GIS computer system is capable of gathering, storing, and analyzing geographically-referenced information (i.e. information for which the location has been identified). GIS combines different kinds of data, in a way that was never possible before. Information is presented briefly and clearly in the form of a map or diagram making it very easy for people to understand a lot of complicated data. Driven by a large population with growing food demands and very limited available land resources for agricultural use, the critical question was: could current soil fertility management practices used in the intensification of plant production adequately meet those demands in a sustainable way? The fertility maps are useful tools to quantifying land resources. These maps are essential for correct fertilizer recommendations, monitoring changes of soil fertility also to predict toxicity or deficiency of plant nutritent elements in soil.

Material and methods
Based on consultations with the expert specialists working in the different counties of the province, the area under various land uses were determined using 1:50000 geographical map of the province. Areas under rain-fed wheat cultivation were about 300,000 hectares. Using the Ilwis software, and a base map with scale of 1: 50,000, the area was divided into 3000 grid cells with the size of 1x1 km. Using Global Positioning System (GPS) a composite soil sample was collected from any particular cell and being analyzed for parameters namely; Fe, Zn, Mn, Cl and Cu. At the time of sampling some additional information like latitude, longitude, elevation, owner's name, date of sampling, kind of water resources, possibility of water logging, present and previous crop, among other variables were collected and recorded. Samples were analyzed in the laboratory of the Department of Soil and Water Research in Golestan province. Electronic layers were created and after interpolation the layers were polygonized. After doing geostatistical analysis on the results for particular in micronutrients, using ArcGIS 9.0 software a distribution map has been drawn. Then the anisotropy of the data sets was evaluated by variogram surface operation and then the spatial correlation of each data set was calculated. Doing variogram analysis, spatial variation of the data sets was studied and a suitable model was selected. Finally through point interpolation by the statistical, kriging technique, the digital map of each micronutrient established and statistical parameters; mean, maximum and minimum recorded concentrations and their standard deviations were calculated.

Results

Some statistical parameters namely; mean, maximum and minimum recorded concentration and standard deviation which are derived for each micronutrient data are presented in Table 1.

Table 1. Some statistical results for micronutrients in soil extractss in Golestan Province.

Element	Number of points	Mean	Maximum concentration	Minimum concentration	Standard Deviation
Zn (meq/L)	2870	0.77	10	0.2	0.65
Fe (meq/L)	2870	12.3	40	0.4	15.77
Mn (meq/L)	2870	3.53	92	0.2	3.52
Cu (meq/L)	2870	2.39	31	0.3	1.55
Cl (meq/L)	2870	8.1	310	0.4	2.5

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Delimitation of naturally handicapped areas due to their pedological features in Hungary according to common European biophysical criteria

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Abstract
EU's Common Agricultural Policy encourages maintaining agricultural production in less favored areas (LFA) to secure both stable production and income to farmers and to protect the environment. Recently the delimitation of LFAs is suggested to be carried out using common biophysical diagnostic criteria on low soil productivity and poor climate conditions all over Europe. The criterion system was elaborated by European Commission's Joint Research Center (JRC) and its operational implementation comes under member state competence. This process requires the existence of an adequate national spatial soil information system with appropriate data structure and spatial resolution as well as a proper methodology for its analysis. Hungary possesses a suitable, nationwide, 1:25,000 scale legacy data set originating from the national soil mapping project, which was digitally processed and developed into the Digital Kreybig Soil Information System (DKSIS). In our paper we present how DKSIS was applied for the identification and delineation of areas in Hungary concerned by the common biophysical criteria related to soil. Soil data linked to soil profiles and SMUs were semantically inferred and jointly analyzed spatially for the compilation of nationwide digital maps displaying spatial distribution of specific limiting factors.

Key Words
Natural handicap, biophysical criteria, inference, spatial soil information system, Less Favored Area.

Introduction
One of the main objectives of the EU's Common Agricultural Policy is to support maintaining agricultural production in less favored areas (LFA) in order to sustain agricultural production and use natural resources, in such a way to secure both stable production and income to farmers and to protect the environment. LFA assignment has both ecological and severe economical aspects. Since its introduction in 1975, the objectives of the LFA measure have evolved, reflecting a shifting constellation of social and environmental needs in less favored areas, and a changing set of priorities. Formerly national governments designated their own LFAs independently based on some common but rather qualitative rules and flexibility was afforded to the Member States in their interpretation. However wide ranges of national criteria were not comparable at European level, the consequent diversity significantly reduced the transparency of the system (CEC 2009).
In Hungary, as the first approximation, the areas with less favored conditions for agricultural production were defined in terms of the one-and-a-half century old "Golden Crown Standard" (Burger 1998). In the next turn the National Rural Development Plan (2004) regularized the designation of LFAs. In this process the areas affected by specific handicaps were identified and spatially delineated using AGROTOPO (1994) spatial soil information system, whose spatial resolution corresponds to about 1:250,000 - 1:100,000 scale. Recently the delimitation of LFAs is suggested to be carried out by using some explicitly defined, common, biophysical, diagnostic criteria on low soil productivity and poor climate conditions all over Europe, which is a promising approach for setting up an objective and transparent system for designating areas affected by natural handicaps (Van Orshoven 2008). It is suggested that they provide a simple and comparable system for LFA designation, unambiguously linked to soil and climate handicaps for agriculture and implementable by all the Member States. As the first step of the cooperation with and operational implementation by Member States, the application of the common criteria should be simulated on the basis of sufficiently detailed soil and climate data, using data sets under member state competence, due to the lack of sufficiently detailed pan-European data. Regionalization of the soil related biophysical, criteria (drainage, texture and stoniness, rooting depth, chemical properties and soil moisture balance) requires the existence of (preferably one) adequate national spatial soil information systems with appropriate thematic and spatial resolution.
In Hungary the national soil mapping project initiated and led by Kreybig was a national survey based on field and laboratory soil analyses and at the same time serving practical purposes. Its aim was the preparation of a map series which gives an insight to the geographical site and extent of soil conditions and soil properties for the production directing authorities, agricultural policy-makers, farmers, and the research institutes

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related to production problems (Kreybig 1937). The similarity between the objectives of the old national mapping and those of the present European activities is noteworthy.
The Kreybig mapping approach identified the overall chemical and physical soil properties of the soil root zone featuring soil patches for agricultural areas. Three characteristics were attributed to soil mapping units and displayed on maps; further soil properties were determined and measured in soil profiles. The unique feature of the Kreybig method was the usage of representative and further, non-representative soil profiles occurring within soil patches. These profiles jointly provide information on the heterogeneity of the area. The Kreybig legacy represents a valuable treasure of soil information, which is developed in the Digital Kreybig Soil Information System (DKSIS; Pásztor *et al.* 2010).

Materials and methods

The elaborated European system consists of detailed definitions, justification and associated critical limits or threshold values for each biophysical criterion as well as indications for its assessment. There is one criterion considering limitations due to terrain features: *Slope*. There are two criteria dedicated explicitly to climatic conditions: *Low Temperature* and *Heat Stress*. *Soil Moisture Balance* is a criterion taking paralelly into consideration soil and climatic conditions. The further four criteria are exclusively defined by pedologic characteristics: *Drainage, Texture and Stoniness, Rooting depth* and *Chemical properties.*
It is recommended by the protocol for soil related criteria that Member States identify the most suitable representation in the national datasets that corresponds to them. Even it is allowed that the fulfillment of a criterion could be estimated from the soil names used in the national soil classifications system. National systems may use different limits but it is suggested to harmonize data using transfer functions. The main expectation is that soil and climate data of sufficient spatial and semantic detail are used.
Spatial and semantic resolution can (and usually does) significantly differ for different datasets. One database may fit better the system's semantic requirements containing more up-to-date and/or sophisticated parameters, which can be explicitly used or easily converted. Another database however might be much more detailed spatially, while its parameters can be applied more indirectly using more complex inferences. Additionally, the databases belong to different institutions and are not necessarily shared even for within country utilization. Thus, even if better results could be achieved by integrated usage of various datasets, generally the solution must be a compromise assigning a sole database, which can offer an optimum basement. The expert group, commissioned with the execution of LFA assignment task in Hungary, discussed thoroughly the various opportunities and decided for the application of DKSIS, which has at least three major advantages in the present context as compared to any other possible Hungarian datasets:

- The main objective of the original mapping is almost the same as that of present LFA assignment.
- DKSIS is the most detailed nationwide spatial dataset covering the whole area of the country.
- The database contains utilizable information to fulfill all the soil related criteria, and due to their spatial features they can also be used for countrywide regionalization of these criteria.

DKSIS data structure

DKSIS contains two types of geometrical datasets simultaneously. Soil mapping units (SMU) are represented by polygons and characterized by three attributes: (i) combined texture and water management categories, (ii) overall soil chemical properties, (iii) areas with shallow depth are also distinguished (yes/no). The approximately 100,000 SMUs were delineated based on overall chemical and physical soil properties of the soil root zone for agricultural areas. The soil conditions for other land use were not identified, however a simplified landuse categorization is also provided, delineating temporarily waterlogged areas; forests; lakes, marshes, rivers and settlements. Detailed soil properties were determined and measured in soil profiles (even temporarily waterlogged areas and forests are seldom represented pedologically this way). The survey applied various pits and boreholes, some of which were deepened to 10 m or to the groundwater level. The most detailed data are provided for "representative sites", localized on survey sheets, examined in situ, and sampled for laboratory analysis (about 30-110 points per map sheet, which covers roughly 250 km^2). The "observed sites" were examined in situ, with description in the explanatory notes, but without laboratory analysis (40-300 points per sheet). The "delineator sites" were used for delineation of soil patches (100-1500 points per sheet). The similarity in soil profiles was used for their coding within a map sheet. If a soil profile with similar geographical position, and very similar properties had already been described, its code was attributed to this one, too. There is representative profile description in the database for about 22,000 plots, and this profile information is transferred for further 250,000 locations.
DKSIS data model and structure reproduces this mapping context, consequently the soil profile database contains hard and soft data simultaneously. This fact facilitates the spatial inference of any profile related

variable, thus achieving much better spatial resolution than what is provided by the application of representative profiles, which method simply attributes the profile information to the supporting SMU.

Semantic fulfilling of soil related biophysical criteria

Criterion on soil drainage: “Areas, which are waterlogged for significant duration of the year.”
Some poorly drainaged areas are very clearly represented in DKSIS. There is a unique landuse category (temporarily waterlogged areas), which is dedicated directly to this limiting factor. However not only these directly denominated areas were assigned to be affected. The original survey used this category for non-agricultural areas (which later also could be turned into cultivation), thus the croplands actually suffering from waterlogging should have been identified, too. SMUs characterized as “soil with poor hydraulic conductivity and very high water retention, prone to cracking” as well as profiles with the heaviest texture properties were selected and restricted being located in deep topographic position.
Criterion on soil texture and stoniness: “Relative abundance of clay, silt, sand, organic matter (weight %) and coarse material (volumetric %) fractions in top soil material.” This item is composed of six independent sub criteria combined with “or” logical function: >15% of topsoil volume is coarse material OR unsorted, coarse or medium sand, loamy coarse sand OR heavy clay (>60% clay) OR organic OR vertisol, clay, silty clay or sandy clay with vertic properties OR rock outcrop, boulder within 15 cm of the surface.
DKSIS provides various possibilities for the physical characterization of soils. SMUs are partly delineated based on these features. There are classes, which directly correspond to one of the sub-criteria (blown sand; stony surface; gravelly surface; peat soils). As for profiles, the field estimation of the textural classes, hygroscopic moisture content (*hy*) and the so-called “capillary rise of water” were taken into consideration in texture class definition.
Criterion on soil rooting depth: “Depth (cm) from soil surface to coherent hard rock or hard pan < 30 cm.”
The original survey distinguished areas with shallow depth, where agricultural management is impeded by dense soil in the plough layer, which is usually considered to be 30 cm. Thus all SMUs with this attribute were identified as handicapped, in spite of that there is no direct measurements on rooting depth.
Criterion on soil chemical properties: “Presence of salts, exchangeable sodium and gypsum (toxicity) in the topsoil.” This is also a complex item composed of three independent sub criteria combined with “or” logical function: salinity: > 4 dS/m OR sodicity: > 6 Exchangeable Sodium Percentage (ESP) OR gypsum: > 15%. Treatment has been similar to that of soil physical properties, since chemical features are also represented in multiple ways in DKSIS. One exception should be mentioned: practically there are no gypsiferous soils in Hungary and consequently gypsum content measurement is not involved in the basic laboratory practice.
Criterion on soil moisture balance: “Number of days within growing period as defined by temperature >5°C (LGPt5), for which the amount of precipitation and water available in the soil profile exceeds half of potential evapotranspiration ≤ 90 days.” The Hungarian Meteorological Service was commissioned with the modeling of potential evapotranspiration and its spatial inference. But this modeling process had to be based on a solid soil background. DKSIS was used for the estimation of field capacity water content (pF 2.5) combining SMU and profile related data on soil physical properties and then for a suitable spatial inference.

Spatial inference of specific limiting factors

Possibilities for the spatial inference of limiting factors were determined by two main considerations.

- The fulfilling of a specific criterion had to be regionalized, that is the final product should be a binary map displaying yes-no categories.
- The fulfilling of a specific criterion could be evaluated using various kind of source data, either based on SMUs, or in profile related form.

Our intention was to establish the decision as much as possible, thus we used multiple decisions on fulfilling a given criterion, if they were available. Decisions were carried out on SMU and soil profile level carrying out proper SQL queries on the profile database and then joining their results to the spatial entities, which resulted in spatial features categorized in binary (indicator) form (i.e. black and white polygons and points). SMUs provide complete coverage, but point information had to be spatially extended. Indicator kriging seemed to be a perfect approach, being a nonparametric method without any assumption on concerning the distribution of the modeled variables (Isaaks and Srivastava 1989; Marinoni 2003). It provides a probability (spatial) distribution map, indicating the probability of fulfilling the criteria within the block used for the calculation (in our case 1 ha cells were used for the interpolation).
Once having a probabilistic approach, the vagueness concerning the spatial behavior of binary classified SMUs might also be taken into consideration. Soil patches provide sharp edges between the two types of decision (fulfilling the criteria or not) in spite of the background soil properties may have much smoother,

continuous variation from one area to the neighboring one. We turned to a fuzzy representation of boundaries to cope with this problem (Wang and Hall 1996).

Results

Semantic and spatial inferences of specific limiting factors resulted in a digital map series. Each map displays a probability field displaying the membership probability of the 1 ha size blocks for the whole area of Hungary. To achieve the final delineation two further steps were required.

- In the case of multiple evaluation, the different results should be combined properly.
- A suitable threshold value should be defined for the membership probability for each criterion (to convert the "grayscale maps" into "binary ones").

As a first approximation, we used a weighted sum of multiple assessments for their combination applying empirical weights according to the reliability of the data source used for the inference. The highest weights were assigned to maps originating from data related to representative sites (considered as hard data), soft data concerning "delineator sites" were less ranked. Since SMU related information is the most generalized, weights of layers related to polygon origin were determined as the lowest, however they play a very important role, stratifying the various soil properties in space. As for thresholds, simply P (fulfilling the criterion) = ½ was used, due to the lack of any knowledge on the distribution of the background variables.

Conclusion

Present work is just in the stage of its finalization, which has been the first result of a rather speeded work process. This means that the digital processing of the whole legacy dataset had to be carried out parallelly with the elaboration of the methodology for its specific analysis while making the most out of the existing data. Consequently not all the steps are elaborated in enough details, but the solid scientific basis was always primary when making compromises. Anyway, the nationwide spatial soil database is finally assembled and its LFA specific analysis is roughly elaborated. In the next step the parameters and thresholds could be fine-tuned, which is also predicted for the basic criteria set up by JRC after a European level evaluation of member state results.

Acknowledgements

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Development of China digital soil map at 1:50,000 scale

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Abstract
In order to meet the increasing demands for soil information of high resolution by different disciplines such as agriculture, environment, economy, and so on, a China Digital Soil Map at 1:50,000 scale (CDSM-50,000) has been developed since 1999. Soil and soil nutrient paper maps at 1:50,000 scale and soil profile records were collected from 2,300 counties of China. These maps and records were achieved during the period of the 2nd Chinese National Soil Survey from 1979 to 1985. A data model of CDSM-50,000 was developed, which contains 9 map layers. Data of about 150,000 soil profiles were, for the first time, integrated into CDSM-50,000. Every profile contains dozens of soil physical and chemical properties, such as soil depth, texture, organic matter, pH value, contents of N, P, K, S, etc. Soil nutrient information of plough layer samplings during the period from 1999 to 2008 was also collected and integrated into CDSM-50,000. To merge different county soil maps with different mapping standards into one map according to the data model of CDSM-50,000, a complicated soil data processing procedure was developed. Map data of 1,100 counties had been already merged to CDSM-50,000. The data model was approved to be successful to organize all soil survey information of China in the last 30 years. Hundreds of examined soil profiles were collected from 5 provinces to test the reliability of developed CDSM-50,000. A quite nice coherence was found between CDSM-50,000 and the reality of soil type distribution. The finished digital soil maps were applied to cropland nutrient management, arable land fertility evaluation, strategy for controlling eutrophication and for study for climate change. This shows that CDSM-50,000 has played a great role for agriculture and environment.

Key Words
Digital soil map, soil profile, large scale, soil quality, organic matter.

Introduction
In China the arable land resources are very limited. According to newly published data, the arable land area is 121.7 million hectares and the per capita arable land area is 0.092 hectares (Ministry of Land and Resources of China 2009), just 40% of the world average. In the available arable land resources there are only 1/3 are fertile soil. The rest are low or middle-low yield arable land. For achieving food security and environment safety of the world most populated country, it is very important to understand the spatial and temporal variation of soil quality precisely. In the beginning of 1980's, a detailed soil survey work was carried out in the whole country. For every counties, hand drawn soil maps at 1:50,000 scale were finished based on large amount of soil profile observation. Since the very few hand drawn copies of paper maps and soil profile records were storied in provincial or even in county bureaus separately, damages are seriously due to acute organisation reform during last 30 years. Purposes of the study are to digitalize these paper soil maps and records, to develop one digital soil model for the whole country, to merge the 2,300 county soil maps and records together, and to enhance the application of soil information in agriculture, environment and economy.

Status of Soil Survey Work in China
A brief soil survey was carried out during the period from 1958 to 1960 in China (Li 1992; Anonymous 1964). A national soil map at 1:10,000,000 scale was drafted (Anonymous 1978). A more detailed soil survey work was finished during the period from 1979 to 1985 (Li 1992). Dozens of thousand of soil scientists and technicians were involved in the work. Based on large amount of soil profile observation and soil sampling, maps of soil and soil nutrient content at 1:50,000 scale were drawn for every county separately. Records of about 150,000 selected soil profiles, which presented main soil types of 2,300 counties in the whole country, were made. Each record contains dozens of soil characteristic such as soil mother material, texture, and contents of soil organic mater, total nitrogen, available phosphorus, potassium and pH in different soil layers with a profile depth of about 1-2 meter. In this survey, status of soil quality of the whole country in the beginning of 1980's was recorded. Recently, continuous attention has been paid to a better understanding of soil quality. A national investigation for soil pollution has been started. Also a national new investigation for soil nutrient status has been carried out since 2005. In these two investigations, geo-coordinates of sampling spots have been acquired by using GPS. Main outputs of soil survey in China in last 50 years were summarized in Table 1.

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Table 1. Soil survey and investigation work in China.

Period	Content	Main Output	Scale	
			Main	Range
1958-1960	Soil Survey	Soil Map of China, Report	1:10,000,000	
1979-1985	Soil Survey	Soil Maps, Reports (2,300 counties)	1:50,000	1:25,000-1:200,000
		Soil Maps, Reports(28 Provinces)	1:500,000	1:200,000-1:1,000,000
		Soil Map of China, Report	1:1,000,000	
	Nutrient Status	Soil Nutrient Maps (2,300 counties)	1:50,000	1:25,000-1:200,000
		Soil Maps (28 Provinces)	1:500,000	1:200,000-1:1,000,000
		Soil Nutrient Maps of China	1:4,000,000	
2000s	Nutrient Status	Database, Reports (most counties of China)		
	Soil Pollutants	Database, Reports (most regions of China)		

Data Model of CDSM-50000 (China Digital Soil Maps at 1:50,000 scale)

Original paper maps of soil and soil nutrient content at 1:50,000 scale and profile records finished in 1980s have been collected from different counties and provinces. Results of soil nutrient status sampled in 2000s were also collected national widely. According to the temporal and geographical features of soil information, a data model with 9 map layers was developed (Table 2). Soil information of 1,100 counties has already been digitalized and merged into CDSM-50,000 (Figure1). The data model has been approved to be successful to organize the miscellaneous soil survey information at county level obtained from 1980s up to now. Hundreds of examining soil profiles was collected from 5 provinces to test the reliability of developed CDSM-50,000. Quite nice coherence was found between CDSM-50,000 and the reality of soil type distribution.

Table 2. Data model of CDSM-50,000 (China Digital Soil Maps at 1:50,000 scale)

Map layers	Geo-feature	Temporal feature
Soil types	Polygon	
Organic matter	Polygon	
Total nitrogen	Polygon	
Available phosphorus	Polygon	1979 to 1985
Available potassium	Polygon	
pH	Polygon	
Soil profiles	Point	
Soil profiles	Point	2000s
Plough layer soil samples	Point	

Mapping of CDSM-50,000

To merge different county soil maps with different mapping standards into one map according to the data model of CDSM-50,000, a complicated soil data processing procedure was developed. By using this procedure Soil Map of China at 50,000 scale has been developed and plotted. The whole map contains 24,000 sub-maps. Two map layers concerning with soil information and necessary basic geographic information (Figure 2). One layer shows distribution of soil types, which was demonstrated by using Soil Classification System developed and widely applied in China (Anonymous 1998). Also soil classification system developed by Gong, which was more adjacent to the system applied in USA was parallel listed (Gong 1999). Through linkage between two soil classification systems, scientists of other country can easily find out the required soil information. The other map layer is soil profiles, which was, for the first time, introduced into the map. Positions of representative profiles of main soil types were labelled on the map (Figure 2). Tables of soil profile characteristics were attached on the map, which showed physical and chemical features of different depth of every representative soil profile labelled on the sub-map. An example was demonstrated in Table 3. The basic geographic information on the soil map includes map layers for administration region, water system, residential area and topographical information.

Application

By using CDSM-50,000, it is easy to get detailed soil information from different places and period in China. Besides improving crop nutrient management for farmers, CDSM-50,000 has also been applied in research works. An analysis of soil fertility changes of arable land in China was showed simply by calculating data provided by CDSM-50,000 (Table 4). It showed that the content of soil organic matter in arable land in about 25 years increased by 33% in China. If we use the arable land area with 121.7 millions hectares and plough layer depth with 20 cm, the net increase of carbon arrived to 953 million tons for the whole country. That means 3,494 million ton carbon dioxide has been additionally fixed in soils. Through advanced farming

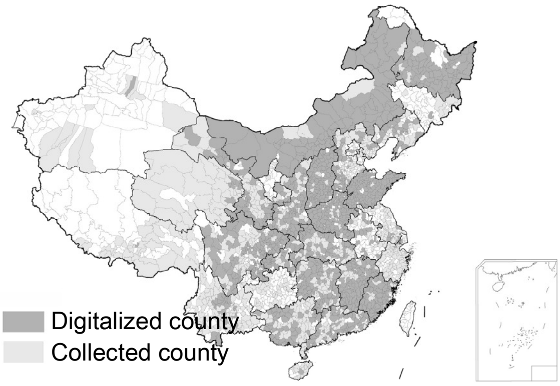

Figure 1. The collected and digitalized soil information by using model of CDSM-50,000.

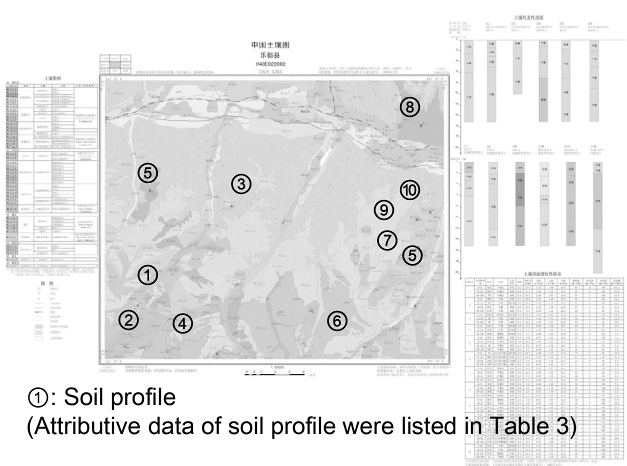

Figure 2. Soil Map of China, Sub-map: Ledu, Ledu county, Qinghai Province.

Table 3. Example table of soil profile characteristics*

Profile Lable**	Parent material	Soil layer	Soil depth cm	Soil texture	pH	OM (g/kg)	Total N (g/kg)	Total P (g/kg)	Total K (g/kg)	Available P (g/kg)	Available K(g/kg)	EC (mg/100g)
①	loess	A	0-12	silty clay loam	9	6.3	0.65	1.64	24.7	2	76	6.8
		B1	12-70	silty clay loam	8.9	2.3	0.44	1.55	23.5	2	82	5.3
		B2	70-150	silty clay	9.2	1.7	0.4	1.85	24.8	3	116	7.1
②	old red soil deposit	A1	0-15	silty clay loam	8.5	30.8	2.31	1.69	25.9	2	212	14.2
		A2	15-30	silty clay loam	8.4	23.9	1.87	1.45	24.6	3	88	16.1
		B	30-50	silty clay loam	8.5	13.9	1.13	1.1	21.6	1	64	11.4
		C	50-150	silty clay loam	8.4	6.4	0.64	1.13	20.2	3	58	6.8
③	loess	A	0-18	sandy loam	8.2	9.8	0.75	1.43	22.2	3	170	7.1
		B1	18-70	silty clay loam	8.4	12.3	1.09	1.69	19.9	3	94	10.8
		B2	70-124	silty clay loam	8.2	8.2	0.72	1.54	18.7	2	72	9.2
		C	124-150	silty clay loam	8.6	5.2	0.43	1.45	21.1	1	63	6.6

*Example Table was attached to Soil Map of China, Sub-map Name: Ledu, Ledu county, Qinghai Province, Soil profiles were sampled and analysed in 1982-1983.
**Profiles listed in Table 3 were labelled on figure 2.

Table 4. Change of soil organic matter, available P and K of China.

Soil parameters		1979 to 1985	2000s	Increase
Organic matter*	(%)	1.82	2.42	33%
	n	1,151,366	85,512	
Available phosphorus**	(mg/kg)	7.9	18.8	138%
	n	907,502	56,515	
Available potassium***	(mg/kg)	105	119.08	13%
	n	667,673	45,225	

* Determination of C; ** Determined mainly by Olsen method; *** Abstracted by NH_4OAC.

practices and soil fertility improvement in China, not only yield increased greatly, but also 139.9 million ton carbon dioxide additionally fixed annually during the last 25 years. It also shows that the concentration of soil available phosphorus increased by 138% and the concentration of soil available potassium increased slightly. With large number of soil samplings from the whole country, the analysis provides a reliable nutrient variation of arable land. Also other evaluations of arable land fertility changes, food security, and environment safety in the country, in a region or in a watershed have been implemented with the help of CDSM-50,000 (Li 2004; Zhang *et al.* 2004). With completeness and continuous enrichment of CDSM-50,000, it will play more important roles in agriculture, environment and research works.

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Effect of long term no tillage on the spatial variability of soybean and maize in São Paulo, Brazil

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Abstract
Crop yield varies in space and in time due to many causes. No tillage preserves soil structure and alters the volume explored by roots and therefore it affects crop yields. The objective of this study was to evaluate the spatial and temporal variability of soybean and maize on a long term no-tillage system. Soybean and maize crops were cultivated under no tillage on a 3.42ha field located at the Campinas Experimental Center of Instituto Agronômico, Campinas, SP, Brazil, from 1985 until 2008 where the soil is a Rhodic Eutrudox with approximately 10% slope. Crop yields were sampled on 2.0x2.5m plots and latter transformed to kg/ha. The length of time with no tillage differently affected the mean values and the spatial variability of soybean and maize but it is not known if the cause is related to the no tillage system or to the variability of weather conditions with time. The spatial dependence for soybean increased with time while for maize it decreased. Uniform management zones could only be established with at least three subsequent crops.

Key Words
Geostatistics, semivariogram, temporal variation, grain crop yield.

Introduction
Long term and frequently monitored no-tillage experiments are rare mostly within tropical conditions. Vieira *et al*. (2002) report on some changes in soil physical properties under no-tillage and crop rotation and concluded that both bulk density and saturated hydraulic conductivity are significantly affected by the changes in organic matter content. Carvalho *et al*. (2002) investigated the effect of soil tillage on the spatial variability of soil chemical properties and concluded that the no-tillage promoted a significant increase in the organic matter content. No tillage system tends to minimize this variability because it preserves soil structure. The amount of variation over an area depends on many environmental conditions and how they acted on soil properties over time. Geostatistics uses a very important component called the semivariogram which is a measure of the similarity between neighboring observations. Long term experiments under tropical conditions using no-tillage are rare. Although it is known that the efficiency of the no-tillage system in conserving soil and water is climate dependent it is still a very recommended management system mainly because it preserves the soil structure. The objective of this study was to evaluate the spatial and temporal variability of soybean and maize on a long term no-tillage system.

Material and Methods
The experimental area is located within the Campinas Experimental Center of Instituto Agronômico, Campinas, SP, Brazil. The soil is a clay texture Rhodic Eutrudox, located in a 3.42ha field of about 10% slope, sampled from 1985 to 1995 at 63 points on a 20m square grid, from 1996 to 2001 at 81 points on a 10m square grid, and from 1997 to 2008 the field was sampled at 302 points on a 10m square grid. Since 1985 this field is being cultivated with grain cereal crops under no-tillage. The climate is subtropical with a mean annual rainfall of about 1500 mm, with 5-6 wet months (November to March) although between year variability may be rather large. The experimental area was regularly sampled every harvest time for the summer and winter grain crops in 2 x 2.5 m subplots, by cutting and weighing all mass above the soil for the last 23 years.
The examination of the temporal evolution of descriptive statistical parameters for the different crops was done in this paper with the purpose of identifying the adequate conditions for future work. The spatial dependence, according to Vieira (2000), can be evaluated by examining the semivariogram and parameters of the model fitted to it. Semivariogram modeling is the foundation for geostatistical analysis, and can also be the most difficult and time consuming portion of the analysis. Vieira (2000) describes the model fitting process and the cross validation of the fitted models. The models fitted are described by the parameters C_0 is the nugget effect, C_1 is the structural variance, *a* the range of spatial dependence Models were fit using least squares minimization and judgement of the coefficient of determination. Whenever there was any doubt on the parameters and model fit,

the jack knifing procedure was used to validate the model, according to Vieira (2000). Cambardella *et al*. (1994) proposed the calculation of a dependence degree (DD) expressed as a ratio between the nugget effect value (C_0) and the sill (C_0+C_1) and classified as Weak if DD>75%, Moderate for 26%<DD<75%, and Strong for DD≤25%. The graphical representation of semivariogram parameters over time can reveal important changes in crop yield as a function of time of using no-tillage system. This kind of analysis can help to explain why crop yield maps quite often do not repeat in time.

One of the major reasons to construct yield maps is to have some indication of the crop yield variability and to delineate uniform regions for management purposes. Comparing maps is not an easy task. In this paper a process of classification of the yield maps is proposed in order to help the delineation of management zones within the field. For this purpose the last two crops of soybean and maize were classified according to the levels low, medium and high of crop yield. After this classification was done, a composed classification of the two crops was done in order to verify the location of places in the field with high yield potential. Thus, the classified maps of soybean and maize were compared at each and every point, creating a new dummy variable with numbers ranging between 1 (lowest yield of both crops) and 9 (highest yield of both crops).

Results and discussion

Figure 1 shows the temporal evolution of the mean and CV values for soybean and maize. Standard deviation bars were added above and below the mean values of soybean and maize yield in order to evaluate adequately the trends expressed by the data. It can be clearly seen that soybean showed a decrease in yield with time while maize showed completely the reverse. Although these results simply represent a general trend with some degree of uncertainty the reasons for this unique and distinct behavior for soybean and maize yields is not known. It is quite possible that the crop reactions to the unchanging soil structure due to the no tillage system are opposite for these two crops in particular when considering their distinct root system. Notice that if it was not for the first point of maize yield for 1986 with approximately 6000 kg/ha the function relating maize yield with time would simply be linear showing a much more pronounced increase with time. The uncertainty on the crop yields, represented by the error bars of one standard deviation above and below the mean value, is also very distinct between the two crops, in general much larger for soybean than for maize. This result agrees with the CV values which increased for soybean and decreased for maize with the time which means that soybean yield not only decreased with time of no tillage but it also became more variable. On the other hand, maize yield increased with the time of no tillage and it also became more uniform.

The temporal evolution of the spatial variability for soybean and maize were evaluated through an analysis of the semivariogram parameters for each harvest. The graphs of the semivariogram parameters as a function of time of no tillage are shown in Figure 2. The nugget effect values for soybean yield decreased linearly with time of no tillage which means that the crop yields became spatially more continuous with time. On the other hand, the maize crop became less continuous with time of no tillage as the nugget effect values show a linear increase with time (Figure 2). The dependence degree for soybean yield showed a very small change with time with a linear relationship almost leveled with the time, whereas for maize yield there was an increase in this parameter with time. The linear relationship between dependence degree calculated according to Cambardella *et al*. (1994), is not very clear although it shows a linear increase with time. As can be seen in Figure 2, if it was not for the last data point, the linear relationship would be much more clear and steep. The general magnitude of the dependence degree indicates that the confidence in the maps generated with values interpolated by the kriging method will be at most medium (Vieira, 2000). The range of dependence increased with time for soybean yield and decreased for maize (Figure 2). This is an indication that the size of the regions considered uniform gets larger wit time for soybean and smaller for maize Vieira *et al*. (2002).

In order to illustrate the comparison of soybean and maize yield maps, a classification of the last two harvest data was done for each one of the two crops. After this classification was done, a composed classification of the two crops was done in order to verify the location of places in the field with high yield potential. Using this composed classified variable it possible then to establish homogeneous zones within the field for future management application. Figure 3 shows the semivariograms and the maps for soybean, maize and for the dummy variable identified in this work as class. Spherical models were fitted to soybean and to maize yield and exponential to the dummy variable class. The yield map for maize shows a very well defined high yield region on the left hand side. The soybean showed very low yield values near the middle of the field, possibly

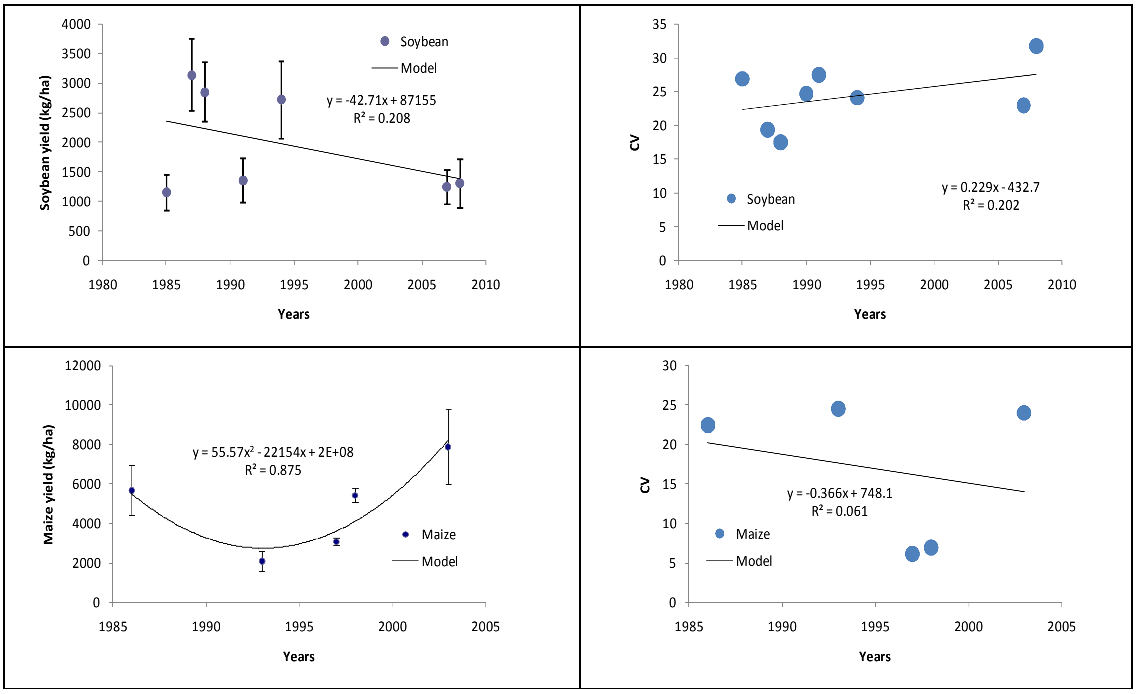

Figure 1. Temporal evolution of mean and CV values for soybean and maize yield. The error bars are one standard deviation above and below the mean value.

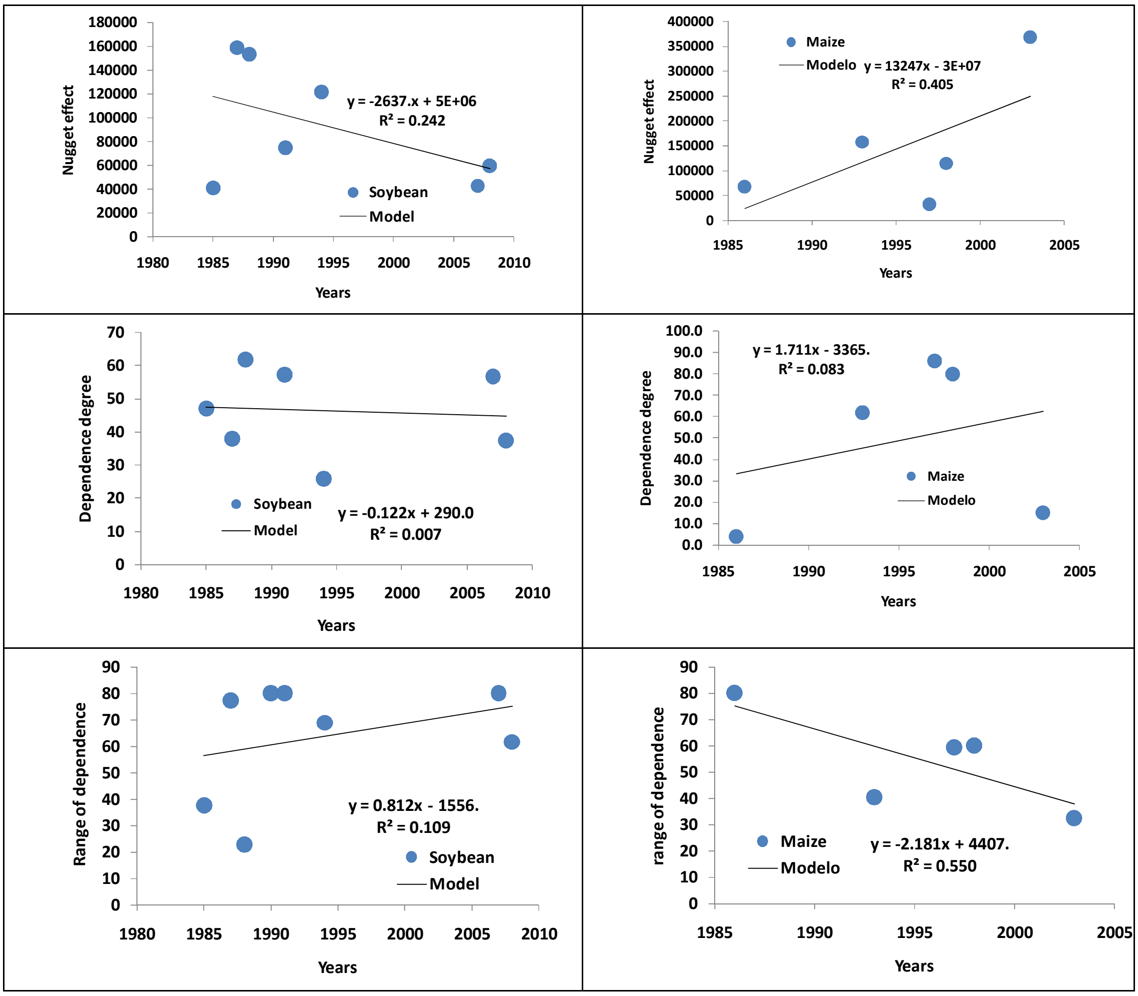

Figure 2. Temporal evolution of semivariogram parameters for soybean and maize.

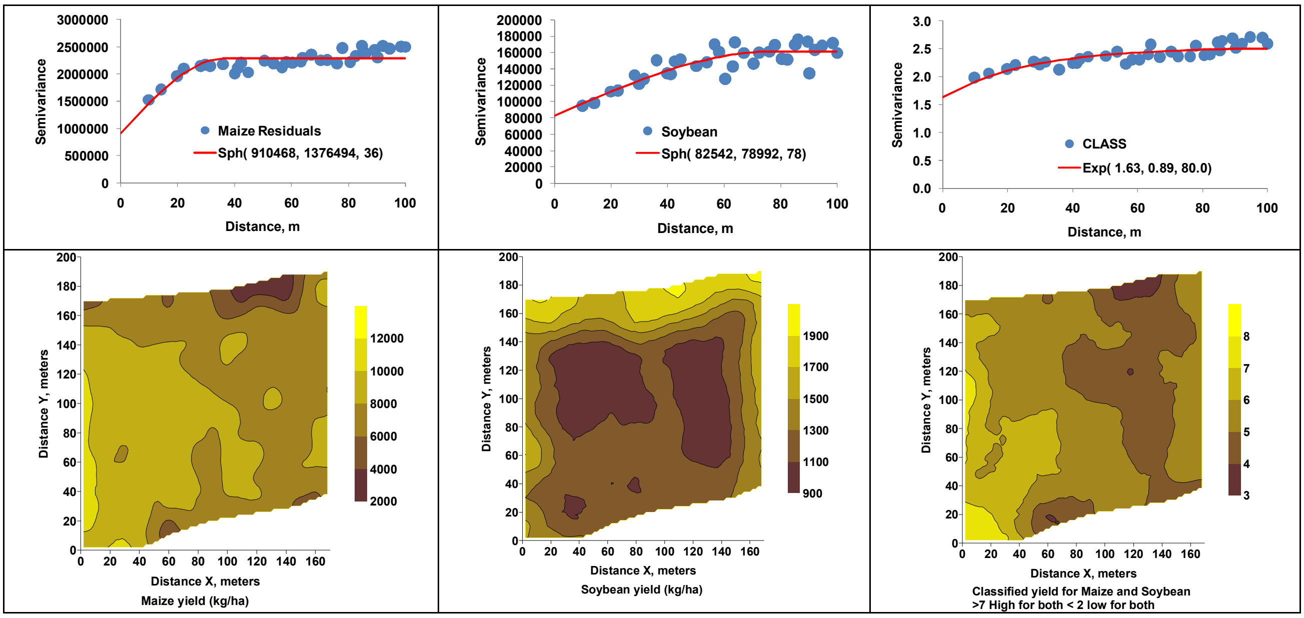

Figure 3. Semivariograms and maps for the last maize and soybean crops and for the variable in low, medium and high yield.

due to bad pest control on this region. The resulting classified map reflects closely the high yield potential of the left side of the field but it also shows regions with lower yield potential near the middle and right side of the field. Although this is a very simple idea, it seems to have potential to be expanded to more yield maps as this would produce a more reliable final result. This idea is yet under development.

Conclusions

Crop yields changed (soybean decrease and maize increase) with time of no-tillage but the real cause was not identified. The yield variability around the mean value showed opposite results as compared to the mean values as soybean became more uniform and maize became more variable with time.

The length of time with no-tillage affected the range of dependence for the both soybean and maize crops and therefore increased the size of the homogeneous management zones.

The classification procedure in order to compare maps and to delineate uniform management zones proved to have potential for future use.

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Optimal spatial scale determining the response of soil organic carbon to climate change using soil database of China

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Abstract
Climate factors are considered significant in regulating soil organic carbon (SOC), but are not equally important at all spatial scales. The scale which provides the optimal relationship between climate and SOC and how that relationship varies at multiple scales are still unclear. To test the variation, 1,022 uplands profiles in Northeast China were obtained from the second national soil survey of China, and the multiple scales were designed as the regional (whole Northeast China), province, city and county. The relationships between climate factors and SOC content at four scales were evaluated for 0-20 cm and 0-100 soil cm using correlation and regression analysis. The results show that differences exist in the degree of correlation and relative importance of temperature and precipitation at different scales. At the regional scale, temperature is the main climate factor controlling SOC content. At the provincial scale, temperature is also the main climate factor controlling SOC content in the Uplands of Heilongjiang and Eastern Inner Mongolia. Soil organic carbon content in Jilin and Liaoning is influenced jointly by temperature and precipitation. At both the city and county scales, a weak or no relationship is observed between climate factors and SOC content. **C**limate factors have limited ability to explain SOC content variability given that SOC is affected by multiple factors which were not taken into account by this research.

Key Words
Scale effect, SOC (soil organic carbon) content, climate, main factor.

Introduction
Because of the important role of soil organic carbon (SOC) in terrestrial ecosystems and its large reservoir size, small changes in the SOC pool may influence global climate change. It is often considered that climate, especially temperature and precipitation, is the most important factor regulating SOC as it strongly influences vegetation type, production and decomposition of plant litter (Alvarez and Lavado 1998). Thus, a better understanding of the relationship between climate factors and SOC at different spatial scales is crucial in assessing the possible impact of projected climate change on the global carbon cycle. Recent research progress on the relationship between climate factors and SOC (Homann *et al.* 2007) had been made. However, contemporary research was mainly carried out at a single scale. Based on study area size, completed research can be divided into local, regional, continental, and global scales. Very few studies exist at the global scale that also considers that SOC density increases with increasing precipitation and decreasing temperature (Jobbágy and Jackson 2000). Local scale studies are also rare. At the regional scale, both soil C content and concentration correlated weakly with temperature and precipitation across all soils and within each soil order in New Zealand (Percival *et al.* 2000). At the continental scale, Homann *et al.* (2007) reported positive relationships to MAP（Main Annual Precipitation, negative relationships to a temperature/precipitation index in all regions, and negative relationships to MAT (Main Annual Temperature), except in the northwest temperate forest region. The relationship between climate and SOC at individual scales has been widely reported, but little information is available at multiple scales. The scale providing the optimal relationship between climate and SOC and how that relationship varies at multiple scales are still unclear. By examining four scales (regional, provincial, city and county), the goals of this paper are to show how the relationship between climate and SOC content in the Uplands of Northeast China varies with scales, and explore optimal spatial scale determining response of soil organic carbon to climate change.

Materials and methods
The study area is located in Northeast China (38º40′-53º30′N, 115º05′-135º02′E) covers an area of 1.24 million km^2, including Heilongjiang Province, Liaoning Province, Jilin Province, and Eastern Inner Mongolia. It has a temperate monsoon climate, but varies across the region. From north to south (~1,600 km)

temperatures generally increase and from east to west (~1,400 km) moisture generally decreases. The data used for this study were obtained from the Second National Soil Survey of China (National Soil Survey Office 1993, 1994a, 1994b, 1995a, 1995b, 1996) conducted in the beginning of 1980s including 1041 upland soil profiles taken from Soil Series of China and Soil Series of provinces, cities, and counties in Northeast China. The SOC content of the 0-20 cm and 0-100 cm depths for each profile were re-calculated based on the total 1041 soil profile data. The spatial resolution of all climatic grid maps is 1 km×1 km. MAT and MAP of 1,022 soil profile points were extracted from the corresponding grid climate data layer using GIS (ESRI, Inc., Redlands, CA). In this study, regional scale refers to all of Northeast China, while provincial scale includes Heilongjiang, Jilin, Liaoning, and Eastern Inner Mongolia. Among 40 cities and 225 counties in the study area, 8 cities and 9 counties were selected as typical areas for the city and county scales, respectively, according to the area of Upland, number of profiles and geographical location. All the statistical analyses were performed with SPSS software 13.0 (SPSS Inc. Chicago, Illinois, USA).

Results and discussion

Relationship between temperature and SOC content at different scales

Based on soil profile and climate grid data, partial correlation analysis between MAT and SOC content taking MAP as the controlling variable were conducted. The relationships between temperature factors and SOC content are diverse at different scales in the Uplands of Northeast China. At the regional scale, SOC content is highly significant and negatively related to MAT not only at 0-20 cm, but also at 0-100 cm. This indicates that increasing temperature generally enhances decomposition more than detrital production. At the provincial scale, SOC content at 0-20 cm in the Uplands has a highly significant and negative correlation with MAT. The relationship between temperature factors and SOC content in Liaoning is significantly different compared with that in Eastern Inner Mongolia and Heilongjiang. A significant difference in Heilongjiang and Jilin is observed in the relationship between temperature factors and SOC content. No difference is observed in the relationships between temperature factors and SOC content in Heilongjiang and Eastern Inner Mongolia. At the city scale, there is a significant negative correlation between temperature factors and SOC content at 0-20 cm in four cities. The results indicate that the relationship between temperature factors and SOC content in the Uplands of Northeast China is scale dependent, and weakens with decreasing scale, especially from provincial to city scales.

Relationship between precipitation and SOC content at different scales

The partial correlation coefficients between MAP and SOC content taking MAT as the controlling variable were calculated. At the regional scale, MAP has a strong and significantly positive relationship with SOC content ($P<0.001$) at 0-20 cm in the Uplands of Northeast China, and a weak relationship with SOC content at 0-100 cm. At the provincial scale, SOC content has a significant and positive relationship with MAP except for Liaoning at 0-100 cm and Eastern Inner Mongolia at 0-20 cm and 0-100 cm. At the city scale, no relationship is observed except for a significant positive relationship between MAP and SOC content at 0-20 cm in Siping and a significant negative relationship between MAP and SOC content at 0-100 cm in Chifeng. The relationship between MAP and SOC content weakens from provincial to city scales (Wang *et al.* 2009).

The Optimal spatial scale determining the response of SOC to climate change

The level of SOC content influences food productivity directly, so it is significant in maintaining food security (Lal, 2004; Johnston *et al.* 2009). Also, global warming will result in decreasing SOC content which has a negative impact on food security by reducing the food productivity of soil. Therefore, there is a growing concern on the relationship between global climate change and SOC content in recent years (Powlson 2005; Smith *et al.* 2008). Presently, there is a steady increase by about 6 million per year in population in China due to the large population base. Conversely, Northeast China is the second largest grain producing area and the largest commodity grain production base. It is considered to have the most potential for increasing food production in the future. Thus, it is very important to examine whether global warming influences SOC content and then food production or not. Our study shows that the relationship between climate factors and SOC content varies with scales. Soil organic carbon content is significant related to climate factors at regional, provincial, and partly city scales, especially for temperature, rather than for the county scale. Different scales contributed to the difference in the relationship between climate factors and SOC content. It is optimal to select provincial scales to study response of SOC content to global warming. However, County is not a suitable scale for the study of the issue.

Conclusion

The relationship between climate factors and SOC content weakens with decreasing scale, especially from the provincial to city scale. In general, the main climate factor controlling SOC content varies at different scales. Temperature is the main climate factor influencing SOC content. At the provincial scale, regional differences were observed in the main climate factor controlling SOC content in the Uplands. Due to the impact of soil texture, human activities and other influencing factors on SOC content, climate factors are not the main factors controlling SOC content at the city and county scales. Regional scale is not the optimal scale to study the relationship between climate factors and SOC content in the Uplands of Northeast China, because regional differences among provinces may be covered up at this scale. As such, the provincial scale is optimal for studying the effect of climate factors on SOC content.

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Soil organic carbon density and storage in Tunisia

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Abstract
The stock of soil organic carbon (SOC) in Tunisia was calculated using soil profile descriptions available in the Tunisian soil literature defined by FAO/UNESCO classification, and the digital soil map 1:500 000. A soil database has been compiled, containing data from 5024 horizons and 1483 profiles. SOC stocks have been calculated for each profile by a classical method for a given depth, it consists of summing SOC stocks by layer determined as a product of bulk density (D_b), organic carbon (OC) content, and layer thickness. D_b values were calculated from pedotransfer functions when we have missing values. SOC stocks by profiles were calculated and linked by soil type to polygons of a digital soil map of Tunisia. In total, Tunisian SOC stocks are 1.006 Pg C in the 0 to 100cm soil depth, and 0.405 Pg C in the upper layer 0-30 cm. The surface horizon (0-30 cm) stored 40% of the soil organic carbon stock. OC stocks were higher in Luvisols 71.6 and 159.2 t/ha in 0-30 and 0-100cm soil depth, respectively. In Podzoluvisols there are 6.19 and 138.8 t/ha, but amounts are lower in Lithosols at 18.4 and 40.4 t/ha.

Key Words
Geographic dataset, sequestration, carbon pools, arid and semi-arid regions.

Introduction
Global climate change threats and the contribution of soil organic carbon (SOC) stock to its mitigation have demanded national estimates of soil carbon stocks (Eswaran *et al.* 1993). SOC stock is the biggest ecosystem carbon reservoir in the world; 1500 - 2000Pg C at 0-100cm (Batjes 1996; IPCC 2001). A good estimation from carbon pools in the soils has been suggested as a means to help mitigate atmospheric CO_2 increases and anticipated changes in climate (Batjes and Sombroek 1997; Lal *et al*. 1998). Regional and global estimates of soil C stocks had to be made by extrapolating means of soil carbon content for broad categories of types of soils or vegetation across the areas occupied by those categories (Batjes 1996; Bernoux *et al.* 2002). Regarding the soil compartment, global carbon pools are difficult to estimate because of still limited knowledge about specific properties of soil types (Sombroek *et al.* 1993; Batjes 1996), and the high spatial variability of soil OC even within one soil map unit. Thus, regional studies are necessary to refine global estimates, mainly at country scale. SOC density according to soil type was estimated by calculating the mean SOC density of its sub-type soils weighted by their area; then SOC storage of the soil type was calculated by multiplying its SOC density by its area obtained from a digital soil map (Yu *et al.* 2007)**.** For Tunisia, it is important to assess the pools of SOC for several reasons. OC is one of the most important constituents of soils; it has a main interest agronomic and environmental. Also, OC storage in Tunisian soils reflects the capacity of arid and semi-arid regions to sequester OC. The objective of this study is to assess and give consistent values and distribution maps, for the 0 to 30cm and 0 to 1m depth of the organic carbon stocks in the soils of Tunisia.

Materials and methods
Study site
Tunisia (32°38°N; 7°12°E and 164.000 km^2) situated in north of Africa and south of Mediterranean Sea (Figure1), has a wide range of natural regions. In fact, the geographical position and the general orientation of the main relieves are influenced at the North by the Mediterranean Sea and at the South by the Sahara.

Soil database
Tunisian soil literature from about 1960 to 2006 was searched for data on soil profiles. Chosen profiles have variable depth, but they are usually more than 1 m in depth. A database was built from previous analytical results from soil profile information for soils pits surveyed by Tunisian research groups by the IRD project and the Ministry of Agriculture of Tunisia. The data contained information for OC, pH, bulk density (D_b),

clay (%), silt (%), sand (%) and $CaCO_3$ (%).The entire soil database comprised 1483 soil profiles corresponding to 5024 soil horizons.

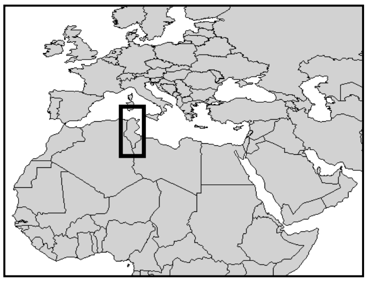

Figure 1. Location of Tunisia in the Mediterranean basin and semi-arid zone

Descriptive statistics of the entire database:

The number of observations varied between 707 and 4716 due to some missing data. The mean D_b value was 1.60 varying between 0.68 and 2 Mg/m^3 (Table 1). All chemical properties, except pH measurements, had a coefficient of variation (CV) > 87%. The OC contents ranged from 0 to 8.99%, and had a CV of 104%. This huge variation in the OC content is due to the great differentiation between the bioclimatic zones in Tunisia (Bernoux *et al.* 1998).

Table 1. Descriptive statistics for the entire database

	Valid cases	Minimum	Maximum	Mean	SD*	CV¤ (%)
Clay (%)	4595	0	88,85	23,76	16,79	71
Fine silt (%)	4433	0	62	13,96	10,73	77
Coarse silt (%)	4429	0	56	10,24	6,43	63
Fine sand (%)	4388	0	89	29,73	18,86	63
Coarse sand (%)	4618	0	96	21,03	19,78	94
pH	3642	4,45	9,95	7,81	0,95	12
OC (%)	4716	0	8,99	0,71	0,74	104
D_b (g/cc)	707	0,68	2	1,6	0,21	13
$CaCO_3$ (%)	3600	0	160	17,18	15,01	87

* Standard deviation

¤ Coefficient of variation

Soil map

The soil map was constructed by the Tunisian Ministry of Agriculture (1973) at the scale (1:500.000). Nine big orders of soils have inventoried; Lithosols, Regosols, Cambisols, Vertisols, Kastanozems, Podzoluvisools, Luvisols, Solonchaks and Gleysols. We digitized this map in the period 2006-2007. The total number of soil map units was 34049.

D_b and stoniness estimation

In Tunisia, Bulk density (D_b) is not determined in most routine analyses, and for most of soil profiles in the database no D_b was reported. The D_b of only 707 soil horizons from the 5024 records have been measured, and it is therefore necessary to estimate D_b's for the rest of the horizons. To this end, so values have to be determined using pedotransfer functions (PTF) (Batjes 1996; Bernoux *et al*. 2002). Using all the available parameters, results showed that:

for superficial layers (≤ 30cm) were: $D_b = 0.9\ (\pm 0.1) - 0.08\ (\pm 0.01)\ OC + 0.007\ (\pm 0.001)$ F-Sand + $0.007(\pm 0.002)$ F-Silt + $0.05\ (\pm 0.01)$ pH. *(R^2=0.58, SE=0.14).*

and for deep horizons layers (>30cm): $D_b = 1.90\ (\pm 0.02) - 0.08\ (\pm 0.03)\ OC - 0.0031\ (\pm 0.0009)$ Clay – $0.0023\ (\pm 0.0007)\ CaCO_3$. (*$R^2$=0.3, SE=0.14).*

Procedure for determining the individual SOC stocks

To estimate SOC stocks, requires knowledge of the vertical distribution of OC in profiles. The way of calculating SOC stocks for a given depth consists of summing SOC Stocks by layer determined as a product of D_b, OC concentration, and layer thickness. For an individual profile with *n* layers, we estimated the organic carbon stock by the following equation:

$$SOCs = \sum_{i=1}^{n} D_b i \; Ci \; Di$$

where SOCs is the soil organic carbon stock (kg C/m^2), $D_b i$ is the bulk density (Mg/m^3) of layer i, Ci is the proportion of organic carbon (g C/g) in layer i, Di is the thickness of this layer (cm). Next step of calculation, SOC density of each great order was multiplied by its respective area to estimate SOC storage for each soil map units. Summation of individually of carbon of the 9 great soil orders gave total carbon stock in Tunisia

Results and discussion

Distribution of SOC density and SOC storage in Tunisia

Statistical results, exposed in Table 2, based on big soil orders, indicated that SOC density varied considerably. Table 2 showed that in 0-30 and 0-100cm depth, Luvisols have the highest SOC densities 71.6 and 159.2 t/ha, respectively. But Lithosols have the lowest SOC densities, at 0-30 and 0-100cm it have 18.4 and 40.4 t/ha, correspondingly. Given a total area of 15520249.8 ha of soil in Tunisia, summation of all soil map units yielded a total SOC storage of 1.006 Pg C in the 0 to 100cm soil depth, and 0.405 Pg C in the upper layer 0-30 cm, and a mean SOC density of 64.86 and 26.12 t/ha at 0-100 and 0-30cm, respectively. Changes in the relative distribution of soil organic carbon stocks with depth have been showed in table 2, the ratio of the total SOC storage of 0-30cm (405.43 Mt) divided by that in the 0-100cm zone (1006.71 Mt). More than 40% of the total SOCS in the upper 100cm of mineral soil is held in the first 30cm.

Table 2. Soil organic carbon (SOC) density and storage by soil order in Tunisia.

	0-30 cm				0-100 cm			
Soil order	n*	SOC density t/ha	SD¤	SOC storage Mt	n*	SOC density t/ha	SD¤	SOC storage Mt
Lithosols	88	18.4	1.48	73.22	63	40.4	2.56	160.76
Regosols	261	31.5	1.97	119.83	145	83.9	4.8	319.16
Cambisols	374	41.6	2.47	100.35	212	101.8	5.77	245.57
Vertisols	80	45.6	2.00	6.75	45	109.7	5.00	16.24
Kastanozems	204	37.4	1.94	51.42	124	93.3	4.37	128.26
Podzoluvisols	170	61.9	2.82	8.78	121	138.8	6.08	19.68
Luvisols	90	71.6	3.73	4.24	60	159.2	7.62	9.43
Solonchaks	100	28.2	1.68	38.39	61	75	4.85	102.11
Gleysols	116	34.8	2.20	2.46	62	77.7	4.21	5.50
Total	1483			405.43	893			1006.71

* Number of soil profiles existing in database.
¤ Standard deviation.

Comparison between Tunisian SOC densities of nine big orders with similar soil orders in the world

These stocks are consistent with data for the world level (Batjes 1996) derived from the WISE (World Inventory of Soil Emission Potentials) soil database. Batjes (1996) reported worldwide mean carbon stock values for the 0 to 30cm layer of 31, 45 and 50 t/ha for Regosols, Vertisols and Cambisols, respectively. It accounted for 0 to 100cm depth of 96, 111 and 96 t/ha for Kastanozems, Vertisols and Cambisols, respectively. But Batjes (1996) calculated for the soils of arid zone slightly higher values for Lithosols (36 t/ha) and for Gleysols (77 and 131 t/ha, respectively for 0-30 and 0-100cm) and lower values for Solonchaks, Luvisols and Podzoluvisols (18, 31 and 56 t/ha, respectively). When the international database of Batjes (1996) derived from the WISE data is used for Gleysols, the estimated total carbon for this group is high, presumably because the international database includes several Gleysols from other regions that contain more carbon than the Tunisian soils.

Elaboration of maps of SOC density

In order to appreciate the geographical distribution of SOC densities and its pattern it is useful to create a map of SOC concentrations. Using as for this the digitized map of soil and the SOC density of the 1483 soil profiles, a SOC density map was constructed. Figure 2 shows that soils have different influences on the OC distribution, depending of the geographical localization, heterogeneity of climate, and geology, which determine the storage of organic carbon in soils.

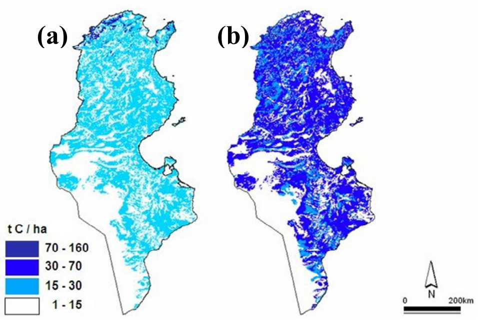

Figure 2. Map of SOC density of Tunisia, (a) in 0-30cm depth (b) in 0-100cm depth

Conclusion

Soils in Tunisia stored 1.006 Pg C and a mean SOC density of 64.86 t/ha within the 100 cm soil depth, and 0.405 Pg C in the upper layer 0-30 cm within a mean SOC density 26.12 t/ha. Due to application of the calculated profile values method for estimating SOC density and linkage with soil map, the results of this first study for estimation Tunisian SOC stock were accurate and reliable. Thus, Information obtained in this study about SOC storage and density of all soil orders, will be a first step accurately estimating and monitoring of the changes of SOC storage in Tunisia.

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Soil-Geographic Database of Russia: Database Management System Soil-DB

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Abstract
The aim of development of the Soil Geographic Database (SGDB) of Russia is the provision of a scientific basis for the state strategy of sustainable rational land use, monitoring of soil cover, and soil conservation. The main blocks of the Soil Geographic Database are the Geographic Database and the Specialized Attributive Database. Relational Database Management System is used for data storage and processing. The Geographic Information Soil Database forms the cartographic basis of the State Soil-Geographic Database of Russia. The soil profile (attributive) database of Russia is based on the concept of representative soil profiles. The representative profiles should have an exact geographical location and be provided with a morphological description and a complete set of analytical data. A series of the profiles typical of a given soil type can be used for calculating averaged characteristics for this soil type. For filling the profile attributive database, a special software—Soil-DB (version 1)—was developed. This program allows a provider of information to login to the site, to create and fill the soil description card, and to send it through Internet to the central server of the System.

Key Words
Attributive database, soil-information space, land use.

Introduction
The aim of development of the Soil Geographic Database (SGDB) of Russia is the provision of a scientific basis for the state strategy of sustainable rational land use, monitoring of soil cover, and soil conservation. The major objectives are as follows:

1) Inventory and formalization of data on Russian soils. Most information on soil profiles is presently kept in hard copies: published articles, monographs, collections, dissertations, and field records. These data should be unified and prepared for collective use.
2) Information supply of research projects and educational programs.
3) Inclusion of Russia into the unified soil-information space of European Community and world, participation in global and regional soil programs.

The main blocks of the Soil Geographic Database are the Geographic Database and the Specialized Attributive Database. Relational Database Management System is used for data storage and processing. The Geographic Information Soil Database forms the cartographic basis of the State Soil-Geographic Database of Russia. It consists of two digital coverages in MapInfo Professional. COVERAGE 1 is a digital map uniting the Soil Map of the RSFSR on a scale of 1: 2.5 M edited by Fridland (1988) (Corrected digital version, 2007), and the digital map of the soil-ecological zoning of Russia on the same scale at edited by G.V. Dobrovol'skii and I.S. Urusevskaya (2007). COVERAGE 2 is the digital map of the administrative division of Russia at a scale of 1 : 1 M. The soil profile (attributive) database of Russia is based on the concept of representative soil profiles. The database has a hierarchical structure ensuring soil description at several levels: SOIL–PIT–PROFILE–HORIZON–SAMPLE. The main object of the database is a specific soil profile with a set of soil horizons characterized by attributive data. The representative profiles should have an exact geographical location and be provided with a morphological description and a complete set of analytical data.

Methods
The Program Soil-DB allows a provider of information to login in the site, to create and fill the soil description card, and to send it through Internet to the central server of the System. All necessary information on the properties and composition of soils is acquired by selecting representative soil profiles characterizing the main soil types in a generalized legend to the soil map on a scale of 1:2.5 M.

Results

The main information element in the program is the card (description of a soil sample). Each user creates their own card file. Any card can be filled in or revised many times, and the changes can be saved on the disk. Because of the large volume and for the sake of convenience, each card is divided into pages (thematic fragments on the screen). The transition from one page to another is made using the menu, where the page titles are selected. Each page contains classified fields, which represent either a menu for selecting one or several items or a window for text or numeric data entry. The Soil-DB interface is shown in Figure 1.

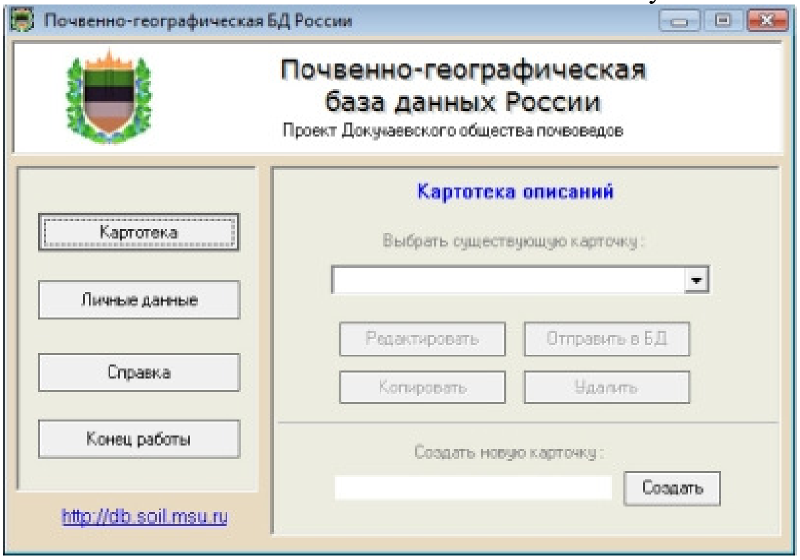

Figure 1. Soil-DB Interface.

The program allows different methods of information entry:
type-in; copy–paste; option selection; multiple option selection; multistep option selection; additional windows for non-formalized data not conformed to the system developed; sending of separate files with additional information to the central server of the System (their names are indicated in the card).
The System operation scheme includes the following steps:
Individual specialists fill available information in standard forms (cards) on their local computers using the Soil-DB program; The program sends the filled cards to the central server through Internet; The received descriptions are examined and edited by experts, who consult with the authors, if necessary, and introduce the changes required; After the card is approved by the expert, it is included as an independent entry in the collective SGDB.

The program is designed for maximum user convenience and comfort of work; therefore, the predominant elements for information entry are pull downs containing the options to be selected by the user. The program contains simple and complex (hierarchical) menus. A simple menu consists of an option window; a complex menu consists of two or three windows with options of the same hierarchical level.

Conclusion

The methodology of the Soil Geographic Database of Russia was developed and realized in the SOIL-DB software aimed at easing the input of individual data to the common database. This database is designed for a wide circle of users, including scientists, teachers, students, and practical workers.

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Spatial distribution of clay by classic inference method (Geostatistic)

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Abstract
The application of technology associated with spatial and temporal variability is necessary, particularly in agricultural research that studies the soil and its productive capacity (Grego and Vieira, 2005). Soil properties related to moisture retention, permeability and aeration have great influence on water management. In this paper geostatistics was used to analyse the variability and to characterize the spatial dependence of grain size at Areão Farm, an experimental area of Escola Superior de Agricultura 'Luiz de Queiroz', University of São Paulo (ESALQ / USP), based on descriptive statistical analysis and spatial inference by using the classical maximum likelihood method, thereby generating the prediction model and therefore the prediction map.

Key Words
Analysis geostatistics, dispersion of clay, kriging, spacial inference, prediction model, prediction map.

Introduction
Knowledge of the variability of soil properties and crops in space and time, is considered now the basic principle for the precise management of agricultural land, whatever its scale (Grego and Vieira 2005). The variation of the textural characteristics of soil occur in response to the deposition of sediment, vegetation, and relief that governs the time of exposure of materials to the action of weathering (Young and Hammer, 2000) and mainly of original material (Cunha *et al.* 2005). Understanding the behaviour of soil particle size is important to understand the distribution of sediments, the formation dynamics of a case and make inferences about the behaviour of the soil. It is worth noting that the size is also considered a useful tool in the definition of taxonomic classes, on the presence of pedogenic processes, and help to understand the movement of water in the soil, fertilization management, as well as the establishment of conservation practices and environmental planning (Mulla and McBratney 2002). The spatial variability of particle size has been studied in various classes of soils where the presence of spatial dependence have been generally between 15 and 10,500 m (Gonçalves, 1997, Souza *et al.* 1997; Vieira, 1997; Salviano *et al.* 1998; Zimback and Cataneo 1998; Gonçalves and Folegatti 2002; Araújo 2002; Rabah 2002;). To be able to study this spatial variability, based on samples analysis and geographic coordinates , geostatistics techniques were applied by establishing a semivariogram model that best describes the spatial variability of the data, which will be used in the interpolation process (kriging method).

Methods
Experiment area
The work was carried out in an experimental farm of the campus 'Luiz de Queiroz', University of São Paulo (ESALQ-USP) in Piracicaba, Sao Paulo State, located in the geographical coordinates, latitude 22 ° 42'S, Longitude 47 º 37 'W and altitude of 546 meters.

Process of data collection
The farm is an area of 180 hectares, which was performed using a grid sampling equipment to the global positioning system (GPS). The work was performed with sampling of soil auger sample undisturbed within a radius of 2 meters from the intersection of a grid with intervals of 100 m, samples were collected at a depth of 0,0-0,30 m, within that radius thus representing the area georeferenced.

Laboratory analysis of samples
The particle size was determined by the pipette solution using 0.1 N NaOH as dispersing chemical and mechanical stirring apparatus at low speed for 16 hours, following the method proposed by (EMBRAPA, 1997), with modifications. The clay fraction was separated by sedimentation according to Stokes law, and the silt and then sand and the fraction determined by difference.

Analysis Descriptive statistics and spatial
The texture attributes were analyzed using descriptive statistical analysis (Table 1) by calculating the mean, median, standard deviation, variance, coefficient of variation, coefficient of skewness and kurtosis coefficient. Then the variable clay, the object of study was analysed using the technique of geostatistics by GeoR package of free software R, the classical inference to achieve the prediction map.

Analysis by classical inference
Box-Cox transformation was performed so that the data follow a normal distribution. For this it used the value of λ near the maximum likelihood. In the case of clay the value of λ = -1 was used for the transformation. Then we analyzed the spatial dependence and tests of effect in the trend of the coordinates between the coordinates and the sampled data, including coordinates and density as a covariate, and between the coordinates and a trend model of first degree and also with a model without trend. The effects were not significant and do not change the distribution of sample data of clay. The process of analysis continued without effect on the trend for the generation of the semivariogram to estimate the dependence between samples.

Results
The analysis of the semivariogram (Figure 1) indicates that the values of the attributes studied present a weak spatial dependence, ie, has randomized the sampling spacing used was higher than necessary to reveal the spatial dependence, with a higher than τ^2 σ^2.

In the data analysis by the method of maximum likelihood models were analyzed with kappas (0.5, 1.5 and 2.5) without trend and the trend in the role of first degree (1^{st}) and function of second degree (2^{sd}) which could be compared and which had the best log likelihood (table 2).

The model with Kappa 2.5 and with a tendency to first degree was presented the best fit within the criteria AIC, not taking the BIC as a criterion for estimating the models, a more rigorous and take into account the number of samples .

By comparing the best kappa according to the data is 2.5, more like the arrangement of the sample data are very widely spaced, they contribute to a behavior of a sigmoid, but was chosen kappa 0.5, for have a more practical sense, based on previous work, thus generating a behavior of a less smooth curve and minimize the parameter estimate τ^2.

Estimates of the adjusted model were:
$$\beta_0 = -0{,}9992 \text{ , } \beta_1 = -0{,}0004,\ \beta_2 = 0{,}0003,\ \sigma^2 = 0{,}0102,\ \phi = 108{,}6315 \text{ e o } \tau^2 = 0{,}0385 \qquad (1)$$

Based on the maximum likelihood method by the criteria AIC and BIC model without spatial dependence is best fit to the data, based on more work done with clay dispersion in agricultural areas, but there is spatial dependence in this case, the dependency exists and is justified because the sampling interval of data is 100 by 100 meters and that the explanation may involve only part of the behavior of the semivariogram (τ^2 is much higher than the σ^2) and therefore, assumes the model to take spatial dependence regardless of the criteria AIC and BIC.

After that, it was estimated the values at positions not sampled in the field using the technique of kriging generating thus the map (Figure 2) clay in the area based on the model set and selected earlier.
The Kriging in geostatistics is used to estimate values of variables to places where they were not measured from the adjacent values (neighbors) interdependent. To use this tool is necessary to have spatial dependence defined by the semivariogram (Salviano, 1996).

The kriging equation used was as follows:
$$\hat{Z}(s_0) = \sum_{i=1}^{k} \lambda_i z(s_i) \qquad (2)$$
being:
$\hat{Z}(s_0)$ - is the estimator for the point s_0 of the region and *k* is the number of neighbours used in estimation;
λ - is the weight assigned to each neighbour $z(s_i)$ is the value observed in each neighbour.

Table 1. Descriptive statistics for the variables: clay, silt and sand (g kg-1), the samples collected at the crossing points of the mesh.

Descriptive Statistics	Attributes granulometric		
	Clay	Silt	Sand
		g/kg	
		Depths of 0,0 to 0,30 m	
Average	50.53	18.12	31,35
Median	51,27	17.46	30,61
Variance	90,65	28,50	47,42
Standard deviation	9,52	5,34	6,88
VC (%)	19	29	22
Asymmetry coefficient	-1,94	0,74	0,90
Coefficient of Kurtosis	11,87	4,25	7,04

Table 2. Comparison of Models by the logarithm of maximum likelihood.

Model considering the effect of linear trend in mean and kappas different		
kappa0.5	kappa1.5	kappa2.5
81.56327	81.61545	81.64824
Comparison of Models by the criteria AIC and BIC Model considering the effect of linear trend in mean and kappas by different criterion AIC		
kappa0.5	kappa1.5	kappa2.5
-151.1265	-151.2309	-151.2965

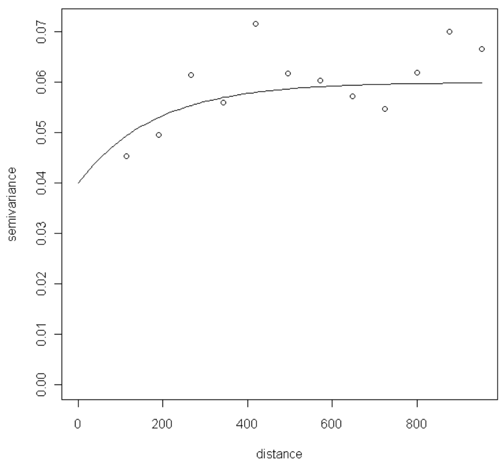

Figure 1. Semivariogram model adjusted second exponential data of clay.

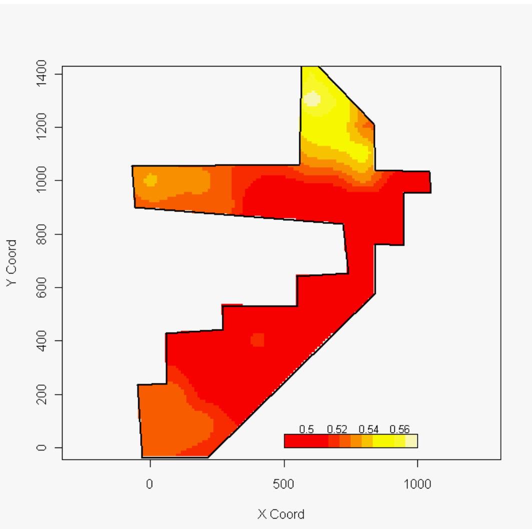

Figure 2. Map predicting the concentration of clay in the study area obtained by the estimate obtained by the method of maximum likelihood (likfit).

Conclusions

The analysis of the semivariogram indicates that the values of the attributes studied present weak spatial dependence. By comparing the best kappa, a value 0.5 was chosen, for a more practical sense, based on previous work. This generated a less smooth curve and minimized the parameter estimate. Based on the maximum likelihood method by the criteria, AIC and BIC models without spatial dependence are best fit to the data. The spatial dependency exists and is justified because the sampling interval of data is 100 by 100 meters and that the explanation may involve only part of the behavior of the semivariogram**.**

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The harmonized world soil database

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Abstract
For more than 30 years the FAO/Unesco Soil map of the World has been the only harmonized source of global soil information. Recent updates and release of new soil information in all regions of the globe was an incentive to tackle the harmonization and integration of the new soil data. The task was undertaken by a consortium of institutes and organizations and resulted in a product with 30 arc second resolution that includes for each soil unit estimates for fifteen top- and subsoil properties. The data come with a viewer, are GIS compatible and are freely available on-line.

Key Words
Soil databases, world soil map.

Background
Soil information, from global to local scale, has often been the one missing biophysical information layer which absence added to the uncertainties of predicting potentials and constraints for food and fiber production. The lack of reliable and harmonized soil data has hampered considerably land degradation assessments, environmental impact studies and adapted sustainable land management interventions. For more than 30 years the FAO/Unesco Soil Map of the World (FAO/UNESCO 1971-1981), based on soil surveys and information collected in the nineteen sixties, was the only harmonized soil map available at a scale of 1:5 Million. It was recognized that the soil information in this map was deficient in many areas and should be improved. At an international scale this was done for some regions since 1995 by FAO, ISRIC and UNEP under the SOTER programme (UNEP/ISSS/ISRIC/FAO 1993). However progress was slow and uneven. Soil information was also improved at national level in many countries, for instance in China (Shi et al. 2004); while a joint effort by USDA, the Dokuchaiev institute and the European Soil Bureau Network resulted in a harmonized Circumpolar Soil Map covering the Northern hemisphere up till 50°North (European Commission 2009). These recent updates and improvements justified this first attempt to harmonize this information in a unique product.

Recognizing the urgent need for improved soil information worldwide and its immediate requirement for the Global Agro-ecological Assessment study, the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA) took the initiative of combining the recently collected volumes of regional and national updates of soil information with the information already contained within the 1:5,000,000 scale FAO-UNESCO Digital Soil Map of the World (FAO/UNESCO 1995, 2003), into a new comprehensive Harmonized World Soil Database (HWSD). This work was undertaken with the International Soil Reference and Information Centre (ISRIC) that together with FAO, is responsible for the development of regional soil and terrain databases and the WISE soil profile database; and with the European Soil Bureau Network, which had recently completed a major update of soil information for Europe and northern Eurasia (Lambert *et al.* 2003), and the Institute of Soil Science, Chinese Academy of Sciences which provided the recent 1:1,000,000 scale Soil Map of China.

Characteristics of the harmonized world soil database
The HWSD contains soil information at scales that vary by region from 1:1 Million in most SOTER, ESBN and China products to 1:5 million in the Soil map of the world. The Harmonized World Soil Database is produced in a uniform raster format with a 30arcsec resolution (1km). The total number of pixels in the map is 15.

HWSD uses 4 distinct sources of data:
1. The European Soil Database (ESDB) extended with information of the Northern Circumpolar soil map at 1:1 M scale. This database is considered of moderate reliability with an adequate scale but often lacking soil profile information.
2. The new Soil Map of China at scale 1:1 Million produced by the Chinese Academy of Sciences. The database is considered of moderate reliability for the same reasons as the one above.
3. The SOTER databases mainly for Eastern, Central and Southern Africa, South America and the Caribbean and parts of Asia. This database is considered of moderate reliability in regions where the scale was smaller than 1:1 Million as is the case in South America and the Caribbean, Congo and Angola or where soil profiles were scarce such as in Mongolia, Egypt and Sudan. The database is considered of high reliability in areas where the scale of the original maps was 1:1 million or better and a complete soil profile database was available (Southern Africa, Central and Eastern Europe).
4. For the areas not covered by the above mainly West Africa, North America, South Asia, and Australia the "old" soil map of the world was re-interpreted. This part of the database is considered of low reliability.

Soil Unit Composition of each grid (classified according to the FAO Revised Legend (FAO 1990)) contains fifteen soil properties for topsoil (0-30cm) and subsoil (30-100cm) are automatically displayed and contained in the database / GIS layers based on legacy data and using simple taxon-transfer functions. This concerns the following parameters: Organic Carbon, pH(H2O), CECsoil, CECclay fraction, Total Exchangeable Bases (TEB), Base saturation %, ESP, Calcium carbonate, Gypsum, Sand fraction, Silt fraction, Clay fraction, ECe, USDA Texture, Reference Bulk Density, Soil Drainage, and Soil Phase information.

Additional information contained in the HWSD as separate layers with different lower resolution (5 arc minutes) are:
1. Land cover/land use shares. This information is classified in seven classes: rain-fed cultivated land, Irrigated cultivated land, Forest land, Pasture land, Barren/slightly vegetated land, Water, Urban land).
2. Terrain slope and aspect distributions within each grid. This information is derived from digital elevation data produced by the NASA Shuttle Radar Topographic Mission (SRTM) with a 90 meter resolution.
3. Soil qualities for agriculture including Nutrient availability, Nutrient retention capacity, Rooting conditions, Oxygen availability, Excess salts, Toxicity and Workability.
4. Rural and urban population distribution.
In addition a number of soil qualities can be derived using modeled relationships between soil properties. Examples are the organic carbon pool and the soil water holding capacity.(See Figure 2).

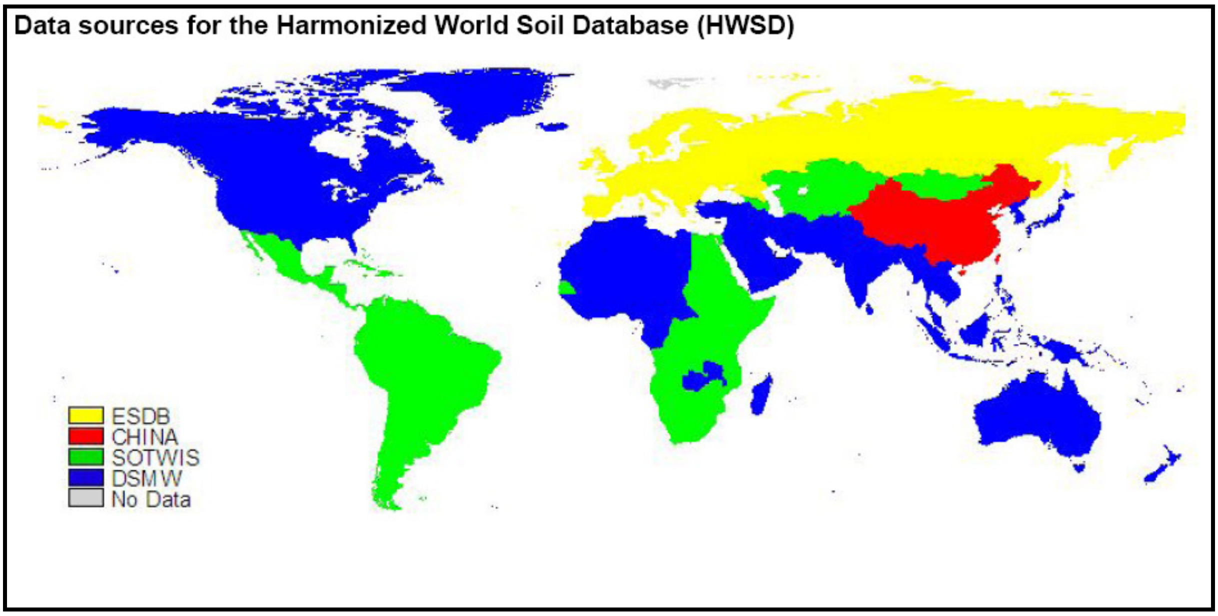

Figure 1. Sources of HWSD.

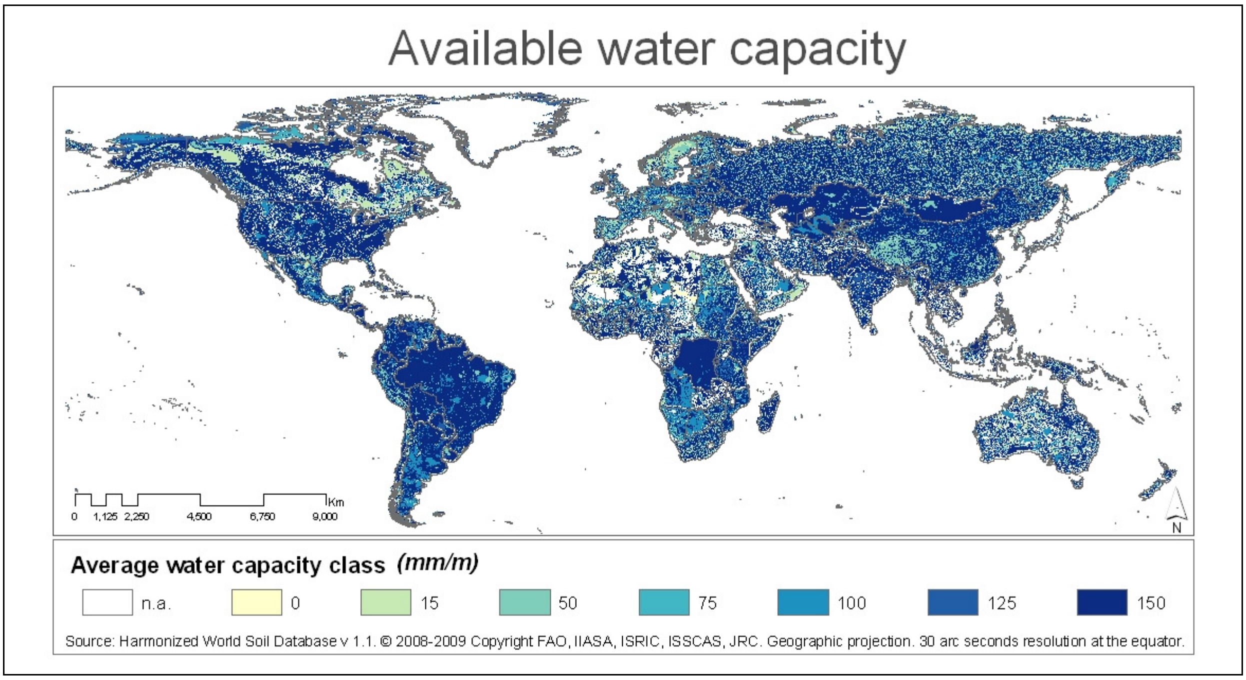

Figure 2. Soil moisture holding capacity derived from soil properties in HWSD.

Conclusions and recommendations

The completion of this comprehensive harmonized soil information will improve estimation of current and future land potential productivity, help identify land and water limitations, and enhance assessing risks of land degradation, particularly soil erosion. The HWSD contributes sound scientific knowledge for planning sustainable expansion of agricultural production and for guiding policies to address emerging land competition issues concerning food, energy and biodiversity. This is of critical importance for rational natural resource management and making progress towards achieving food security and sustainable agricultural development, especially with regard to the threats of global climate change and the need for adaptation and mitigation.

The HWSD constitutes improvements for about 60% of the land area as compared to the FAO/UNESCO Soil Map of the World. The GlobalSoilMap.net (Sanchez *et al.* 2009) digital soil mapping project that will provide the global information system of the future is in his first year and completion for Sub-Saharan Africa let alone the World is some time off. Readily available databases such as those present in Australia, Canada and the United States can easily be transformed in a similar 30 arc sec product. In other regions such as West Africa and South Asia many countries have the soil maps and soil profile databases available to contribute to an expanded HWSD. On going discussions in the framework of the Group on Earth Observations (GEO) aiming towards the development of a Global Soil Information System (GLOSIS) as a "system of systems of soil data and information" as part of the Global Earth Observation System of Systems (GEOSS) have already identified a possible improved HWSD as an intermediate product to be complete at short term, prior to the final release of the future GlobalSoilMap.net (GEO 2009-2011 Work plan 2009). It is therefore strongly recommended that an initiative is launched to complete the HWSD based on existing legacy information. This in turn will be a solid basis on which future global digital soil mapping can build.

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VSIS an new system for Victorian soil data

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Abstract
The Victorian Soil Information System (VSIS) is a new information system for storing and accessing primary soil data. The system comprises soil profile data, which is fundamental to land use and biophysical modelling, and inference systems supporting management of the land resources. VSIS is sympathetic to the design of the existing national Australian Soil Resource Information System (ASRIS) but contains additional elements to support soil monitoring (time series), detailed metadata and Victoria's standards and classifications. Part of the VSIS development was to formulate and build linkages for future streamlined data exchange and interoperability between VSIS and ASRIS. VSIS contains approximately 3,000 soil profile sites that have been described and analysed according to national standards. VSIS is a web-based application that allows for data to be viewed and extracted using a SQL queries tool and through a Geographical Information System (GIS) mapping interface. The system supports the seamless integration of both spatial and aspatial queries to support efficient search and discovery of the data asset. Current VSIS can only be access via the Department of Primary Industries Victoria (DPI) intranet.

Key Words
Soil Profiles, On-line GIS.

Introduction
The first formal soil and land survey in Victoria occurred in 1928 near Swan Hill (VRO 2009). Since then hundreds of surveys and projects have assessed landscapes across Victoria and collected detailed soil and land data (VRO 2009). It is estimated that well in excess of 70 million dollars has been invested through the years in Victoria in collecting primary soil attribute data.Early precursors to the VSIS had their origin in a sequence of dBase3, Microsoft™ Access and eventually Microsoft™ SQLServer implementations all based on an evolving data model. The initiation of the Australian Soil Resource Information System (ASRIS) (McKenzie *et al.* 2005) saw the formation of a new data model based around a conceptual model for a soil profile. Large parts of this model were subsequently adopted and now form the core of the VSIS although extensions to support time-series data and metadata have been added. Primary functions of the VSIS are to aid data consolidation, ensure secure storage to prevent loss, provide a ready access point for this information and significant knowledge resource. This paper describes the current VSIS solution in what will be a continually evolving approach to storing, accessing and using soil- and land-based data and data products.

Principles behind VSIS
The key principles driving the development of the VSIS are:

- The need to create a primary consolidated database to store and secure soil data that becomes a single point of truth for Victorian soils data.
- The need to improve the accessibility and visibility of soils data.
- The need to improve the management and use of Victorian soils data.

The VSIS development combines these principles with the aim to create an environment whereby the State of Victoria and relevant stakeholders within it can derive the best value from soils data both now and into the future. Indeed the drivers behind the VSIS system are similar to those for the counterpart Soil And Land Information (SALI) system in Queensland (Brough *et al.* 2006) and the S-map system in New Zealand (Lilburn *et al.* 2004). To achieve the consolidated database required the development and deployment of a common data model that can accommodate a diversity of soil data. This is largely provided by the emerging national standard embodied within ASRIS. Additionally data entry tools were developed to facilitate entry of soil data currently held as hard copy records or field sheets. To improve accessibility new approaches to viewing, querying and assembly of the data were developed. This fulfils aspects of the whole data cycle by allowing soils data to be directly interrogated (Nichol *et al.* 2005; Nichol, 2006) and downloaded to desktop computers so that it could be integrated with research and modelling activities. Overall the system needed the capacity to cope with state-wide data and allow state-wide spatial viewing of soil site data. A key strategy is for the VSIS to become a focal point to store and access all available soils data and thereby guiding future collection programs and projects.

VSIS system overview
A simplified overview of the VSIS is shown in Figure 1. Broadly the system has three major components: a core backend database, the VSIS web application, and an associated data entry sub-system called the Victorian Soil data Entry System (VSES). At present the VSES is a Microsoft™ Access database application that integrates all the codes, code lists and naming conventions used in Victoria to describe soils, and matches the VSIS, ASRIS (McKenzie *et al.* 2005) and the "Australian Soil and Land Survey Field Handbook (NCST 2009). A supplemental business process within DPI reviews the data after entry to detect when valid values have been applied incorrectly (i.e. in the wrong context) or any other anomalies. Users of the VSIS can query, view and download to their desktop any of the data held within the system. The VSIS is currently hosted within the state government wide area network (WAN) hence current usage of the system is currently restricted to state government personal.

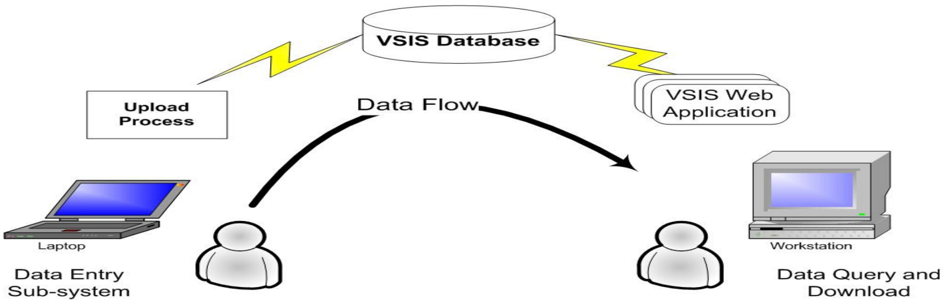

Figure 1. Highly simplified VSIS system model.

Data model/database
A pictorial and conceptual version of the VSIS data model is shown in Figure 2. The main entities within the model are *agencies* which commission soil survey *projects* that examine or assess soil *features* (i.e., pits, cuttings and soil cores etc) from which *samples* are taken or identified. Finally measurements or *observations* are made against the samples or profile sections. Each successive entity inherits the key fields from parent entities and as the data model is interrogated these form a combined key to uniquely identify records. Functional within the data model *agency* provides an institutional context and *project* often provides details regarding the people and purpose associated with the data collection. Spatial location (x,y or latitude, longitude) is defined at the *feature* level and the time of collection and depth information (z) is associated with a *sample*. In this way the data model provides a multi-dimensional contextual framework for soil data. The association of dates with *samples* enables the VSIS to be used to record soil monitoring data.

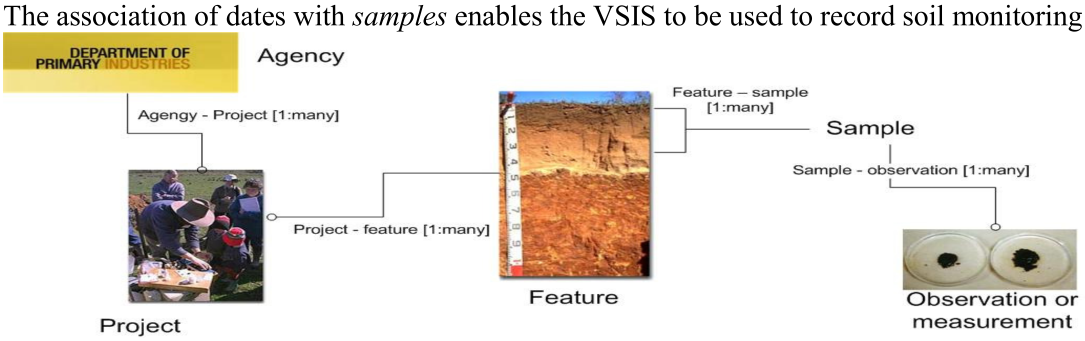

Figure 2. Pictorial and simplified version of the VSIS data model.

VSIS web application and interface design
The VSIS web application is designed according to the functional business model that was generated after business and user consultations. The current web application interface has been broken into six major components: Home, Map View, Soil Query, Administration, Support and VSIS Feedback. The visualisation/mapping, search and delivery functions are well developed in the current version of the VSIS; further work is required to expand the administrative functions within information management and to automate more of the data processing functions. The 'Map View' (Figure 3) screen is divided into a mapping

pane that displays spatial information such as the location of soil pits and auger holes and a range of polygonal datasets that can all be turned on and off in the view as the user desires. Selecting the ‘Query’ icon activates a concise but powerful query tool in the pane below the map view. This enables users to build a query to select soil features based on soil properties and other criteria. The results can be view spatially and textually as well as downloaded to the desktop either directly into applications such as Microsoft™ Excel, or as an ESRI shape-file with an associated table for linkage of attributes.

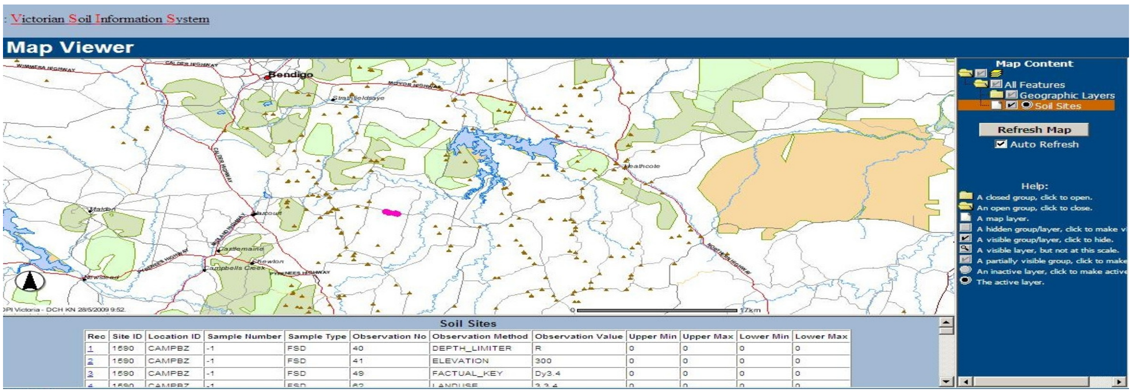

Figure 3. The VSIS ‘Map View’ screen.

The ‘Soil Query’ tool (Figure 4) provides an extremely powerful and flexible mechanism for querying the VSIS database in a user friendly environment. Any table or field within a single or multiple tables can be used to construct a complex query. The queries can also be saved as a file on the desktop and re-loaded for execution at a later date thus allowing users to store and exchange queries. Once a query is executed the results can be downloaded to a file on the desktop to be used as an input for modelling software or used for a pedotransfer function.

Conclusion

While the current version of the VSIS addresses the core functions required to improve soils data reticulation in support of research and landscape modelling (Nichol 2006; Nichol *et al.* 2005), the future development of VSIS will need to begin to address the integration of the data required for soils inference modelling in a more systematic fashion. This will require moving away from the historical digital soil mapping that is currently stored in the system towards an approach that stores the inference model and processing rules, thereby enabling consistent and repeatable production, storage and delivery of soil parameter surfaces or three-dimensional models. This aligns with the directions that the SALIS system (Brough *et al.* 2006) and S-map system (Lilburn *et al.* 2004) have taken. It is likely that some of these models may not be stored in the VSIS itself but rather in the model information and knowledge environment system. Further work will need to be done to develop an underlying data service so that the soils data can be integrated with other data to support online services and modelling. The development of a community-based XML schema (SoilSciXML) to support the exchange of soil data will aid the above endeavours and additionally improve the potential for interoperability between state and federal systems. The integration of data from the Laboratory Information Management system (LIMS) and the soil sample archive database into VSIS will enable a consolidated single point of truth for soil information in Victoria.

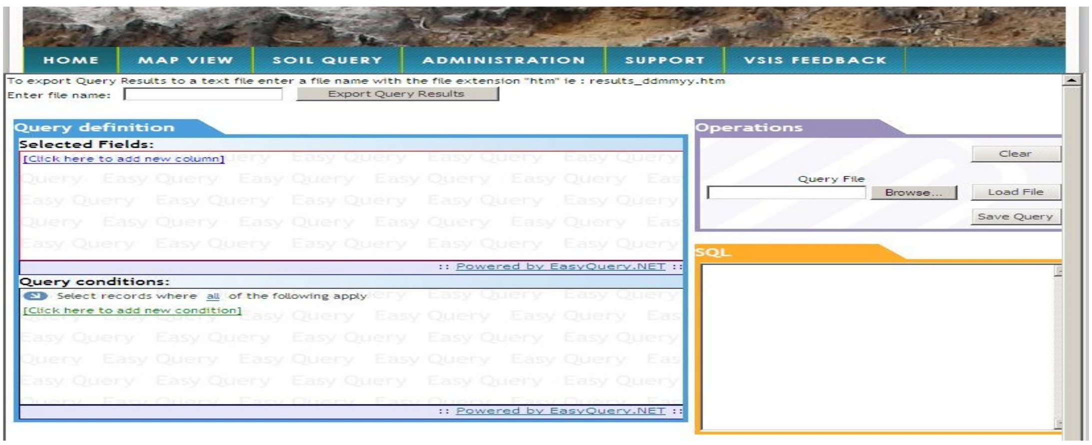

Figure 4. The VSIS 'Soil Query' screen.

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