Pedometrics 2007

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Biannual Conference of Commission 1.5 Pedometrics,
Division 1 of the International Union of Soil Sciences (IUSS)

August 27 to 30, 2007

University of Tuebingen, Institute of Geography

Programme & Book of Abstracts

Eberhard Karls Universität Tübingen

BGR
Federal Institute for Geosciences and Natural Ressources

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German Society of Soil Sciences

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Pedometrics 2007 - August 25-26, 2007

Pre-Conference Workshop on **Spatial Uncertainty Propagation**

Tutors: Gerard B.M. Heuvelink (Wageningen University) and James D. Brown (University of Amsterdam)

When soil information is used in environmental modelling or for decision making, then the uncertainties contained in the data that are stored in the soil information system will propagate through the models and affect decisions. It is important that users of soil information are able to determine whether the accuracy of the information used is sufficient for the intended use. If it is not, then this will result in inaccurate model results and poor decisions. This two-day workshop presents theory and practice of spatial uncertainty propagation analysis, by presenting and discussing various uncertainty propagation techniques. The emphasis is on Monte Carlo simulation methods. Workshop participants will receive a copy of and learn to use the Data Uncertainty Engine software tool, which is specifically designed to help users define, assess, store and simulate uncertain spatio-temporal environmental data. Considerable attention is given to the effect of cross- and spatio-temporal correlations on the results of an uncertainty analysis and on methods to determine the relative contribution of individual uncertain inputs to the accuracy of the final result. The techniques are illustrated with examples on soil pollution, pesticide leaching and digital terrain analyses. Many of the examples will be carried out by the workshop participants themselves. After completing this workshop, participants will have a clear understanding of how uncertainties in soil information can be represented statistically using probability distributions, how uncertainties propagate through spatial analyses, and how to apply uncertainty propagation techniques in their own work.

Pedometrics 2007 - August 26, 2007

17:00 – 22:00 Registration & Welcome Social

Pedometrics 2007 - August 27, 2007

8:30 – 17:00 Registration Open

9:00 – 9:45 Keynote Talk — ***Chair: Thomas Scholten***

Developing Pedometrics: A History and Geography of Ideas	*Alex McBratney*

9:45 – 10:45 General Session – *Sampling*

Comparing Sampling Patterns for Kriging the Spatial Mean Temporal Trend	*Dick J. Brus*
Using Projected Process Kriging and Ancillary Data to Determine Efficient Soil Sampling Schemes for Geostatistical Analysis	*Ben Ingram*
Instance Selection and Classification Tree Analysis on Large Datasets in Digital Soil Mapping	*Karsten Schmidt*

10:45 – 11:00 Break

11:00 – 12:20 General Session – *Digital Soil Mapping* — ***Chair: Raphael Viscarra-Rossel***

Total Regressions in Trend and Transfer Function Analyses	*Galina Koptsik*
Spatial Prediction of Water Influenced Soil Parameters Using Dempster-Shafer Theorem	*Ruprecht Herbst*
Assessment of Total Soil Carbon and Soil Carbon Fractions at the Watershed Scale Using Geospatial Upscaling Techniques	*Gustavo M. Vasques*
Mapping Soil Colour from Munsell Colour Chart Codes	*Tomislav Hengl*

12:20 – 13:50 Lunch on own

13:50 – 14:35 Keynote Talk — ***Chair: Brian Slater***

Effects of Neighbourhood Size on Terrain Derivatives and Digital Soil Mapping	*Zhu A-Xing*

14:35 – 15:35 General Session – *Mixed Topics*

Spectral Soil Material Classes	*Nathan Odgers*
Soil Data Simulation for Landscape Modelling	*Valerie Viaud*
Soil Profile Distance Measures and Classifications	*Florence Carré*

15:35 – 15:50 Break

15:50 – 17:10 General Session – *Geostatistics* — ***Chair: Tomislav Hengl***

Non-stationary Variance Models for Kriging Soil Properties	*Murray Lark*
Robust Universal Kriging	*Andreas Papritz*
Development and Application of REML Estimators for Contaminated or Multivariate Soil Properties	*Ben Marchant*
Geostatistical Modeling of the Spatial Distribution of Soil Dioxin in the Vicinity of an Incinerator	*Pierre Goovaerts*

17:10 – 18:30 Poster Session 1 — ***Chair: Budiman Minasny***

19:00 Guided Tour in Tübingen

Pedometrics 2007 - August 28, 2007

9:00 – 9:45	**Keynote Talk**	***Chair: Florence Carré***
	On Not Data Mining in Pedometrics	*Murray Lark*
9:45 – 10:45	**General Session – *Digital Soil Mapping***	
	Multi-Scale Digital Terrain Analysis and Feature Selection in Digital Soil Mapping	*Thorsten Behrens*
	Using Machine Learning to Update Soil Surveys: A Case Study in Southeastern Ohio, USA	*Brian Slater*
	Soil Types Classification and Pollution Mapping with Machine Learning Methods	*Mikhael Kanevski*
10:45 – 11:00	***Break***	
11:00 – 12:40	**General Session – *Uncertainty***	***Chair: Peter Finke***
	Modelling Spatial Variability and Uncertainty of Cadmium Leaching to Groundwater for an Urban Region in Northern Germany	*Christof Beyer*
	The Temporal-Spatial Variability of Soil Organic Matter Contents in the Alluvial Region of Huang-Huai-Hai Plain of China	*Huang Yuanfang*
	Uncertainty Analysis in Soil Sample Locations within Digital Soil Mapping Approaches	*Rosina Grimm*
	Uncertainty Evaluation of PTF at Hillslope Scale	*Giovanni B. Chirico*
	Uncertainty Analysis of the GeoPEARL Pesticide Leaching Model	*Gerard Heuvelink*
12:40 – 14:00	***Lunch on own***	
14:00 – 15:20	**General Session – *Soil Sensing***	***Chair: Pierre Goovaerts***
	Integration of Visible-Near Infrared Reflectance Spectroscopy and (Co) Kriging for Estimations of Soil Variables	*Ali V. Bilgili*
	Spatial Retrieval of Soil Reflectance from SPOT Multispectral Data Using the Empirical Line Approach	*Emanuelle Vaudour*
	Using Hyperspectral γ-Ray Energy Spectra for Proximal Soil Sensing	*Raphael Viscarra-Rossel*
	Detection, Regionalization and Classification of Subsoil Compaction in Agricultural Loess Soils by Electromagnetic Induction Probing	*Gunnar Hoefer*
15:20 – 15:40	***Break***	
15:40 – 16:50	**Poster Session 2**	***Chair: Ben Marchant***
16:50 – 18:10	***General Session – Mixed Topics***	***Chair: Lubos Boruvka***
	Pedodiversity of Southern African Drylands - Quantification and Implications for Biodiversity	*Andreas Petersen*
	On Effective Linearity of Soil Process Models during Spatial Aggregation	*Ron Corstanje*
	On Measuring Pedodiversity	*Budiman Minasny*
	Quantifying Soil Permeability through 2D Multifractal and Wavelet Approach	*Ana Maria Tarquis*
18:15 – 19:00	**Open Pedometrics Business Meeting**	***Chair: Murray Lark***
	Major Topics: Pedometrics 2009, www.pedometrics.org	
19:30 – 22:00	***Conference Dinner***	

Pedometrics 2007 - August 29, 2007

9:00 – 9:45	**Keynote Talk**		***Chair: Ruprecht Herbst***
	Sampling for Soil Survey and Monitoring. Examples from the Netherlands		*Dick J. Brus*
9:45 – 10:45	**General Session – *Fuzzy Logic***		
	Development of Knowledge on Soil-Environment Relationships for Digital Soil Mapping Using Fuzzy C-Means (FCM) Clustering		*Yang Lin*
	An Object-based Approach for Fuzzy Soil Class Prediction		*Jens Hannemann*
	Predicting Spatial Distribution of Soil Properties: Fuzzy vs. Statistical		*Zhu A-Xing*
10:45 – 11:00	***Break***		
11:00 – 11:10	**Best Poster Award**		
11:10 – 12:50	**General Session – *Digital Soil Mapping***		***Chair: Andreas Papritz***
	Object-based Data Model for Digital Soil Mapping		*Lukas Brodsky*
	Advanced Terrain Analysis for Digital Soil Mapping		*Michael Bock*
	Mapping the Possible Occurrence of Archaeological Sites by Bayesian Inference		*Peter A. Finke*
	Evaluating Two Scales of Polygon Soil Maps and an Electrical Conductivity Survey in Characterizing Within-field Soil Textural Variability		*Udayakantha W.A. Vitharana*
	Bringing Soil Inference Systems to Life: Knowledge Structures, Error Propagation and User Interaction		*Grant Tranter*
12:50 – 13:50	***Lunch on own***		
13:50 – 15:00	**General Session – *Mixed Topics***		***Chair: Volker Hennings***
	Land Suitability Analysis for Selected Crops Using GIS and Multi-criteria Approach in Central Vietnam: Thua Thien Hue Province		*Van Chuong Huynh*
	Use of Geostatistical Simulation Methods to Assess the Probability of Overland Flow Occurrence		*Beate Zimmermann*
	Accounting for Extensive Topographic and Pedologic Secondary Information to Improve Soil Mapping		*Annamaria Castrignanò*
	Pedometrical Analysis of Soil Characteristics in an Area with Heavy Deposition Load		*Lubos Boruvka*
17:00	***Punting on the Neckar River***		

Pedometrics 2007 - August 30, 2007

9:00 – 22:00	**Post-Conference Field Trip**	introducing the culture, the soilscapes, and the vine of Baden-Wurttemberg

Pedometrics 2007 - Poster Presentations

Poster Session 1

- Digital Soil Mapping, Geostatistics, Fractals -

Modelling Landslide Hazard, Soil Redistribution and Sediment Yield of Landslides on the Ugandan Footslopes of Mount Elgon	*Lieven Claessens*
Implementation and Validation of Expert Knowledge for Digital Soil Mapping in Senegal	*Bas Kempen*
A Digital Soil Map of the Lower Hunter Valley, New South Wales, Australia	*Nathan Odgers*
DSM Recompilation of Soil Degradation Regions in Hungary	*Laszlo Pásztor*
An Approach to Computing Topographic Wetness Index Based on Maximum Downslope Gradient	*Chengzhi Qin*
Using DSM Data for Wind Erosion Events in Europe – Bridging the Gap between DSM and DSFM	*Hannes Reuter*
Regional Estimation of Infiltration Rates in South-Eastern Australia	*Benny Selle*
Mapping Available Soil Micronutrients in an Atlantic Agricultural Landscape by the Indicator Approach	*Eva Vidal-Vazquez*
Integrating Statistical and Visual Approaches to Predict Soil Attributes from Digital Terrain Data	*Feras Mousa Ziadat*
Regionalization of Saturated Hydraulic Conductivity in an Intramontainous Basin in the Northern Apeninn	*Tim Häring*
Geomorphological Mapping using Data Mining Technologies. An example from the Rivo Basin in Molise, Italy	*Michael Märker*
Space–time Kalman filtering of soil redistribution	*Gerard Heuvelink*
Soil mapping at a scale of 1:50,000 in Germany – analysis of existing maps and definition of quality criteria	*Ernst Gehrt*
Characterizing Mercury Injection Porosimetry Curves of a Soil Prone to Crusting by Multifractal Parameters	*Jorge Paz Ferreiro*
Fractal and Multifractal Parameters for Assessing Texture of Experimental Plots	*Jorge Paz-Ferreiro*
Soil Contamination with Geostatistics Techniques	*Fatima-Zohra Benmostefa Largueche*
A Geostatistical Approach for Mapping the Geogenic Soil Gas Radon Potential in a South Italy Area	*Gabriele Buttafuoco*
A Non-Parametric Density Algorithm of Classification Applied to Augering Data from a Detailed Soil Survey	*Annamaria Castrignanò*
Using Geostatistical Analyst in Hydrochemical Data Processing – Study Case: Teleorman-Calmatui Interfluve's (Romania)	*Doina Dragusin*
Geostatistical Analysis of Soil Surface Microtopography Decay under Simulated Rain	*Glecio Machado Siqueira*
Determining spatial structures of SOC in woodlands of Southeast Tanzania in the framework of the Clean Development Mechanism.	*Joni Rossi*
Heavy Metals in European Soils: a Geostatistical Analysis of the FOREGS Database	*Luis Rodriguez Lado*

Pedometrics 2007 - Poster Presentations

Poster Session 2

- Sampling, Soil Sensing, Uncertainty, Mixed Topics -

Assessment of the Impact of Support Choice on Soil Mapping	*Christiano Ballabio*
Determining an Appropriate Interval for Soil Sampling Prior to Geostatistical Mapping	*Ruth Kerry*
Sample Design Optimizing for Joint Estimation of Multiple Soil Variables	*Radim Vasat*
Monitoring the Variation of Soil Water Content and Soil Bulk Density at the Plant Root Zone at Ile-Ife, South West Nigeria, using Dual-Energy Gamma-Ray Transmission Technique	*Oladipo Adejumo*
Relative Assessment of Visible, Near Infrared and Combined Spectroscopy for Predicting Various Soil Properties	*Hamoudazag Aïchi*
Mapping Patterns of Surficial Properties of Soils in the Negev Desert, Israel, Using Soil Profile Database and Remote Sensing Data	*Onn Crouvi*
Spectral Signatures for Soil Carbon: Assessment of Total, Recalcitrant, Hydrolysable and Dissolved Organic Fractions	*Sabine Grunwald*
Using a legacy soil sample to develop a mid-IR spectral library	*Raphael Viscarra-Rossel*
Interpretation of Soil ECa Measurements at Landscape Scale	*Jürgen Kühn*
Airborne Radiometric Survey Data and a DTM as Covariates for Regional Scale Mapping of Soil Organic Carbon Across Northern Ireland	*Barry Rawlins*
Predicting Soil Moisture Characteristics Using Mid-Infrared Spectra and Pedotransfer Functions: The Pros and Cons	*Grant Tranter*
Using Wavelets to Preprocess and Compress Soil Diffuse Reflectance Spectra for Multivariate Calibrations	*Raphael Viscarra-Rossel*
Using Sequential Gaussian Simulation to Assess Spatial Uncertainty of Soil Moisture Content in Lower Austria	*Masoomeh Delbari*
Inherent Uncertainty As a Physical Restriction for Soil Quantification	*Sergey Koptsik*
Statistical Probability Models of Soil Properties (One Example of Chestnut Soils in the South of West Siberia)	*Irina Mikheeva*
Exploitation of Supervised Fuzzy K-Means Classification for Soil - Landform Relationship Description	*Vit Penizek*
3D Digital Soil-Geology Models of the Near Surface Environment	*Andreas Scheib*
Shallow landslide susceptibility modelling - A comparison of different approaches for the coast of Jasmund Peninsula (Rügen/Germany)	*Christine Thiel*
Comparison of Magnetic and Geochemical Analyses of Czech Soils	*Jan Kopac*
Parent Materials and Land Use Effects in Population Frequency Distribution Parameters of Selected Soil Variables (A Case Study is South Part of Ahar Region)	*Farzin Shahbazi*
The Quantity and Form of Soil Organic Carbon in UK Urban Areas	*Barry Rawlins*
Scale-dependent Accuracy of Land Quality Maps Designed for Risk Area Identification in the EU Soil Framework Directive	*Volker Hennings*

Keynotes

Developing Pedometrics: A History and Geography of Ideas

McBratney, A.B.

The University of Sydney, NSW, Australia

I have been asked to deliver this talk as the recipient of the Richard Webster Medal which I am very honoured to do. I think development in science comes largely from creativity and serendipity. Both are helped by effort:- the well-known 99% of perspiration. Concentrating on the creative aspect of development, I will examine several ideas in pedometrics which I have pursued with my colleagues. I will give a rationale for them, gives examples of their use, and speculate on where they have taken us, and where they might take us. From this might stem some generic approach to problem formulation and solving in, or using, pedometrics.

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Effects of Neighbourhood Size on Terrain Derivatives and Digital Soil Mapping

Zhu, A.-X.*[1,2], Burt, J.E.[2], Gao, J.[2], Qin, C.[1], Yang, L.[1,3]

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Many terrain attributes, such as slope gradient, slope aspect, profile curvature, contour curvature, are computed from digital elevation model (DEM) over a neighbourhood (spatial extent). The need of this neighbourhood is just for defining the mathematical function approximating the surface but more importantly is to capture the geographic meaning of these attributes. Methods currently available for computing these derivatives in popular GIS software (such as ArcGIS) tie the spatial extent to the resolution of the DEM used. With the increase of spatial resolution of DEM, the spatial extent decreases. When it decreases to a certain level the geographic meaning of these terrain derivatives is lost. This paper illustrates this effect by examining the combination effect of DEM resolution and neighbourhood size on the computed terrain derivatives and the impact of this combination on digital soil mapping. We employed a least-squares regression polynomial approach for computing terrain derivatives over a user specified neighbourhood size. The method first creates a least-squares regression polynomial to produce a filtered (generalized) terrain surface over a user defined neighbourhood. Slope gradient, slope aspect, profile and contour curvatures are then computed by analyzing the fitted polynomial (the filtered terrain surface). To examine the effect of combination of DEM resolution and neighbourhood size on terrain derivatives, we employed different resolution of DEM with various neighbourhood sizes. The combination effects were examined in two steps. We first compare the computed terrain derivatives (slope gradient in this case) at different neighbourhood size for each resolution of DEM with the slope gradient values measured by the field soil scientists in the field. We then examined the impact of DEM resolution and neighbourhood size on the accuracy of digital soil mapping under the context of knowledge-based digital soil mapping (SoLIM). Case studies in two Wisconsin watersheds show that the dif ference between the field observed gradient values and the computed ones is at the smallest at neighbourhood size of 100 feet and that the resolution of DEM has little impact on the difference. The accuracy of the soil map, produced from knowledge-based digital soil mapping approach in which terrain derivatives play a major role, first increases as the neighbourhood size increases. It reaches maximum at neighbourhood of 100 feet and then decreases as the neighbourhood size increases after that point. DEM resolution again does not seem to impact the accuracy of the soil map very much. This study concludes that, at least for knowledge-based soil mapping, the DEM resolution does not seem to be as important as the neighbourhood size in computing the needed terrain derivatives, as long as the DEM resolution is finer than the optimal neighborhood size.

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On Not Data Mining in Pedometrics

Lark, R.M.

Environmetrics Group, Rothamsted Research, Harpenden, Herts. U.K

In this talk I shall consider some of the issues in statistical inference that arise when we use the power of computers to find predictive statistical models for soil properties. I shall demonstrate some of the hazards of selecting predictors by automated methods of inference, using simulation.
Recently it has been proposed that these problems might be mitigated using the methods of False Discovery Rate (FDR) control (Bunea et al., 2006). I shall demonstrate this approach and discuss its relevance in digital soil mapping and the development of pedotransfer functions (Lark et al., 2007).
Finally I shall consider the implications of these questions for the use of Data Mining techniques such as CART and Neural Networks in Pedometrics.

Bunea, F., Wegkamp, M.H., Auguste, A., 2006. Consistent variable selection in high dimensional regression via multiple testing. Journal of Statistical Planning and Inference 136, 4349–4364.
Lark, R.M., Bishop, T.F.A., Webster, R. 2007. Using expert knowledge with control of false discovery rate to select regressors for prediction of soil properties. Geoderma 138, 65–78.

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Sampling for Soil Survey and Monitoring. Examples from the Netherlands

Brus, D.J.

Wageningen University and Research Centre, The Netherlands

Several case studies will be presented, illustrating that different aims of study ask for different sampling strategies. Two case studies concern sampling in space. The first one deals with estimating cumulative frequency distributions of contaminants in the soil of the Netherlands, the second one with mapping nutrient concentrations in the soil of a field of approx. 2 ha. For the first aim a design-based approach, involving probability sampling is the best choice, whereas for the latter aim a model-based approach with purposive sampling is preferable. Special attention will be paid to the use of prior information in the form of observations at points or spatially exhaustive information on (maps of) covariates in the sampling design. A third case study concerns sampling in space and time, aiming at estimation of the current spatial means and change of spatial means between successive sampling rounds of soil acidification parameters under forest in the province of Utrecht. Sampling locations are selected by probability sampling, whereas sampling times are selected purposively. In space-time the pattern is rotational, more specific 50% of the observations of a given sampling round is replaced by new ones in the next round. Finally I will discuss the estimation of the average change per time unit (year) for this sampling design, and alternative combinations of probability and purposive sampling in space and in time.

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Talks

Comparing Sampling Patterns for Kriging the Spatial Mean Temporal Trend

ter Braak, C.J.F.[1], Brus, D.J.*[1], Pebesma, E.[2]

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In monitoring the environment one often wishes to estimate or test the temporal trend in a variable that varies across a region. A useful executive summary is then the temporal trend in the spatial mean of the study area as a whole or of subregions. In this paper the best linear unbiased predictor of the spatial mean temporal trend and its variance are derived under a universal kriging model. Five samples of equal size and different pattern in space-time are compared in terms of this universal kriging variance: 1) static-synchronous with a sampling interval of one time unit (year); 2) static-synchronous with a sampling interval of five years; 3) synchronous (dynamic); 4) rotational; 5) 4-period synchronous (serially alternating) (terminology after de Gruijter et al., 2006). The patterns differ in number of revisits of a site, the time-spacing between revisits, and in the geographical spacing between the sites of a given sampling round. In static-synchronous sampling all sites are revisited in all sampling rounds, in synchronous sampling no sites are revisited, and in rotational sampling some sites are revisited, i.e. a part of the sites is replaced by new ones. In the 4-period synchronous sampling, after four sampling rounds no new sites are selected anymore, and the sites are resampled in the same order. These patterns are compared in a square area of 100 x 100 space units (meters), monitored during a period of 16 years. The sample size is 144, giving nine observations per year. The autocorrelation in space-time is modeled by a Matérn covariance function with geometric anisotropy, combined with pure nugget. Spatial ranges varied from 20 - 200 meters, temporal ranges from 0.5 - 30 years.
For small spatial ranges, a static-synchronous pattern with sampling interval of five years is optimal, regardless of the temporal range. For larger spatial ranges, the best pattern depends on the temporal range. If the temporal range is small (less than 1/20 of the spatial range), then the static-synchronous pattern with sampling interval of one year is best. For larger temporal ranges (between 1/20 and ca. 1/4 of the spatial range) the 4-period synchronous pattern is best, whereas the static-synchronous pattern with sampling interval of five years is best for larger temporal ranges. The gain in using the 4-period synchronous pattern or the synchronous pattern with sampling interval of five years instead of the static-synchronous pattern can be substantial. The potential loss with respect to the static-synchronous pattern is only minor for the 4-period synchronous pattern, but can be substantial for the synchronous pattern with sampling interval of five years. Unless one has good knowledge of the spatial and temporal range, the 4-period synchronous pattern is thus a good choice.

J.J. de Gruijter, D.J. Brus, M.F.P. Bierkens, M. Knotters (2006) Sampling for Natural Resource Monitoring. Springer Verlag, New York.

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Using Projected Process Kriging and Ancillary Data to Determine Efficient Soil Sampling Schemes for Geostatistical Analysis

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Kriging involves inverting matrices. The computation necessary to invert a matrix grows as O (n3) where n is the number of data points. In the machine learning community and for applications requiring real-time mapping of data from large monitoring networks, methods have been sought to reduce the computation time involved with kriging. One such method, projected process kriging (Ingram et al. 2007), measures the variation in the data and projects excess observations onto a representative subset of the data minimizing any loss of information. This means that the computational complexity only grows as nm2, where n is the total number of observations and m is the size of the subset of the observations retained for prediction. Therefore computation time for large data sets can be markedly reduced.

Soil scientists rarely have too many data unless ancillary data are being used to infer soil properties. Soil samples should always be collected and analyzed for proper interpretation of ancillary data as relationships with soil properties can be complex. Considerable research has focused on investigating different sampling configurations and intervals. For geostatistical analysis samples are usually collected on a grid or a nested grid. McBratney et al. (1981) showed that a sampling interval with a given error can be determined from an existing variogram of the property of interest, but this would require an intensive reconnaissance survey. Kerry and Oliver (2003) suggested that because variograms of certain types of ancillary data show similar scales of variation to more permanent soil properties, half the range of these can be used as a suitable sampling interval to make sure the scale of variation is captured. However, when sampling intervals are large some patterns of variation in the soil can be missed due to the configuration of sampling points (Frogbrook and Oliver, 2000).

A reliable variogram is required for kriging but computation by the method of moments requires about 100 samples (Webster and Oliver, 1992) which is beyond the budget of many surveys. Some (Lark, 2000 and Kerry and Oliver, 2007) have suggested that the Maximum Likelihood (ML) variogram can be computed reliably with fewer samples (50-60), but it has more restrictive assumptions and is not as commonly used. Also the best sampling scheme for computing ML variograms with fewer samples needs further investigation.

Our study aims to show how projected process kriging can be used with dense ancillary data to identify the 50-60 sample locations that are most informative for computing an accurate ML variogram. Soil samples were collected on 30-m grids in several fields in southern England. Ancillary data for these fields was used to select points from the 30-m grids for calculating ML variograms. The parameters of these were used for cross-validation and compared with the results from variograms from the original 30-m data. Kriged maps produced using the ML variograms and sparse soil data were compared with those from the original 30-m data to see if the main patterns were retained.

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Instance Selection and Classification Trees Analysis for Large Datasets in Digital Soil Mapping

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Decision tree based predictions are promising and important techniques in the field of digital soil mapping. It is a robust prediction technique widely used in many environmental disciplines, like ecology, remote sensing and pedometrics. Yet, handling large datasets can be inefficient in terms of computation time and prediction accuracy.

In contrast to most studies which encompass less than 200 soil observations, digital soil class predictions can easily comprise several thousand to millions of training "samples" if the prediction is based on gridded spatial datasets where every pixel serves as a separate sample. Thus, instance selection (Liu and Motoda 2001) is an important pre-processing process in machine learning to reduce computation time while preserving or increasing prediction accuracy. The latter can be achieved due to removing noisy and/or redundant information. On the other hand, instance selection can lead to a trade-off between sample size and prediction quality. Thus, we compare different sampling designs to validate the impact of instance selection on a digital soil class mapping task.

We applied proportional and disproportional stratified random sampling schemes with 7 different dataset sizes on 6 soil classes based on a cross-validated decision tree approach. To compare the results we used both the prediction accuracy in the training and the validation area.

Additionally, we applied grid learning procedures to analyse the classification tree algorithm. Grid-learning or grid-search is a simple method to find the best parameter combination for modelling in a n-dimensional space. Thus, optimized combinations of parameter settings and sample sizes can be provided.

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Total Regressions in Trend and Transfer Function Analyses

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Ordinary regression analysis is used extensively in soil research. In its simplest linear form it is even implemented widespread in worksheets, even more so in mathematical and statistical packages, and is based on the assumption that only the target variable is subject to error/variation, whereas all other variables are represented by exact values. However, with soil measurements there is always intrinsic scatter in addition to measurement errors in most soil variables. The contribution of intrinsic scatter (natural variability) is often notably larger than the measurement error. Moreover, the variability is a fundamental, inherent feature of soil and can not be removed even in theoretical ideal experiments. When ordinary least squares regression is applied for parameter estimation, it is well-known that the estimates turn out to be biased, and this bias term can never be completely removed. Because such problems were recognised long ago, different errors-in-variables methods were developed, and have received considerable attention in different branches of science during the last decades. These methods are however, still rarely applied in soil research. In the absence of fundamental (process based), quantitative relations, statistically derived (pedo) transfer functions, are used rather often. Neglecting intrinsic variability and measurement errors bias the derived slopes of these empirical relations, thus potentially leading to incorrect deductions.

Pedotransfer functions are mathematical relationships between soil parameters, which show a sufficient level of statistical confidence and are used to derive unknown parameters from the measured ones. Pedotransfer functions are most often used to predict soil hydraulic characteristics; different soil chemical and biological characteristics have also been related. In the present work ordinary and total multivariate linear regression models are applied to solid–solution partitioning of heavy metals in soils, models that de-facto became a standard in risk assessment studies. Here dependencies between mobile and total heavy metal concentrations are searched in relation to other soil variables, such as pH, organic matter and clay content, considering concentration variables at logarithmic scale. The difference between the two approaches results not only in different slopes, but also, fixing the acceptable level of confidence, in qualitatively different models chosen. The use of total regression for such type of models is obviously preferable, as variations/errors for different chemical variables are often compatible, and quite close for the solid-phase metal forms. Another and not the least practical advantage is that direct and inverse regressions for the developed total regressions do coincide, exactly as the user is accustomed when working with deterministic functions. Changes in intercepts with change of measurement units also can be more reliably predicted. The practical significance of the concept is important for environmental monitoring, ecological risk assessment and soil remediation.

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Spatial Prediction of Water Influenced Soil Parameters Using Dempster-Shafer Theorem by Multitemporal and Multimodal Captured Conductivity Measurements as Basis for Root Growth Modelling

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With the technology of Precision Farming a management instrument is available which can be used to react precisely on crop and soil heterogeneity. In connection with this, the spatial analysis and modelling of root growth with particular emphasis on soil and plant water effects strongly influences variable rate management strategies on the fields. The rooting depth defines the space from which the crops save their nutrient and water uptake by the roots and so affects the plant growth and the crop yield in conjunction with climatic conditions. Previous Pedo-Transferfunctions (PTF) in Germany to calculate the effective rooting depth are based on static methods. Input data for the PTF are the texture class, the humus content and the bulk density of the soil strata. Particularly the vertical integration of complex soil stratifications is not solved satisfactorily. The PTF do not sufficiently consider lateral water fluxes and do not calculate the capillary rise from the ground water with precision. The correlation between the calculated rooting depth by the above mentioned PTF and the measured rooting depth in the field is 0.2. Therefore, it is necessary to develop dynamic PTF. For the investigation of the research fields, we used multi temporal and –modal captured EM38 measurements as co-variables to discriminate soil water induced differences of potential root growth. This concept is based on the idea that, with increasing drying out depth during the vegetation period, the conductivity will decrease. We focused on the technique of the Dempster/Shafer theory, an extension of the Bayesian probability theory, to predict spatial soil parameters under consideration of diffuse lateral water influxes. As a result of this approach, extreme dry areas in the field got up to 20 % less of the calculated rooting depth of the PTF, softly dry areas in the field 30 % more, fresh areas are neutral and wet to very wet areas up to 20 % less. Regarding Gleysols, the upper border of the reduction horizon is the ma ximum rooting depth. The correlation between the predicted rooting depth and the measured rooting depth is increased from 0.2 to 0.8.

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Assessment of Total Soil Carbon and Soil Carbon Fractions at the Watershed Scale Using Geospatial Upscaling Techniques

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There is an increasing demand for cost-effective and accurate methods to create digital maps of soil carbon (C) pools in order to assess carbon sequestration potential at the landscape scale. The objective of our study was to create maps of five different carbon attributes (total, recalcitrant, hydrolysable and two dissolved organic carbon fractions) based on their interaction with ancillary landscape environmental data. Sequestration of carbon into long-lived soil carbon pools is sought as an alternative to offset the increasing concentration of CO2 in the atmosphere. It typically involves movement of fixed carbon into the stable recalcitrant pool from the smaller labile pool which has greater relative exchange with the atmosphere. Our approach targets multiple aspects of soil carbon and provides a comprehensive assessment of how different biogeochemically active carbon pools interact with the landscape through its environmental attributes in a wide variety of soils.

We used 141 soil samples collected at four depths in the Santa Fe River watershed (SFRW), comprising 3,585 km2, in north-central Florida. Samples were collected following a random design, stratified by soil order and land use. The environmental properties selected for this study included: digital elevation model and derived topographic properties, Landsat ETM+ imagery and derived indices and reflectance transformations, soil, climate, land use, and geology data, acquired from various data sources. Soil samples were analyzed for total C, hydrolysable labile C, mineralizable C, and dissolved organic C at two fraction sizes (< 0.2 µm and < 0.7 µm) by hot water extraction. Stable recalcitrant C was calculated as the difference between total C and hydrolysable C. Parametric and non-parametric multivariate regression methods were used to relate soil C to environmental variables. Different sets of environmental predictors were tested for multivariate model development. Regression kriging was applied to account for the random variability left in the residuals from the multivariate global trend model.

We based our soil landscape model in well-known conceptual models of soil formation and included a wide variety of environmental explanatory data. We hypothesize that human factors like land use/land cover are more influential in the concentration of carbon in the soil then natural factors, such as topography or climate. Understanding the lability/recalcitrance of soil carbon is important to assess future gains/losses across larger landscapes.

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Mapping Soil Colour from Munsell Colour Chart Codes

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Munsell Colour Chart codes have been used for description of soil profiles since the beginnigs of soil survey. Soil colour is one of the easily determined soil characteristics – the correct designation can be quite fast and does not require special training. Soil colour code can then be used to directly infer about the occurrence of diagnostic properties and to estimate organic matter content, minerals, pH and other characteristics. So far, nobody has dealth with the problem of creating maps of soil colour from the Munsell codes at point locations. This paper presents a comparison of techniques to produce maps of soil colour in RGB bands over the whole area of interest. The Munsell Colour Chart codes were transformed to RGB values, then to HIS and CIELAB values and then finally interpolated using regression-kriging with DEM parameters, soil map units and Landsat bands as auxiliary predictors. The interpolated values are then back-transformed to RGB values to display the soil colour as seen in the field. The techniques have been compared using three study areas coming from different landscapes.

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Spectral Soil Material Classes

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Conventionally, soil horizons and layers are recognised in the field by contrasts in colour, texture and structure. There is an argument that soil horizons are a fundamental individual. Horizon classes are now recognised in soil classification systems such as the World Reference Base and the Référentiel Pédologique and of course a subset—the so-called “diagnostic horizons”—are recognised in soil taxonomy. Many years ago, FitzPatrick (1967) set up a taxonomy of soil horizons.

It would be useful if we could objectively and quantitatively recognise such classes in the field. The visible, near-infrared and mid-infrared spectra from diffuse-reflectance spectroscopy offer the possibility of rapid characterisation of soil properties. In addition, Palacios-Orueta and Ustin (1996) investigated the use of remotely-sensed imagery for obtaining these spectra. If we consider the spectra to be a fingerprint of the soil material, then perhaps they can be used to identify soil horizon classes.

In this study, we have taken 2800 soil horizon specimens and obtained their MIR spectra. The horizon specimens have come from 286 soil profiles in the Hunter Wine Country Private Irrigation District in the Hunter Valley of New South Wales, Australia. Using a slightly modified version of the fuzzy k-means algorithm, we have created a set of spectral soil material classes. We are currently investigating the spatial distribution of these spectral classes and the potential for rapid identification of new specimens.

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Soil Data Simulation for Landscape Modelling

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Landscape dynamic modelling approaches of soil processes, combining soil landform and land management complexity, have become increasingly common in soil science research. Those approaches require accessing diverse spatially explicit input data. Soil characteristics can be provided by soil surveys. However at the landscape scale, the information may be incomplete, too sparse or heterogeneous. The alternative is to use spatial simulation techniques which enable to produce the pattern of soil characteristics over a whole landscape. The objective of this work was to develop procedures to generate virtual soil landscapes, which combine several soil characteristics and comply with spatial structures that occur in a real landscape. Soil simulation is integrated as input of a landscape model driving soil organic matter dynamics. Simulations were based on topography, the field map, and the soil survey of an actual 12-km² agricultural landscape located in Brittany (western France). We focused on three main characteristics of the soil organic layers: thickness, soil organic carbon stock and texture. Geostatistical analyses were conducted and existing relationships established from empirical studies were used to assess the spatial variability of each characteristic and the correlation between the characteristics at different spatial scales. Stochastic simulation methods were used to generate simultaneously virtual maps of several soil data, taking account of the co-variations between the characteristics and of relationships between soil organization topography, landscape features and land-use.

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Soil Profile Distance Measures and Classifications

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The quantitative grouping of sequences of soil layer descriptions into soil profile classes has not been developed much since the 1960's with the exception of the work of King and Girard (1988).
Here we tackle the problem from pedological, utilitarian and joint points of view. A Web Based Application, OSACA, has been developed for this purpose. It calculates the taxonomic distances between observed profiles based on layer (horizon) characteristics. Characteristics can be either observed soil properties or layer class memberships.
The inter-profile distance is calculated in three ways: 1/ pedological distance, this focuses on the sequences of layers with scant regard to thickness, 2/ utilitarian distance, the metric is weighted by the layer thickness 3/ joint-distance, a combination of the pedological and utilitarian distances (the metric includes the relative layer thickness).
Given the inter-profile distance matrix, OSACA then proceeds to either allocate profiles to existing classes, or create a new classification of the profiles. The pedological distance is maybe more useful for creating classes for pedogenetic and geomorphic studies, whereas the utilitarian distance is maybe more useful for environmental applications. The methods are described for a set of soil profiles for New South Wales Australia.

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Non-stationary Variance Models for Kriging Soil Properties

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Geostatistical mapping of soil is based on the assumption that observations are a realization of a random function. This random function must be modelled, conventionally on the assumption that it is stationary in the mean and the variance. If the assumption of a stationary mean is not plausible (e.g. there is a pronounced trend) then we assume that our data conform to a linear mixed model (LMM) in which the mean is described by a function of either the spatial co-ordinates or some ancillary variable. The remaining variation is described by a random effect in the model, and the parameters of this random effect must be estimated by Residual Maximum Likelihood (REML) to minimize bias.

The assumption of stationarity in the variance remains, and could break down in two ways. First, the autocorrelation might vary in space. In some parts of a landscape the random variable might be correlated only over short distances, while in a different part of the landscape, maybe in a different geomorphological regime, autocorrelation is seen over longer distances as well. Second, the variance of the random function may vary in space, even if the autocorrelation does not.

Our problem is that nature only provides us with one realization of the random function, so we can only estimate its properties on the basis of some assumptions of stationarity. These assumptions might be restricted to a local window but such windowing procedures are arbitrary, and this approach may be impractical unless we have very large data sets. The contention of this paper is that the assumption of stationarity in the variance cannot be satisfactorily relaxed within the Matheronian framework of geostatistics, because this requires that we obtain point estimates of the variogram for lag bins prior to modelling, so the stationarity assumption is required from the beginning. By contrast, the LMM requires only that we can specify a positive definite covariance matrix for our data, or for our data and target points at which estimates are required. It is possible, in principle, to specify a parametric form for such a matrix without requiring stationarity assumptions, and the parameters of such a non-stationary variance model can then be estimated by REML.

Two sets of results will be presented for non-stationary variance models of data on the soil. In one the autocorrelation is assumed to be stationary, but the variance is not, and a parametric model of the variance is proposed and estimated by REML along with fixed effects to describe a non-stationary mean. In the second example non-stationarity in the autocorrelation is treated with a variance model which includes parameters of a bijective mapping of the coordinates of geographical space to a new space. In both cases the evidence against a null hypothesis of stationarity is evaluated with a likelihood ratio test, and the local kriging variance estimates at a test subset of the data and compared with those obtained with a stationary model.

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Robust Universal Krigin

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Robust statistics evolved in the 1970-80s in the quest for statistical methods that are not easily upset by outliers. Excepting variogram estimation, robust procedures are rarely used in the geostatistical analyses of environmental data even though such data are frequently tainted by outliers. There were many outliers in a data set on the cadmium content of the soils near a metal smelter in northwestern Switzerland. The emissions of the smelter and the geology controlled the spatial distribution of Cd, but displacement of polluted soil in the course of building works corrupted that pattern and was the main cause for the many outliers. The trend of log(Cd) was modelled by a linear regression where distance from and direction to the plant and information on geology and land use were the explanatory variables. The trend model was fitted by the highly robust MM-estimator. The least square fit of the model was less accurate and masked the outliers. Several ways were explored to control the influence of the outliers on the kriging predictions. In my presentation I shall explain the various approaches and discuss their pros and cons. An important conclusion is that robust estimation of the variogram on its own without special treatments of the outliers in kriging will not give much better predictions than the non-robust standard approach. Robust regression techniques and some modification of the universal kriging predictor are necessary to avoid that the outliers corrupt the predictions.

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Development and Application of REML Estimators for Contaminated or Multivariate Soil Properties

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In geostatistical surveys a soil property is commonly assumed to be second order stationary. It is often necessary to relax this assumption when the local mean of the property varies in space or with some auxiliary variable that is exhaustively sampled. In such a case the standard methods of moments variogram estimator is biased since it is influenced by both random variation and deterministic spatial variation and therefore an alternative estimator is required. The state-of–the-art solution is the residual maximum likelihood (REML) estimator (Patterson & Thompson, 1971). This estimator has been applied for individual soil properties where the residuals from the deterministic trend follow a normal distribution (Lark et al., 2006).

However we often wish to apply geostatistical techniques when the soil property exhibits more complicated behaviour. For example we may require an estimator which is robust to outliers in the sampled data which are due to a contaminating secondary process or we may wish to explore the coregionalization of a number of different observed soil properties (or of a single soil property observed at different times).

In the second order stationary case robust variogram estimators akin to the method of moments have been developed and linear models of coregionalization (LMCRs) may be fitted to multivariate data via the cross-variogram (for collocated data) or the pseudo cross-variogram (for non-collocated data). We expand the REML estimator so that these situations may be considered when the second order stationary assumption is relaxed.

We demonstrate that upon second order stationary simulated data our novel REML estimators are at least as accurate as their conventional counterparts based upon the method of moments. We see that when fitting the LMCR the REML estimator does not need to distinguish between collocated and non-collated data. We also present a number of case studies where our novel REML estimators are applied to soil data for which stationarity in the mean is implausible and hence the conventional estimators could not have been applied.

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Geostatistical Modeling of the Spatial Distribution of Soil Dioxin in the Vicinity of an Incinerator

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Deposition of pollutants around punctual sources of contamination, such as incinerator, can display complex spatial patterns depending on prevailing weather conditions, the local topography and the characteristics of the source. Deterministic dispersion models often fail to capture the complexity observed in the field, resulting in uncertain predictions that might hamper subsequent decision-making, such as delineation of areas targeted for additional sampling or remediation. This paper describes a geostatistical methodology to combine field data with the predictions of dispersion model. The approach generates a set of equally-probable maps of the spatial distribution of pollutants which can be post-processed to compute the probability that target thresholds are exceeded locally or on average over polygons of various size (i.e. census units). The methodology is used to delineate areas with high level of dioxin TEQ (Toxic Equivalents) around an incinerator in Midland, Michigan. The information available consists of: 1) 53 soil TEQ concentrations measured during sampling campaigns in 1980-1990s, and 2) air concentration and total deposition flux values (both dry and wet) predicted at the nodes of a 500×500 receptor grid (spacing = 50 m) using EPA Industrial Source Complex (ICS3) dispersion model. One hundred simulations of TEQ values were generated using sequential Gaussian simulation with local means inferred from the calibration of the output of the dispersion model. Simulated point values were then aggregated to estimate the probability that the average concentration at the census block level exceeds a negotiated threshold of 90 ppt. Blocks with the largest probability and population at risk were targeted for a recent soil sampling campaign. Analysis of the 51 new soil samples demonstrated the accuracy and precision of the model of uncertainty: probability intervals include a proportion of observations that exceeds what is expected from the model, while being narrower than intervals inferred f rom the sample histogram.

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Multi-scale Digital Terrain Analysis and Feature Selection in Digital Soil Mapping

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In this study we analyze the influence of terrain attributes in terms of scale extended topographic features on the spatial distribution of soils classes.
Concerning the prediction of soil class maps scale plays an important role in terms of prediction scale as well as the available training data. Furthermore soil formation and soil forming factors vary and respond on different scales. To provide a framework to evaluate and incorporate scale within the prediction approach we present a spatial data mining approach which helps analyzing both, the scale of soil classes and the predictive power of different terrain attributes on different scales. Therefore, a multi-scale digital terrain analysis approach based on multiple local average filters is proposed based on filter sizes ranging from 3*3 up to 31*31 pixels for a 20 m resolution DEM and a 1:50 000 soil map. Consequently, the feature space is largely extended, resulting in highly correlated features (terrain attributes). Thus, techniques to subsequently reduce the feature space in order to extract the relevant soil forming features are required.
The feature selection approaches evaluated are:

- two different principal components analysis approaches,
- two different ANOVA F-test techniques,
- and four different random subset approaches.

The prediction results which are based on a statistical classification tree verify that each soil responds on different scales as well as different attributes. Furthermore, the computationally fastest ANOVA-based feature selection approach is competitive in terms of prediction accuracy and the resulting condensed datasets eases the soil scientific interpretation. Finally, we conclude that multi-scale as well as feature selection approaches, yet, have not received the attention they deserve in the soil science community as both offer the possibility to learn more about soil formation in a spatial context and help to increase prediction accuracy.

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Using Machine Learning to Update Soil Surveys: A Case Study in Southeastern Ohio, USA

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Machine learning methods have been used for predictive soil-landscape model induction from existing soil maps in a number of digital soil mapping studies. Machine learning techniques can also be used to examine uncertainties in prior mapping to facilitate updates. Few attempts have been made to extract signatures of environmental correlates for digital soil mapping at the soil series or component level within map units of Order 2 US county soil surveys. Major challenges for updating these surveys to produce a seamless coverage include map unit contrasts across county lines, and disparate intensity, vintage, and quality of survey information between counties. Application of soil resource data by a variety of users, particularly land use planners, will be adversely impacted unless progress is made in developing more reliable and seamless soil maps.

Machine learning methods were used to build predictive models for two counties (Monroe and Noble) in southeast Ohio, USA where soil survey updates are in progress. Both counties are within a single Major Land Resource Area (Central Allegheny Plateau, MLRA 126), and hence have a consistent range of major environmental correlates. Models were based on 10m resolution raster datasets for terrain attributes, surficial geology, climatic attributes, and historical vegetation. Information on soil map units and associated environmental correlates were extracted by sampling from existent county soil maps, and associated geospatial layers.

A major challenge in developing training sets for machine learning from traditional county survey maps is the uncertainty associated with impure map units. In machine learning, such uncertainty can be considered as a type of “multiple label” or “ambiguous label” problem; each sample point within a map unit can be considered to possibly belong to one of several taxonomic components, and a general probability of each component (label) is known only for all occurrences of the map unit. Several methods were used to involve estimated component percentages to disambiguate training set labels for machine learning from the existing maps. Firstly, sampling methods were investigated to analyze and reduce noise in the spatial datasets. The most successful noise reduction resulted from spatially constrained sampling by buffering map unit boundaries and by rejection of statistical outliers in the training sets. Secondly, a sequential disambiguation of training set labels was effected by applying a k-nearest neighbor classification, followed by decision tree learning. Finally, the use of a cost-sensitive classifier was investigated.

A variety of machine learning methods were compared to build models from disambiguated training sets and models applied to all locations for the county, and alternately to the adjacent county. A Random Forest classifier proved to make the most useful map predictions. Within each county, model predictions proved useful for locating many individual components within map unit consociations and associations. Overlay of predictions and prior mapping provided information on areas of uncertainty in each county. Predictive mapping also provided information useful for assessing optimal map unit density and composition for updates.

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Soil Types Classification and Pollution Mapping with Machine Learning Methods

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The pollution of soils with heavy metals and radio-nuclides is a complex phenomenon. The interdisciplinary approach is often required in modeling. The measurements collected on soil pollution usually form a multivariate dataset which includes information of different kinds. These are the soil types, concentrations and radioactivity of pollutants which comes in the form of both "hard" and "soft" measurements, the related information on land cover type, etc.
Given the growing amount of such information, the algorithmic approaches to data modeling have developed rapidly last years. In particular the methods based on data mining and machine learning have been used in a growing number of applications. These methods follow a data-driven methodology, aiming at providing the best possible generalization and predictive abilities for the given task.
In this paper, the approach to multi-class classification of soil types with machine learning methods such as Probabilistic Neural Networks (PNN) and Support Vector Machines (SVM) is presented. The task is important for the modeling of radio-nuclides vertical migration, which properties are highly dependent on the soil type. The real case study deals with the data on Chernobyl accident, where high variability of environmental parameters and initial fallout at different scales highly complicates the solution of the whole problem of prediction mapping and risk assessment. Particularly, the official soil type maps do not provide sufficient information for modeling, while the information on soil types accompanies radioactivity level measurements and can be used for soil types mapping. The PNN and SVM methods are compared with the nearest neighbor method, the simplest baseline approach to spatial classification.

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Modelling Spatial Variability and Uncertainty of Cadmium Leaching to Groundwater for an Urban Region in Northern Germany

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Over the last 100 years soils in and around the city of Nordenham in northern Germany have received high loads of heavy-metals by air-borne immissions from a close-by metal smelter. Based on measured soil properties and cadmium-contamination data the leaching of Cd to groundwater in the Nordenham region was predicted using a deterministic transport model embedded into a stochastic framework. The main objective in this study was to account for the spatial variability and uncertainty of Cd-sorption controlling soil properties (pH, organic carbon content) and to analyze their propagation into uncertainty in local and area-related model outputs, i.e. Cd-breakthrough concentrations at the groundwater surface. For this purpose a two-dimensional (or "nested") Monte Carlo approach was used. Uncertainties in regionalized model inputs were estimated by multiple conditional simulation. Local scale numerical Monte-Carlo-simulations of Cd-displacement then were performed on a regular grid of single 1D random soil columns over the study area. This simulation strategy allowed a local evaluation of predicted Cd concentrations in soil and at the groundwater surface with regard to uncertainty from imprecise knowledge on local soil properties and spatial variation at the field scale. Additionally a spatially aggregated evaluation for single blocks at the field or plot scale (100 x 100 m) was carried out, yielding area-related concentrations with associated uncertainties from imprecise knowledge.
The validity of the transport model was tested by retrospective simulations from the initial operation of the smelter until the year of soil sampling. By comparing the modeled to the observed Cd-distribution in soil the transport model could be validated for undisturbed soils used as meadow land, while for areas with strong anthropogenic influence Cd-displacement was underestimated. Hence forecast simulations were run for meadow lands and a period of 200 years.
The simulated Cd-breakthrough concentrations at the groundwater surface show strong spatial variation even at the block scale. Spatial variability is superimposed by a high degree of predictive uncertainty. However, uncertainty does not question that the limit of the German drinking water ordinance of 5 µg l-1 will be exceeded significantly in the future on the majority of the regarded plots even for spatially averaged concentrations. Also the dates of the forecasted limit value exceedance show a distinct spatial variation and uncertainty which is mainly caused by the local depth of the groundwater surface and the sorption strength of the soils. On most of the plots, limit value exceedance can be expected within the next 50 to 150 years.

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The Temporal-Spatial Variability of Soil Organic Matter Contents in the Alluvial Region of Huang-Huai-Hai Plain of China

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The temporal-spatial variability of soil organic matter (SOM) contents was studied in the alluvial region of Huang-Huai-Hai Plain (HHH Plain), Quzhou County, Hebei Province, based on the analysis of the content change in the arable layers of the 124 sites sampled in 1980 and 2000, separately. The results indicated that the spatial variability of SOM became more randomly during the 20 years. According to the semi-variance spherical models, the nugget/sill ratio and spatial correlated distance changed from 0.57 and 33km in 1980 to 0.73 and 24km in 2000. The results indicated that the average SOM content of this district in 2000 was 12.89g kg-1, increased 46.8% in contrast with that in 1980 (8.78g kg-1). While SOM contents of 6% arable land in the county have decreased in the recent twenty years. The regional analysis showed that the accretion rates of the SOM in the southwest and the southeast regions were higher than that in the center region and the north region of Quzhou County. The SOM contents in 2000 for Fluvo-aquic soil, saline soil and drab soil increased 45.51%, 82.48% and 68.57% than that in 1980, respectively. The changing of SOM variation was probably caused by not only the variance of natural conditions such as soil and topography, but also the difference of agricultural management between different households, which were the basic management unit under the Household Contract Responsibility System employed in China's countryside since 1980.

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Uncertainty Analysis in Soil Sample Locations Within Digital Soil Mapping Approaches

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In digital soil mapping soil observations are linked to GIS layers of different environmental predictors via their spatial coordinates. The relationship between a target soil property and its environment is then quantitatively modelled and predictions are applied to locations in-between the original soil observations.
Many studies have examined the influence of the uncertainty of environmental predictors in soil landscape models. However, there might be a considerable uncertainty in the spatial coordinates of soil measurements, too. Even when localisation devices like a global positioning system (GPS) are used, uncertainties of up to 100 m might be possible e.g. the GPS device is not accurate enough, or on the other hand the forest canopy or highly variable terrain may affect the accuracy of GPS measurements. However, the spatial coordinates of soil observations are the basis for linking soil informations to its environment, and hence for deriving quantitative relationships between environmental predictors and the target soil property.
In this study we demonstrate the influence of shifting spatial coordinates on the prediction results. Therefore, we both randomly and systematically shift each point observation of a dataset in a n*n window around their original location, resulting in a number of new datasets each with a slightly different environment at the involved points. For each of the created datasets we developed a prediction model using the Random Forest algorithm, which is a combination of bagging and random feature selection. The influence of sample location uncertainties is then evaluated in terms of the overall prediction accuracies and the identification of specific areas with high impacts on prediction performance.

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Uncertainty Evaluation of PTF at Hillslope Scale

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Modeling soil hydrologic processes across different landscape elements is of prime importance for many studies applied to environmental and land-use planning problems. Nevertheless, the application of soil hydrological models at large spatial scales is often limited, chiefly because it requires the determination of soil hydraulic parameters that are difficult to assess by direct observations, especially over relatively large land areas. Pedotransfer functions (PTFs) are being developed as simplified methods to translate readily available soil data into parameters required by soil hydrological models. In this study we designed a general methodology for assessing the uncertainty in estimated soil hydraulic properties and simulated soil water budget resulting from the application of PTF at hillslope scale. The proposed procedure takes effects exerted by the spatial density of the available PTF input soil data also into account. Two sources of uncertainty are examined: (i) the error in estimated PTF input soil data and (ii) PTF model error. This methodology has been applied to an experimental hillslope in Southern Italy, where an intensive field campaign has been conducted to gather several PTF input soil data and soil hydraulic properties. A sequential Gaussian simulation algorithm is used to generate multiple equally probable images of PTF input soil data, consistent with the estimated spatial structure and conditioned to the measured soil core properties. Commonly used PTFs are then applied to evaluate the uncertainty in the predicted soil hydraulic properties. The predicted soil hydraulic properties are also employed into a soil-vegetation-atmosphere model to evaluate the uncertainty in the simulated evaporation, transpiration and soil water budget variation during a wet to dry transition season. With specific reference to practical directions when planning field campaigns, outcomes of this study suggest that the application of PTFs provide accurate and precise estimates of the soil water reten tion characteristic, transpiration flux and soil water storage variation at the hillslope scale even for a relatively coarse sampling resolution of basic soil hydraulic properties. The examined PTFs show worse level of performance when they are applied to predict the hydraulic conductivity and evaporation fluxes. In this case the PTF model error is much more significant than the input uncertainty, even at very high sample resolution. A major implication of the outcome obtained is that if one would reduce the prediction uncertainty of these quantities, the PTF model structure has to be improved prior of reducing the uncertainty in the PTF input soil data.

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Uncertainty Analysis of the GeoPEARL Pesticide Leaching Model

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GeoPEARL is a spatially distributed model describing the fate of pesticides in the soil-plant system. It calculates the drainage of pesticides into local surface waters and the leaching into the regional groundwater. GeoPEARL plays an important role in the evaluation of Dutch pesticide policy plans and has also been used to verify the current Dutch Pesticide Authorisation procedure. In this study we analysed how uncertainties in soil and pesticide properties propagate through GeoPEARL for three representative pesticides. The GeoPEARL output considered was the 90 percentile of the spatial distribution of the temporal median of the leaching concentration over a period of twenty years (P90). This is also the output used in Dutch policy plans and authorisation procedures. The spatial distribution is defined over all locations in the Netherlands where the pesticide may be applied. The uncertain pesticide properties are the coefficient of sorption on organic matter and the half-life of transformation in soil. Both were assumed constant in space and time and were represented by lognormal probability distributions. Uncertain soil properties considered were horizon thickness, texture, organic matter content, hydraulic conductivity and the water retention characteristic. Probability distributions were derived from meta-data stored in the Dutch Soil Information System. A regular grid sample of 258 points covering the agricultural area in the Netherlands was randomly selected. At the grid nodes, realisations from the probability distributions of uncertain inputs were generated and used as input to a Monte Carlo uncertainty propagation analysis. The results showed large uncertainties in P90, with interquartile ranges larger than the median for all three pesticides considered. Often the probability distribution also straddled the regulatory limit of 0.1 microgram per liter. Further analysis showed that the pesticide properties were the main sources of uncertainty and that uncertainty in soil organic matter c ontributed to a lesser extent. These results suggest that improved assessment of soil properties will hardly improve the accuracy of the predicted pesticide leaching. Instead, more accurate assessment of the pesticide properties is required, but this is not easy because these uncertainties in fact reflect the simplified process descriptions of GeoPEARL.

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Integration of Visible-Near Infrared Reflectance Spectroscopy and (Co) Kriging for Estimations of Soil Variables

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In precision agriculture, geostatistic and reflectance spectroscopy have been commonly used in explaining the spatial variability and in prediction of various soil parameters with various degrees of success. Characterizations of soils using reflectance spectroscopy is of interest because it allows for rapid analysis of large data sets and provides data that can be combined with spatial interpolation techniques. In this study, we evaluated VNIR spectroscopy and two geostatistics methods; ordinary kriging (OK) and cokriging (CK). The latter used both actual observation values and values predicted by VNIR spectroscopy as a covariable to predict various soil parameters. 512 soil samples were collected from a grid (800x400m) on a 32 ha field in the Tokat region of Northern Turkey. Soil variables considered were CaCO3, organic matter, clay, sand, silt (%), pH, electrical conductivity (EC, dsm-1) and cation exchange capacity (CEC), Ca, Mg, Na and K (cmolkg-1) content. R2 and Root Mean Square Error of Prediction (RMSEP) were used to evaluate the accuracy of predictions. VNIR and OK were compared using all 512 soil samples with one-out cross validation and also by systematically and randomly using 13, 25, 50 and 100 % of the grid data for calibration and the remaining 87, 75 and 50 %, respectively, for validation. Good VNIR predictions were obtained for CaCO3, SOM, Clay, Sand, CEC, exchangeable Ca and Mg and poor predictions for silt, EC, exchangeable K and Na using both techniques. VNIR gave better estimates for SOM, and slightly better for Clay and Sand while OK provided better results for CaCO3. Overall, the combined use of VNIR and Geostatistics through cokriging improved the prediction accuracy of soil variables by providing the highest R2 and lowest RMSEP values.

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Spatial Retrieval of Soil Reflectance from SPOT Multispectral Data Using the Empirical Line Approach

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The use of empirical relationships to calibrate remotely sensed data has been reported by many authors, but few studies were devoted to the specific retrieval of soil reflectance and most studies have used two calibration targets only, using few (≤ 5) validation targets to assess the error in the empirical relationships. Absolute corrections based on empirical line methods have seldom been applied to satellite data, particularly SPOT images. In this study, which deals with bare cultivated soils, the empirical line method was used to retrieve soil reflectance from 3 programmed SPOT satellite images with 20 m and 10 m resolution based on independent sets of 8 calibration and 15 validation field targets of bare soil. Root mean squared errors (RMSE) between corrected and measured values at calibration sites were lower than 0.53% for the two visible bands and ranged between 0.61 and 1.97% for the near-infrared band, whereas at validation sites they were all lower than 2.5% except for the near-infrared band of 23 March (3.86%). Errors could be due to changes in soil moisture and roughness related to soil management practices, or slight vegetation growth over the end of the study period. Such accurate results have been facilitated both by the flat topographical conditions of the Beauce region (Western Parisian Basin, France) and the homogeneous sky conditions in a small study area (2500 ha).

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Using Hyperspectral γ-ray Energy Spectra for Proximal Soil Sensing

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The development of proximal soil sensors to collect fine-scale soil information for environmental monitoring, modelling and precision agriculture is vital. Conventional soil sampling and laboratory analyses are time-consuming and expensive. In this paper we look the preprocessing of γ-ray energy spectra and the multivariate calibrations derived to predict various surface and sub-surface soil properties.

The spectra were collected with a proximal, on-the-go γ-ray spectrometer. We surveyed two geographically and physiographically different fields in New South Wales, Australia and collected hyperspectral γ-ray data consisting of 256 energy bands at more than 20 000 sites in each field.

Significant amounts of pre-processing were necessary to expose the correlations between the γ-ray spectra and the soil data. We first filtered the spectra spatially using local kriging then further de-noised, normalised and detrended them.

Bootstrap aggregation with partial least squares regression (or bagging-PLSR) was used to calibrate the γ-ray spectra of each field for predictions of selected soil properties. The resulting bagging-PLSR models of each field were tested using leave-one-out cross-validation. Robust predictions were obtained for clay, coarse sand and Fe contents in the 0–15 cm soil layer and pH and coarse sand contents in the 15–50 cm soil layer.

Proximally sensed γ-ray spectrometry proved to be a useful tool for predicting soil properties in different soil landscapes.

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Detection, Regionalization and Classification of Subsoil Compaction in Agricultural Loess Soils by Electromagnetic Induction Probing

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The regionalization of subsoil compaction on the field scale is still an open problem. This is mainly because selective and specific measurements for a location are representing only the local compaction state of the soil while ignoring the spatial variability of physical soil properties. Non-destructive probes, on the other hand, provide a better spatial resolution but do in general not show the state of mechanical stress. Apparent electric conductivity (ECa) is considered as an easy measurable parameter which is potentially able to detect inhomogeneities in the field which can, in turn, be used to select specific locations for subsequent investigations regarding the compaction state of the soil.
The fields under study are located south of Hannover, in the northwest of Germany. The site Schellerten is classified as weichselian loess (>1.8 m) over jurassic clay and the site Ruthe also as weichselian loess (>1.2 m) over quaternary gravel. An easy-to-apply method which measures the apparent electrical conductivity (ECa) of soil is performed with the EM38 probe (Geonics, Canada). Subsoil compaction was assessed by the penetration resistance (PR) (Penetrologger, Eijkelkamp, the Netherlands) from the soil surface down to 0.8 m soil depth with a vertical resolution of 0.01 m. We measured at approximately 10,000 locations the apparent electrical conductivity and at 5,000 locations the penetration resistance. Measurements were taken in April 2005 up to April 2007. Further, we used at the site Ruthe a Ground Penetrating Radar to add detailled information of soil discontinuities on a small scale.
Generally, the statistical range for ECa is always larger than the grid size of 2 to 5 m which was used for probing. The geostatistical range is about 12 m for Schellerten and 21 m for Ruthe. Contour plots from Ruthe show a clear structure of the ECa data indicating areas with higher absolute values at the margin of the field. Data indicate clearly the trend of a local maximum of PR in about 0.3 to 0.5 m depth at all sites and classes. Slightly higher PR values are observed for fall (lower water content) compared to spring, without affecting the general PR-characteristics. To access the degree of compaction, we defined a hydrostatic stress depth function with zero at the soil surface and the individual PR in 0.8 m. The compaction state of real soil, e.g. in the subsoil from 0.2 - 0.8 m depth, is indicated by the area between the measured PR depth function and the hydrostatic state (normal compaction), expressed by the factor MS (mechanical strength). The site Schellerten shows a much higher range of ECa values (20 -90 mS/m, compared to 15 –22 mS/m of Ruthe) but a strong correlation between MS and ECa. The additional results from the Ground Penetrating Radar (Ruthe) back the results from the PR measurement and partly the spatial variety of the ECa results.
Conclusions: (1) On apparent homogeneous loess sites ECa values can vary considerably. Regionalization with the EM-38 probe allows an easy and rapid definition of subplots for further detailed investigations. (2) The mechanical strengths of such subplots indicate that locations with higher ECa have in general higher PR values, indicated by the parameter MS. The parameter MS characterizes the deviation of the local compaction state from the non-compacted state at moderate water content variations, even for high variations of the apparent electrical conductivity.

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Pedodiversity of Southern African Drylands - Quantification and Implications for Biodiversity

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Soil as part of the ecosystem is strongly interrelated with plants and animals living on and in the soil. Consequently, soil properties influence the composition of the symbiosis. Vice versa, plants and animals may alter soil properties and have an impact on the edaphic geodiversity on various spatial scales. Both, biodiversity and edaphic geodiversity (pedodiversity) are to a great extent determined by geology, topography, climate and human activities. Within the BIOTA Southern Africa project the soil science subproject focuses on soil as an important environmental factor which is strongly interrelated with biodiversity. Our approach follows the general hypothesis that within a given area a higher variability of abiotic factors will cause an increase of biodiversity. The various edaphic properties not only influence biodiversity but can themselves be altered by organisms (e.g. fertile islands, round spots).

The future value of long-term monitoring of biodiversity depends on a number of prerequisites which have to be fulfilled. Besides the standardization of the procedures, the constancy and accessibility of investigated sites (observatories) and the documentation of data, detailed information on the abiotic properties of all sites are needed. Besides the pedodiversity (soil types, soil properties and their distribution) this includes topography, habitat structure, and geology as well as climate data.

Soils are an interesting component to look at because they reflect the influence of the main drivers for the ecosystem. Therefore, the soil properties could be used for abiotic diversity analyses and the detection of patterns and processes. The pedological database within BIOTA Southern Africa provides excellent possibilities for pedodiversity analyses with different tools. It contains 22 observatories with 527 profiles classified by the World Reference Base for Soil Resources. The classification was done with at least three attributes (qualifiers) for all profiles which enables comparative analyses at the same level.

The talk will present the results of two different procedures for the measurement of pedodiversity on a given area: a) using a taxonomic classification (WRB) and b) using a strictly parametric based classification. Both approaches are tested by the application of a set of diversity indices. Using this toolbox enables comparisons with the results of the biotic components and provides an integrative value of the soil diversity.

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On Effective Linearity of Soil Process Models during Spatial Aggregation

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Soil process models are often developed at a scale (e.g. the pedon) finer than that at which the output is needed and the inputs are available. If the model is linear with respect to its inputs, then predictions at the coarser scale can be obtained with the aggregated inputs treated as effective parameters. If the model is nonlinear, then this procedure gives biased estimates of the aggregate output variable. It is therefore necessary that we understand the behaviour of soil models in this respect. For more complex models, particularly those that are solved numerically, this is not a trivial task.

Several approaches have been suggested to assess whether models are linear in their behaviour, either based on observing the model response to a range of values of inputs and parameters or by comparing how the model behaves at different scales. Most soil models will not be strictly linear. The practical question is whether this nonlinear behaviour is practically important, given other sources of uncertainty.

We quantify model linearity by computing the weighted mean-squared deviations of the model output from a linear approximation, over the model's parameter space. We can then consider a model nonlinear if, for example, this number is in excess of the analytical variability for our data on model outputs. So for in a model deemed effectively linear, nonlinearity introduces no more uncertainty than the measurement error. As only a portion of the full parameter space is of interest in any given problem, we use as the weighting function a probability density function (pdf) for the model inputs. What we therefore obtain is an assessment of model effective linearity that depends on location (i.e. where we are in parameter space) and the variability within the units over which we are aggregating (and so their scale, there will be more variability within a soil map unit than within an agricultural field). This approach is then easily extended to more than one input parameter. The weighted lack of fit is obtained in multivariate space (plane, cube, etc) and the weights are obtained from the joint pdf's of the input parameters. The model may be linear with respect to one parameter or variable but nonlinear with respect to another. We also assess the contribution of any single input parameter to model nonlinearity by computing a lack of fit from a postulated linear response to this parameter given a mean (non linear) response to all other parameters. This allows us to identify parameters or groups of parameters for which the model is linear at a given scale.

We have applied this method to two case studies. The first consists of a model of ammonia volatilization in soil after urea application and the second is a functional model of leaching from soil (SLIM model). Where a model was not effectively linear, we were able to obtained different versions of these models by including/excluding modular components, 'lumping' certain input parameter combinations or replacing certain processes with simpler, functional models.

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On Measuring Pedodiversity

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Pedodiversity is a way of measuring soil variation usually using taxa. Soil scientists have pragmatically adapted the concept of biodiversity and used indices such as Shannon's index using taxa from well-accepted international soil classification systems.

This paper gives a rationale for pedodiversity measurement. It is argued that taxonomic distance needs to be incorporated into pedodiversity calculations to get an effective estimate. New measures of pedodiversity which take into account both information on the relative abundance and also the taxonomic differences between soil classes are introduced. We compare these measures with a number of well-known diversity indices and show their merits.

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Quantifying Soil Permeability through 2D Multifractal and Wavelet Approach

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With the advent of modern non-destructive tomography techniques there have been many attempts made to analyze pore space features mainly concentrating on the visualization of soil structure. Multifractal formalism and the wavelet transform have revealed as useful tools in these cases where highly complex and heterogeneous medium are studied.

Intact soil samples were collected from four horizons of an Argisol, formed on the Tertiary Barreiras group of formations in Pernambuco state, Brazil (Itapirema Experimental Station). The natural vegetation of the region is tropical, coastal rainforest. With different porosities and spatial arrangements have been obtained. From each horizon, three adjacent samples were taken having a set of 12 samples. The intact soil samples were imaged using an EVS (now GE Medical. London Canada) MS-8 MicroCT scanner with 45 mm resolution (250x250x250 voxels). Though some samples required paring to fit the 64 mm diameter imaging tubes, field orientation was maintained.

In order to described porosity structure a threshold value was applied to convert these images in binary and the number of pixels representing pores in a vertical projection was quantified (pore maximum depth, PMD). This approach creates a matrix with elements ranging from 0 to 250.

Based on these matrixes two analyses were performed: generalized dimensions and wavelet transform in 2D. In both of them correlations among the horizons and replicates were studied.

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Development of Knowledge on Soil-Environment Relationships for Digital Soil Mapping Using Fuzzy C-Means (FCM) Clustering

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For areas with no soil survey experts or soil maps available, knowledge about soil-environment relationships is a key to digital soil mapping using knowledge-based approaches. A methodology based on an unsupervised fuzzy clustering method (FCM, fuzzy c-means clustering) is studied to acquire the knowledge. The method consists of four steps. Firstly, environmental factors which play decisive roles in formation and development of soil at local area are derived, and an environmental database is built up from these environmental factors. Secondly, fuzzy membership maps are generated by running FCM on the environmental database and combination of environment conditions (environmental niches) are identified.
Then, field efforts are allocated on cluster centroids (in those areas with high membership values) to relate unique environmental factor combinations to soil types. Finally, the typical environmental conditions of each soil type and spatial series of soil type distribution are obtained, then a soil-landscape model is established. To assess the validity of the soil-landscape model constructed using the FCM approach, the soil-landscape model is used under the SoLIM (soil-land inference model) approach to generate soil maps for the area. The SoLIM approach combines the knowledge of soil-environmental relationships (soil-landscape model) with the environmental conditions characterized in a GIS to infer the spatial distribution of soils. The quality of the soil maps from SoLIM largely depends on the quality of the soil-landscape model. Thus, the SoLIM approach provides us with the opportunity to examine the method.
The method is employed in a watershed which is located in Heshan farm Nenjiang county Heilongjiang province China. Four environmental factors (Slope, planform curvature, profile curvature, and wetness index) were generated to build up the environmental database. Then knowledge on relationships between soil and environment were developed by FCM and a soil map at the subgroup level was created for the area. To validate the soil map, observations of soils at 45 field sites were made. The sites were selected in two ways, through regular sampling and transecting inspection. The field observed soil at these sites was then compared with the soil type obtained from the inferred soil map at these locations. Soil subgroups from the inferred soil map match field observed soil subgroups at 34 of the 45 sites, which accounts for about 76% of accuracy. Conventional soil maps of America typically achieved 50-60% of accuracy. The biggest scale in the 2nd Chinese Soil Survey is 1:50000. Few regions have bigger scale soil maps. There is no big scale soil map in our study area. In addition, the accuracy of transacting points was 80%, which indicated that the harden soil map could capture local variation of soil information as well as the overall soil information.
Therefore, we can conclude that soil mapping by using this methodology is effective. At the same time, the clustering results of environmental factors can improve efficiency of field sampling.

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An Object-based Approach for Fuzzy Soil Class Prediction

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The state-wide digital prediction of soil units is controlled by expert perceptions, the quality of input data and landscape heterogeneity which all influence the prediction uncertainty. Expert perception depends on soil landscape doctrine which can vary from state to state. Data quality refers to scales and semantics. Landscape heterogeneity affects the soil class variability.
The presented fuzzy expert system is similar on the interference approach of Zhu et al. (2001) and aims at the reproducible integration of existing soil and auxiliary data as well as expert knowledge. Reproducibility means that all steps of data integration are stored and can be changed if necessary. The expert system consists of two modules: (1) Within the transformation module, all soil and auxiliary data are transformed into so called 'soil category layer' (SCL) which are defined by specific value range. SCL represent soil-forming processes and properties like 'clay illuviation' or 'clay content' and characterise the soil units which should be predicted. SCL which represent the same soil-forming process are combined to layer-stacks whereas each layer can be weighted according scale and data quality. The layer-stacks are merged by interference operations into final SCL. Final SCL can also be used to assess data quality. (2) Based on final SCL the segmentation and classification module enables the delineation of soil objects and the definition of fuzzy soil units. The region-growing segmentation approach leads to multi-scale soil-object structures (Möller et al., 2007). This means that all objects are surrounded by neighbouring objects, and each object is related to larger and smaller scales via parent-children relationships. As a consequence each object carries a data set of information including attributes of statistics, neighbouring and hierarchical relationships which all can be used for soil class definition. The classified soil units are characterised by memberships which express core and transition zones.

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Predicting Spatial Distribution of Soil Properties: Fuzzy vs. Statistical Approaches

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Information on spatial distribution of soil properties is needed in many ecological modelling, land use planning, natural resource management and other geographic analysis. Currently, there are two main types of approaches in providing such information. One is the soil map-based approach and the other is the statistical/geostatistical approaches. The limitations of the soil map-based approach are that it requires the existence of soil map and that the so-derived soil property map is not only unrealistically discontinuous over space but also often incompatible with other detailed spatial data (such as data from digital terrain analysis and remote sensing techniques). The statistical/geostatistical approaches can produce spatially continuous soil property maps but these techniques are only suited for small areas due to its stationarity assumption and its dependence on large field data set. This paper presents an approach for mapping spatial variation of soil properties by combining fuzzy logic with prototype category theory. The approach first identifies prototypes of soil categories through purposeful sampling and treats these prototypes as the critical points of spatial variation of soil properties. It then maps the spatial variation of soil property by linearly weighting the property values at these critical points. A case study in Northeast China for mapping A-horizon organic matter content was conducted to illustrate this new approach. The case study shows that the new approach is more advantageous in predicting spatial variation of soil properties than the statistical approaches. Not only can it achieve higher accuracy but also needs much fewer field observations. In addition the established relationship is more portable than that captured by the statistical approach.

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Object-based Data Model for Digital Soil Mapping

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Vector or grid-based spatial data models are used within digital soil mapping. The input data layers of soil and environmental factors are either grid-based data of different pixel size or vector data with different minimal mapping unit or sampling density. Application of quantitative soil models combining number of predictors requires integration of the inputs into one common data model.

In this paper, object-based data model for digital soil mapping is proposed and its parameterisation is analysed. Objects refer to spatial segments that are separate regions of pixels, at defined level of homogeneity, or polygons. The definition of homogenous regions in geographic space is done by segmentation algorithm. The implementation with homogeneity criteria is defined by standard deviations weighted by object size. A scale parameter is used to control average image object size. The parameter is an abstract term, which determines the stop criterion for optimisation process. The choice of the parameter is related to spatial variation of the data. Spectral signatures of bare soil on 30x30 km area measured by Landsat 7 were used in the evaluation. Four different concepts were analysed, where the tested values of scale parameter ranged from 1 to 97. The optimal parameter setting was determined by (a) spatial dependence structure (nugget variation); (b) information content of objects (Harelik's GLCM entropy); (c) overall accuracy of classification by pre-defined fuzzy model and by qualitative visual interpretation.

The scale parameter determined by nugget variation resulted in model with rather small objects. This concept was considered to create objects that represent level of uncertainty at noise variation. Objects determined by Harelik's GLCM entropy showed exponentially growing function. Increasing the size of the objects increases the information through reducing the uncertainty to a maximum level. Practical segmentation parameter value was considered as a scale at which the function is at 95% of the maximum value. Overall accuracy of classification by pre-defined fuzzy model showed function with a local maximum that determines optimal parameter setting. This method showed clear results, however, higher sensitivity to the selection of reference polygons (boundary delineation) was experienced. Determination of scale parameter by qualitative visual interpretation of objects size is possible but subjective approach. The resulting range of scale values varied from about 6 to 30 depending on the choice of validation criteria. It can be concluded that the recommended value can differ by purpose of application and can be represented as a range of suitable values.

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Advanced Terrain Analysis for Digital Soil Mapping

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For application in Digital Soil Mapping (DSM) new developments in terrain analysis have been made. Besides advanced geomorphometric terrain and process parameters also new approaches for terrain classification have been developed. All methods are realised as modules for SAGA-GIS (SAGA is developed in co-operation with research group Geo-System-Analysis, University of Hamburg).

1. Advanced terrain parameters derived from Digital Terrain Models: As an addition to "local" terrain parameters (with defined spatial adjacencies for computing, such as slope gradient and aspect) several new variants of "relief intensity" have been realised. These variants offer amongst others conclusions about terrain symmetry and curvature (without "salt and pepper").

Enhanced structure lines as base for complex terrain parameters and to subdivide terrain have been realised: channel lines, crest lines and slope discontinuities. To supplement complex terrain parameters (with unforeseeable adjacency range for computing, such as drainage area) enhanced wetness index, solifluction index and relative altitude above/below channel resp. crest lines have been developed. Combined terrain parameters are combinations of complex terrain parameters. The combined parameters "terrain classification index" (combination of wetness index and altitude above channel lines) and "relative slope position" (combination of altitude above channel lines and altitude below crest lines) deliver a promising base for the regionalisation of soil properties by means of regression analysis and kriging.

2. New approaches for terrain classification: To deliver areas with homogeneous conditions for soil development (e.g. for calculating zonale regression equations and semi-variogram functions) a classification of terrain units is useful. If there is an insufficient number of soil profiles the classification of terrain in terrain units (relevant to soil properties) will serve as data base for DSM. A method for the pre-classification of terrain parameters is "increasing local contrast" in continuous data sets. Based on the contrasted terrain parameters a further method to identify discontinuities (natural breaks) in continuous grid data has been developed.

A selection of complex and combined terrain parameters is first pre-processed by increasing local contrast and by the identification of discontinuities and then classified by means of segmentation techniques to obtain geomorphometric terrain units. For the future it is planned to identify the geomorphologic content of the geomorphometric terrain units by using maps with geo-genetic content (e.g. small or medium scale geological maps).

3. Applying terrain analysis to Digital Soil Mapping (DSM): As the above presented terrain parameters and the approaches for terrain classification are quite new developments not every new parameter or terrain classification could be tested for DSM until now. Therefore a selection of applications of advanced terrain analysis in DSM shall be presented, e.g:

(i) Regionalisation of ground water depth based on complex terrain parameters and regression analysis (ii) Regionalisation of silt and sand percentages based on combined terrain parameters using zonale kriging (iii) Several terrain classifications to support DSM and conventional soil mapping.

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Mapping the Possible Occurrence of Archaeological Sites by Bayesian Inference

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Archaeological prospection aims at finding artefacts at or below the soil surface. Prospections are done by systematic surveys, but artefacts may also be found accidentally. Surveys that cover large areas are usually carried out by fieldwalking, trial trenching or other 'intrusive' techniques are used on smaller areas, usually when threatened by disturbance. As a consequence, the spatial configuration of sampling locations should usually be rather considered a result from opportunity sampling than from some form of systematic or probability sampling. Recorded find attributes in fieldwalking are usually the type of artefacts present, the period, spatial coordinates and some measure of concentration. Sometimes also the absence of finds is recorded.

In the past several attempts were made to construct so called 'predictive maps', for example for heritage management purposes. These often grossly simplify archaeological reality and its relation with the physical environment, ignoring important (spatial) parameters and sampling bias, and using inadequate spatial analytical techniques.

The archaeological record generally poses two problems in this respect: (i) the spatial configuration of the sampling points is often suboptimal for geostatistical mapping, and (ii) to make optimal use of field evidence, both negative and positive occurrences should be used when mapping the possible occurrence of findings. This is currently not the case.

Two kinds of predictive modelling are employed in archaeological research. The inductive approach is data-driven: an inference model is constructed using archaeological finds and spatial attributes mainly derived from landscape and soil data. When this inference model is applied, predictive maps can be made. The deductive approach is knowledge-driven: a spatial prediction model is built based on expert judgement. Both types of model may be validated with independent data. A major weakness of the inductive method is its dependency on the data configuration, while the deductive approach may show a strong personal bias and be less well portable to other areas. We have formulated a method to the map the probability of occurrence of finds taking into account full cover auxiliary information. The method is based on the Bayes' theorem and can be considered an extension to methods developed by Aspinall and Gorsevski et al.. Information on the presence and the absence is used to calculate prior probabilities which are refined with conditional probabilities for specified classes in the auxiliary information. The advantage of such method is that produced maps are easily updated if data from new surveys become available. We applied the method on (mostly fieldwalking) data from prehistoric hunter-gatherer findspots, both in an inductive and in a deductive context. The inductive approach consisted of a fuzzy k-means classification of available soil- and DEM-related attribute maps followed by mapping the Bayesian probability of the occurrence of findings. The deductive approach was implemented by doing the Bayesian calculations on an expert evaluation map of the same area. Both approaches were compared with a validation sample.

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Evaluating Two Scales of Polygon Soil Maps and an Electrical Conductivity Survey in Characterizing Within-field Soil Textural Variability

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Sustainable soil use and management requires a clear understanding of within field soil variability. Although proximal soil sensing has proven to be a valuable tool for this, the value of existing classical polygon soil maps cannot be neglected. In light of this the efficacy of different scales of classical soil maps to provide such information is worthwhile to be explored. Therefore, we conducted a study to evaluate the potential of two scales of polygon soil maps (1:5000 and 1:20000), covering the same area and using an identical legend, to describe soil texture in comparison to proximally sensed apparent electrical conductivity (ECa). A 16 ha farm land in the sandy loam region of Belgium was selected for this study. The subsoil of this area is composed out of tertiary marine (sandy to clayey) sediments whereas the topsoil is a quaternary niveo-eolian sandy loam deposit. The 1:5000 map identified 7 soil units with contrasting top- and subsoil textural classes, whereas only 2 soil units were identified on the 1:20000 map.

The top- and subsoil of the study field (0-30 cm and 50-80 cm) was sampled at 135 locations using a grid cum random sampling schemes and analyzed for texture. The topsoil texture varied from sandy loam to sandy clay loam, whereas the subsoil ranged from loamy sand to silty clay. Also the coefficient of variation of the textural fractions indicated larger subsoil variation in comparison to the topsoil. Both layers showed a well structured spatial variability with distinct spatial patterns, but these are different between the top- and subsoil. To evaluate the efficacy of top and subsoil textural characterization between soil mapping units and fuzzy ECa classes, we performed an analysis of variance. The complement of the relative variance, known as EMBED Equation.3 , was used as a criterion to evaluate the success of the three classifications of both layers. We found a poor classification of top and subsoil textural fractions by the 1:20000 soil map with EMBED Equation.3 less than 0.11. However, a larger EMBED Equation.3 value (approx. 0.3) was obtained for the 1:5000 soil map for top and subsoil clay contents. A fuzzy k-means classification of ECa produced much better result (EMBED Equation.3 = 0.45) for the subsoil texture, but it was less successful for the topsoil. These findings therefore indicate the usefulness of proximal ECa sensing for soil texture mapping and its complementarity to the classical soil maps, especially for characterizing subsoil properties.

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Bringing Soil Inference Systems to Life: Knowledge Structures, Error Propagation and User Interaction

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Soil inference systems have been proposed as a means of integrating the multitude of developed pedotransfer functions, offering potential as a means of predicting missing soil information or soil properties that are expensive or difficult to measure. Whilst McBratney et al. (2002) addressed some of the key conceptual features of the system, as yet no work has been presented on bringing soil inference systems to life. As such, this work looks at the development of a soil inference system, SINFERS and examines the systems mechanisms.

The systems knowledge structure is presented, where control knowledge is organized to effectively and efficiently utilise the systems working memory. We discuss the role and design of the systems rule-base with pedotransfer functions acting as knowledge rules for the system. We also present a method for identifying the 'best' prediction and a computationally efficient method for error propagation. In addition, links to government supported soil databases, ideas on the systems interface and user interaction are explored.

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Land Suitability Analysis for Selected Crops Using GIS and Multi-criteria Approach in Central Vietnam: Case study of Huong Binh Commune in Thua Thien Hue Province

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In Central Vietnam, many different soil types can be distinguished having great potentials for growing of fruit trees, industrial crops and forests. However in some areas, using of these land resources in general and in agriculture in particular is still spontaneous. Therefore, strategic tools for sustainable land use planning are necessary. The main problem for agricultural development is the lack of basic information on physical-chemical and topographic soil features, land use classification and farming system analysis.

Thus, the goal of this study was to investigate the applicability of the GIS techniques in combination with a multi-criteria approach for analysing the land suitability for certain fruit crops in Huong Binh commune of Central Vietnam.

At first, the databases for GIS analyses had to be developed. The data were obtained through scientific literature review, evaluation of expert opinions, interviews of local farmers, professional officers and other information of the local authorities. The crucial data sources were included in thematic maps and compared with land use requirements of the selected fruit crops. The suitability assessment in the studied area has been done in two ways: physical suitability evaluation and social-economic, environmental suitability evaluation.

On the basis of the established GIS databases, in the Huong Binh commune with a total investigated research area of 3,260ha, 35 land units could be distinguished after overlaying the thematic maps. Firstly, the classification of physical land suitability for citrus trees in that 35 land units revealed that there is no area of high-suitability level (S1) for citrus trees, the area of medium-suitability level (S2) is 1,240.34ha, and the area of low-suitability level (S3) is 1,559.06ha. The area of non-suitability level (N) is 460.57ha. The limitations of suitability included three dominant factors as soil type, soil slope, topsoil depth and two additional factors as soil texture and soil fertility. Next, for land units with physical suitability level S2 and S3 the classification of social, economic and environmental suitability for citrus trees was conducted according the multi-criteria approach. There were three main criteria and 17 sub-criteria applied for this analyses. The final result of this analyses shows that the area of level S2 is 1,327.42ha and the area of level S3 is 1,472.59ha.

Integration of GIS and multi-criteria approach for land suitability analysis could be a useful methodology for further research in Vietnam. This approach makes it possible to select suitable land use types and crops for each administrative unit at commune level. This helps to realize an effective agriculture development program, to increase inhabitants' income, to prevent erosion and soil degradation, to protect living environment and social sustainability.

Keywords: Land suitability, citrus trees, GIS, Central Vietnam.

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Use of Geostatistical Simulation Methods to Assess the Probability of Overland Flow Occurrence

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The soil saturated hydraulic conductivity (Ks) is among the most important state variables that control the partition of rainwater reaching the soil surface into flow-paths of either prevailing vertical or temporary lateral directions. Nevertheless only some measure of central tendency is commonly used for the Ks-based classification of near-surface flow paths, e.g. when the susceptibility to overland flow is evaluated in a landscape or parts of it, respectively. Our motivation was therefore to assess if the incorporation of the spatial structure of Ks into concepts of near-surface hydrology may lead to a more sophisticated consideration of soil water movement under event conditions.
We used datasets from two tropical rainforest ecosystems, comprising a montane and a lowland rainforest, where we measured field-Ks at three and two soil depths (n = 150/depth), respectively, via a combination of a design- and model-based sampling approach. Domain sizes differed between 3000 m² (montane rainforest) and 1.2 km² (lowland rainforest), but small-scale spacing was very similar.
We performed a structural analysis that constitutes a 'synthesis' of methodologies that occupy centre stage in a multitude of recent geostatistical publications: trend modeling, suitability of robust variogram estimators, and use of the Matérn function. We also explore anisotropy and estimate its significance via a bootstrap approach. The simulation is done after checking the bivariate Gaussian distribution of the transformed data, which helps to choose the appropriate simulation algorithm. We then use a 'threshold approach' to assess the probability of overland flow occurrence: we extract a 'threshold', e.g. the median or maximum of the maximum 30-minute rainfall intensities from rainfall data, which is available for both regions in 5 and 10-minute intervals for many years. Finally we display the probability of exceeding those 'thresholds' by means of probability maps.
We found strong trends, which were due to topography and to different land uses in the montane rainforest and in the lowland rainforest, respectively. In the first case, we removed the first order polynomial trend by linear regression, and in the second case we classified land-use categories and subtracted the category mean from the corresponding data points; the subsequent variogram analysis was done with the residuals. This revealed similar autocorrelation structures of log-Ks for both ecosystems, with very short correlation lengths in the topsoil which extend to double figures deeper in the soil. Since the Ks-data is log-normally distributed, we used the method of moments estimator after examining the median of the theta distribution (Lark, 2000). The smoothness parameter of the Matérn model indicates a very rough spatial process, and we used this model to fit the theoretical variograms. We are currently working on the anisotropy detection and started with the simulations, which in addition should evaluate the uncertainties of the structural analysis, e.g. the sensitivity of the simulation results to proper trend modeling or the choice of the variogram estimator.

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Accounting for Extensive Topographic and Pedologic Secondary Information to Improve Soil Mapping

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Soils are natural bodies which generally vary over space and time across landscape in a quite complex way. To assess and model spatial variability, most times, several variables are sampled in addition to the one used to quantify and describe the main phenomenon under study. One of the major advantages of geostatistics over simpler spatialization methods is that sparsely observations of the primary attribute can be complemented by secondary attributes that are more densely sampled. Incorporating secondary information generally leads to more consistent phenomenon under study. Various methods were developed for incorporating dense secondary information, among them multicollocated cokriging, which retains only the secondary data collocated with the available data of the primary variable, and simple cokriging with varying local means obtained as a function of the dense secondary function partitioned into crisp classes. The latter is also a simplified approach for nonstationary cases.

The objective of this paper was to prove, through a case study, how dense secondary information can be used to improve the estimation of the primary attributes via multicollocated simple cokriging with varying local means.

The study was conducted for the whole Province of Siena in central Italy, an area of about 3,820 km2. The heights above sea level range from about 300 m of the river valley floors to the 1,738 of Mount Amiata, with the nearly 1,000 m a.s.l. of Chianti and Cetona mounts. Main soil typologies are Cambisols, Luvisols, Regosols and Andosols on metamorphic and volcanic rocks, and limestone; Cambisols, Regosols and Vertisols on Plio-Pleistocene marine sediments. Soil samples were taken at 742 locations according to a sampling carried out after a landscape analysis based on thematic maps and photointerpretation and, among others, the following soil properties were determined: depth, particle size and available water capacity.

A multivariate geostatistical analysis was performed using four soil properties (depth, sand and clay contents and available water content). Elevation from a DEM of 20 m x 20 m resolution was added as auxiliary variable. Since all variables showed non-normal distributions, they were transformed through a gaussian anamorphosis and standardised to zero mean and unit variance. Then, a linear model of coregionalization (LMC) was fitted to the matrix of all experimental auto- and cross-variograms. The individual gaussian variables were interpolated using three different approaches: 1. cokriging of the four main variables; 2. multicollocated cokriging using elevation as secondary variable; 3. as the point 2 but using a simple cokriging with local variable means, estimated from the means in the soil unit present at each node of the interpolation grid. The estimates then were back-transformation to produce the maps of the raw variables.

All these methods were compared in terms of precision and accuracy through cross-validation and a validation test using an independent data set of 170 samples. Multicollocated simple cokriging with local variable means, which effectively utilises both secondary information, showed overall superior performance.

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Pedometrical Analysis of Soil Characteristics in an Area with Heavy Deposition Load

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Atmospheric deposition can strongly affect soil acidity as well as the content of potentially toxic elements. The region of Silesian Beskydy Mountains in the north-eastern part of the Czech Republic suffers from strong deposition in the past coming from iron and steel works concentrated in the area. The aim of this contribution is to analyse soil characteristics in this area using a combination of different pedometrical methods.

Soil samples were collected from individual soil horizons on 25 sites. In addition to basic soil characteristics (soil pH, humus quality parameter, available nutrients), content of potentially toxic elements (Cd, Cu, Mn, Pb, and Zn; 2M nitric acid extraction) and the content of mobile Al forms (extracted with 0.5M KCl) were determined. The relationship between the characteristics and the effects of altitude, aspect, forest composition, distance from local iron works, and other factors were analysed using multiple regression, principal component analysis, and geostatistics.

It is shown that the surface organic horizons are affected by the deposition the most. The deeper mineral horizons exhibit very small effects of deposition. Accumulation of lead in the surface organic horizons is fairly high. It increases with increasing altitudes. The effect of local iron works on soil pollution and its spatial distribution is clearly apparent. Nevertheless, simultaneous deposition of base elements (Ca, Mg) reduces soil acidification, decreasing thus the risk of heavy metal mobilization and release of potentially toxic Al forms. The effect of organic matter decreasing the mobility of Pb and toxicity of Al is shown. Difference between beech and spruce forest was also proved. Soils under beech forest had higher pH, smaller mobile Al concentration, but bigger Ca, Mg, K, Zn a Mn content compared to beech forest. Kriged maps showed the spatial trends of soil characteristics and pollution. Generally, the combination of pedometrical methods provided better insight in the data and influencing factors.

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Posters

Modelling Landslide Hazard, Soil Redistribution and Sediment Yield of Landslides on the Ugandan Footslopes of Mount Elgon

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In many parts of the east African highlands, landsliding as a geomorphological process is very important for understanding soil-landscape relationships and soil formation and redistribution in space and time. In this study, the LAPSUS-LS landslide model, together with a digital terrain analysis of topographic attributes, is used as a spatially explicit tool to simulate recent shallow landslides in Manjiya County on the Ugandan slopes of Mount Elgon. Manjiya County is a densely populated mountainous area where landslides have been reported since the beginning of the twentieth century. To better understand the causal factors of landsliding, 81 recent landslides have been mapped and investigated. Through statistical analysis it was shown that steep concave slopes, high rainfall, soil properties and layering as well as human interference were the main factors responsible for landslides in the study area. LAPSUS-LS is used to construct a landslide hazard map, and to confirm or reject the main factors for landsliding in the area. The model is specifically designed for the analysis of shallow landslide hazard by combining a steady state hydrologic model with a deterministic infinite slope stability model. In addition, soil redistribution algorithms can be applied, whereby erosion and sedimentation by landsliding can be visualized and quantified by applying a threshold critical rainfall scenario. The model is tested in the Manjiya study area for its ability to delineate zones that are prone to shallow landsliding in general and to group the recent landslides into a specific landslide hazard category. The digital terrain analysis confirms most of the causal topographic factors for shallow landsliding in the study area. In general, shallow landslides occur at a relatively large distance from the water divide, on the transition between steep concave and more gentle convex slope positions, which points to concentration of (sub) surface flow as the main hydrological triggering mechanism. In addition LAPSUS-L S is capable to group the recent shallow landslides in a specific landslide hazard class (critical rainfall values of 0.03-0.05 m day-1). By constructing a landslide hazard map and simulating future landslide scenarios with the model, slopes in Manjiya County can be identified as inherently unstable and volumes of soil redistribution can yield four times higher than currently observed. More than half of this quantity can end up in the stream network, possibly damming rivers and causing major damage to infrastructure or siltation and pollution of streams. The combination of a high population density, land shortage and a high vulnerability to landslides will likely continue to create a major sustainability problem.

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Implementation and Validation of Expert Knowledge for Digital Soil Mapping in Senegal

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Digital soil mapping approaches that use quantitative data for prediction are difficult to implement in countries with limited data on soil and auxiliary variables. However, in many such cases there is a wealth of qualitative information available such as catenas or general purpose soil surveys. This type of information opens possibilities for more qualitative approaches to digital soil mapping when quantitative mapping is unfeasible.

In this study we aimed to develop a qualitative digital soil mapping approach through decision trees to map the soil organic carbon (SOC) content for a data-poor environment in the peanut basin in Senegal. A proper validation of the results was carried out to test the question whether we could carry out a successful digital soil mapping exercise on basis of the abundance of information in the literature, supplemented with a small soil data set.

Topsoil SOC content was measured at 40 locations. The SOC content is low throughout the area with an average of 0.43% with a standard deviation of 0.16. However, even small differences in SOC content have a great impact on agricultural production in the study area. A literature review provided an overview of the driving factors of soil variability in the peanut basin. The landscape unit, the topographic position, the distance to the village and vegetation effects were identified as the main factors that explain the spatial variation of SOC. These factors were represented in the decision tree by variables that were derived from a digital elevation model with 50-m spatial resolution and a Landsat7 ETM+ image. Threshold values and actual predictions for the decision tree were based on literature and the 40 soil observation points. Predictions of the SOC content were made on a 30 m grid. Validation data were collected using double cluster random sampling. A total of 155 locations were sampled.

Validation of the model results showed a poor model performance. The model accounted for 13% of the variation present in the area. Evaluation of the modeling approach showed that the variables that were used, were important sources of variability. However, the threshold values and regression equations that were derived from literature review and the small soil data set were not suitable to estimate the model. A larger soil data set is needed to calibrate the model.

Digital soil mapping on the basis of qualitative data from literature complemented with a small soil data set proved to be unfeasible, although a proper model structure could be created from them. To develop a digital soil map for the study area, we used the extensive validation data to calibrate the prediction model, hereby keeping the model structure unchanged. This calibrated model described 44% of the SOC variation.

Keywords: Qualitative soil mapping, Decision trees, Cluster random sampling, Catena, Soil organic carbon, Peanut basin, Senegal.

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A Digital Soil Map of the Lower Hunter Valley, New South Wales, Australia

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This poster describes an attempt at making a digital soil map for the Hunter Wine Country Private Irrigation District (PID) in the lower Hunter Valley of New South Wales, Australia. The availability of quantitative environmental data and modern statistical techniques make the creation of digital soil maps an increasingly feasible option worldwide, and indeed, production of these maps on large scales is already being undertaken (McBratney et al., 2003).
Until now, no predictive, quantitative digital soil maps have been made for this region. We used the scorpan-SSFe approach outlined in McBratney et al. (2003) to make a digital soil map of soil classes with a resolution of 25 m. Reference soil data was provided by 286 soil cores extracted from across the Private Irrigation District, sampled using a Latin hypercube sampling design. These cores were described and allocated to the Australian Soil Classification system (Isbell, 1996).
We compiled the scorpan environmental variables for the area: the digital elevation model and its derivatives including slope and curvature, Landsat ETM bands, NDVI and ASTER and Hyperion bands. We used a classification tree to spatially predict the distribution of soil classes, and also incorporated the taxonomic distance between soil classes (Minasny and McBratney, 2007). Because of this, the classification has more of a pedological basis than if we merely completed a data mining exercise.
We demonstrate from the map that there is quite a diversity of soil types across the PID area. More rudimentary soils such as Kandosols and Rudosols exist on the hillier, rougher terrain in the west and southwest of the PID, whereas Dermosols, especially, are widespread throughout the parts of the PID under viticulture. Chromosols and Kurosols may exist under undisturbed land amongst the vineyards.

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DSM Recompilation of Soil Degradation Regions in Hungary

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The Commission of the European Communities in the Thematic Strategy for Soil Protection proposes a Framework Directive as the means of a comprehensive approach to soil protection and ample freedom on how to implement its requirements is left to Member States. Various threats occur in specific risk areas, which must be identified which will be required by Member States in a national or regional approach possibly on the basis of common elements. Over time more harmonised monitoring approach and methodology may be developed, exploiting ongoing work of the European Soil Bureau Network on harmonisation of methodologies. Soil Information Working Group of the European Soil Bureau Network elaborated common criteria and approaches to identify risk areas for five specific soil threats. Member States will be free to develop and combine approaches to combat further and concurrent threats.

In the frame of Land Degradation Mapping Sub-project of PHARE MERA ’92 identification, delineation and description of Hungary’s major land degradation regions (areas of potential land degradation risk) at 1:500.000 scale were accomplished by building and analysing an extent digital land degradation geographic database in the late ‘90s. The applied GIS analysis techniques were mainly based on traditional cartographic methods and had not fully exploited the opportunities, which were later emerged in digital soil mapping.

Recently the available techniques provided by DSM together with the renewed interest in spatial delineation of areas endangered by various soil threats has been combined in the recompilation of land degradation regions of Hungary. The available information related to soil degradation processes on nationwide scale was organized into an integrated digital land degradation geographic database. The following land degradation factors were distinguished and identified: acidity, erosion, excess inland water, extremely coarse texture, extremely heavy texture, nitrate leaching hazard, salinity-alkalinity, salinity-alkalinity in the deeper layers, shallow depth, water-logging. Territories affected by various limiting factors of soil fertility were determined by complex queries of the integrated GIS evaluating the proper influencing factors. Different levels of specific threats were determined in the form of categories. For the overall characterization of degradation regions, indices were introduced, which can be used for the comparison of the individual regions and characterizes the territorial extension of the soil degradation processes and the grade of the required soil conservation actions. These indices can serve as spatial land degradation indicators.

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An Approach to Computing Topographic Wetness Index Based on Maximum Downslope Gradient

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As an important index for both predictive soil mapping and distributed hydrological modeling at meso-scale and topo-scale, topographic wetness index (TWI) is designed for quantifying the control of topography on hydrological processes and for modeling the spatial distribution of soil moisture and surface saturation. This index is formulated as), where a is the upslope contributing area per unitβTWI=ln(a/tan is the local gradient. The computation of both aβcontour length and needs to reflect impacts of local terrain on local drainage. Manyβand of the existing flow direction algorithms for computing a use global is oftenβparameters, which leads to unrealistic partitioning of flow. approximated by the slope gradient around the pixel. In fact, the .βdownslope gradient of the pixel should be a better approximate to. This paper examines how TWI is impacted by a new flow routing algorithm adaptive to local terrain and the employment of maximum downslope. The new flow routing algorithm takes a multiple flowβgradient as direction approach and is adaptive to local terrain conditions. It partitions flow by altering the flow partition exponent based on local maximum downslope gradient. Quantitative evaluation using artificial surfaces has shown that the error of a computed using the new flow routing algorithm is lower than that of a computed by the widely used single flow direction and multiple flow direction algorithms. The proposed approach for computing TWI was applied to a small catchment (about 60 km2) with low relief in the Nenjiang watershed in Northeastern China. The widely used algorithm for TWI was also applied as reference algorithm. The results show that the distribution of TWI by the proposed approach is adaptive to terrain conditions. The impact of the new TWI on digital soil mapping is also studied.

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Using DSM Data for Wind Erosion Events in Europe – Bridging the Gap between DSM and DSFM

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The Soil thematic strategy has been adopted in September 2006 by the European Commission to improve the protection of the protection of European Soils. Wind erosion is one of the threats outlined in there. Areas of wind erosion have been already outlined in several publications, however usually not using long term time series of meteorological data. However, usually Digital Soil Mapping as well as the related uncertainty of the textural values has not been applied in the prediction of wind erosion events. The authors will report results on application of wind erosion modelling using DSM data for the application of the soil function wind erosion risk.

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Regional Estimation of Infiltration Rates in South-Eastern Australia

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The Shepparton Irrigation Region in south-eastern Australia includes about 300,000 ha of irrigated land and is an important agricultural production area in Australia. In recent years, there has been considerable pressure for irrigation industries to use the limited water resources more efficiently. Deep percolation, i.e. water percolating below the plant rootzone, is a potential water loss affecting the irrigation efficiency. Subsoil infiltration rate is the key soil variable governing deep percolation under irrigated lands in the Shepparton Irrigation Region. Information about the spatial distribution of infiltration rates is needed to assess deep percolation losses of irrigation water at regional scales.
However, water transport properties, such as infiltration rates are typically highly variable, even at field scales. Furthermore, these properties are often poorly correlated with other readily available soil properties, such as soil texture, bulk density or organic carbon. During a
two years study, information on chemical and physical properties (including the subsoil infiltration rates) of major soils in the Shepparton Irrigation Region was gathered.
In total, 251 soil profiles were sampled. Classification and Regression Trees and Artificial Neural Networks were used to estimate subsoil infiltration rates from measured chemical and physical soil properties and GIS data. Preliminary results suggest that the information content of this soil and GIS data is sufficient for providing reliable estimates of subsoil infiltration rates.

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Mapping Available Soil Micronutrients in an Atlantic Agricultural Landscape by the Indicator Approach

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Taking into account the spatial variation in soil nutrient status is a prerequisite for an optimized use of precision agriculture techniques. The potential of site-specific management to increase crop yield and to reduce inappropriate fertilization has been demonstrated, however a lack of field-proven decision criteria for variable rate fertilizer application remains, which is mainly true for micronutrient amendments. Nutrient maps based on intensive soil sampling are useful to develop site-specific management practices. Geostatistical methods have been increasingly used to determine the spatial correlation and the range of spatial dependence at different sampling scales. If spatial dependence occurs, the modelled semivariograms can then be used to map the investigated variable by kriging, an interpolation method that yields unbiased estimates with minimal estimation variance. Moreover, the indicator kriging approach may be used to model the uncertainty of mapping soil properties. Until now, most of the research on nutrient spatial variation focussed on macronutrients due to its economic and ecological importance. However it is well-known that an adequate and balanced supply of all plant nutrients is required for high yields. The objectives of this paper were to examine and to map the spatial distribution of the micronutrients Cu, Zn, Fe and Mn on an agricultural area in Galicia, Spain, under Atlantic climatic conditions. The surface of the study area is 25 ha at it comprises three major soil units with a difference of about 35 m between the lowest and the highest point. The coordinate position of seventy-three randomly located sampling points was recorded with a topographic total station. Soil samples were collected from the 0-30 depth and analyzed for Cu, Zn, Fe and Mn with DTPA extraction. The frequency distributions of Cu and Zn depart from normal, whereas for Mn and Fe the coefficients of skewness and kurtosis indicate closeness to normal distribution. The indicator approach was used to tr ansform the miconutrient content values into binary values having the mean values of each nutrient as the threshold. All four elements analyzed showed spatial dependence, as measured by the indicator semivariograms. The strength of spatial dependence as assessed by the values of nugget effect and range of spatial dependence decreased in the order Cu>Mn>Fe>Zn. Spherical models were fitted and validated with the jack-kniffing technique, which showed that they were all satisfactory. The joint spatial dependence of the combination of two or more of the studied micronutrients was also examined by means of indicator semivariograms. In contrast to individual microelements, indicator semivariograms obtained for their combinations showed nugget effect or a low proportion of structural variance. The indicator maps of individual nutrients constructed with the values estimated by kriging showed some similarity in the spatial distribution, suggesting the delimitation of uniform management zones. These similarities neither were identified with topography nor with any other single soil property such as organic matter content, pH and clay content. It is possible that the factor o factors that affect nutrient contents changes across the study area.

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Integrating Statistical and Visual Approaches to Predict Soil Attributes from Digital Terrain Data

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Information about the spatial distribution of soil attributes is indispensable for many land resources management applications. The ability of soil maps to supply such information for modern modeling tools is questionable. Geographic Information Systems, through the use of terrain attributes derived from Digital Elevation Model (DEM), provide alternatives to predict soil attributes. The objectives of this study were to investigate the possibility of predicting soil depth using some terrain attributes and to suggest an approach to predict other soil attributes. Soil depth was determined at 652 field observations over Al-Muwaqqar watershed in Jordan (70 km2). Terrain attributes derived from 30 m resolution DEM were utilized to predict soil depth. The results indicated that the use of multiple linear regression models within small watershed subdivisions enabled the prediction of soil depth for 77% of the field observations within ±50 cm. The study revealed noticeable visual coincidence and good correlation between the spatial distribution of the predicted soil depth and polygons that represent amalgamated classes of three terrain attributes; slope steepness, slope shape and compound topographic index. These results suggest that the modeling of the soil-landscape relationships within small watershed subdivisions using the three terrain attributes is a promising approach to predict other soil attributes.

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Regionalization of Saturated Hydraulic Conductivity (Ksat) in an Intra-mountainous basin in the Northern Apennine (Mugello)

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The aim of this study was to characterise the hydraulic properties of the different terraces in a small subcatchment (12 km2) in the Mugello Basin, Italy. The Basin is located about 30 km north of Florence is characterised of clayey lacustrine sediments and up to four different fluvial terraces. With a so called Amoozemeter (Compact Constant Head Permeameter) measurements of Saturated Hydraulic Conductivity (Ksat) at 31 locations were made. At each sample point Ksat was measured in four different depths (20, 50, 95 and 120 cm). Based on a Digital Elevation Model with a resolution of 10*10m and several Soil- and geologic Maps the regionalization was conducted with bagged Multivariate Adaptive Regression Splines (MARS).

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Geomorphological Mapping Using Data Mining Technologies. An Example from the Rivo Basin in Molise, Italy

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Geomorphological mapping was conducted in the past with traditional methods such as field mapping of geomorphological forms and processes as well as lithostratigraphic and pedological analysis. This paper aims to demonstrate the ability of digital geomorphic mapping for the prediction of the spatial distribution of geomorphological processes and related features. Therefore, an inference model was defined using environmental parameters such as parent material, soil characteristics, land use and topographic attributes. The analysis was carried out in the Rivo Basin in Molise, Italy with a catchment area of 80 km². To derive the spatial distribution patterns of geomorphological processes and related features the random forest (RF) modelling approach was applied on relevant physiographic layers. This method has several advantages compared to other modelling approaches, for instance, the fact that it is neither sensitive to over fitting nor to noise. The RF based digital geomorphic mapping approach provided detailed spatial estimates of geomorphological processes and related forms and also information on the predictor importance. To the knowledge of the authors it is the first time that this method is applied in geomorphological mapping. The environmental variables that explained most of the variation were topographic attributes, indicating water driven surface and subsurface transport processes as well as climatic dependencies. The distribution was best explained by the duration of solar radiation. The digital geomorphic mapping approach introduced in this study might easily be applied to similar landscapes. However, a careful analysis of geomorphological pattern and forms for the model creation is essential.

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Space-time Kalman filtering of soil redistribution

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Soil redistribution is the net result of erosion and sedimentation. Assessment of soil redistribution in a given landscape over a given period of time may be done using process-based and empirical approaches. Process-based approaches rely on knowledge of how environmental processes acting in the landscape cause soil to move from one place to another. Empirical approaches rely on measurements of soil redistribution, which may be interpolated in space and time using (geo) statistical methods. In this paper we use space-time Kalman filtering to combine these two basic approaches. The Kalman filter operates recursively to predict forward one step at a time the soil redistribution from the predicted soil redistribution at the previous time and the measurements at the current time. The methodology is illustrated with a case study from a seven hectare segment site, located on the hummocky till plains of Saskatchewan, Canada. Tillage erosion causes soil to move downward along the steepest gradient, whereby the amount of soil loss per year is assumed linearly related to slope angle. Measurements of cumulative soil redistribution from 1963 to 2000 were derived using Cesium-137 as a tracer. In total 99 measurements were taken, using a regular sampling design with a grid mesh of 25 m. The soil redistribution measurements differed meaningfully from the deterministic model predictions (R-square=0.389), causing the Kalman filter to make a marked adjustment to the soil redistribution map. The adjustment was particularly strong along the transportation route near the measurement locations. Use of the space-time Kalman filter to predict soil redistribution is attractive because it makes optimum use of process knowledge and measurements, but routine use of the technique is hampered by the computational load and by parameterisation problems. Sensitivity analyses showed that the model results are most sensitive to the system noise. Future research must therefore be directed to realistic assessment of the errors inflicted by the assumptions and simplifications of the soil redistribution model.

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Soil Mapping at a Scale of 1:50,000 in Germany – Analysis of Existing Maps and Definition of Quality Criteria

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On of the most important future challenges of soil mapping in Germany is to produce a comprehensive and consistent soil map at a scale of 1:50,000 that can serve as a basis for environmental planning and soil conservation and protection issues. Based on existing maps of some of the federal states and taking into account new concepts in digital soil mapping a group of specialist was formed to set work on under the auspice of the Ad-hoc-AG Boden of the Geological Surveys of Germany and the Federal Institute for Geosciences and Natural Resources.
Main objective of this working group is to develop a guideline how to produce soil maps 1:50,000 at a high standard and of consistent quality. Another objective is to allow a comparison of existing maps and mapping concepts of various providers in order to guarantee a high quality over all federal states of Germany. Work flow starts with the analysis of existing maps and the derivation of parameters to describe the quality of a soil map at a scale of 1:50,000 (e.g. size and number of polygons, number of different soil classes, soil properties to be described quantitatively and qualitatively, level of soil classification, etc.). Subsequent, new methods to calculate and describe quality criteria should be formulated and tested. Finally, a parameter set should be formulated that serves as minimum standard in respect of content and spatial delineation. The poster shows first results from the analysis of existing maps and the derivation of quality parameters.

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Characterizing Mercury Injection Porosimetry Curves of a Soil Prone to Crusting by Multifractal Parameters

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Intensive cultivation of some agricultural soils can lead to soil structure and modifications of other soil physical properties. Degradation by rainfall changes the physical state and the structure of the soil surface, which results on decreasing aggregate stability and modifications of the soil porous system. This is mainly true in soils prone to crusting. The soil pore space is defined by the relative arrangement of the soil particles and aggregates, so that it is complementary to the solid phase. Both pore space and aggregates may be used for assessment and characterization of soil structure. Parameters are needed to recognize and monitor changes in pore size distributions caused by soil degradation processes or by differences in soil management systems. Scaling effects in soil physical properties have been frequently described, so that they are thought to be more the rule than the exception. Fractal and multifractal models have been found useful to quantify the scaling properties of different soil physical properties and have been widely applied to the study of soil pores system. The objective of this work was to evaluate multifractal parameters from Hg injection porosimetry curves on the uppermost soil surface layer before and after degradation by rainfall. Depositional crusts were produced by means of successive events of simulated rainfall and drying periods between them on a loamy textured agricultural soil prone to crusting. Samples were taken from the freshly tilled soil surface and also from the surface degraded after 140 mm cumulative rainfall at the 0-2 cm depth. Pore size distributions (PSDs) were determined by mercury intrusion porosimetry in ten replicates before and after rainfall. Soil pore size distributions from Hg intrusion porosimetry could be fitted reasonably well with multifractal models. Multifractal characterization was carried out by means of the scaling of the moments ranging from -10 < q < 10 of the probability distributions of Hg PSDs. Multifractal singular) and generalized fractal dimensions or Rényiαity spectra, f (dimensions, Dq, were computed. The generalized dimensions, Dq, for q = 0, q = 1 and q = 2 are known as the capacity, the information (Shannon entropy) and the correlation dimensions, respectively. These are termed as D1, D2 and D3 and were used for assessing differences between original and degraded data sets. Mean values of entropy dimension, D1, and correlation dimension, D2, in the aggregate set from the degraded soil surface decreased, whereas the difference between capacity and (D0 - D2) and the Holder exponent of orderΔcorrelation dimensions 0, of this data set increased. Changes in average multifractal0αzero, parameter values estimated from PDSs after surface degradation were not always statistically significant. Entropy dimension, D1, best discriminates between PDSs of recently prepared and degraded soil surfaces.

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Exploitation of Supervised Fuzzy K-Means Classification for Soil - Landform Relationship Description

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Terrain is one of the most important soil forming factors. Terrain characteristics can be used for soil prediction. Application of pedometrical methods demands quantitative and continuous analysis. Fuzzy classification is a tool for continuous transformation of terrain into landforms. Aim of this study is to use fuzzy classification for description of soil-landform relationship.

The study area (6.3 km2) contains two different landscapes: southeast part is hilly, northwest is more flat. Soils are represented by Cambisols, Luvisols, Stagnosols and Gleysols. Digital terrain model, used for the terrain analysis, was processed from contours with 2 meters vertical spacing at pixel size of 10 meters.

Terrain of the whole study area was divided in eight units. These units were divided on the basis of four terrain characteristics: slope, slope curvature (horizontal and vertical), and topographic compound index. The supervised fuzzy k-means classification was used. Pixel memberships to all classes were calculated. Final allocation to the terrain units was based on the highest value of the membership at a given pixel. The relationship of soil and terrain units was analysed by the overlap of the soil map and delineated terrain units. Percentage proportion of terrain units was calculated for each soil unit.

Study shows that soil units are related usually to one prevailing landform. Luvisols are bound to flat areas. Soils with more significant hydromorphic features (Gleyic Luvisols and Stagnosols) are present at the concave flat areas. Cambisols prevail at the hilly part of the area, when the hydromorphic subunits are bound to concave parts of the hilly landscape. Only Gleysols occur uniformly on several types of landforms. This can be caused by underestimation of alluvium or by overestimation of Gleysols at the reference soil map. This study shows that fuzzy classification of terrain can be helpful tool for description of soil-landform relationship. Consequently, its results can then serve for terrain exploitation in digital soil mapping.

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Soil Contamination with Geostatistics Techniques

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The main objective of this study is to investigate whether Kriging is a useful tool to estimate the spatial distribution of ground pollutants in contaminated land. The second objective of this work is a more practical one. It consists on the identification of areas that should be subjected to remedial actions and also on deciding which contaminant needs to be considered when remediation processes are taken.

To achieve the described objectives, a contaminated site has been studied and the following steps have been followed:

The contamination concentration limits beyond which action needs to be taken to remediate the ground contamination, in which case it is important to determine the areas that should be subjected to the appropriate remediation measures. A presentation of a case study will follow. A brief site description is given. Next, a spatial analysis of the site has been carried out. It consists essentially of:

Firstly a primary process of the data which means that histograms and an unprocessed representation of the pollutant's distribution has been plotted for each contaminant. Secondly a graphic presentation of the pollution using Kriging interpolation technique is shown. Finally conclusions concerning Kriging applications are given. An assessment concerning Kriging is presented and a balance between the advantages and disadvantages of its use is discussed.

Key words: ground contaminants, remediation, assessment, regionalised variables, semi-variogramms, geostatistics interpolations techniques.

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A Geostatistical Approach for Mapping the Geogenic Soil Gas Radon Potential in a South Italy Area

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Radon is a natural radioactive gas emanated constantly in small amounts from the Earth to the atmosphere. Many scientists use to measure outdoor soil gas radon concentrations to assess the geogenic radon potential because it is the main source for indoor radon concentrations independent on the construction features of building. Spatial distribution of soil gas radon concentrations has become an important issue in terms of radiological protection because constitute a serious human health hazard. Geostatistical methods provide us a valuable tool to study spatial structure of radon concentration and mapping its spatial distribution. Stochastic simulation is a development of geostatistics and estimates the conditional cumulative distribution functions at each location. Statistical information deriving from stochastic simulation allows to estimate the probability that each pixel exceeds a threshold value and to produce the probability map of high radon concentrations in the soil gas. The main aim of this paper was to explore the spatial structure of soil gas radon concentration in a south Italy area and mapping the geogenic soil gas radon potential. Another aim was mapping the risk of occurrence of high soil radon gas concentration. The experimental area was located in the Catanzaro-Lamezia plain (south Italy) with a surface of about 1105 km2. It is a graben bordered by E-W trending normal faults and constitutes the central part of the Calabro-Sicula rift-zone. Measurement of radon concentration were made at 4420 points collecting soil gas radon into Lucas cells and then measuring their alpha activity in the laboratory. Measurements were made in July 2004 and the samples were collected as uniformly as possible with an average sampling density of 4 samples per km2. To reduce the influence of few high values of soil gas radon a Multi-Gaussian approach was used. An isotropic model was fitted to the experimental variogram including three basic structures: 1) a nugget effect; 2) a spherical model with a short range=3.78 km and 3) a spherical model with a long range=23.90 km. Stochastic simulation was used to map the risk of occurrence of high soil radon gas concentration: 500 alternative equi-probable images of the unknown radon concentration were generated using the conditional sequential Gaussian simulation algorithm. Counting the number of times that each pixel exceeded the threshold value and converting the sum to a proportion we produced the probability map of exceedence. We used as threshold value the upper quartile of the data distribution function because in Italy no radon level of risk in outdoor air exists. Map of soil gas radon concentration and probability map reflected the impact of fractures and faults on the spatial distribution of radon concentration because they act as a preferential way for gases migration. The results showed that the highest radon values occur preferentially along elongated zones similar to the most representative trends obtained by geomorphological and mesostructural analyses, i.e. E-W trends and, secondarily, NW-SE orientations.

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A Non-Parametric Density Algorithm of Classification Applied to Augering Data from a Detailed Soil Survey

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Soil maps on a semi-detailed scale are frequently used as the basic level of information for regional land use assessment. The region of interest is subdivided into a generally small number of contiguous homogeneous areas which will be the subject matter of land use projects. However, semi-detailed maps are impractical for soil suitability predictions concerning quality crops, which require a level of detail that can be guaranteed by intensive surveys only. The change of scale on the one hand increases the importance of field observations, on the other hand magnifies gradual vertical and horizontal soil transitions which delineation involves more the character than the geographical space. The surveyor delineates gradual transitions as sharp boundaries under the assumption that her/his field apprentieceship is large enough to limit the intrinsic subjectivity of boundary delineation. We did the present investigation with the purpose of decreasing surveyor's subjectivity by means of an analytical procedure capable to combine the classification of homogeneous soil groups and the delineation of gradual soil type transitions not easily observable in the surface. The proposed clustering algorithm is based on nonparametric density estimate, where a cluster is defined as a region surrounding a local maximum of the probability density function, and does not require any previous information about the number of the groups. The approach was applied to data recorded in 1836 auger borings of a 42000-ha conventional soil survey carried out on a 1:25000 map scale in the lower part of the fluvial plain east of Venice. The morphological quantitative attributes of five genetic horizons – A, Bw, Bg, Bk and C – were first reduced in number so as to remove attribute redundancy. Their multivariate spatial structure was investigated by fitting a linear model of coregionalisation; in more detail the whole data set was split into subsets: the first one including the clay contents at the horizons A, B and C and th e second one the variables gley at the horizons B and C and the variable mottle at the horizon B. For each of the two variables, mottle at the horizon C and thickness of the horizon B, a univariate analysis was preferred. All variables were interpolated on a 200 x 200 m grid using cokriging for the two subsets and kriging for the last two variables. As the variables were not measured in comparable units, a standardisation was used which scaled all the variables to the same mean 0 and to the same variance 1. Moreover, to obtain spatially contiguous clusters the clustering algorithm was applied to the data set of the interpolated soil variables and also the coordinates were included in the attribute space. After several trials, the better subdivision of the area was obtained with 8 distinct classes, whose significance was tested using approximate nonparametric tests. The clusters were also consistent with the main soil-forming processes of the area in terms of spatial variability and pattern distribution of the delineated soil units. One of the main advantages of the approach is that it gives information on the intrinsic spatial structure of the cluster, on the distribution of the residual within-class variation and on the soil transition properties at the boundaries between the different clusters. .This study has demonstrated that, by combining continuous classification with geostatistical interpolation, it is possible automatically locate boundaries between multivariate soil classes. The investigated approach might be applied as an analytical sequence capable of using both the spatial distribution of soil classes and the landform analysis to formulate a spatially detailed territorial model representing the basic level of information for a locally-oriented land use assessment.

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Using Geostatistical Analyst in Hydrochemical Data Processing – Study Case: Teleorman-Calmatui Interfluve's (Romania)

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Groundwater's good qualitative status represents the main objective of Groundwater Directive (GWD) 2006/118/EC, which recommends an analysis and a particular methodology to evaluate it. The paper aim is to realize a hydrochemical assessment using geostatistical tools, on the database provided from monitoring and extraction wells, regarding the groundwater bodies delimited in Teleorman-Calmatui interfluve.

The selected period is 1970 to 2005 and the observation frequency is one two four samplings per year. The first step into this analysis is hydrochemical database creation and validation. Exploring the range values for each indicator parameter and than application of the appropriate interpolation method is the next stage to prepare, and the final one is to obtain prediction maps for each chemical parameter. The final results will provide a useful methodology and good/poor groundwater status delineation.

Key words: GWD, Geostatistical Analyst, Teleorman-Calmatui interfluve, hydrochemical database, interpolation method.

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Geostatistical Analysis of Soil Surface Microtopography Decay under Simulated Rain

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The microrelief or roughness of the soil surface affects many processes, such as water infiltration, overland flow generation and routing and sediment production and transport. Soil microrelief is produced by soil tillage and changes with management and rainfall. Traditionally, random roughness was defined as the spatial distribution of clods and aggregates at the scales of less than one meter. Random roughness (RR) is frequently used as an index for characterizing microtopography and also as an indicator for soil structure. On agricultural fields, random roughness is superimposed by periodic features induced by cultivation. In turn, both types of microrelief components, i.e., disordered or random roughness and oriented or periodic roughness, may be superimposed to the natural landscape convexities and concavities at larger scales. Soil microrelief currently is assessed by point elevation measurements acquired using either pinmeter or laser scanner. The most widely used soil microrelief index, random roughness, is given by the standard deviation of point height measurements and ignores the spatial patterns of aggregate distribution. This can lead to serious errors in characterizing microrelief patterns. Consequently, use of geostatisitcs and fractals for describing soil surface roughness has also been proposed. The objectives of this work were to investigate the decay of initial surface roughness induced by simulated rainfall under different soil residue cover and to compare the performances of classical statistical and geostatistical indices. A conventionally tilled loamy soil with low structure stability, thus prone to crusting was packed on 1m2 microplots. Microplots were subjected to three successive rainfall events of 25 mm each, at 65 mmh−1 intensity, given 75 mm cumulative rainfall. Five treatments without replication were tested with corn straw quantities varying from 0 to 4 t ha−1. Soil surface microrelief was measured during the initial stage and after each of the simulated rainf all events (five treatments and four surface stages) so that 20 data sets were acquired. Point elevation data were taken at 2 cm intervals using a pinmeter. Based on these height measurements digital surface models were generated and subsequently analysed using variograms. All data sets showed spatial dependence and spherical models with or without a nugget component were adjusted to experimental semivariograms. A very significant relationship was found between the random roughness index, RR and the sill (C0+C1). All the treatments showed a clear trend of sill value reduction with increasing precipitation. However, roughness decay was lower in treatments with higher straw cover (3 and 4 t ha-1). Residue cover clearly enhanced maintenance of soil aggregate structure and consequently limited soil surface roughness decline. The control treatment, without straw, showed the lowest nugget effect (C0), i.e., the lowest space discontinuity of all treatments in this study. The range of spatial dependence (a) also showed a trend to decrease as the cumulative rain increased, which was most apparent in treatments without or with relatively low straw cover (0, 1 and 2 t ha-1). The suitability of using sill variance and range for describing patters of soil surface microrelief decline is discussed.

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Determining Spatial Structures of SOC in Woodlands of Southeast Tanzania in the Framework of the Clean Development Mechanism

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Over the last 40 years, population increase in Southeast Tanzania has induced a high land pressure and the replacement of huge areas of woodland by agricultural land. In combination with poor farming practices and a lack of conservation management this resulted in land degradation, erosion and fertility decline. Local institutions are willing to handle these problems by implementing soil conservation management measures such as reforestation of the escarpment. Funds can be found in the Clean Development Mechanism, a Kyoto Protocol Mechanism helping industrialized countries to meet their carbon emission reduction target through aforestation and reforestation projects carried out in developing countries against financial benefits. However, the Kyoto Protocol limits reporting of C sequestration activities to those that are both "measurable and verifiable". Even if allowed as part of an accounting system, credit for C sequestration activities could be discounted if high standards of measurement cannot be met. Precise measurement of soil organic carbon (SOC) is highly insecure and labor-intensive due to the substantial spatial variability, especially in forest soils. A good knowledge of the amount of carbon in the soil as well as its spatial variation will lead to a sampling strategy which is accurate and cost-effective.

On two plateaus in Southeast Tanzania, five forest types were selected. A nested unequal survey was used to take 144 topsoil samples per woodland. A spherical semivariogram model fitted most woodlands. The pristine coastal forest has the highest SOC content (12.61 ton.ha-1) and standard deviation. This is the result of the high organic matter input and extremely variable vegetation composition. Carbon stocks are much lower in the miombo woodland (8.80 ton.ha-1) and vary over a much shorter distance, as can be seen in the range (36m) which is 5 times shorter than in the coastal forest. This type of woodland typically shows a patchy pattern of closed forest, open grass and burnt ground. The teak plantation's mean SOC stocks are not significantly different from the coastal forest, but the variance is almost two times smaller as a result of clearing and homogenization of the soil before planting and little variation in vegetation. The low SOC content of the pine plantation (6.74 ton.ha-1) is the result of the changes in litter inputs and microbial diversity in coniferous forests. The monotonous vegetation, the thick litter layer and homogenization of the soil diminish the variability of soil organic carbon, explaining the low SD (2.21) and the pure nugget effect of the semivariogram. In cashew fields the undergrowth is cut and removed yearly, thus biomass litter input becomes minimal and decomposition is stimulated. This explains the lowest amount of SOC (4.87 ton.ha-1) and variability (SD=1.22). The magnitude of the range has more than doubled, implying that the field is very homogeneous and that the variation is spread over a large area.

When SOC shows a spatial structure, sample sizes can be calculated based only on independent samples, which are located at distances wider than the range of the variogram. Mean values don't change, but standard deviations are reduced with 10 to 30% compared to the classical statistical methodology. This results in a reduction of the requisite number of samples, which is 36, 31, 24 and 14 for respectively coastal forest, miombo woodland, teak plantation and cashew plantation with a precision of 1 ton.ha-1. In the cashew plantation too few independent samples are available to perform the calculations correctly. The samples can now be organized in a grid with dimensions exceeding the range of spatial dependence. Since in the pine plantation no spatial structure was observed, no improvements can be made compared to the classical statistical methodology. Samples are all independent of each other and a random design with 28 samples is optimal.

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Heavy Metals in European Soils: A Geostatistical Analysis of the FOREGS Geochemical Database

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The poster presents results of mapping concentrations of eight critical heavy metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) in European soils. 1588 georeferenced topsoil samples taken from the FOREGS Geochemical database were interpolated using block regression-kriging. Fully-automated techniques were used to estimate the regression model, fit the variograms and run the predictions. Auxiliary raster maps (DEM-parameters, MODIS NDVI time series, night light image, geological and land cover maps, cumulative earthquake magnitude map) were converted to 36 principal components. The study revealed that the FOREGS Geochemical database is suitable for geostatistical analyses: the predictors explained from 21% (Cr) up to 36% (Pb) of variability; the residuals showed clear auto-correlation structure. High concentrations of Cd, Cu, Hg, Pb and Zn can be linked with human activities, i.e. industrialization and intensive agriculture. A significant correlation between the contents of Ni (r=0.40) and Cr (r=0.29) and the magnitude of earthquakes was also observed. Automation of the geostatistical mapping and use of auxiliary spatial layers opens a possibility to develop mapping systems that can automatically update outputs by including new field observations and higher quality auxiliary maps. This work also demonstrates the benefits of organizing joint European monitoring projects, applying standardized methods and sampling protocols.

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Assessment of the Impact of Support Choice on Soil Mapping

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Whereas geostatistical approach deals with spatial variability of soil properties, it is crucial to know how these properties are measured and on which volume of soil, to avoid meaningless results. Moreover, the mechanism behind property variability should be supposed, because a property might show a very strong spatial dependence if the sample is representative of a pedological process. On the contrary, it might show little consistency if the inferred process is not taken into account in the sampling phase.
Organic Carbon (OC) content is related to vegetation cover, but a different kind of vegetation could lead to a different kind of humus and a very different vertical distribution of organic matter through the profile. So it is quite common to find soil with the same average concentration of OC, but with a different, or even an opposite, vertical concentration gradient. In such an eventuality, the choice of the support becomes very conditioning on the further spatial analysis and mapping results. For instance, is it better to map the OC concentration in the A horizon, in 0-5 cm. layer, or the mean OC content over the whole profile? Of course, it depends on the purposes of the final map and on process considerations, but also on the spatial consistency of the data. It is possible that the average concentration of OC could show no spatial structure, whereas the total amount of OC in the A horizon could show a very strong spatial dependence.
The objective of our work was to assess the impact of soil profiling on the mapping results. The study area is a doline on a plateau area with a mean elevation of 1900 m site in the Italian Alps; the area is currently used as a pasture in summer. 110 soil profiles were described and sampled over an area of about 1.5 ha. OC has been mapped in different ways: 1) Oc in the first genetic horizon (A); 2) In the epipedon; 3) in the 0-10 cm layer; 4) in the 0-25 cm layer; 5) over the whole soil profile. Moreover, we took into account either the whole volume of the soil (including skeleton) or only the finest soil. For each case it was possible to give a specific interpretation of the mapping results: cases 1 and 2 are related to pedogenetic processes; cases 3 and 4 deal with the relationships between soil and herbaceous and arbustive vegetation, respectively; case 5 has a high ecological significance.
The different types of OC data were compared by multivariate geostatistical techniques and by factorial kriging to identify the spatial scales and the common processes investigated by each approach. Factorial kriging allowed also to group the methods on the basis of their similarity. This was evaluated on both visual inspection of the different cokriged maps of OC and spatial analysis of their differences. The latter also revealed the areas where the discrepancies were the highest.

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Determining an Appropriate Interval for Soil Sampling Prior to Geostatistical Mapping

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Accurate geostatistical predictions are needed to map soil properties to deal effectively with contaminated sites and for site-specific management of the soil and of crops. To do this effectively requires an accurate variogram and data that are spatially dependent. To compute Matheron's method of moments (MOM) variogram reliably, Webster and Oliver, (1992) showed that a sample size of at least 100, and ideally, 150 is required. In addition, the sampling should be at an appropriate interval namely one that resolves the spatial variation at the level of interest, e.g. drainage basin, agricultural field or trial plot. In many situations there is no prior knowledge of soil variation and a reconnaissance survey to determine this with a minimum sample size of 100 sites is often prohibitively expensive or impractical.

Once the variogram is known, McBratney et al. (1981) showed that it can be used with the kriging equations to determine an appropriate sampling interval with a known tolerable error. Kerry and Oliver (2003) showed that variograms from certain types of ancillary data, such as aerial photographs of bare soil, the soil's apparent electrical conductivity, ECa, elevation, etc. have similar ranges (scales of variation) to variograms of the more permanent soil properties, for example particle size distribution, soil depth, etc. Kerry and Oliver (2004) showed that this also applies to average variograms of soil properties from sites on similar parent materials and topographic settings. Therefore, variograms from such ancillary data or average variograms of soil properties could be used to determine an appropriate sampling interval and so dispense with the need for a detailed reconnaissance survey.

As a suitable tolerable error is often unknown to apply the approach of McBratney et al. (1981), Kerry and Oliver (2003 and 2004) suggested that a sampling interval of just less than half the range of ancillary or average variograms could be used. Their results showed that the main features of the variation present in maps from more densely sampled data are retained when this general 'rule of thumb' is used, but are lost when larger intervals are used. This recommendation was based on a 'rule of thumb' and our aim here is to test its efficacy with simulated data.

Large intensive data sets with a standard normal distribution and known underlying variograms representing different scales of variation (ranges) and degrees of structured and random variation (nugget:sill ratios) were generated by simulated annealing. These data were sub-sampled to produce data at intervals smaller than and equal to half the underlying variogram range. Variograms were computed from the sub-sampled data and modelled. The model parameters were used for cross-validation, whereby each point was removed in turn and the remaining points used to interpolate the value at the missing point. The mean squared errors from computing variograms from sub-samples with an interval based on the 'rule of thumb' and other smaller and larger intervals were compared. The effects on the errors of the scale of variation and/or the degree of structured and random variation were also examined. The results of this detailed investigation will be presented.

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Sample Design Optimizing for Joint Estimation of Multiple Soil Variables

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Over the last decades extensive work has been done on the geostatistical optimization of soil sampling strategies. Many methods were developed, the majority of which focuses on the minimization of the spatial maximum or average kriging variance. A minimum required precision can be set and the optimum grid spacing can be computed from that when the variogram is known (Christakos and Olea, 1992). Sampling on a regular grid (triangular, square or hexagonal) is appropriate for many practical case. Alternatively to locate individual sampling points more precisely in the area of interest, simulated annealing may be used. In this way, irregulary shaped areas and optimization conditional to existing data points can be dealt with (van Groenigen et al., 1999). Brus et al (2006) propose the mean of the squared shortest distance as a minimization criterion, and minimize it with the k-means algorithm of cluster analysis.
In practice, arable land sampling usually aims to describe the spatial distribution of not just one but multiple target variables. The strength and character of the spatial dependence of each soil property, as expressed by the variogram, may be different and the mutual relationships (i.e. cross-variograms) between soil properties may also vary from case to case. Clearly, there is a need for extending the existing sampling methodologies such that they yield the optimized sampling scheme for simultaneous estimation of multiple soil properties. In this paper we present, test and evaluate a method that does so by minimizing the weighted sum of the spatially averaged kriging variances.
Two fields of similar size and soil type (Cambisol), located in the central part of the Czech Republic, were sampled in the spring using a systematic square grid (90 sampling points for field I, 57 sampling points for field II) along with a systematic unaligned grid (53 sampling points) for field II. The measured soil properties are active pH, exchangeable pH, carbon content and A400/A600 ratio. The latter is an indicator of the humus quality. Correlation analysis showed significant linear relationship between active pH and exchangeable pH, active pH and A400/A600 ratio, carbon content and A400/A600 ratio, and between exchangeable pH and A400/A600 ratio. Variograms and cross-variograms were fitted and used to design an optimal sampling scheme using simulated annealing. Comparison is made with the existing designs, the optimal designs for individual soil variables and with spatial coverage designs. Results show that simultaneous optimization of sampling designs for multiple soil properties has distinct advantages over separate optimization schemes.

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Monitoring the Variation of Soil Water Content and Soil Bulk Density at the Plant Root Zone at Ile-Ife, South West Nigeria, Using Dual-Energy Gamma-Ray Transmission Technique

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A radiological method of simultaneously measuring temporal values of soil bulk density and volumetric soil water content at different depths within the root zone for most agricultural plants is presented in this work. The results show that temporal soil water available to plants at the root zone is at optimum level only for a short portion of the growing season; hence, irrigation is needed to maintain adequate soil water availability to the root of plants. The seasonal values obtained for soil water content at the different soil depths should go a long way to quantitatively assist designers of sprinklers and drip irrigation systems to develop systems that will deliver water, at rates that will achieve optimal agricultural production and quality in this part of the world.

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Comparison of Magnetic and Relative Assessment of Visible, Near Infrared and Combined Spectroscopy for Predicting Various Soil Properties

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Soil spectroscopy is a useful tool to simultaneously assess various soil properties and to characterize their spatial variability. During the last decade intensive research was carried out on this topic as spectroscopy provides a good alternative that may be used to enhance or replace conventional methods of soil analysis. Moreover, the diffuse reflectance measurement is rapid, timely, less expensive, straightforward, non destructive and sometimes more accurate than conventional analysis.
The aims of this paper are threefold: i) assess different chemical and physical soil parameters independently in the visible (VIS), near infrared (NIR) and the combination (VIS-NIR) spectral range; ii) compare the predicted values of each parameter obtained in each spectral domain and the combined VIS-NIR; and then iii) deduce the most suited spectral range to predict each soil property and assess whether the combined spectra improve predictions or not. We constituted a spectral database by collecting 125 A-horizon soil samples (0-20 cm) from various sites in Brittany's Armorican Massif (France), in order to cover the spatial variability of the regional range of soil types. Samples were then analysed for 10 parameters including OC, Fe, N, CEC, pH and texture (clay, coarse and fine for both silt and sand) using conventional laboratory analytical techniques (AFNOR, 1996). A Principal Component Analysis (PCA) was performed in order to both explore the samples chemical and physical characteristic variability, to study the correlations between variables and to group samples into separate classes. Afterwards, the samples were separated into calibration data set and validation data set. Spectral laboratory measurements, ranging from 400 to 2500 nm, were conducted on soil samples which had been oven-dried, grounded and sieved at 2mm. A Partial Least Squares regression (PLSR) algorithm was then used to calibrate models, which were independently validated for the prediction of soil properties considered from the soil spectra.
Our results show that predictions are precise for 4 soil properties (OC, CEC, coarse sand and coarse silt) whatever the spectral region considered. In this case the VIS spectral range gives good predictions. The use of the NIR or the combination VIS-NIR does not improve them significantly and is sometimes less precise. When considering VIS, NIR and the combination VIS-NIR to predict the soil OC content, we obtain R^2 of 0.82, 0.79 and 0.77 and RMSE of 0.43, 0.47 and 0.49 respectively. The most precise prediction is given by the model calibrated in the VIS range. For the other soil parameters the precision of predictions is not satisfactory except for the clay content where the combination VIS-NIR improves the precision, R^2=0.53 and RMSE=1.54, as regards results obtained in VIS and NIR spectral range, R^2 of 0.23, 0.44 and RMSE of 16.31, 3.84.

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Mapping Patterns of Surficial Properties of Soils in the Negev Desert, Israel, Using Soil Profile Database and Remote Sensing Data

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The Negev in southern Israel (29º-31ºN) is part of the larger Saharo-Arabian desert belt. The Negev desert covers an area of ~10,000 km^2 across a steep climatic gradient from semi-arid (~300 mm yr-1) to hyper-arid (<50 mm yr-1) climates. The geomorphology and distribution of soil groups in the Negev are known and mapped (e.g. sand in the Northwestern Negev, loess mantle in the Central-Northern Negev) and are a consequence of complex interactions between tectonics, bedrock lithology, dust deposition and climate and its variability. However, the understanding of the causes for the spatial patterns of soil characteristics is limited. This problem is common for most of the world's deserts, which lack quantitative data of soil characteristics.
We constructed a regional soil database and combined it with remotely sensed images to first map and then predict top-soil characteristics. The database is comprised of >300 soil profiles from published reports, papers, theses, and data collected for this study. We modeled the spatial distribution of grain size fractions, salinity (EC), and soil thickness using simple interpolation algorithms (e.g. IDW). The interpolated maps agree with the qualitative geomorphologic and soil maps of the Negev, and add new, previously unnoticed patterns in the clay fraction distribution (which are related to dust deposition) and in the soil salinity.
We used the ASTER and Landsat data to map several surface characteristics including, for example, the band ratio 6/8 of the ASTER data indicative of the content of surficial clay minerals using the Al-OH absorption feature at 2.2µm (band 6). Then, we used the soil database to validate the remote sensing map, assuming that there is a correlation between the clay fraction and the clay minerals content. A good correlation between the clay fraction (taken from the soil point database) and the estimated clay minerals content (sensed by the sensor) was found, suggesting that we can use remotely sensed images to estimate clay minerals and clay fraction contents in places where no ground data exist. This is especially important in remote deserts, which are not easily accessible and are less studied.

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Spectral Signatures for Soil Carbon: Assessment of Total, Recalcitrant, Hydrolysable and Dissolved Organic Fractions

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Rapid, cost-effective and reliable methods are in need to assess the soil carbon (C) pools and carbon sequestration potential at landscape scales. Visible/near-infrared diffuse reflectance spectroscopy is a rapid and cost-effective method that provides inferences on multiple soil properties. The objective of our study was to relate six different carbon attributes (total, recalcitrant, hydrolysable, mineralizable, and two hot water extractable size fractions) to soil spectral signatures derived using visible/near-infrared diffuse reflectance spectroscopy. Long-term sequestration of carbon in soils typically involves movement of fixed carbon into the stable recalcitrant pool from the smaller labile pool which has greater relative exchange with the atmosphere and shows faster turnover rates. Our approach targets multiple aspects of soil carbon and provides a comprehensive assessment of biogeochemically active carbon pools of a wide variety of soils.

We used 141 soil samples collected at 0-30 cm in the Santa Fe River Watershed in north-central Florida representing typical soils and land uses. Dominant soils were Ultisols (36.7%), Spodosols (25.8%), and Entisols (14.7%) and less prominent are Histosols (2.0%), Inceptisols (1.1%), and Alfisols (1.0%). Land use consisted mostly of upland forest, including pine plantation (42.7%), agriculture (18.7%), wetland (13.8%), rangeland (12.0%), and urban (6.8%). Soil samples were analyzed for total carbon, hydrolysable labile C with 6 N HCl, labile mineralizable C, and labile dissolved organic C by hot water extraction. Stable recalcitrant C was calculated as the difference between total C and hydrolysable C.

Visible/near-infrared diffuse reflectance spectroscopy was used to scan the same soil samples. Chemometric modeling was used to relate the laboratory measurements to spectral data using five different parametric and non-parametric regression methods: stepwise multiple linear regression, principal components regression, partial least squares regression, regression trees and committee trees. Results indicated that robust models for all soil properties, except hydrolysable C, could be developed with slightly better results derived using partial least squares regression. Our chemometric models have the potential to more rapidly assess total, labile and stable carbon pools at landscape scales.

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Using a Legacy Soil Sample to Develop a Mid-IR Spectral Library

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This paper describes the development of a diffuse reflectance spectral library from a legacy soil sample. When developing a soil spectral library, it is important to consider the number of samples that are needed to adequately describe the soil variability in the region in which the library is to be used; the manner in which the soil is sampled, handled, prepared, stored and scanned; and the reference analytical procedures used. As with any type of modelling, the dictum is ‘garbage in = garbage out’ and hopefully the converse ‘quality in = quality out’. The aims of this paper are to: (i) develop a soil mid infrared (mid-IR) diffuse reflectance spectral library for cotton-growing regions of eastern Australia from a legacy soil sample, (ii) to derive soil spectral calibrations for the prediction of soil properties with uncertainty and (iii) assess the accuracy of the predictions and populate the legacy soil database with good quality information. A scheme for the construction and use of this spectral library is presented. A total of 1878 soil samples from different layers were scanned. They originated from the upper Namoi, Namoi and Gwydir valley catchments of north-western New South Wales (NSW) and the McIntyre region of southern Queensland (Qld). A conditioned Latin hypercube sampling (cLHS) scheme was used to sample the spectral data space and select 213 representative samples for laboratory soil analyses. Using these data, partial least squares regression (PLSR) was used to construct the calibration models, which were validated internally using cross validation and externally using an independent test data set. Models for organic C (OC), cation exchange capacity (CEC), clay content, exchangeable Ca, total N (TN), total C (TC), gravimetric moisture content θ_g, total sand and exchangeable Mg were robust and produced accurate results ($R^2_{adj} > 0.75$ for both cross and test set validations). The root mean squared error (RMSE) of mid-IR-PLSR predictions was compared to those from (blind) duplicate laboratory measurements. Mid-IR-PLSR produced lower RMSE values for soil OC, clay content and θ_g. Finally, bootstrap aggregation-PLSR (bagging-PLSR) was used to predict soil properties with uncertainty for the entire library, thus repopulating the legacy soil database with good quality soil information.

Keywords: mid-IR diffuse reflectance spectroscopy, spectral library, partial least squares regression, bagging-PLSR, legacy soil data

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Interpretation of Soil ECa Measurements at Landscape Scale

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Measurements of the apparent electrical conductivity (ECa) in soils are a common tool in digital soil mapping to get spatial information on soil type or soil properties distribution. Yet ECa measurements cannot be used solely, they have to be combined with other spatial data. Such information are e.g. easily available digital elevation models (DEM), digital soil maps, remote sensing data and others. One common application of digital soil mapping is the use in precision agriculture. Precision agriculture is done until present mostly at the field scale, and ECa maps of single fields are used to define management zones. Sometimes e.g. clay maps are derived of ECa measurements by using pedotransfer functions (PTF). However, it can be stated that the ECa signal in soils reflects some influencing factors which are connected to the landscape and which should be regarded at a regional scale. Such factors might be the regional water balance at the scale of watersheds and the geological and geomorphological conditions of the environment.

We examined in the study region of Wulfen in East Germany the influence of landscape characteristics on ECa measurements. The research area is part of the "Magdeburger Boerde" landscape, it is dominantly flat, and it is covered by younger Quaternary sediments, including loess. Climate is relatively dry with a mean annual precipitation of about 450 mm. About 15 field ECa maps were combined to a regional ECa map, whereas the single fields were chosen by their location in representative landscape positions. For the same region a highly precise laser DEM with a spatial resolution of 5 m and accuracy in height of 5 cm was prepared. Existing geological maps in the scale 1:25.000 were digitized to identify areas of different substrate textural classes and carbonate contents. On these fields about 100 soil profiles were investigated and soil samples were examined in the laboratory for soil texture, bulk density of soil, carbonate, soil water, organic matter and nutrient contents and pH.

It was observed that in the study area, where carbonate occurs in a large percentage of the soils, dissolved carbon may move from soils on upper terrain positions downward to soils near waterlines and depressions, where it may occur up to the soil surface. As carbonate content is one of the factors amongst several others, that influences the ECa signal, e.g. soil water content, cation exchange capacity, salt content, soil temperature and clay content, it may be necessary to correct the ECa measuring not only, as is done in the regular case, by soil moisture, soil temperature and salt content, but also by the carbonate content. Otherwise high ECa values may suggest a high clay content by using PTF for creating clay maps, where in fact soil is only rich in carbonates. In that case clay maps derived of ECa measurements may be inappropriate.

We suggest for future use of ECa measurements a change from the field scale to the regional scale, and to consider soil and landscape water balance, geomorphology and geology.

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Airborne Radiometric Survey Data and a DTM as Covariates for Regional Scale Mapping of Soil Organic Carbon across Northern Ireland

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The recently completed soil geochemistry and airborne geophysical survey of Northern Ireland (TELLUS) provides a unique dataset for the investigation of spatial soil inference systems (SSINFERS). Through better understanding of these SSINFERS we can increase the precision of maps of soil properties and reduce the number of measurements required to map these soil variables in similar environments, or to monitor the future change in these variables across Northern Ireland.

The soils of Northern Ireland have formed since the last glaciation and are dominated by gleys (54 %) with a significant proportion of peat (14.1 %); land use is predominantly pasture (75 %), with a smaller proportion devoted to arable agriculture (6 %). The soil survey comprised the collection of 6862 samples at a resolution of 1 sample per 2 km2 on a non-aligned grid.

The airborne radiometric survey estimated the concentrations of K, Th and U in the upper 35cm of the soil at intervals of 65 metres along flight lines with a line separation of 200 metres. Based on a nominal survey altitude of 56 metres, 80% of the signal originates from an elliptical support with an average radius of ca. 130 metres. An independent set of 456 topsoil texture determinations (based on a 5 km survey grid) were also available.

A classification by soil parent material (bedrock geology and Quaternary deposits) accounted for 68, 63 and 44 % of the variance of K, Th and U respectively based on a random subset of 20,000 (0.02%) radiometric survey points. This suggests that the high-resolution airborne K, and to a lesser extent Th, would be effective in distinguishing between soil types at scales of around 1:50,000.

Pearson correlations between soil texture (proportions of clay, silt, sand) with the radiometric elements were generally poor, the nine coefficients ranging from r= -0.28 to r= 0.22. We might have expected the K to correlate with clay because the predominant clay minerals (mica and mica-smectite) have K integral to their structure. We suggest that this relationship should be investigated further at spatial scales of less than 5 km.

The relationships between mineral topsoil (typically 5-20 cm depth) soil organic carbon (SOC) measured by loss on ignition, radiometric K and altitude were explored via linear models of coregionalization (LMCRs) and linear mixed models (LMMs). These models indicated that SOC had a strong negative correlation with K, largely reflecting the dilution of K-bearing soil minerals by increasing organic matter contents. However in soils with low SOC the LMCRs indicated that there was a positive correlation between SOC and K over short distances (<2 km) probably reflecting the ability of clay minerals to protect SOC.

A substantial component of the spatial variation of SOC (particularly over short distances) could be accounted for by the variation of K and altitude. Thus the uncertainty of predictions of SOC can be substantially reduced by including these variables as covariates upon cokriging, or as fixed effects upon applying the best linear unbiased predictor. We design sampling schemes for future monitoring of SOC in Northern Ireland based upon the LMMs and demonstrate the potential savings upon including altitude and K as fixed effects.

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Predicting Soil Moisture Characteristics Using Mid-Infrared Spectra and Pedotransfer Functions: The Pros and Cons

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The allure of cheap, rapid and relatively accurate predictions of various soil properties has led to ever increasing interest in spectroscopic techniques. A large majority of this work has focused on developing spectral multi-variate calibrations for a number of soil properties. Whilst predictions have proved relatively accurate for a number of properties, some properties remain problematic, particularly those properties functional of soil structure such as the water retention. In this work we look at the efficacy of diffuse mid-infrared spectroscopy in predicting water retention and whether better predictions can be achieved using pedotransfer functions using spectroscopic predictions as inputs.

Whilst good predictions were achieved for particle size distribution and moisture retention of disturbed samples, moisture retention predictions for intact samples were found to be very poor. Unsurprisingly, better predictions were observed at dry end matric potentials where moisture retention is correlated with particle size distribution rather than soil structure. The neural network PTF was found to have better goodness-of-fit for all matric potentials, however predictions at larger matric potentials (wet end) were still poor as MIR is unable to accurately predict soil bulk density.

In light of this work, we propose that whilst MIR spectroscopy may be a valuable predictor of fundamental soil constituents such as particle size fractions and organic carbon, predictions of soil properties functional of soil structure such as volumetric moisture retention, may prove difficult. MIR in combination with pedotransfer functions should provide improvements to moisture retention predictions through better representation of the functional processes, in this case the van Genuchten function.

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Using Wavelets to Preprocess and Compress Soil Diffuse Reflectance Spectra for Multivariate Calibrations

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Soil spectra can often be noisy and the spectral libraries used for multivariate calibration can be large. Often these libraries are used and re-calibrated many times over for different soil analysis, making computation of the models quite demanding. Wavelet analysis can be used to preprocess and compress soil diffuse reflectance spectra.

Although encouraging results have been published concerning the use of DWT for signal compression and denoising, its application in multivariate calibration has received comparatively little attention, with very few contributions reported in the literature. The aims of this paper are: (i) to investigate the use of the discrete wavelet transform (DWT) as an effective de-noising and data compression tool for soil mid infrared (MIR) spectra and (ii) to combine the DWT with PLSR for improved modelling and prediction of soil properties.

The selection of wavelet coefficients for inclusion in the PLSR model (W-PLSR) was made first on the thresholding of the wavelet coefficient variance and then on the correlation with soil OC. This W-PLSR strategy is applied in a case study involving MIR determinations of soil organic carbon (OC). The dataset comprises 600 soil samples from NSW Australia. Their spectra were collected in the range between 2500–20000nm.

Considerable compression was achieved with respect to the original wavelength domain. The effect of varying the wavelet and the threshold level on the prediction ability of the resulting models is investigated. The results show that W-PLSR can outperform standard PLSR for predictions of soil OC.

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Using Sequential Gaussian Simulation to Assess Spatial Uncertainty of Soil Moisture Content in Lower Austria

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Soil moisture content has a vital role in a variety of hydrological processes such as infiltration, runoff and erosion. Mapping the spatial pattern of soil moisture is then essential for appropriate addressing these processes. Geostatistics is often used to characterize the spatial variability of soil moisture. This information may then be used for estimation of soil water content e.g., by ordinary kriging (OK) or modeling location-specific uncertainty (local uncertainty) of the estimates by indicator kriging (IK). Kriging-based algorithms however smooth out the details and are incapable of detecting multi-location uncertainty (spatial uncertainty) of soil moisture. Sequential Gaussian simulation (sGs) is in contrast a geostatistical conditional simulation, which can model the spatial uncertainty through generation of several equally probable stochastic realizations of soil moisture spatial distribution across a study area. In this study sGs is used to map soil moisture content and more specially to provide a quantitative measure of its spatial uncertainty in a small catchment in Lower Austria. The results show that spatial pattern of soil moisture content is well recognized using the sGs. Reliable spatial uncertainty assessment of soil moisture is very helpful when this information is used in decision-making processes e.g. identification of areas with high level of water content which may results in surface runoff and water erosion.

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Inherent Uncertainty as a Physical Restriction for Soil Quantification

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High variability of measured properties at different temporal and spatial scales is typical for soil research, and understanding the origin of data uncertainty is fundamental for understanding environment. The general character of observed variability and physical consideration of the particular case of relation between soil surface area and particle size distribution results in the fluctuation hypothesis: variability arises from soil nature as a mixture of discrete and heterogeneous elements (elementary particles, aggregates, etc.).

Quantitative models of soil must necessarily be based on a finite number of (physical) samples of what in principle can be viewed as an infinite object. Furthermore, it is not in principle possible to repeat a measurement on a particular soil sample. Accounting for these features makes the measurability of soil properties, the repeatability of observations on the same objects and thus their quantification a real problem. Solving it seems impossible within the present paradigm, oriented on studies of real bodies/systems.

If the discrete nature and heterogeneity of soil is a physical basis of variations at different spatial and temporal scales, the observed uncertainty is really an inherent feature of soils, and not only the result of a lack of adequate current understanding. Given such understanding of the nature of uncertainty challenge the soil paradigm, the concept of a soil object that can be studied quantitatively within the paradigm of exact sciences (physics, chemistry) arises at macroscopic scales only; smaller scales do not allow neither deterministic, nor probabilistic description. This analysis suggests, as a conceptual starting point, the concept of the ideal, infinite body, which allows nondisturbing repeatable measurements and exact quantitative description. The notion of ideal soil body is a physical equivalent of statistical notion of entire assembly. From practical point of view a notion of soil arises at polypedon or larger spatial scale only, at smaller scales soil seem to be non-measurable and thus non-quantifiable. This concept equally suits both the probabilistic and deterministic approaches to soil – the two complementary approaches to the description of fluctuating phenomena. The obviously more informative first approach, no doubt, will dominate in future, while the less demanding lumped second approach, in analogy with the development of physics, may turn out to be a quicker way towards a quantitative theory of environment. Such understanding of soil nature puts forward the fundamental problem of averaging of microscopic physical and chemical laws over spatially extended soil bodies. While the discrete nature of soil is a fundamental, inevitable restrictor for scales of soil quantification, the typically done in indirect soil measurements linking of mostly surface area related properties to easily measured weight of soils aggravate uncertainty drastically and, as a matter of principle, can be avoided. Analysis of nuggets on variograms is a simple but valuable tool to decide w hether traditional statistical treatment of available soil data is appropriate, or conceptually new experimental approaches are required. The practical significance of the concept is important for environmental monitoring, ecological management and remediation.

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Statistical Probability Models of Soil Properties (One Example of Chestnut Soils in the South of West Siberia)

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Variability of soil properties even within uniform unit of soil cover (at reasonable level of hierarchy) causes necessity to apply statistical and probability approaches for evaluation of these random values. Easiest models of random values are their statistical or probability distributions. In classical statistical theory statistical and probability distribution are not synonyms. The first is empirical one, and the other is theoretical one. They often strongly differ from famous normal or lognormal distributions. Indeed there are many technical and theoretical problems to receive the only reliable function of this or that distribution. So we conducted statistical investigation of statistical and probability distributions of chestnut soils. We analyzed data of two soil surveys (1:25000) conducted at the big part (1,6 million ha) of Kulunda steppe situated in south of West Siberia.

For assessment of local variability of properties we quantitatively evaluated fluctuation in an individuum (pedon) of chestnut soil under different use (virgin soil, unirrigated arable soil, and irrigated arable soil). It was shown that these fluctuations make up 20-40% of the property changeability in an elementary soil area (that is area, occupied by one soil series).

We used new approach for determination of statistical distributions of attributes and suggested it for evaluation the changes of soil properties under monitoring. Automatically choosing of distribution from rather big set of known functions, optimal data grouping, the evaluation of parameters of distribution according to the method of maximal validity, the multiplicity of testing alternatives and polycriterial checking of hypothesis provide an evaluation of the specific type of function and parameters of statistical distribution of attributes very precisely and reliably. We named the distribution received by such a way on ground of big samples of reliable input data as statistical probability distribution.

The functions and parameters of statistical probability distribution were determined for chestnut soil properties in elementary soil areas. It was shown that the statistical probability distributions of soil properties are suitable for reliable and integral evaluation of the effect of soil forming factors on soil properties and, hence, for the comparison of current and future anthropogenic and natural changes. Comparison of statistical distributions of soil properties at different time moments obtained using this technique gives the more precise and reliable assessment of actual changes of soil under anthropogenic and natural processes. We recommended this technique for specialists in soil science and ecology, who interested in statistical analysis and monitoring of natural objects.

This approach was applied to the description of the variability of soil properties within series (Mikheeva, 2001, 2005). It is reasonable to use statistical entropy as a system criterion to estimate soil formation and evolution of soil cover (Mikheeva, 2004). The value of entropy may be calculated using probabilistic distribution. We can consider the value of entropy calculated from statistical probabilistic distributions of soil properties as one of the systemic statistical and probability characteristics of variability of soils, reliable to some mistakes of input data.

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3D Digital Soil-Geology Models of the Near Surface Environment

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Research in the top few metres of the ground beneath our feet has traditionally been split between soil science, geology and several sub-disciplines. This has lead to different working practices, classifications and boundaries as well as inconsistent approaches to databasing and modelling. A significant uncertainty lies within the "transition zone" between the pedosphere and geosphere. The British Geological Survey (BGS) set out to investigate this zone through multidisciplinary field surveys at both a site specific and catchment scale in representative soil-geoscapes across the UK. The spatial 3D soil-geology model is developed by the combination of spatial soil and geoscientific findings.

Whilst undertaking these studies the BGS were particularly interested in investigating whether technologies developed to map geology in 3D can be used to routinely develop spatial models of the soil-geology environment, and if technologies used in digital soil mapping can assist in reducing uncertainties associated with such models at a variety of scales.

The presented soil-geology model is an example of recent work carried out on an area of approximately 2 km2 near Shelford, Nottinghamshire, UK. The site lies on the River Trent floodplain and an adjacent gentle slope of Triassic mudstone. The whole site is underlain by typical red mudstones of the Triassic Mercia Mudstone Group with some interbedded greenish grey siltstones and sandstones.

This is overlain by up to 5 m of Pleistocene and Holocene river terrace deposits, varying from sand to coarse gravels and Holocene alluvial and colluvial deposits. Fieldwork was orientated along several parallel traverses running from the hilltop, downslope towards the River Trent.

The study of the survey area comprised of two main stages. Firstly a field survey which included techniques such as a detailed soil and geological survey, pitting and drilling, installation of piezometres, soil moisture tests, high-resolution electrical mapping, electrical resistivity tomography, ground penetrating radar, magnetic susceptibility, gamma spectrometry, remote sensing and terrain analysis.

The second stage involved the digital assembly of data, processing, and the development of the 3D soil-geology model. Each survey delivered its own results in form of maps, tables and property models which were collated into one software package (GSI3D by INSIGHT GmbH).

Developing a solid 3D soil-geology model in GSI3D utilizes a Digital Terrain Model, mapped geological and soil line work, downhole borehole and augerhole data, and geophysical data. This enables the geoscientist to construct regularly spaced intersecting cross-sections by correlating boreholes and the outcrops-subcrops of units to produce a fence diagram of the area. Mathematical interpolation between the nodes along the sections and the limits of the units or horizons produces a solid model comprising of a series of stacked triangulated volume objects.

The final 3D model shows several top- and subsoil horizons in conjunction with the underlying Holocene, Pleistocene and red Triassic Mercia Mudstone parent materials.

These models can aid studies of near surface processes including the movement of water, dissolved agricultural nutrients and associated eroded soil particles.

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Shallow landslide susceptibility modelling - A comparison of different approaches for the coast of Jasmund Peninsula (Rügen/Germany)

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The Pleistocene and Holocene deposits of Jasmund Peninsula (Rügen/Germany), consisting of till, clay and sand, are prone to landsliding. However, field investigations within a pilot study area showed that the types of movement vary. Whereas the northern coastal part is dominated by slope creeping and very few large rotational landslides, the eastern and southern coast portions show a great amount of shallow translational movements.

To evaluate the sliding susceptibility of the Pleistocene and Holocene sediments, firstly a landslide inventory-based statistical modelling approach was followed. Among nine derived factor maps displaying thematic information attributed to slope stability, the geological map and the topographic attributes slope and distance to drainages were found to be the most sensitive factors to be incorporated in the model. Secondly, a physically based slope stability evaluation with a cohesionless infinite slope model combined with a simple topographic wet-ness index was conducted. The material parameters required for the deterministic modelling were derived empirically for each mapped sedimentary unit from particle grain size analysis of various samples taken in the field.

As for both modelling approaches more than 70% of the mapped landslide area is covered by the two highest susceptibility classes, they can be considered suitable for shallow sliding susceptibility assessment along the coast of Jasmund. However, the statistical model cannot depict for the creeping movements along the northern cliff portion. A more realistic representation of the sliding susceptibility for this terrain is given by the physically based factor of safety mapping. Anyway, in other parts, the statistical model shows a better agreement with the field observations, indicating that a combination of the two different approaches might be the best solution to model the landslide susceptibility in the study area.

Following this hypothesis, a weighted overlay approach (50% each map, equal interval slicing) was used to join the statistical and the physically based model. The results clearly indicate a success of the weighted overlay as more than 75% of the mapped landslides are covered by the two highest susceptibility classes.

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Geochemical Analyses of Czech Soils

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All industrially developed countries are nowadays more or less facing the nuisance called soil contamination. Though chemical methods are the most accurate in determination of the content of given contaminants hence primarily used for their mapping, it is proved that some indirect methods can express nearly similar results and to be less time consuming and even more importantly money saving. One of these approaches could be a method based on the measuring of magnetic properties. It is used mainly for prediction of heavy metals contamination at potential hot spots. Magnetic properties depicted in this paper are presented by magnetic susceptibility.

The relationship between geochemical analyses of heavy metals contents (measured by Central Institute for Supervising and Testing in Agriculture) and magnetic susceptibility (measured by Geophysical Institute, Academy of Sciences of the Czech Republic) was studied. Soil samples were taken from topsoil and subsoil at different agricultural land use all over the Czech Republic. Pollution Load Index (PLI) was determined in order to evaluate all heavy metals at once, in addition to separate analyses of each element (Cd, Cr, Cu, Pb, and Zn). Bivariate and multivariate statistical methods were used for obtaining and assessing basic statistical data (factor analysis and cluster analysis – fuzzy k-means). Furthermore, variogram was calculated to describe spatial dependence.

It was found out that both concentrations of heavy metals and magnetic susceptibility were significantly higher in topsoil compared to subsoil and the element the most correlated to magnetic susceptibility was Cu. Analysis of variance as well as factor analysis revealed increased values of heavy metals in hop fields and permanent grasslands. Only magnetic susceptibility in subsoil showed spatial dependence at the whole area of the Czech Republic. Graphical delineations of cluster analysis results corresponded approximately to the maps of magnetic susceptibility, Cu and PLI.

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Parent Materials and Land Use Effects in Population Frequency Distribution Parameters of Selected Soil Variables (Case Study: South Part of Ahar Region)

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Data of 179 soil samples have been taken from 88 study points(44 prifiles&44 augers) located in south part of Ahar region (47000/00//to 47007/30//East longitude and 38024/00// to 38028/30// North latitude) contain of different parent materials such as Silty shale,marl and limestone, Old terraces,Volcano- sedimentary rocks, Porphyritic andesite, trachyandesite associated with basic dykes, Cultivated area, Recent alluvium, Conglomerate and marn based on geology map, so that the Conglomerate and marn and Old terraces with special reference to highly expanding associated with wheat and barley rainfed were studied. EC (1:2.5 ratio, and extracted of saturated paste), pH (1:2.5 ratio, saturated paste and extracted of saturated paste), carbonate and O.C. are 7 selected parameters.1:2.5 ratio and extracted of saturated paste pH with probably of 1 and 5 percent respectively follow normal distribution and the others abnormal distribution (logaritmic converting was not useful) in the case of without parent material and land use effectives. Rainfed wheat associated with Old terraces due to normalize distribution of carbonate and pH ratio(5%) and the others either simple or logarithmic conditions show abnormal distribution and so rainfed barley with the same parent material influence to normalization of all parameters excluding of EC (both of them). Conglomerate and marn associated with rainfed wheat follow normal distribution (5%) of O.C.,pH (all of 3 cases) and abnormal distribution of carbonate parameter with logarithmic transformation. Rainfed barley vs wheat associated with Conglomerate and marn due to O.C.
and EC follow abnormal distribution while all of them can be converted to normal distribution applying of logarithmic transformation tools instead of EC (1:2.5 ratio).Using of statistical parameteric and nonparameteric methods respectively to normal and abnormal distribution are recommended. Meanwhile, Logaritmic (R2=0.7), Linear (R2=0.86), Polynomyaly (R2=0.85), Power (R2=0.85) and linear (R2=0.95) relationships between EC extracted and 1:2.5 ratio at the five comparing situations have been resulted. Highly regression coefficient for the 5th case caused to recommendation of linear equation applying to keep out EC extracted saturated paste from the EC 1:2.5 ratio of that soil.

Key words:
Frequency distribution, Regression coefficient, pH (soil reaction), EC (Electrical conductivity), Logaritmic convert, Extracted saturated paste.

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The Quantity and Form of Soil Organic Carbon in UK Urban Areas

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The occurrence of substantial quantities of black carbon (BC) in urban soil due to local dispersal following incomplete combustion of fossil fuel complicates the determination of labile SOC (soil organic carbon). Estimates of SOC content were available from LOI (loss on ignition) analyses undertaken on samples from comprehensive soil geochemical surveys of several UK urban areas. We randomly selected ten samples from each decile of the LOI distribution for each of the surveys of Coventry (n=808), Stoke-on-Trent (n=737) and Glasgow (n=1382) to investigate the proportions of labile and BC. We determined their TOC (total organic carbon) and BC contents, and by difference the labile SOC content, and investigated the linear relationship of the latter with SOC estimates based on LOI analyses. There was no evidence for difference in the slope for the three urban areas. We used a linear regression of labile SOC based on LOI analyses (R2 = 0.81) to predict labile SOC for all samples from the three urban areas.
The mean BC content of the ten samples from Glasgow (34%) was significantly greater than Coventry and Stoke-on-Trent (16 - 17%) which we attribute to greater anthropogenic activity in the former. Analysis of the thirty samples showed that LOI at 450 degrees C accounts for a consistent proportion of BC in each sample (R2=0.97). Differences between TOC (combustion at 1050 degees C) and an LOI estimate of SOC may be a cost-effective method for estimation of BC. Previous approaches for estimating urban SOC based on, for example, half their mean SOC content of soils from their equivalent associations under pasture, underestimated the empirical mean value.

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Scale-dependent Accuracy of Land Quality Maps Designed for Risk Area Identification in the EU Soil Framework Directive

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The European Commission is preparing a Directive on the protection and sustainable use of soil. The proposed framework requires the identification of areas at risk to soil threats, such as erosion, compaction and soil organic matter decline. Before this backdrop, soil scientists have to advise politicians on the level of detail of soil information maps/data used as basis for risk identification.
A number of models for assessing the risk of water erosion have been developed over the last 40 years. All influencing factors (soil erodibility, rainfall erosivity, degree of protection provided by vegetation or crops, angle of the slope and its length), i.e. each cause of soil loss variation may not only operate independently or in combination with other factors but also over a wide range of scales. Areas where fine-scale soil maps and very detailed soil loss measurements are available can serve as reference areas for evaluating the accuracy of coarse-scale land quality maps. In this study not only the effect of soil spatial variability was investigated, but also the spatial resolution of climate and relief information as well as the regional applicability of pedotransfer rules was considered.
Comparisons show that the area affected by water erosion is underestimated when only coarse-scale land quality maps are used. Any information provided by nationwide outline maps has to be linked to results of regional and local monitoring networks. Recommendations concerning the appropriate scale for risk area identification can be given. This case study may serve as an example how a pedometrical approach can be applied to support decisions in soil protection policy.

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