ΠΕΔΟΜΕΤRON

The Newsletter of the Pedometrics Commission of the IUSS

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From the Chair

Dear Colleagues,

This issue of Pedometron is timed to coincide with the biennial meeting of the Pedometrics Commission, *Pedometrics 2007*, which is taking place in Tübingen, Germany, from 27th August. I am sure that, as in the past, the Pedometrics meeting will be a great success, and offer my thanks to Thorsten Behrens, Thomas Scholten and Volker Hennings for their work in organizing it. If you are at the meeting and reading this in hard copy then welcome! If not, then where are you? Keep an eye open for the announcement of *Pedometrics 2009* and make sure that you come next time.

In 1900 the mathematician David Hilbert, while attending the International Congress of Mathematicians, issued a list of 23 problems in mathematics. He saw these as the key questions that needed to be addressed if the subject was to advance. Several of these problems remain unsolved, others turned out to be uninteresting, others set the agenda for much of 20th Century mathematics. Hilbert was an important figure in the history of mathematics, but one of his most important contributions was to ask the questions, even if others answered them.

If pedometrics is to continue to flourish as one of the most active branches of soil science then we need to keep on asking new questions. This is one reason why we have started the Profile section in Pedometron. However, I would like to try to kick-start the process. Here are five questions that I think we should be addressing. What do you think? Which ones would you add? Email them to me at chair@pedometrics.org and I will issue a full list for discussion on the website, www.pedometrics.org.

1. Does a soil classification, map legend, and mapped soil boundaries convey any information that can not be captured by the (cross-)variograms, point observations and kriged estimates of sufficient soil properties?

2. If information on a soil variable is an input (e.g. to crop management) then can we derive its production function so that the user can decide how much data on that variable it is rational to pay for?

3. *I do not believe that you are right in your thesis that it is impossible to derive statistical conclusions from a deterministic theory* (Einstein to Karl Popper, 1935). Who is right, at least for soil science?

4. Is Soil Variability a component of Soil Quality, and does more mean better? As a corollary, is pedodiversity the same as soil variability?

5. I want to predict the volumetric water content of the soil at a site. How can I decide which is more useful, a soil map based on broad soil classes such that the map units are 80% pure but the within-class coefficient of variation is 100%, or a map based on narrower classes for which the map units are 60% pure but the within-class coefficient of variation is 30%?

In the meantime, here's to a successful conference.

Murray

Inside This Issue

An Introduction to Tübingen & South-West Germany

Tübingen and the Eberhard Karls University

(from various sources, especially Wikipedia, edited by Thorsten Behrens and Thomas Scholten)

Tübingen is located in Baden-Wurttemberg, a state of the Federal Republic of Germany, in the southwestern part of the country, east of the Upper Rhine bordering to Switzerland and France. The city is situated on a ridge between the Neckar and Ammer rivers about 30 kilometers southwest of Stuttgart, the capital of Baden-Wurttemberg.

Tübingen is a traditional university town and amongst the cities in Germany with the highest quality of life. It is best described as a mixture of an old and distinguished academic flair including liberal politics and German-style fraternities, with rural, agricultural and typical Swabian elements. Tübingen's first official appearence in records dates back to 1191. Due to the city's lack of heavy industry the historic old town of Tübingen with its crooked cobblestone lanes, narrow stairs between houses, canals, and traditional half-timbered houses survived World War II. Picturesque buildings and landmarks include the town hall (Rathaus) and the market square (Marktplatz) as well as the castle (Schloß Hohentübingen). The central landmark of Tübingen is the collegiate church (Stiftskirche). It, along with the rest of the city, was one of the early converts to Martin Luther's protestant church. Famous Tübingen residents include the poet Friedrich Hölderlin, Alois Alzheimer from whom Alzheimer's disease takes its name, Friedrich Miescher who was the first to discover DNA, and Wilhelm Schickard who developed the first mechanical computer. The philosophers Friedrich Schelling and Georg Wilhelm Friedrich Hegel, and the astronomer Johannes Kepler studied in Tübingen. Joseph Alois Ratzinger (now Pope Benedict XVI) held a chair in dogmatic theology at the University. Hermann Hesse worked in Tübingen as a bookseller trainee from 1895 to 1899. Also, the current President of Germany, Horst Köhler, studied in Tübingen.

Source: Wikepedia

Today, Tübingen has about 83.000 inhabitants and 24.000 students. Nightlife in Tübingen is centered on the numerous pubs in the old town along with a large number of clubs. Tübingen is one of the five classical "university towns" in Germany; the other four being Marburg, Göttingen, Freiburg and Heidelberg.

The University of Tübingen, officially called Eberhard Karls University, is one of Germany's oldest universities, internationally noted in medicine, natural sciences, and human sciences. It is not a campus university, but is spread throughout the old town and on the adjacent hills. The University was founded in 1477 by Count Eberhard V (Eberhard im Bart), later the first Duke of Württemberg, a civic and ecclesiastic reformer who established the school after becoming absorbed in the Renaissance revival of learning during his travels to Italy. The University is made up of 14 faculties: Protestant Theology, Catholic Theology, Law, Economics and Business Administration, Medicine, Philosophy and History, Social and Behavioral Science, Modern Languages, Cultural Sciences, Mathematics and Physics, Chemistry and Pharmacy, Biology, Geosciences, and Information and Cognitive Science.

The Faculty of Geosciences is one of the top ten geosciences faculties in Germany. It consists of three institutes: Geosciences (formerly Geology, Palaeontology and Mineralogy), Geography, and the natural science branch of Early Prehistory and Quaternary Ecology.

The Institute of Geography and the Chair of Physical Geography

(Thomas Scholten and Thorsten Behrens)

The Institute of Geography (IGT) was founded in 1897 with the appointment of Alfred Hettner as the first full professor on the newly created Chair of Geography in the Klinikumsgasse 12 (‘Old Burse’). From 1920 to 1977, the institute had its residence in Tuebingen’s castle ‘Hohentuebingen’. Today’s address is the ‘Old Children’s Hospital’ in the Ruemelinstraße 19-23. About 1.000 students are educated at present accompanied by 6 full professors and 45 employees.

The Chair of Physical Geography is part of the Institute of Geography (IGT). The chairholder and director of the IGT, Prof. Dr. Thomas Scholten, together with

Dr. Thorsten Behrens and Dr. Peter Kühn started their work in Tübingen in October 2005 at the 'Old Children's Hospital' in the Ruemelinstreet 19-23. Main challenge to cope with during the first years is to facilitate the laboratory of soil science and geoecology and to run the computer pool for GIS and Data Mining approaches in Soil Science and Geomorphology.

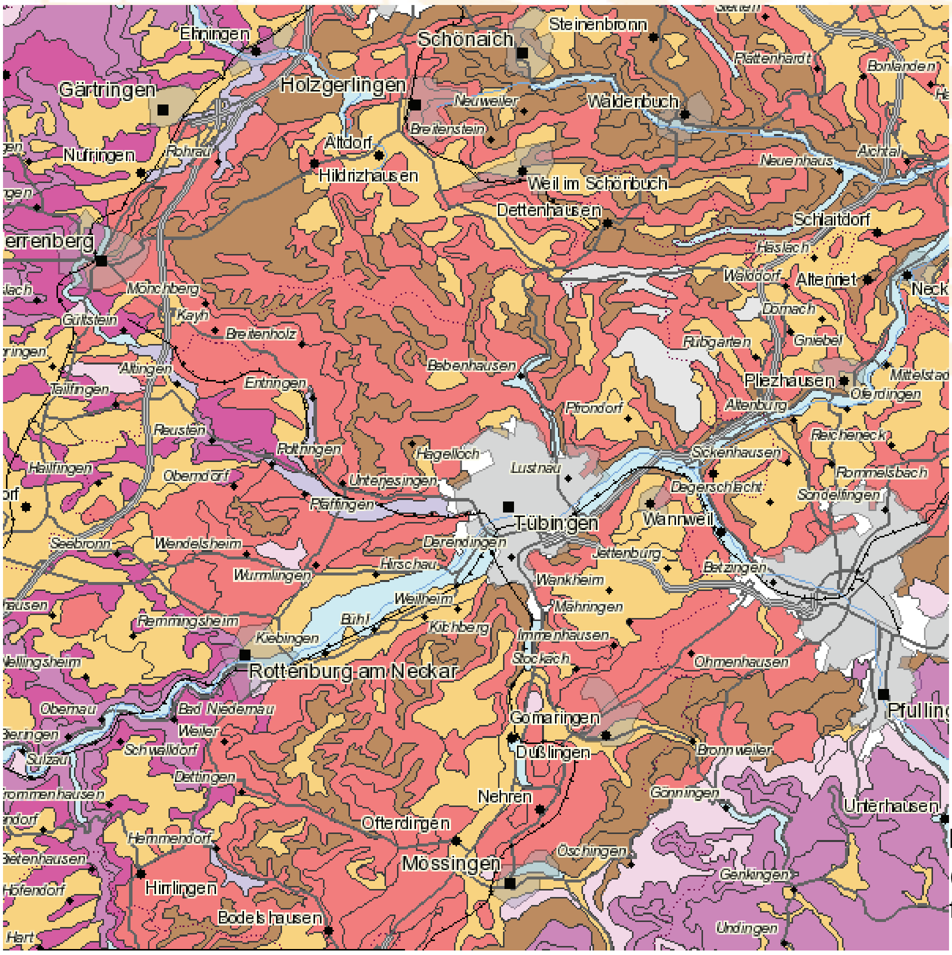
Key issue of the soil science working group is a process-based understanding of soil formation and landscape development and how this is influenced by natural and human factors. Research activities focus on soil-landscape modelling, GIS-based digital mapping and landscape reconstruction. Macro- to micro-environmental analyses of soils, sediments and colluvial deposits serve as a basis for reconstruction of site properties at different time slices. Methods used range from palaeopedological and pedoarchaeological analysis using geochemical and micromorphological approaches to fingerprinting and sediment source identification techniques. These results from field mapping and laboratory analysis will be transferred to integrated modeling systems based on the linking of process-based approaches and GIS-based techniques in order to get a better understanding of the development and mechanisms of land use and cultural change over time. The methodological approach comprehends pedometrical methodologies and data mining techniques like artificial neural networks, vector quantization, feature selection and geostatistics.

The soil science working group in Tübingen has a unique and rich methodological ensemble used for research and teaching in Soil Science, Geoecology and Geomorphology as well. The full spectrum of field, laboratory and GIS analysis is offered with special emphasis on soil and erosion mapping (field), micromorphology and substrate analysis (laboratory), as well as digital terrain analysis, machine learning, and statistical sampling (GIS and Pedometrics). Interdisciplinary research and teaching is well established between soil scientists, geographers, ecologists, geologists and archaeologists. Similarly, a strong cooperative research approach is followed.

Soils and Landscapes around Tübingen

(Thorsten Behrens and Thomas Scholten)

Tübingen (48° 31′ N, 9° 3′ O, 305 m asl, 8.7° C mean annual air temperature, 741 l/m² mean annual preciptation) is located in the Neckar Valley, about 30 km to the south of Stuttgart. The cuesta landscape of the Swabian Alb borders the neckar valley about 20 km southeast of Tübingen with its overwhelming 800-1000 m high northwards facing ridge. The Schönbuch nature park connects north of Tübingen with a mean height of about 500 m asl. The park covers 15,600 ha of almost entirely forested hills between Stuttgart and Tübingen. It is situated in Triassic (Keuper) hills and represents a landform which is characteristic for large parts of southern Germany.



The soils occuring in Tübingen and its surrounding area are domiated by Haplic, Vertic and Stagnic Cambisols developed in pleistocene periglacial slope deposits and regolith from sandstone and claystone. Luvisols developed from Loess accumulations are associated with Calcaric Cambisols and Stangnic Luvisols. Rendzic Leptosols and Terra Fusca occur regularly on the Swabian Alb on Jurrasic limestone. The soil classes mapped at a scale of 1:150 000 are shown in Fig 1. Based on the broad range of parent material the available water capacity is highly diverse starting from 10-90 mm in the in Rendzic Leptosols up to > 200 mm in the Loess

Haplic Cambisol	Luvisol	Fluvisol
Eutric Cambisol	Phaeozem	Gleysol
Stagnic Cambisol	Vertisol	Rendzic Leptosol

Figure 1: Soils around Tübingen (1:150 000, www1.lgrb.uni-freiburg.de/geoviewer).

Environment and Physiography of South-West Germany

(Karl Stahr und Wolfgang Fleck, EUROSOIL 2004 Excursion Guide Book)

Geology and Physiography

The geological boundaries of South Germany are the Alps to the South, the Rhine rift valley and the Hessian depression until the Vogelsberg to the West and the crystalline massif of the Bohemian shield continuing into the Thuringian Forest to the North and East. Therefore, the shield of South-western Germany is mainly a triangle.

The area can be divided into five major landscapes: morphologically the highest, but geologically the most voluminous and oldest are the Black Forest and the Odenwald, built up in the central part by granite and gneiss. From this crystalline height to the east occurs the famous cuesta landscape of the Germanic Triassic (Buntsandstein, Muschelkalk and Keuper). This cuesta landscape is topped by the last cuesta, the Jurassic limestone of the Swabian and Franconian Alb, which crosses South Germany from Schaffhausen (Switzerland) to the north-east (Bayreuth, Bavaria).

Southwards of this limestone follows a Tertiary basin filled with Molasse and Alpine Oligocene and Miocene debris. At the same time the Upper Rhine Graben developed. The rifting and bending was induced by the alpine tectonic events. At the same time in different parts of South-western Germany volcanic events changed the landscape i.e. the Kaiserstuhl volcano in the Rhine valley, the Hegau volcanoes in the Molasse basin, the big Swabian gas volcano perforating the Swabian Alb and the cuesta landscape further to the North. During the Oligocene, two meteoric events formed craters in the Swabian Alb (Nördlinger Ries and Steinheimer Becken).

Superimposed upon these major landscapes we do find traces of Pleistocene development. From the Alps the glacial and fluvio-glacial cover sediment reached or crossed the Danube. In the western lowlands along the Upper Rhine Graben and the low cuesta landscapes we find thick deposits of aeolian periglacial loess, whereas in the higher altitudes we find a cover of a few meters of periglacial solifluction deposits being the parent rock for the formation of Holocene soils.

The summit of the Black Forest is the 1.493 m high Feldberg. This central elevation is made up by gneiss derived from the Assyntian and Variscian orogeny. Today we find in the central part of the Black Forest mainly gneiss, metamorphic rocks of sedimentary and plutonic origin. In the North and the South several granite plutons have intruded during the Variscian period. During the Late Palaeozoic the top of the old Black Forest mountains had been eroded until a peneplain was derived. In the peneplain a few deep depressions have been filled with Permian gravel and sandstone (Rotliegendes). The Black Forest was later covered by Triassic and Jurassic sediments and only after the formation on the rift valley these sediments have been eroded again down to the basement and deep fluvial and partially glacial valleys have been incised towards the West while the gentile inclination to the east led to broad valleys, tributaries of the early Danube river.

The Swabian and Franconian cuesta landscapes are built up of Mesozoic sediments. These materials have been deposited in the so-called German Basin, later German Sea, which was a bay of the Atlantic Ocean. It developed in the Late Palaeozoic (Zechstein) with its maximum during the upper Jurassic and then regrading quickly, giving arise to the terrestrial development during Cretaceous and Neozoic periods. The cuesta landscapes are built up of sandstone from the lowest Triassic formation, (Buntsandstein) followed by the marine sequence of the Muschelkalk: limestone, marls, gypsum and salt layers. Later during the Keuper period a fluvial to marine, partly terrestrial deserted environment influenced the basin. From this time we have a great variety of rocks: marls, sandstone, limestone, gypsum layers, topped again by a sequence of sandstone and marls. These Keuper mountains are typically developed as cuesta landscapes around the cities of Tübingen, Stuttgart, Heilbronn and Nürnberg.

The Swabian Alb is the youngest and most prominent cuesta in South-western Germany. The Jurassic sediments form a sequence mainly of clays, marls and hard limestone. Today the highest parts of the Upper Jurassic limestone in the south-western part reach altitudes above thousand meters. The western part of the Swabian Alb has undergone terrestrial development since the early Cretaceous. Today's landscape is mainly hummocky to hilly resulting from the different solubility of the limestone varieties. To the South-east the so called Plain Alb was again flooded during the Miocene by the Molasse sea, which spread between the Alps and the Alb. On the South-eastern Alb we do find a lot of remnants of the Tertiary development and especially the shore line as a prominent cliff. Since that time the Western Swabian Alb has been tectonically lifted about 1000 m.

Due to this uplift, river systems have incised. The most prominent is the bending Danube river, whose origin goes back to the late Tertiary. The Danube river system meanwhile suffers from the greater power of the more recent developed Rhine system, which meanwhile cuts off many parts of the former Danube catchment. The most spectacular ones are the Wutach river gorge, which cut off the Feldberg-Donau and incised more than 400 m within the last

16.000 years. The other one is the Aach-Spring, which delivers karstic water, which sinks into the limestone caves from the Danube bed.

In the South the Swabian Alb dives under the pre-alpine Molasse trough. Up to 3.000 m sediment brought up by the growing Alps have been sedimented under marine and fluvial conditions, generally sandy marls or sands. The Tertiary sediments are responsible for all the major landforms especially the higher hills like the Bodanrück, Sipplinger Berg, Schiener Berg and so on. The Molasse trough is continuing towards the West through the so-called Swiss Midland around Zürich, Bern and Geneve. Within the Molasse region an outstanding landscape is the Hegau volcanic area. The volcanoes have had their active phases during the Miocene. Most of them being strato-volcanoes, others being sub-volcanoes. The eastern row of these volcanoes like Hohentwiel, Hohenkrähen and Mägdeberg are phonolitic while the western row with Hohenstoffeln, Hohenheven and Hewenegg are basaltic (olivine-melilitite). The last important landscape is the Upper Rhine Graben. Since late Eocene this prominent rift valley has subsided more than five kilometers. It is filled with more than three kilometers Tertiary, Pleistocene as well as Holocene sediment. Due to the fact that the rifting is still active, the old Rhine terraces are buried below young fluvial sediments. Therefore, the river and terrace system here is very simple. Only the floodplain and the lower Würmian terraces are well developed. However, at the foothills of the Black Forest we do have some rift assemblage. Around Freiburg, some of these rift shoulders are found as hills within the Rhine plain like the Tuniberg. Furthermore we find here the old huge volcanic ruin of the Kaiserstuhl with its unique composition of rocks: phonolitic, limburgitic, carbonatitic, intrusive and explosive.

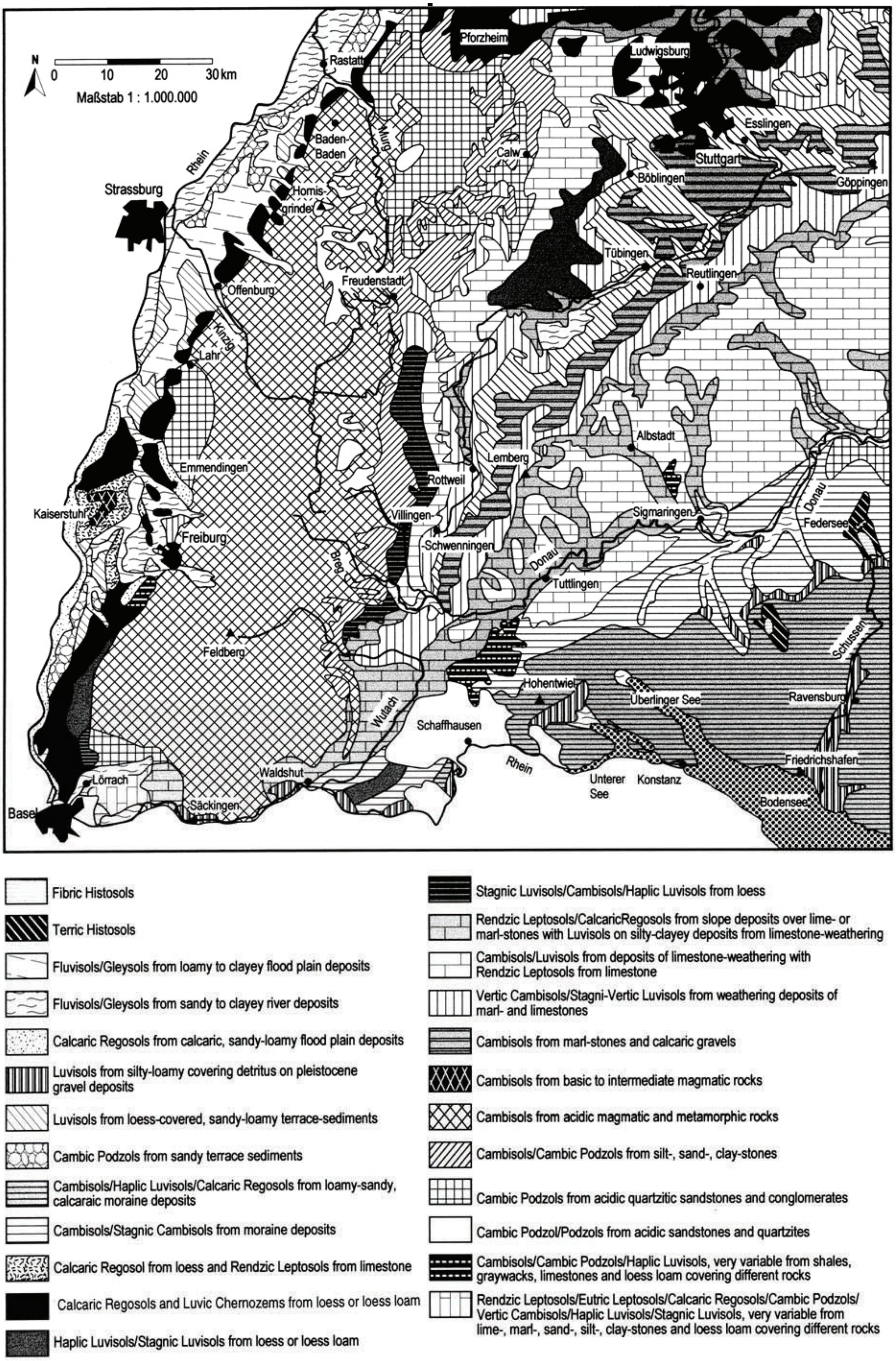
All these landscapes are overprinted by the glacial and periglacial processes in the last 2 million years. The pre-Alpine lowlands have been glaciated at least four times. Also some valley glaciers have been found in the higher altitude of the Black Forest. The Kaiserstuhl areas, the rift shoulders of the upper Rhine Graben and parts of the cuesta landscape of Central Württemberg are dominated by loess deposits, generally 10 to 30 m deep and found in altitudes between 200 to 450 meters. Higher altitudes do have much thinner loess cover ore more common, the occurrence of periglacial cover layers with a thickness of 1 to 3 m. This is mainly important in the granite, gneiss and Buntsandstein area. Other areas do not show such thick periglacial layers or due to human activities these layers have been eroded.

The major Holocene geological activities are the formation of bogs and fens in the depressions and former lakes, the deposition of river sediments of different grain sizes in the bigger river floodplains and finally erosion, predominantly in old agricultural areas.

Soilscapes of South-West Germany

With respect to soil development, the Upper Rhine Graben is divided into two parts. The floodplain of the Rhine river, which is occupied in its southern part mainly by Calgaric Regosols, due to the rapid incision of the Rhine during the last 150 years caused by the construction of the Rhine channel. In the part North of the Kaiserstuhl the floodplain is more active in its groundwater dynamics and therefore Eutric Cambisol, Eutric and Calcic Gleysol occur. In the North of the Black Forest, especially between Karlsruhe and Heidelberg, the lower lying floodplains do show bog development (Eutric Histosols). The soilscape on the Würmian terrace is much simpler. In the south it is dominated by Haplic to Chromic Luvisols, in the North tending partially to a Haplic Luvisol with a banded argic B-horizon. In the northern part also sand dunes occur. There we find Dystric Cambisols.

In the Black Forest a very clear altitudinal zonation of soils occurs. The loess covered foothills are dominated by a sequence of Calcaric Regosol, Haplic Luvisol and Cumulic Anthrosol dominates. Above this part in the height of 400 until 600 m a.s.l. in a submontane zone we do find intergrades between Dystric Cambisol and Alisol. In this part also stagnic properties are frequently observed. From 600-900 m we mainly find typical Dystric Cambisols on periglacial solifluction deposits. Also above, from 800 to 1.100 m Dystric Cambisols prevail. They have higher humus content and often a very low base-saturation. However, podzolization is rarely found. The highest part of the Black Forest above 1.100 m was glaciated. There, we find Stagnic Cambisols, sometimes Leptosols and in the granite area also Podzols. In the south-west of the Black Forest up to the top altitudes a big earthworm (Lumbricus badensis) is found in particular areas. There, an acid brown earth with strong humus enrichment deeper than 0.4 m occurs. Earthworm caves can be detected down to 2 m. This humid Cambisol – a rather unique one – has stored more than 300 t of organic matter per hectare.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Offenburg
Freudenstadt
Kinzig
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Emmendingen
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Lemberg
Rottweil
Kaiserstuhl
Villingen-
Schwenningen
Freiburg
Sigmaringen
Donau
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Tuttlingen
Breg
Feldberg
Schussen
Hohentwiel
Überlinger See
Ravensburg
Wutach
Schaffhausen
Rhein
Friedrichshafen
Waldshut
Lörrach
Säckingen
Basel
Unterer See
Konstanz
Bodensee
Fibric Histosols
Terric Histosols
Fluvisols/Gleysols from loamy to clayey flood plain deposits
Fluvisols/Gleysols from sandy to clayey river deposits
Calcaric Regosols from calcaric, sandy-loamy flood plain deposits
Luvisols from silty-loamy covering detritus on pleistocene gravel deposits
Luvisols from loess-covered, sandy-loamy terrace-sediments
Cambic Podzols from sandy terrace sediments
Cambisols/Haplic Luvisols/Calcaric Regosols from loamy-sandy, calcaraic moraine deposits
Cambisols/Stagnic Cambisols from moraine deposits
Calcaric Regosol from loess and Rendzic Leptosols from limestone
Calcaric Regosols and Luvic Chernozems from loess or loess loam
Haplic Luvisols/Stagnic Luvisols from loess or loess loam
Stagnic Luvisols/Cambisols/Haplic Luvisols from loess
Rendzic Leptosols/CalcaricRegosols from slope deposits over lime- or marl-stones with Luvisols on silty-clayey deposits from limestone-weathering
Cambisols/Luvisols from deposits of limestone-weathering with Rendzic Leptosols from limestone
Vertic Cambisols/Stagni-Vertic Luvisols from weathering deposits of marl- and limestones
Cambisols from marl-stones and calcaric gravels
Cambisols from basic to intermediate magmatic rocks
Cambisols from acidic magmatic and metamorphic rocks
Cambisols/Cambic Podzols from silt-, sand-, clay-stones
Cambic Podzols from acidic quartzitic sandstones and conglomerates
Cambic Podzol/Podzols from acidic sandstones and quartzites
Cambisols/Cambic Podzols/Haplic Luvisols, very variable from shales, graywacks, limestones and loess loam covering different rocks
Rendzic Leptosols/Eutric Leptosols/Calcaric Regosols/Cambic Podzols/ Vertic Cambisols/Haplic Luvisols/Stagnic Luvisols, very variable from lime-, marl-, sand-, silt-, clay-stones and loess loam covering different rocks

Dokuchaev Re-visited

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V.V. Dokuchaev (1846-1903) is credited as one of the founders of soil science–in Russian "pochvovedenie" which translates as "pedology" (Vernadsky, 1969; Tandarich and Sprecher, 1994; Gradusov, 2004). He was professor of mineralogy at the University of St. Petersburg (Vernadsky, 1969). He is famous for his research on the study of the formation and properties of soils, especially of Chernozems (Dokuchaev, 1879). He is credited with: developing a genetic classification of soils; laying the foundation for research on pedogenesis and soil geography (Vilenskii, 1968; Gradusov, 2004); the concept of sequential horizons in a soil profile and A-B-C horizon nomenclature; and the recognition that soil is the product of the interaction between climate, and living organisms upon parent material, as conditioned by local relief, over time—thus a factorial model of soil formation (Schaetzl and Anderson, 2005). He "identified the factors controlling global soil distribution and developed the doctrine of soil zones, including the laws of horizontal and vertical bio-climatic zonation of soils" (Bockheim et al., 2005). Over time, the concept of 'zonal soils' has somehow become associated more with vertical differentiation of horizons, as evident from the attack by Paton et al. (1995) and the discussion of Johnson (2000).

Although theories of pedogenesis and terminology promulgated by Dokuchaev and the Russian school still hold sway today in much of eastern Europe (Gradusov, 2004; Dobrovolskii, 2004), these have lost favor in the West. A dominant theme of the book by T.R. Paton et al. (1995) is that "zonal soil concepts have corrupted our thinking about pedogenic processes and have led to flawed interpretations of the genetic pathways of soils". In the new book on soils by Schaetzl and Anderson (2005), zonal soil concepts are described as "conceptually flawed". Because the role of bioturbation in forming soil horizons is now recognized more, Charles Darwin, who published an early monograph on the role of worms in soils in 1881, is given more kudos, somehow diminishing Dokuchaev's standing.

Curiously, the new reviews on the history of soil science have not taken into account the results of recent research on soil modelling. However, recent examples of models used for predictive soil mapping in Australia (e.g., Gessler, 1996; Moran and Bui, 2002; Henderson et al., 2001) and elsewhere, e.g. the USA (Qi and Zhu, 2003), Canada (Florinsky et al., 2002), France (Chaplot et al., 2003), central Europe (Dobos et al., 2000; 2003; Hengl et al., 2002), and China (Cheng et al., 2004), have used predictors that represent climatic, topographic, and geological factors of soil formation as well as biotic (including anthropogenic) factors. Therefore, these models can be examined in light of pedogenetic theory to see if they are consistent with it or if they can reveal any new insight.

In their review McBratney et al. (2003) listed numerous examples of models used for digital soil mapping (DSM). Most of these were generated to map small areas (< 10,000 ha) and used only terrain attributes as predictors. Many of the terrain attributes used in these models are trying to capture information about the way water moves over and through hillslopes and catchments. In an earlier review of the literature on terrain analysis and soil mapping, McKenzie et al. (2000) made a strong case for terrain attributes as predictors.

В. В. Докучаев-семинарист (1867)

В. В. Докучаев — студент Петербургского университета (1871)

The modelling in DSM has uncovered predictive relationships between the spatial distribution of soils or soil properties and topography at the local scale. That terrain attributes should be good predictors of soil type or soil properties at a local scale is consistent with decades of empirical studies and traditional views of soil catenas. However, terrain attributes are also useful at the regional scale as demonstrated in Croatia by Hengl et al. (2002), in Canada (Florinsky et al., 2002), and in Australia (Moran and Bui, 2002). Thus the weight-of-evidence from predictive modelling is sufficient to establish that the relationship between soil distribution and topography goes beyond empiricism. We should no longer be reading in current literature that the relationship between the distribution of soils and topography is an assumption as stated by Bockheim et al. (2005).

There are only a few models developed for digital soil mapping over very large extents (>10^6 km^2) that have used a range of predictors selected to represent soil-forming factors: the models derived for the European Soil Database by Dobos et al. (2001); those developed during the Murray-Darling Basin Soil Information Strategy (MDBSIS) project (Bui, 1999); and those developed as part of the Australian Soil Resources Information System (ASRIS) (Henderson et al., 2001).

Bui et al. (2006) discuss a spatially explicit evaluation of the ASRIS models and conclude that climate variables and lithology drive the continental scale variation. The results suggest that the state factors of soil formation form a spatially variable hierarchy of interacting variables, with climate being the most important factor at a continental scale. The results accord with the original views of Dokuchaev/ zonal soils theory which emphasized climate over other factors. Lithology is almost equally important in defining continental scale spatial patterns of soil properties. Different climatic variables dominate in different regions and the interaction between soil-forming factors is spatially variable.

For example, in the topsoil pH model, precipitation in the driest month is used to refine the broad pattern defined by the single threshold used for the annual mean moisture index and elevation is used over other large areas (Fig. 1). In the spatial domain defined by rules 6, 7, and 8 for topsoil pH (Fig. 2), comparison of the variables used in the multiple condition statements suggests that, given similar limitations of rainfall, pH reflects variations in land cover or forest type and geochemistry of lithology (felsic vs mafic).

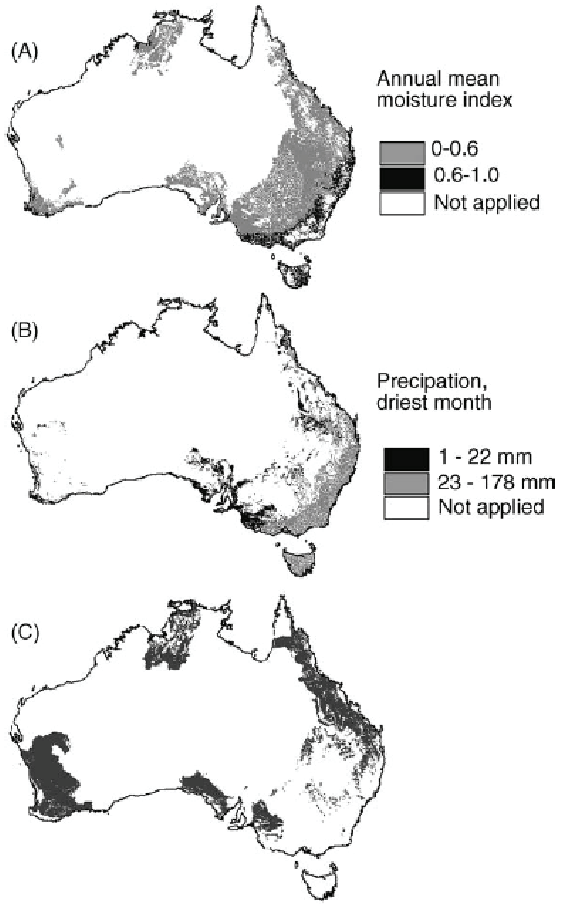
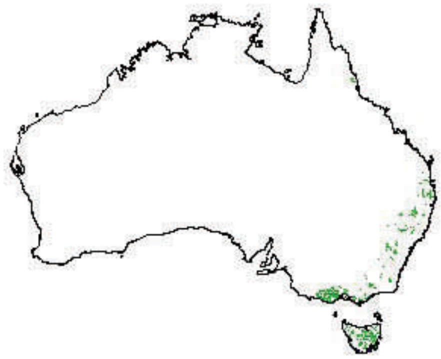


Figure 1. Where important predictors for the topsoil pH model were used. (A) Annual mean moisture index; (B) precipitation in the driest month; and (C) elevation (from Bui et al., 2006)

For the % clay models, the broad scale pattern is governed by the distribution of rock types and soil types, whereas small scale variability is influenced by climatic, terrain, and land cover variables. The importance of the lowest monthly radiation in the topsoil % clay model suggests that solar radiation (and heat transfer through soil) limits the depth of weathering. The topsoil % clay model indirectly captures the observed relationship between increasing clay content, clay mineralogy, and latitude observed by Norrish and Pickering (1983): north of 31° S, high clay soils are more smectitic. In the ASRIS topsoil % clay model, this becomes: north of 31° S, which corresponds to a radiation threshold, clayey soils have higher clay content (Fig. 3).

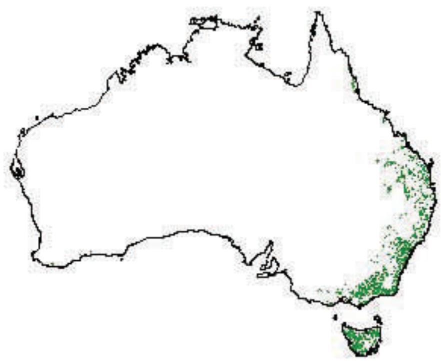
A. Rule 6: [mean 4.6, range 2.8 to 8.1, est err 0.44]

if clim14 > 22 and mss2 $\leq$ 50 then pH_A = linear model



B. Rule 7: [mean 4.65, range 2.84 to 8.7, est err 0.46]

if clim14 > 22, clim28 > 6446, mss2 > 50, and lith = {1,5,6,7,9,10,12,13,15,17,18,19} then pH_A = linear model



C. Rule 8: [mean 4.83, range 3.38 to 7.96, est err 0.45]

if clim14 > 22, clim28 > 6446 and lith = {2,3,8,11,14,16,20,21,22}

then pH_A = linear model

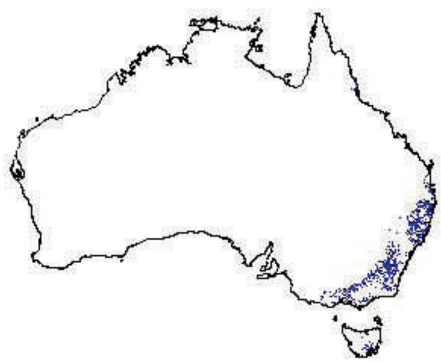


Figure 2. The spatial extent defined by three condition statements for the topsoil pH model. MSS 2 is a chlorophyll absorption band. It is a locally important condition variable in the topsoil pH model where the pattern delineated by the thresholds of the climatic predictor variables corresponds to forested areas.

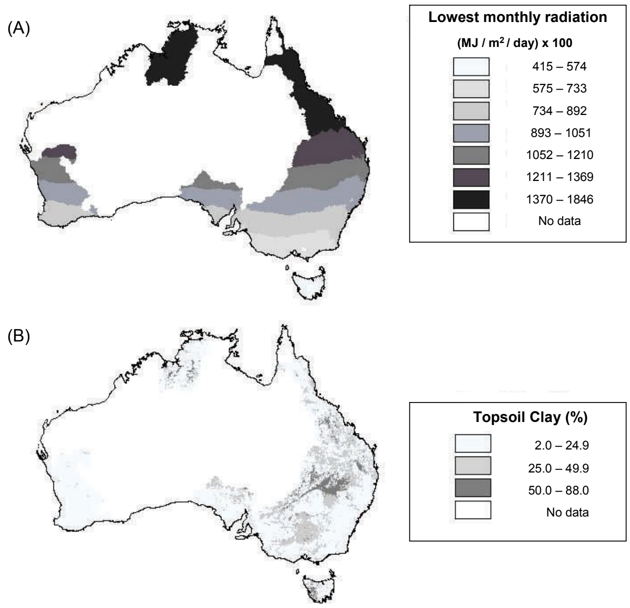


Figure 3 (A) Spatial pattern of the lowest monthly radiation surface and (B) % clay in topsoil.

Thus examination of recent models used for digital soil mapping over large extents suggests that the continental to regional scale distribution of soils is controlled by the effect of climate and its interaction with lithology and biota. That climate and lithology exert control on the distribution of soils and organisms should not be considered a theoretical assumption, however the form of the relationship is spatially variable and not a universal law.

What the results of the recent predictive soil models show conclusively is that soils are an integral part of environmental (geo- or eco)systems. Thus, soils are a central component of an Earth systems model (Bretherton, 1985). Dokuchaev, who was an early "systems" thinker (Dobrovol'skii, 2004) would be happy.

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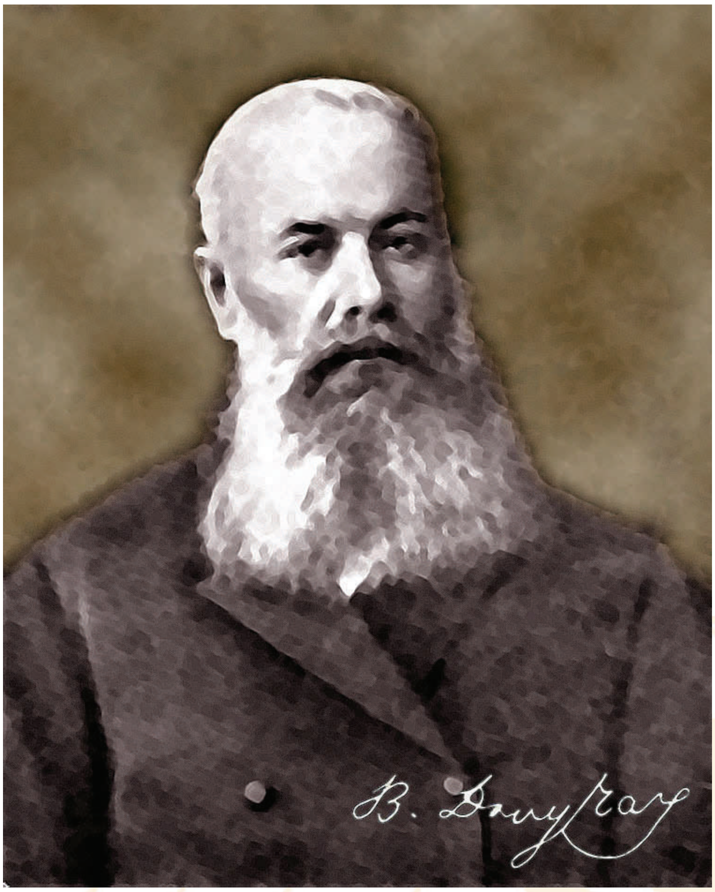

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How much do we ~~love~~ cite ourselves?

Budiman Minasny, Alex. McBratney & Alfred Hartemink

Introduction

We are proud of our work and often we love our papers, so we like to cite them. But how much are we citing ourselves? Is self-citation common and is there any narcissism in soil science? As a first step, we think it is useful to know how many references there usually are in a paper and how many times we cite our own papers.

Self-citations account for between 10% and 20% of all references but it differs between disciplines (Hyland 2003). Self-citations have few nice properties: increase the number of citations and thus the *h* index, and they also may promote scholarly reputation or we might even gain professional credit (Hyland 2003). In a study of citations by Norwegian scientists, Fowler and Asknes (2007) showed that the more one cites oneself, the more one is cited by other scientists. Their analysis suggests that each additional self-citation increases the number of citations from others by about one after one year, and by about three after five years.

Data analysis

We analysed and manually counted papers from Pedometrics Special Issues which have been published in Geoderma. There are eight symposia starting in 1992. They are detailed in Table 1.

There were a total of 96 papers, and we manually counted the number of references for each paper and the number of self references. Self references are references cited in the paper which are written by **any** of the paper's authors.

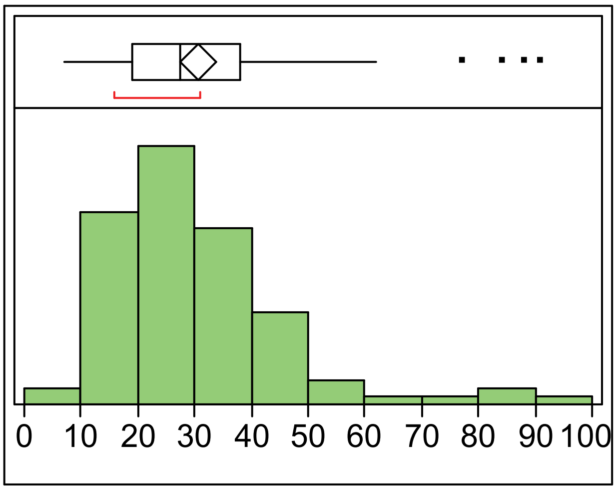

Figure 1. Distribution of no. of references in research papers.

Results

How many references in a paper?

Figure 1 show the distribution of the number of references in research papers (review papers excluded). The distribution is slightly skewed to the left, with a minimum of 7, a maximum 91, a median of 27, and an interquartile range of 19-38 references. So Pedometrics papers have an average some 20 to 30 references.

There is slight increase in the number references over time (Fig. 2), possibly due to the advances in electronic and online journals; it is easier to find more relevant references. But also the field of Pedometrics is expanding and it becomes necessary to refer to more work: there were simply less papers in the beginning.

Table 1. Pedometrics special issues in Geoderma.

Symposium	Location	Year Published	No. papers
PM1992	Wageningen	March 1994	20
Fuzzy Sets	St. Louis	June 1997	12
PM1997	Madison	April 1999	7
PM1998	Montpellier	Sept. 2000	14
PM1999	Sydney	Sept. 2001	11
PM2001	Gent	March 2003	8
PM2003	Reading	Oct. 2005	14
PM2005	Florida	Aug. 2007	10

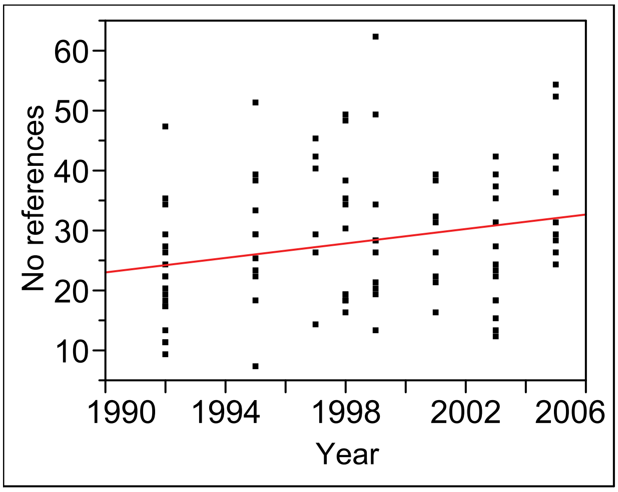

Figure 2. Number of references as a function of time.

Percent of self citations

Figure 3 and Table 2 show the percentage of self-citations for Pedometrics papers. The minimum and maximum self citations are between 0 and 60%, with a median of 15%. In general, Pedometrics papers have a self citation rate of around 15%.

Review papers have larger self-citation rates (interquartile range of 20 to 30%) compared to research papers (10 to 18%), but this notion is based on only seven review papers.

We attempted to see if there is any relationship between percentage of self-citations with other attributes of the papers (such as the number of references, number of authors, number of pages, and year published), but no pattern was found.

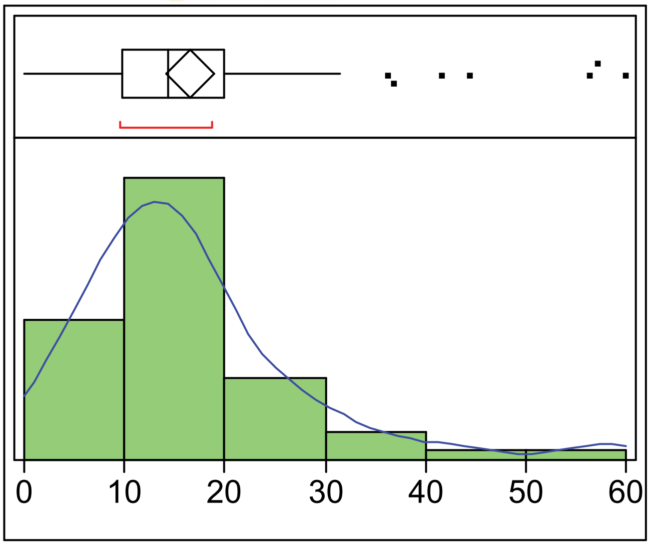

Figure 3. Distribution of percentage of self-citations in Pedometrics papers.

Although there is an indication that the number of self references increases with increased number of references (Figure 4), we believe it is a matter of personal preference or style.

In conclusion

Are large self-citation rates narcissistic or manifestations of laziness or extreme conviction? As summarized by Hyland (2003) "the factors which motivate writers to cite their own work are doubtless varied and complex, involving psychological factors influenced by the individual writer's confidence, experience and self-esteem." We have not enough data to underpin it but the impression exists that high rates of self-citation is quite accepted in some countries. Some will, some won't.

Hyland (2003) found that self citation is higher in the "hard" sciences (biology, engineering and physics), where it is over 12% of all references, compared with only 4% in the (so-called) soft fields (sociology, philosophy, linguistics, marketing). So Pedometrics is perhaps is slightly above the norm for the hard sciences, but we don't know whether Pedometrics has higher rates than other branches of soil science. As the subdiscipline of Pedometrics is still very young and initially dominated by a few people and a few seminal papers that are often cited, we think that the number of self citations will decrease over the years when Pedometrics further matures and the number of Pedometricians and papers increase.

Table 2. Statistics of self-citations

100.0%	maximum	60.0
99.5%		60.0
97.5%		56.8
90.0%		30.8
75.0%	quartile	19.8
50.0%	median	14.3
25.0%	quartile	9.8
10.0%		4.5
2.5%		0.0
0.5%		0.0
0.0%	minimum	0.0
Mean		16.5
Std Dev		11.5
N		96

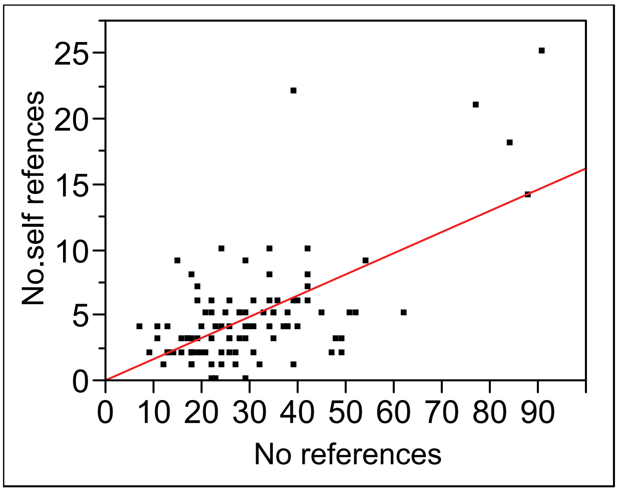

Figure 4. Number of self references as a function of no. references.

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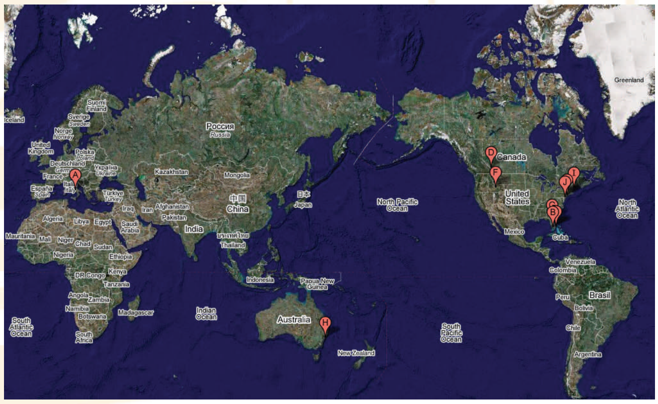
Another one of Google's products is Google Experimental Research that extracts dates and locations from search results and present them as spatial and temporal trends. Although they are based on web pages, the results show some interesting trend.

Timeline for : Digital soil mapping

The "boom" in digital soil mapping is happening in the mid 1990s and highest peak in 2004 coincidence with the paper "On Digital Soil Mapping". The decline in 2005 is the time lags of the page search, undoubtedly will have higher web-page volumes as time goes on.

Areas where Pedometrics are mostly practiced, marked by the red dots.

Pedometrics itself does not pick up much search volumes. The areas picked up by Google obviously have related web-page and continuously use the term "Pedometrics". So the lesson is: to make us more visible on the map of the world, we should use the "Pedometrics" more often on our webpage.



A Soil Art

Recently when I visited my Scottish homeland I was reminded that I knew about one of the soil arts long before I knew anything about the science of soil. I come from a farming background and my family have always competed in ploughing competitions. On my visit my brother showed me the minutes of the local ploughing society going back some 150 years.

In a ploughing match the competitors either using a horse and plough, or now more commonly, a tractor and plough, ploughs an allotted piece of land, of perhaps 0.5 ha in area in a few hours (five or six). There are various points for straightness and regularity in amplitude and phase and so on. The art, the real challenge, is to take a plot of land and even though it may be variable in space it has to appear like uniform corduroy. So the challenge, and the art, is uniformity from variability – I think it's an interesting concept on which pedometricians can reflect.

At the beginning of the competition the ploughpersons draw lots for the plots of land – a number literally drawn from a hat. Given soil variability, which is well-recognised by the ploughing and farming communities, this is seen by all as the fair thing to do – clearly some plots are easier to plough than others. I have it on good authority that practice is more than 150 years old. So when R.A. Fisher suggested randomisation in the conduct of field experiments perhaps he was only applying a well-known practice among the ploughing community – and of course he was doing it for much the same reason.

The world ploughing champion, Andrew Mitchell, at work at the world ploughing championships in Ireland. Note the uniformity of the work.

I guess we all know who the world Formula 1 champion is, or the Wimbledon or Roland Garros champion, but what about the world ploughing champion? Well there is a fiercely competitive annual world ploughing championships (www.worldploughing.org). The most recent world championships were held in Co Offaly, Ireland in September 2006, I'm pleased to report that the current world champion is Andrew Mitchell, a precocious 17-year old Scot. He'll be defending his title in September in Lithuania (http://www.world-ploughing-contest-2007.com/). Sėkmės! Geros kloties!

Ploughing match ~1890 Hall, NSW (now ACT), Australia (National Library of Australia)

Digital Soil Mapping and Soil Science

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Soil science on the slide?

I was recently asked to give a presentation at the annual meeting of the Canadian Land Resource Network (CLRN). The mandate of the CLRN is "to provide a network for the coordination, discussion and development of technologies and guidelines for the maintenance, use and application of soil resource information for Canada". This group was initially created to act as a forum for pedologists employed by federal and provincial government agencies in Canada. With declining numbers of government soil scientists, participation in the CLRN meetings has increasingly broadened to include university and private sector pedologists. I was asked to provide an introduction to, and overview of, automated predictive digital soil mapping (DSM). There is considerable curiosity, as well as considerable skepticism, about DSM among the soil survey community in Canada.

At the CLRN meeting Scott Smith (Soil Data Lead for the National Land and Water Information Service) gave an introduction in which he itemized the numbers of soil scientists employed in the public sector in Canada and compared these to previous levels. By his count, there are presently only 40 research scientists and 60 technicians with a soil science background employed in federal government jobs that have any connection to soil inventory or soil information. Of these, approximately 42 permanent employees contribute around 30 person years of effort the soil inventory and information efforts operated by Agriculture and Agri-Food Canada and only 2 individuals, both nearing retirement, are tasked with conducting research in the area of pedology.

The other keynote speaker at the CLRN meetings was Dr. Dan Pennock. He was there in his capacity as President of the Canadian Society of Soil Science. Dan was asked to speak on the role of universities and soil science societies as collaboration incubators. Dan's talk presented a chronology of the decline in the teaching of soil science, and in particular of the discipline of pedology, in Canada, in the numbers of students studying it and in numbers of people practicing it. He noted that many previously stand-alone departments of soil science had found it necessary to amalgamate with other natural resource or environmental departments in order to survive. He observed that many universities no longer employed any researchers whose focus was on pedology, soil classification or soil genesis. One thing he said that really stuck home to me was that he was often embarrassed to have to teach classes material about soils that was 20 or 30 years old, out of date and even demonstrably incorrect, because there had not been any major advancements in the subject in 30 years. He compared soil science unfavorably to hydrology. Hydrology has developed deterministic, mathematical models to explain and study hydrological processes. Students of hydrology expect (and want) to be taught how to use these models. These same students, exposed to a soils course, would very rapidly see that the science was outdated, not quantitative and not modern. They would (and do) realize that they are better off acquiring the more advanced knowledge offered by hydrology that that offered by pedology. So, soil science suffers in comparison to more quantitative disciplines and students opt to take courses that are more relevant and useful to them.

In a similar vein, Alfred Hartemink's presentation at the Rio DSM workshop in July 2006 provided a good illustration of what is sure to happen if soil science (and especially pedology) doesn't change to adopt new methods. Alfred also presented statistics on the decline in numbers of soil surveyors worldwide. These statistics were very instructive and they lead to the inescapable conclusion that there is no option to keep things the same. Soil science, and in particular pedology, must either change (modernize) or disappear.

Sharpening the old grease pencil

With respect to Digital Soil Mapping (DSM), I try to emphasize to traditional soil surveyors that what I am doing is actually not a very big change from the conventional soil-landscape approach to soil survey. I have just added some new tools to my old grease pencil, air photo and stereoscope. I am still trying to uncover and apply the same kinds of models of soil-landform relationships. Some other approaches (e.g. single soil property maps) are a bit of a new paradigm, but even these are fundamentally based on familiar assumptions about soil-landscape relationships.

I find it difficult to understand why conventional soil surveyors would resist adoption of DSM tools and techniques that expand and reinforce their traditional skills and capabilities and yet, such resistance is quite widespread and quite common. In the interests of the long term survival and growth of soil inventory, I urge traditionalists to embrace the opportunities offered by DSM to quantify and systematize their knowledge and to modernize their discipline.

Head to head

I can understand how traditional soil surveyors may become upset when their methods and products are criticized or challenged. I believe that the best way to address this resistance is to set up head-to-head tests where all methods (a variety of traditional and new approaches) are applied to the same area in the best way they can be applied and then the results are tested and compared in terms of reliability, costs and time to produce. Such comparisons will almost certainly show that the claims of traditional mappers to produce "better" maps cannot be substantiated. Traditional maps (prepared for sufficiently large areas) will almost always end up taking longer to produce, being more costly and not being any more accurate (and often less accurate). I encourage agencies responsible for operational soil mapping to propose and conduct such side-by-side evaluations in their jurisdictions.

A couple of principles

The more I thought about my CLRN presentation, the more that I realized the importance of two basic principles of DSM that I had appropriated from a previous presentation about pedotransfer functions prepared by Budiman Minasny and Alex McBratney. These principles are:

Principle No. 1: Effort – Do not predict something that is easier to measure or map than the predictor. Mathematically, Efficiency of Predicted/ Efficiency of Predictor > 1.

Principle No 2: Uncertainty - Do not make DSM predictions unless you can evaluate their uncertainty, and for a given problem, if a set of alternative DSM predictions is available, use the one with minimum variance.

I believe that many DSM practitioners have a tendency to lose track of principle no 1; this being that you should not try to predict anything that is easier, faster and more accurate to map directly. We often get too preoccupied with the elegance of our predictive models and will put unwarranted levels of effort into trying to model something that we could map directly much faster and better. I also think that we often fail to properly implement principle no 2, that being to measure and report on the uncertainty of any predictions that we make.

Upon reflection, I have come to the conclusion that the DSM community should make a point of publicizing and promoting these two basic principles of DSM. DSM is a new field and there has been very little written or published to provide theoretical principles or basic constructs. I think that these 2 points of Budiman and Alex's (taken from pedotransfer functions) provide an important starting point and we ought to adopt them and make them central to all DSM efforts.

I see DSM as one vehicle for modernizing and systematizing pedology and believe that is has an important role to play in ensuring the continued relevance of pedology and to its continued ability to contribute to addressing environmental issues globally and locally.

Join our online discussion on this topic at: www.pedometrics.org. You need to register and have a username on the website to access the discussion. Log-in the site, and click on the Digital Soil Mapping and Soil Science article, and select "Comment on this article".

Upcoming Events

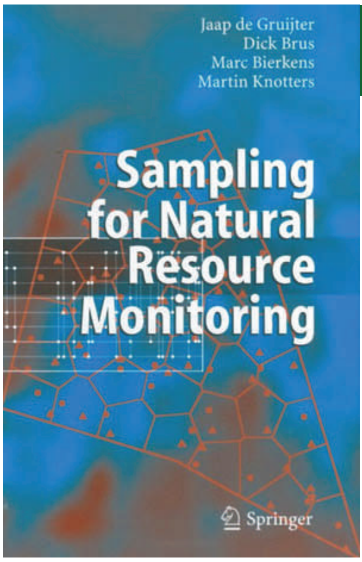
Geocomputation 2007. National Centre for Geocomputation at the National University of Ireland in Maynooth, Co. Kildare, Ireland. 3- 5 September 2007. http://ncg.nuim.ie/geocomputation/

Global Workshop on High Resolution Digital Soil Sensing & Mapping. 5-8 February 2008. Sydney, Australia.
http://www.digitalsoilmapping.org

European Geophysical Union, EGU 2008. Vienna, Austria, 13 – 18 April 2008. The Digital Soil Mapping WG will have a session titled: **Digital soil mapping: novel approaches to the prediction of key soil properties for modelling physical processes** http://meetings.copernicus.org/egu2008/

Accuracy 2008, The eighth symposium on spatial accuracy assessment in natural resources and environmental sciences. 25-27 June 2005. Shanghai, China http://2008.spatial-accuracy.org/

International Geostatistics Congress Santiago, Chile 1-5 Dec 2008 http://www.geostats2008.com/



Book Review by Murray Lark

De Gruijter, J., Brus, D., Bierkens, M.F.P. & Knotters, M. *Sampling for Natural Resource Monitoring*. Springer-Verlag, Berlin, 2006. XIII+332 pp. hardback. ISBN 3-540-22486-6.

If there is one problem that should keep pedometricians gainfully employed in the short to medium term it is the question of how to monitor soil quality at national and regional scales. This is certainly true in the European Union, which approved a Soil Protection Thematic Strategy in September of 2006: http://ec.europa.eu/environment/soil/index.htm

Monitoring the soil effectively requires proper sampling strategies, and many of the critical issues that this raises in research and practice will be familiar to pedometricians, not least from the contributions that the authors of this book have made at Pedometrics meetings. Jaap de Gruijter, Dick Brus, Marc Bierkens and Martin Knotters have often been consulted by scientists who require sampling schemes for monitoring, and have not felt able to recommend a book that would meet the researchers' needs. The aim of this book is to fill this gap.

Part I of the book addresses some general problems. In Chapter 2, for example, the authors discuss the difference between design-based and model-based statistical methods. Design-based and model-based methods are suited to different kinds of problem, and require different sampling strategies. The first two authors have done much to clarify our thought about these issues in previous work, and it is summarized here. This Chapter is critical to understanding the rest of the book.

Chapter 3 sets out the authors' general philosophy of sampling. This is extremely valuable. The objectives of a sampling exercise, the choice of sampling strategy, the specific design and the subsequent statistical analysis are all closely linked, and this integration must be recognized in a *complete sampling scheme*. This has implications for, among other things, the measurement techniques that are selected and how the final sampling scheme is optimized. This key message needs a wider audience than pedometricians. Chapter 5 addresses sampling optimization, and what this means in the model-based and design based contexts.

The material in Part I provides a foundation for what follows, which is a discussion of approaches to spatial sampling (Part II), temporal sampling (Part III) and spatio-temporal sampling (Part IV). In all cases the general problem has to be identified. Do we require global estimates (e.g. a regional mean, or a temporal trend), or are we interested in local estimates (which may be 'local' in time and space?) In general design-based approaches are most appropriate for the first case, and model-based for the second. Estimates of appropriate variances allow the design-based sampling to be optimized, and estimates of the spatial (or temporal, or spatio-temporal) covariance model parameters allow the model-based sampling to be optimized. This latter problem is by no means fully solved and is an area of active current research. For example, how should we account for the uncertainty in covariance models when they are used to optimize sampling, particularly since the best sampling scheme to obtain the model will not, in general, serve well for the model-based prediction itself?

In summary, this is an excellent book which pedometricians will find indispensible. I have one doubt about it, which might be addressed in future editions. The authors' intention was to provide a general text that could be used by environmental scientists. I did wonder whether such readers need a gentler introduction to the design-based/model-based distinction, especially as this is so critical to the rest of the book.

As with all good books, I was also provoked into thought while reading it (and while waving it under the noses of the bureaucrats in charge of a project on soil monitoring with which I am involved). The central message is that sample schemes must be selected, and designs obtained on the basis of a clear understanding of the objectives of the exercise. In practice, when monitoring is designed at national scale, there may be many objectives, driven by different interest groups (farmers, environmentalists, archaeologists, regulators, politicians …). Furthermore, these groups may have difficulty articulating their requirements (objectives, quality measures and constraints as the book structures them) in an adequate way to allows the pedometrician to proceed to a decision. Revise that, I speak from (bitter) experience and say that they DO have difficulty articulating those requirements. This did make me wonder whether the process of eliciting this information from a client might be one that we should attempt at least partly to formalize, so that we can obtain the information that WE need from the information that THEY are able to provide. The approaches to elicitation of prior probabilities from experts that Bayesian statisticians have developed might offer a general model for this. Anyone interested in a workshop ...?

Alex's Preferred Pedometrics Papers

I thought it would be useful to write a short series on my favourite pedometric papers. I guess it might stir up others to do likewise. The selection of these will be a bit idiosyncratic – some combination of cleverness, solution of a particular problem, seminality, good examples, novelty, imagination and inspiration. I've deliberately decided to take a historic view so I'm only considering papers prior to 1980 – prior to the appearance of geostatistics in the soil science literature and before the birth of pedometrics as a named entity. I'll present my top six pre-geostatistical pedometric papers in this and subsequent issues not in rank order, but rather chronologically.

I don't know what could be generally regarded as the first pedometric paper and I'm leaving it open for others to nominate possible contenders. It will be interesting to see what turns up. The first one might be closer to the beginning than the end.

My top six most preferred pre-geostatistical pedometrical papers (1)

Forbes, J.D., 1846. Account of experiments on the temperature of the earth at different depths, and in different soils, near Edinburgh. *Transactions of the Royal Society of Edinburgh 16*, 189-236.

The first paper in my top six is from a long time ago. The full text can be found at http://tinyurl.com/223w47, and I commend everyone to read it. It concerns the measurement of soil temperature at various depths on a weekly basis for several years at three sites, namely a soil developed in 'traprock', one in sandstone and one in sand, in the environs of Edinburgh. The work was done just prior to the classical Rothamsted field experiments being set-up. I like the work because it combines good data gathering, a listing of all the data, and state-of-the-art data analysis to provide firm conclusions. Forbes demonstrated experimentally, and modelled with physical theory based on the prior work of Lambert, Quetelet, and Fourier, both the annual temperature wave and its variation with soil material and its attenuation with depth. He gives some equations to describe the temporal relationships (e.g., see his Table XVI →) - where are the modern equivalents?

The nature of the soil data and their analysis is representative of an area that has not really been investigated in pedometrics much to date; namely that of time-series analysis. The recent paper of Kuzyakova et al. (2006) is a welcome exception. We have been concerned with spatial variation and now we have moved on to space-time variation but we seem to have skipped, or deliberately avoided, a firm understanding of temporal variation of soil properties over different time scales. So principally I rank this paper not because of its elegance and depth, which it certainly has in good measure, but because from 160 years back it points the way forward! The Forbes paper also suggests that we can look further back in time to the work of the German physicist, Johann Heinrich Lambert - which we're still investigating. Budiman and I present an analysis of the Forbes soil temperature data in a separate note in this issue.

Kuzyakova et al. 2006. Time series analysis and mixed models for studying the dynamics of net N mineralization in a soil catena at Gondelsheim. Geoderma, 136, 803-818.

The author of the paper, James Forbes, was Professor of Natural Philosophy at Edinburgh University. He was a leading physicist, and was one of the first environmental physicists. He was a Fellow of the Royal Society of London and was awarded the Rumford Medal in 1838 and the Royal Medal in 1843. He was the teacher and mentor of James Clerk Maxwell who stands in importance with Newton and Einstein. More details about James Forbes can be found at (http://en.wikipedia.org/wiki/James_David_Forbes).

TABLE XVI. CONTAINING THE EQUATIONS TO THE ANNUAL CURVES.

3 FEET.

Observatory,	$y_n = 45{\cdot}49 - 7{\cdot}39 \sin(n \,.\, 30^\circ + 43^\circ) + 0{\cdot}362 \sin(n \,.\, 60^\circ + 29^\circ)$
Ex. Garden,	$y_n = 46{\cdot}13 - 9{\cdot}00 \sin(n \,.\, 30^\circ + 49^\circ) + 0{\cdot}737 \sin(n \,.\, 60^\circ + 63^\circ)$
Craigleith,	$y_n = 45{\cdot}88 - 8{\cdot}16 \sin(n \,.\, 30^\circ + 47^\circ) + 0{\cdot}284 \sin(n \,.\, 60^\circ + 34^\circ)$

6 FEET.

Observatory,	$y_n = 45{\cdot}86 - 5{\cdot}06 \sin(n \,.\, 30^\circ + 23^\circ) + 0.433 \sin(n \,.\, 60^\circ + 7^\circ)$
Ex. Garden,	$y_n = 46{\cdot}42 - 6{\cdot}66 \sin(n \,.\, 30^\circ + 29^\circ) + 0{\cdot}501 \sin(n \,.\, 60^\circ + 5^\circ)$
Craigleith,	$y_n = 45{\cdot}92 - 6{\cdot}16 \sin(n \,.\, 30^\circ + 36^\circ) + 0.368 \sin(n \,.\, 60^\circ + 340^\circ)$

12 FEET.

Observatory,	$y_n = 46{\cdot}36 - 2{\cdot}44 \sin(n \,.\, 30^\circ + 344^\circ) + 0{\cdot}075 \sin(n \,.\, 60^\circ + 330^\circ)$
Ex. Garden,	$y_n = 46{\cdot}76 - 3{\cdot}38 \sin(n \,.\, 30^\circ + 348^\circ) + 0{\cdot}230 \sin(n \,.\, 60^\circ + 319^\circ)$
Craigleith,	$y_n = 45{\cdot}92 - 4{\cdot}22 \sin(n \,.\, 30^\circ + 13^\circ)$

24 FEET.

Observatory,	$y_n = 46{\cdot}87 - 0{\cdot}655 \sin(n \,.\, 30^\circ + 85^\circ)$
Ex. Garden,	$y_n = 47{\cdot}09 - 0{\cdot}920 \sin(n \,.\, 30^\circ + 275^\circ)$
Craigleith,	$y_n = 46{\cdot}07 - 1{\cdot}940 \sin(n \,.\, 30 + 327^\circ)$

XVIII.—*Account of some Experiments on the Temperature of the Earth at different Depths, and in different Soils, near Edinburgh.* By JAMES D. FORBES, Esq., F.R.S., Sec. R.S. Ed., &c. Corresponding Member of the Institute of France, and Professor of Natural Philosophy in the University of Edinburgh.

Before Pedometry there was Pyrometrie
Analysing the Forbes Soil Temperature Data

Introduction

What would you do if you were given Forbes' soil temperature time series? The data from a paper by Forbes (1846) are weekly observations of soil temperature at four depths for six years at three sites (Figure 1).

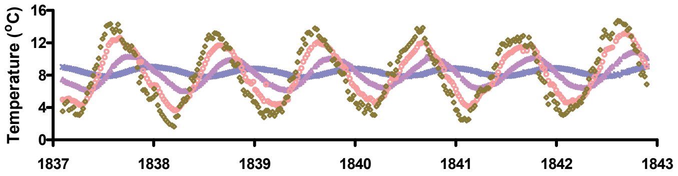


Figure. 1. Soil temperature at different depths

Would we do we do an ARIMA, a Kalman Filter, a Fourier transform, a spectral analysis, a transfer-function model or a wavelet analysis? All of these are possibilities for this kind of data. Let's do a wavelet analysis on the near surface temperature data (Figure 2).

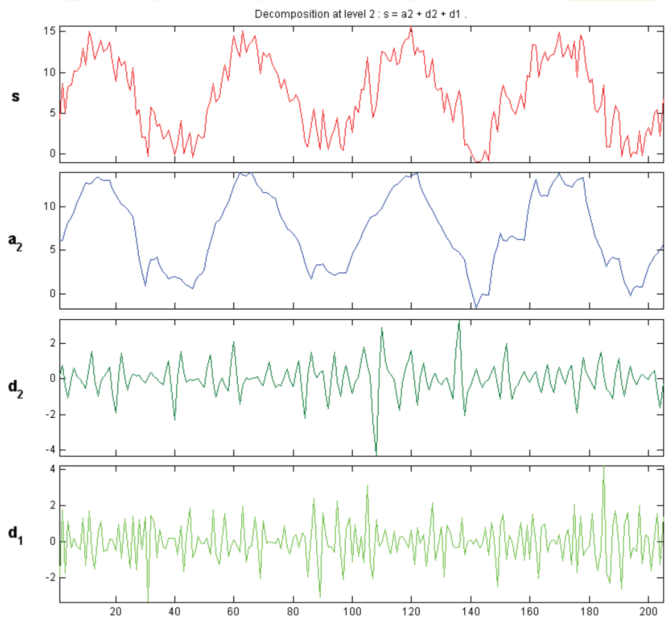


Figure 2. Discrete wavelet transform on the near-surface temperature data.

What does Figure 2 show? It shows some kind of quasi-periodic behaviour with a lot of noise superimposed on it. This is helpful in an exploratory kind of a way, but we want to understand the mechanism behind the data. Are there physical processes we can model? The variation of soil temperature with depth has attracted scientists back to Lambert (1779) who wrote about it in his book *Pyrometrie*. (We shall write a little more about this, in a separate note, anon.) Lambert was the first to show periodic variation in soil temperature with depth. The greater the depth, the smaller the fluctuation, and the greater the time-lag in temperature response.

We'll model the data based on physical theory – we probably prefer a mechanistic model to an empirical one whenever we have the opportunity although from the wavelet analysis we have seen that the data are noisy - for us this represents the interface between soil physics and pedometrics.

The model of temperature *T* as a function of depth *z* and time *t* is (Carslaw and Jaeger, 1959):

$$T_{z,t} = T_{av} + A\exp\left(-\frac{z}{z_d}\right)\cdot\sin\left(\omega\left(t-t_0\right)-\frac{z}{z_d}\right) \quad (1)$$

This is the solution of general heat transport equation under annual periodic fluctuation boundary conditions:

$$t=0 \qquad z\geq 0:\ T=T_{av}$$
$$t\geq 0 \qquad z=0:\ T=T_{av}+A\cdot\sin\left(\omega\left(t-t_0\right)\right)$$
$$t\geq 0 \qquad z\rightarrow\infty: T=T_{av}$$

where T_{av} is average temperature, temperature *A* is the amplitude at the soil surface, ω is the angular frequency of temperature oscillations, and t_0 is a phase constant.

The damping depth z_d, represents the reduction in amplitude of the temperature variation with depth, and is the depth at which the amplitude is e^{-1} (0.37) times its value at the surface. The damping depth is related to the thermal properties of the soil:

$$z_d = \sqrt{\frac{2D_h}{\omega}} = \sqrt{\frac{2\lambda_h}{\omega C_h}} \quad (2)$$

where D_h is thermal diffusivity, C_h is volumetric heat capacity, and λ_h is thermal conductivity.

The Forbes soil temperature data analysis

The Forbes data consist of soil temperature at four depths (7.79, 3.90, 1.95, 0.97 m from the surface) monitored weekly (generally on Monday) from February 1837 to 1842 for three sites: Observatory, Experimental Garden, and Craigleith. The temperature at Observatory was taken immediately after noon, at the Experimental Garden about 2 pm, and at Craigleith Quarry between 11 am and 12 pm. The data are available at http://tinyurl.com/223w47, entered manually by our colleague Paul McDougall.

Forbes calculated the time where maximum, and minimum temperature occurred and also the reduction in temperature with depth. He observed the exponential decrease of temperature with depth and thus fitted a linear function:

$$\log_{10} \Delta T = A + Bz \qquad (3)$$

where ΔT is the temperature range at depth z, and the constant B is related to the thermal properties of the soil. The value of B is related to Poisson's constant a (which is the related to the damping depth):

$$a = \frac{\sqrt{\pi}}{B} \log_{10} e \qquad (4)$$

The constant a is related to the conductivity power k and volumetric heat capacity c:

$$a = \sqrt{\frac{k}{c}} \qquad (5)$$

Forbes measured the density and thermal capacity of the rock and sand, and deduced the value of k.

We converted the temperature data from degree Fahrenheit to degree Celsius, and depths from French feet into metres. We then fitted equation (1) to the temperature series data for 4 depths (7.79, 3.90, 1.95, 0.97 m) simultaneously using nonlinear least-squares. Since the average temperature is varying within years, we fit a stiff spline to represent the average temperature with time.

The results

The results of our analysis and Forbes calculations are given in Table 1. The goodness of fit is presented in Table 2, and Figures 3-5 show the temperature data and fitted time series. The model fits reasonably well with an overall root mean squared error (RMSE) about 0.6 C°. From Table 1 we can see that Craigleith Grove which is a sandstone has a higher thermal conductivity than the other two sites.

There are still some trends in the residuals not explained by the model, especially at the lowest depth (8 m). The model underpredicts the temperature at 8 m for the sites at Observatory and Craigleith.

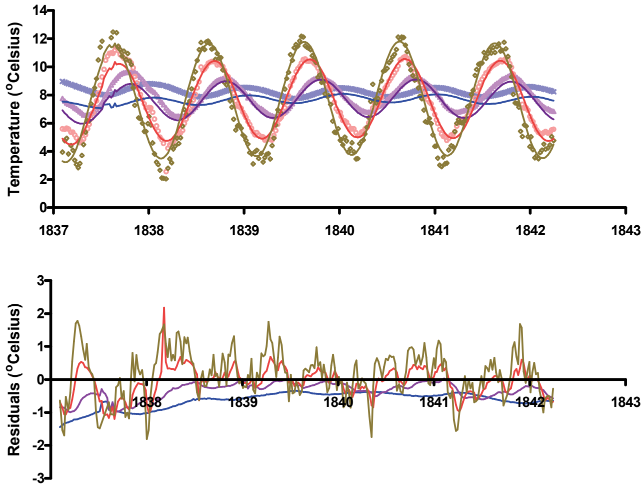


Figure 3. Temperature at the Observatory.

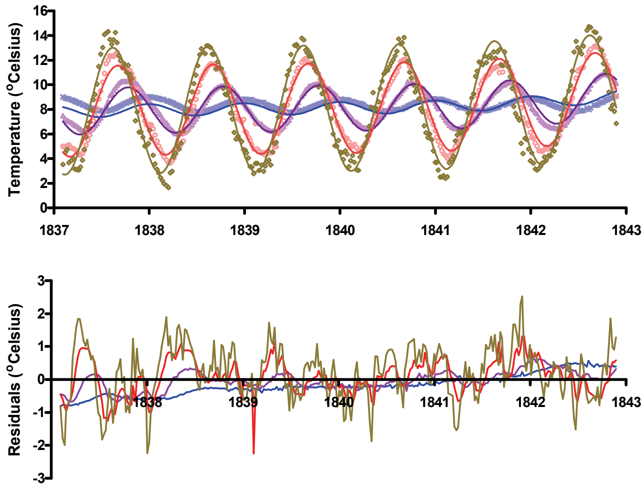


Figure 4. Temperature at the Experimental Garden.

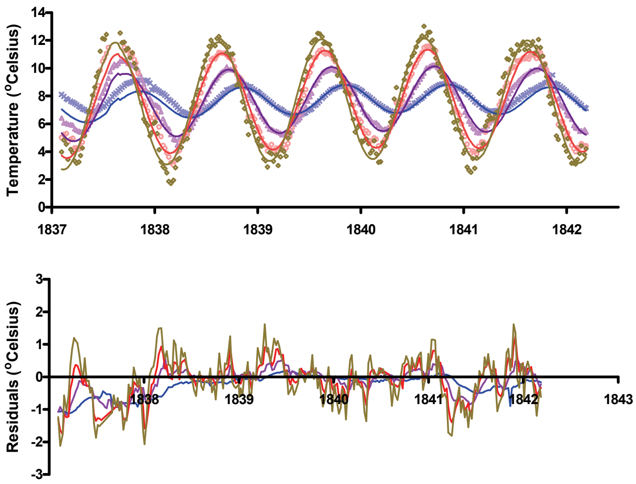


Figure 5. Temperature at the Craiglieth.

Table 1. Physical and Thermal properties of Forbes' experiments.

	Symbols	Units	Observatory (Porphyritic	Experimental Garden (Sand)	Craigleith Quarry
Height above sea level		m	107	21	46
Bulk density	ρ	g cm^{-3}	2.562	1.547	2.408
Specific heat capacity	c_p	kcal kg^{-1} °C^{-1}	0.2062	0.19432	0.19205
Volumetric heat capacity	c	cal cm^{-3} °C^{-1}	0.5283	0.3006	0.4623
Forbes' calculations					
B	B	m^{-1}	-0.168	-0.147	-0.096
Poisson's Constant	a	m	4.588	5.242	8.04
Conducting power	k	10^4 cal cm^{-1} °C^{-1}	11.12	8.26	29.884
Reinterpreted Forbes' calculations*					
Specific heat capacity	C	kJ kg^{-1} K^{-1}	0.862	0.812	0.803
Volumetric heat capacity	C_h	MJ m^{-3} K^{-1}	2.208	1.257	1.933
Damping depth	z_d	m	2.589	2.957	4.536
Thermal Conductivity	λ_h	W m^{-1} K^{-1}	1.474	1.095	3.962
Our calculations					
Average temperature	T_{av}	°C	7.788	8.211**	7.655
Amplitude	A	°C	5.822	7.147	5.318
Phase constant	t_0	year	0.322	0.314	0.335
Damping depth	z_d	m	2.649	2.910	4.727
Thermal Diffusivity	D_h	m^2 yr^{-1}	22.048	26.610	70.188
Thermal Conductivity	λ_h	W m^{-1} K^{-1}	1.5439	1.0603	4.3024

* Our recalculation of his units and renaming of some of his terms into SI units and commonly accepted modern soil physics terminology
** Which explains why one of the authors moved from Scotland to Australia.

Table 2. The goodness of fit for the mechanistic temperature wave model to Forbes data.

		All depths	T4 1 m	T3 2 m	T2 4 m	T1 8 m
Observatory	n	1071	264	269	269	269
	RMSE (C°)	0.583	0.725	0.448	0.426	0.677
	R^2	0.919	0.943	0.954	0.934	0.314
Craigleith	n	1051	260	259	266	266
	RMSE (C°)	0.544	0.737	0.562	0.407	0.406
	R^2	0.945	0.948	0.953	0.949	0.839
Exp. Garden	n	1199	300	300	299	300
	RMSE (C°)	0.551	0.847	0.527	0.291	0.365
	R^2	0.726	0.769	0.845	0.593	0.056

Relationship between Forbes parameters and contemporary parameters

No units for heat capacity and conductivity were given in Forbes' paper. Based on "standard" values of heat capacity (http://www.engineeringtoolbox.com/specific-heat-solids-d_154.html), we were able to deduce the units of specific heat capacity he used as kcal kg^{-1} $^{o}C^{-1}$, thus the units of other properties can be inferred. Here we deduce the contemporary values for Forbes calculations so we can compare it with our own.

The sine term in equation (1) has maximum and minimum values at +1 and -1, and so equations for T_{max} and T_{min} become :

$$T_{\max} = T_{av} + A\exp\left(\frac{z}{z_d}\right)$$

$$T_{\min} = T_{av} - A\exp\left(\frac{z}{z_d}\right)$$

Subtracting the above two equations gives :

$$\Delta T = T_{\max} - T_{\min} = 2A\exp\left(\frac{z}{z_d}\right)$$

Taking logarithms:

$$\log \Delta T = \log 2A + \frac{z}{z_d}$$

which is the same as Eq. (3).

From Equations (2) and (5) we can see that Poisson's constant is related to damping depth:

$$z_d = a\sqrt{\frac{2}{\omega}}$$

After converting the units to SI and adjusting for the damping depth we now have Forbes' estimates in contemporary units which can be compared with our calculations (Table 3).

As can be seen the relative differences are about 2-4% for the damping depth and 3-8% for the thermal conductivity. So amazingly, Forbes' calculations in the 1840's are comparable with our own calculations using a state-of-the-art computer and a nonlinear least squares analysis.

The measurement of heat capacity, and estimation of thermal conductivity compares well with values reported in contemporary books and references. It should be noted that from the bulk density (Table 1), the data of Observatory and Craigleith are for consolidated material rather than soil.

Table 3. Comparison between damping depth and thermal conductivity calculated by Forbes (1846) and our calculations.

	Damping depth (m)		Thermal conductivity (W m^{-1} K^{-1})	
	Forbes (1846)	This note (2007)	Forbes (1846)	This note (2007)
Observatory	2.589	2.649	1.474	1.544
Exp. Garden	2.957	2.910	1.095	1.060
Craiglieth	4.536	4.727	3.962	4.302

The model fits reasonably well even though the assumptions of uniform volumetric heat capacity and thermal conductivity are not met and the periodic boundary condition is somewhat more erratic. We could improve the model by taking into account some of the unexplained variation – we could for example make the model stochastic – this is commonplace in hydrology, and perhaps this is the role of the pedometrician on the soil physics-pedometrics interface. Nevertheless the analysis captures the main source of variation.

Conclusions

(1) Given a set of data the first question we would ask is, 'is there any physical or chemical or biological mechanism that could describe these data?' If there is, we should try to incorporate it into the model, if not and that is often the case, we have to move to exploratory data analysis with techniques dependent on the nature of the data (spatial, temporal, multivariate etc.).

(2) Forbes' analysis and ours are essentially the same. We think this suggests two things. First, Forbes was particularly advanced – after all he was one of the finest physicists in the world at the time and we are fortunate that he turned his attention to the soil. Secondly, theoretically soil science seems to be languishing – we desperately need some innovation.

Acknowledgment

We'd like to thank Paul McDougall for entering the data (and there are quite a lot of them)

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Buntebarth G., Temperature measurements below the earth's surface - A history of records. http://home.tu-clausthal.de/~pggb/Temp-%20measurements.html

Carslaw, H.S., Jaeger, J.C., 1959. Conduction of Heat in Solids. Oxford University Press.

Forbes, J.D., 1846. Account of experiments on the temperature of the earth at different depths, and in different soils, near Edinburgh. Transactions of the Royal Society of Edinburgh 16, 189-236.

Lambert, J.H., 1779. Pyrometrie oder vom Maaße des Feuers und der Wärme, Berlin.

Vacant Positions *For More info see www.pedometrics.org*

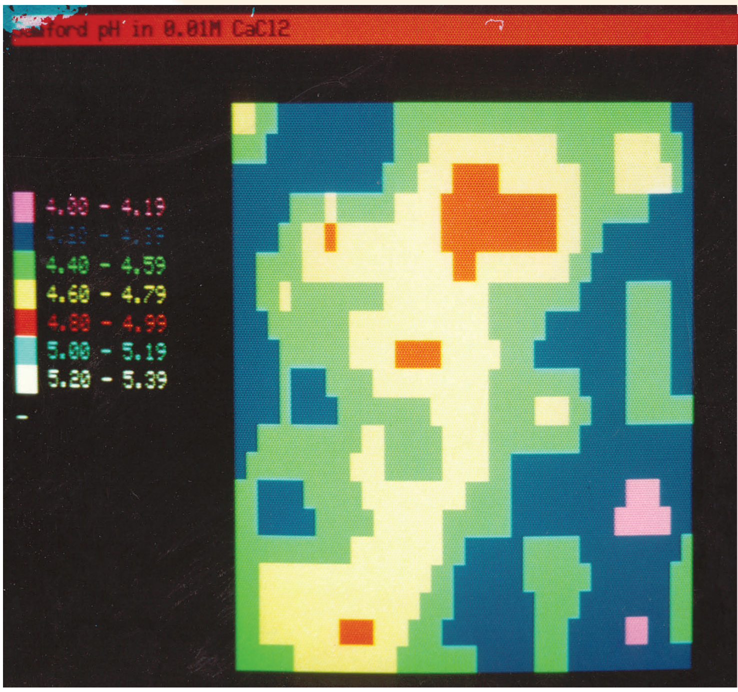
Post-Doc - Geospatial Digital Soil Modeling / Soil Carbon Sequestration (University of Florida). A highly motivated applicant is sought to conduct research on "Rapid Assessment and Modeling of Changes in Soil Carbon Storage and Turnover in a Southeastern U.S. Landscape (Florida)". Deadline: 30/01/2008. For more info contact: Sabine Grunwald http://grunwald.ifas.ufl.edu

Ph.D. Assistantship: Soil Landscape Analysis (Everglades, FL). Deadline to apply: 30/09/2007.Ph.D. Graduate Studies. Research interests: Geostatistics, statistics, geospatial analysis, ecosystem properties and processes, and wetlands. Requirements: M.S. in natural resources, environmental science, geospatial science or related field. For more info contact: Sabine Grunwald http://grunwald.ifas.ufl.edu

M.S. Assistantship: Remote-sensing supported digital soil mapping. M.S. Graduate Studies at the University of Florida. Research interests: GIS, remote sensing, soil mapping, and quantitative analysis. Study area: Water Conservation Area 2A, Everglades, Florida. Deadline: 30/09/2007. http://grunwald.ifas.ufl.edu

Looking for: Articles, photos, information about your work, theses, upcoming events, pictures, art works, poems, etc.

Send to: vchair@pedometrics.org.



An early, and cartographically naïve (abysmal), colour digital soil map. It's simply a nearest-neighbour interpolation of 121 pH values on a 10-metre grid. Photograph of screen of Intergraph terminal on a Unix system – circa 1983. The software to do this was home-made. Intergraph released the first computer graphics terminal to use raster technology in 1980. The data shown in the map were analysed more fully in G.M. Laslett, A.B. McBratney, P.J. Pahl and M.F. Hutchinson (1987). Comparison of several spatial prediction methods for soil pH. *Journal of Soil Science* 38, 325–341. (http://dx.doi.org/10.1111/j.1365-2389.1987.tb02148.x)

Alex

Pedometrician profile

Suk Young Hong 홍석영

National Institute of Agricultural Science and Technology (NIAST), Korea.

How did you first become interested in soil science?

I studied agronomy for my undergraduate and graduate (Master's). After finishing Ph.D. coursework, I became a researcher at Soil Management Division, National Institute of Agricultural Science and Technology (NIAST), Rural Development Administration (RDA), in 1995, Korea. At work, I started my job with reflectance measurement of crops and soils, and cropland classification using remotely sensed images. The reason I became interested in soil science was from the frustration, why remote sensors can't see the soils but only the very soil surface. That brought questions in my mind, 'what are the soils', 'what is the relationship between soil horizons', 'which factors affect soil reflectance and why', etc.. An article, 'Reflectance properties of soil' written by Marion F. Baumgardner (1985, Advances in Agronomy) helped for soil reflectance part.

How were you introduced to pedometrics?

While I am interested in soils in space and time in relation to remote sensing, I found an announcement for the 'First Global Workshop on Digital Soil Mapping(Montpellier, France)' in 2004. I went there, met Pedometricians (Philippe Lagacherie, Alex McBratney, Budiman Minasny, Marc Voltz, David Rossiter, Inakwu Odeh, and many more), and became to know of the concept of pedometrics. Talking and working with Budiman, Raphael and Alex for a short time in Australia in early 2007, I am learning and getting more interested in pedometrics.

What recent paper in pedometrics has caught your attention and why?

McBratney, Minasny, Viscarra Rossel. 2006. Spectral soil analysis and inference systems: A powerful combination for solving the soil data crisis. Geoderma 136, 272-278.

An idea for the soil inference system the authors suggested, are progressive and refined. SPEC-SINFERS will help to make the digital soil mapping happen practically.

What problem in pedometrics are you thinking about at the moment?

That would be 'data' and 'scale'. There might be different quantity and quality of dataset from place to place, to map soils digitally for different purposes. That is also related with scale matters.

What big problem would you like pedometricians to tackle over the next 10 years?

How real the soils predicted by digital soil mapping techniques are and how useful the results for the assessment of agriculture and environment.

Non-Pedometrician profile

David Powlson

Rothamsted Research, UK.

Professor David Powlson leads research at Rothamsted Research (UK) on the dynamics of organic carbon in soil, the role of soil carbon within the global carbon cycle and interactions with climate change. His Ph.D. research was the development of a technique for measuring the soil microbial biomass. After a post-doctoral period in Malaysia working on the management of acid sulphate soils, he returned to Rothamsted and conducted research on various aspects of carbon and nitrogen cycling in soils and interactions between agriculture and the wider environment.

How did you first become interested in soil science?

During my degree course in chemistry I decided that I wanted to take part in agricultural efforts to increase food production worldwide.

What are the most pressing questions at the moment in your area of soil science?

Managing land in the face of climate change. This includes identifying strategies to mitigate climate change through land management but also *utilising* land for a range of purposes whilst minimising net greenhouse gas emissions and maintaining a wide range of soil functions.

Making efficient use of plant nutrients to achieve required levels of food production but with tolerable environmental impacts. There are different challenges in regions of the world with intensive agriculture and in developing regions, where it is essential to increase fertilizer inputs. But the same soil science principles apply.

What statistical and mathematical methods are used in your area of soil science?

Models are now essential tools in research on carbon cycling, especially to attempt quantification of long-term trends. In some of my work I use long-term field experiments; in these a major challenge is disentangling effects of inherent soil variability from trends between treatments and changes in soil properties over time.

Are you aware of any work by pedometricians that might be relevant to your science?

There has been much work on ways of sampling to cope with soil heterogeneity.

What big problem would you like pedometricians to tackle over the next 10 years?

Converting their knowledge of soil heterogeneity into sampling strategies that are realistic in terms of resources normally available and achieving greater predictive ability, so that knowledge learned in one situation is more readily applicable to others.

Dealing with up-scaling, especially devising rational means of estimating soil properties or functions over large areas (inevitably using inadequate date) and providing means of expressing uncertainty ranges when this has to be done.

Third announcement and important dates for the first

Global workshop on High resolution digital soil sensing & mapping

www.iuss.org

5 – 8 February 2008
Sydney – Australia

CSIRO

A workshop for those developing and using proximal sensors and digital soil maps where there is a particular need for high spatial resolution (10 m or less) information.

Important dates in 2007

29 June	– 400 word abstracts due at the conference website http://www.digitalsoilmapping.org/2008/DSM_2008.html
01 July	– registration opens
01 October	– notice of acceptance
30 November	– six-page paper due

Registration

01 July – 31 October	AU$ 550	
After 01 November	AU$ 650	
Student	AU$ 450	
Workshop dinner	AU$ 120	Depending on numbers

Broad topics for submission of abstracts

- Proximal soil sensor development
- Applications of proximal soil sensing techniques
- Proximal soil sensor calibrations
- Signal processing
- Soil inference systems
- Prediction methods for large data sets

Keynote speakers

Jaap de Gruijter (NL)	Soil sampling
Bosse Stenberg (SE)	Soil spectroscopy
Noel Cressie (US)	Spatial stats for large data sets
Viacheslav Adamchuk (US)	Soil sensors

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Pedomathemagica

A quiz for Pedometrics 2007

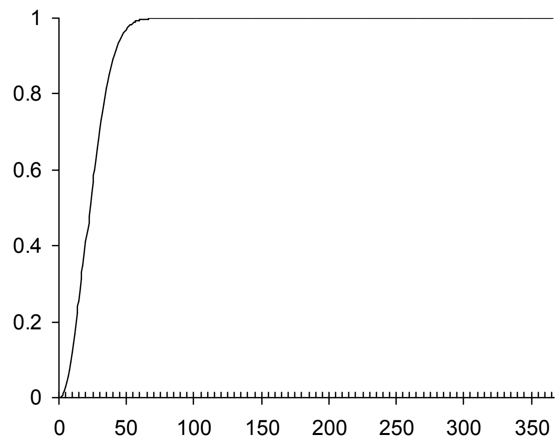
Return your answers in person to Murray Lark no less than half an hour before the Conference Dinner and you will be in with a chance to win a First Edition (Second Impression) of Jenny's *Factors of Soil Formation*, rescued from Rothamsted Library's waste bin by the Chair of Pedometrics himself. In the event of a draw the Chair will take responsibility for random selection of the winner. If the best entry is inadequate the Chair will retain the book until next time. The Chair's decision is final.

1. Spatial sampling and Sample space.

A pedologist is studying a landscape in which the only soils are Rendzinas and Calcareous Brown Earths, and these occur with exactly equal frequency. You provide her with independently and randomly drawn sets of coordinates for two sites which she visits and at each of which she digs a pit. She comes into your office and says "At least one of the profiles was a Rendzina". What is the probability that one of her pits was in a Calcareous Brown Earth?

2. Label the axes.

The Figure below might look like a variogram (with a spot of local drift), but it isn't. In fact it has nothing to do with the soil, but it illustrates an interesting and, for some, counterintuitive result in probability. Can you give the correct labels for the ordinate and the abscissa? A clue: while the function (y) is very close to 1 when x is larger than about 70, it reaches exactly 1 (its upper bound) only at the maximum value of x as plotted (x=366).

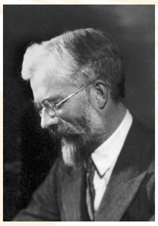


3. Catena Aurea. All five of the expressions below are equal to each other, and each is associated with one of the pictured individuals. With which individual is each expression associated? What do the expressions equal?

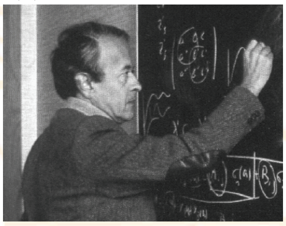
$$e^{\pi i}+1 \;=\; \mathrm{E}\left[\frac{\partial \log \ell}{\partial \theta}\right] \;=\; F\left(cl', o', r', s_1, s_2, \ldots\right) \;=$$

$$\mathrm{E}\left[Z(\mathbf{x}) - Z(\mathbf{x}+\mathbf{h}\right] \;=\; s^2\left(b \subset R\right) - \bar{s}^2\left(b \subset B\right) - \bar{s}^2\left(B \subset R\right)$$

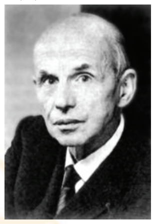
(a)



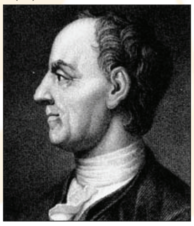
(b)



(c)



(d)



(e)

THE KNACK

Every mystery
Has at least
One unravelling
Every enigma
Has an inverse
And an even more
Miraculous solution
There is no square
No box no hypercube
Only an unbounded compass
Of opportunities
And expeditions powered
By ingeniously unfurled
Oblique sails
Of the intellect
To fatefully espy
Some offbeat isle

- David van der Linden