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Chair: Murray Lark Vice Chair & Editor: Budiman Minasny

From the Chair

Dear Pedometricians,

I have just finished reading a biography of Desmond Bernal, a founding father of the crystallography of macromolecules, a farsighted exponent of science policy, and a Marxist polymath. During the Second World War Bernal played a leading role in preparing for the Normandy landings, and I was interested to learn that one of the problems that he faced was a classical one in pedometrics.

The question was how to predict the trafficability of beaches for military vehicles, given that they were held by the enemy and could not be inspected at leisure. If you read Richard Webster's article in this issue of *Pedometron* you will see that essentially the same problem motivated the British Army to fund his doctoral research. Bernal answered the problem using the following sources of information.

1. Trials on similar beaches on the coast of Eastern England.
2. Holiday photographs solicited from the British public.
3. The 12th Century Anglo-Norman epic *Roman de Rou* which reported how Duke William of Normandy (later William 1st of England) escaped from his enemies by using little-known causeways on the Norman coast
4. Airphotographs
5. Articles written in the *Journal of the Linnean Society of Caen* by a 19th Century priest from a parish in Normandy who had an interest in geology.
6. A few core samples obtained from selected beaches in raids by special forces.
7. Accounts of a 14th Century legal dispute over taxes that allowed him to identify silted-up harbours.

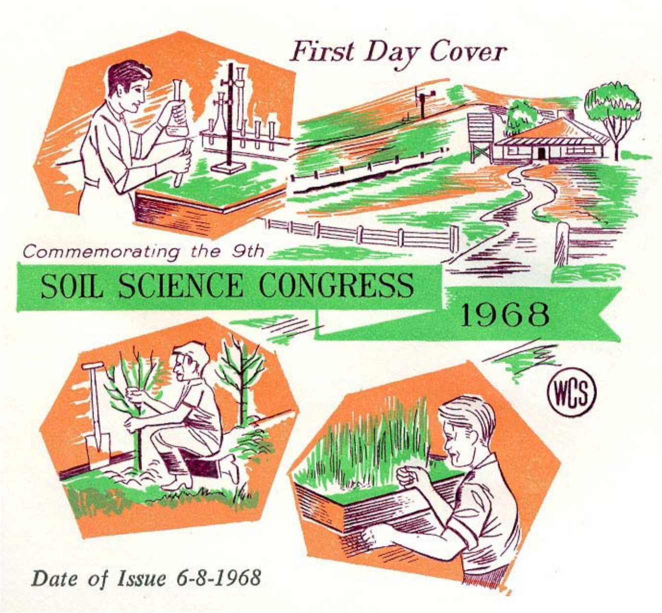
Continued next page …..

INSIDE THIS ISSUE

In short, any information was grist to his mill, and allowed him to predict trafficability with considerable success. The moral of the story is that very few really interesting problems are entirely new, and that it pays to know your history. For this reason the latest *Pedometron* contains two articles of historical interest. The first is Richard Webster's story of how he came to be interested in pedometrics, and recognized that geostatistics offered a solution to pedometrical problems. In the second Budiman and I describe how the 18th Century Comte de Buffon could be regarded as one of the first pedometricians.

There is much more in this issue, with research articles on fractals, soil carbon and bibliometrics and reports from meetings. We also have nominations for the best papers in Pedometrics in 2005 and 2006, thanks to Jaap de Gruijter and Inakwu Odeh for their nominations.

This will be the last *Pedometron* before *Pedometrics 2007*. The Pedometrics meeting is always dynamic, informative and sociable. I have no doubt that Tübingen 2007 will live up to the high standards set by past meetings, so submit your abstracts and register to attend in Germany this August (see www.pedometrics.de and Thorsten's advertisement below).



Finally, I would like to draw your attention to a new feature on the Pedometrics website (www.pedometrics.org). On the left-hand panel on the front page there is a button labelled "Donate Pedometrics". This takes you to page where I set out an appeal for donations to allow us to maintain and expand our activities. Please look at this, and if you feel able please follow one of the options to make a donation.

I hope to see you all in Tübingen.
With best wishes for your
Pedometrical endeavours

Murray

chair@pedometrics.org

www.digitalsoilmapping.org

IUSS Working Group on Digital Soil Mapping

Plans for 2007–2008

Introduction

The next few years will be exciting and challenging for the Working Group on Digital Soil Mapping. Our plans are evolving rapidly as a consequence of developments arising from the 2nd Global Digital Soil Mapping Workshop in Rio during July 2006. The Working Group recognizes the worldwide need for timely and accurate spatial information on the functional properties of soils. The information is required by the broader scientific community (especially for simulation modelling), land managers, planners and policy makers. Members of the Working Group have been instrumental in developing new technologies for measuring and predicting soil properties and we are keenly aware of the opportunities for dramatically improving access to soil scientific knowledge. The Rio meeting confirmed our common interest and started a collaboration that will yield many benefits within and beyond soil science.

We propose to make a new digital soil map of the world using state-of-the-art and emerging technologies for soil mapping and predicting soil properties at fine resolution. This new global soil map will be supplemented by interpretations that assist decisions relating to a range of global issues including food production and hunger eradication, climate change, and environmental degradation.

Recent developments

At the Rio meeting, Alex McBratney proposed that the Working Group should aim to produce soil information for the Globe starting with plant available water capacity. This suggestion sparked vigorous discussions that continued at the World Congress of Soil Science and subsequent meetings. As a consequence, Alfred Hartemink, Alex McBratney and Pedro Sanchez convened a meeting at The Earth Institute at Columbia University, New York, to conceive and plan how such a Global soil information system could be developed. The New York meeting ran from the 4th to the 6th of December 2006 and it was attended by 30 scientists from universities, research centres and developmental organizations from around the world (all attendees paid their own way). The meeting was a resounding success because of the strong institutional and scientific support for the concept. A consortium to implement the project was formed at the New York meeting and the plan is to establish nodes as follows:

- North America – National Resource Conservation Service, National Geospatial Development Centre, Washington, USA
- Latin America – CIAT (International Centre for Tropical Agriculture) in Cali, Colombia, and EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária) in Rio de Janeiro, Brazil
- Europe and Eurasia – Institute for Environment and Sustainability (IES) of JRC (Joint Research Centre of the European Union) in Ispra, Italy
- Africa – ICRAF World, Agroforestry Centre in Nairobi, Kenya
- Australasia – Commonwealth Scientific and Research Organization (CSIRO) in Canberra, Australia

The project will be coordinated by ISRIC – World Soil Information in Wageningen, The Netherlands. ISRIC is the ICSU (International Council of Sciences) World Data Centre of Soils. Nodes in the Asian region are yet to be identified.

Funding for the project will come from several sources but the starting point will be submission of an invited proposal to the Bill and Melinda Gates Foundation in the first half of 2007. We anticipate a project with an initial five year phase that includes a proof-of-concept component at the start. A second five year phase is also expected.

This exciting development is only just beginning. Plans will be posted when they become available at: http://www.globalsoilmap.net

Participants of the Global soil map meeting.

Other activities

The global soil map will clearly be the primary focus for the Working Group on Digital Soil Mapping. Most other activities were foreshadowed in the 2006 Annual Report and they include:

- Publication of *Digital Soil Mapping with limited data*. This collection of papers from the Rio meeting will be edited by Alfred Hartemink, Alex McBratney and Lou Mendonça-Santos and published in Elsevier's series on Developments in Soil Science.
- Planning for the Workshop on High-Resolution Digital Soil Sensing and Mapping to be held in Sydney, Australia from 5th to 8th February 2008. This meeting will bring together individuals interested in digital soil mapping as well as those using sensors and digital soil maps for precision agriculture and perhaps also soil contamination. The meeting will focus on resolutions of <10 m. This is in contrast to the Montpellier and Rio Workshops that addressed coarser resolutions.
- At least one Global Workshop on Digital Soil Mapping (similar in scope to the Montpellier and Rio meetings) – the date and theme are still be confirmed.
- A symposium in conjunction with the annual Soil Science Society of America Annual Meetings – this will be at a time that complements the schedule for Pedometrics meetings.
- A major symposium at the 19th World Congress in Brisbane.

Outlook

The Working Group on Digital Soil Mapping is gaining momentum and 2007/2008 will be a momentous period. Updates and further information on the Working Group will be posted regularly at: http://www.digitalsoilmapping.org/

Prepared on behalf of the Working Group on Digital Soil Mapping by:

Neil McKenzie (Chair),
Acting Chief, CSIRO Land and Water, Australia.
Florence Carre (Secretary),
Institute for Environment & Sustainability, EU Joint Research Centre, Italy.

Chance and vision on the road to pedometrics

Richard Webster

A first degree in pure chemistry at Sheffield University might seem an unlikely start to a career in statistical pedology. A *Pattern of Islands*, Arthur Grimble's account of his life as a young officer in the British colonies, might seem an even less likely lead into the subject. But I was fascinated by it. So when by chance I learned that the Colonial Office's 'recruiting sergeant' was in the University to lure chemists into tropical agricultural science I was easy meat.

I was awarded a post-graduate scholarship so that I could study soil science and statistics at London University and Rothamsted, and on completion of this 'conversion' to agricultural science I was posted to Northern Rhodesia (now Zambia) as Soil Chemist in 1957. The Land Use Survey of the Copperbelt, an 8000-km^2 region in the north of the country containing several large copper mines, had recently been completed. The original intention of my posting was to evaluate the agricultural worth of the soils mapped by the survey. The fiasco of the East African Groundnut Scheme was fresh in people's minds, and both the Colonial Office and the local Department of Agriculture were keen that future agricultural development would be based on sound information about the suitability of land derived from farming experience, insofar as it existed, field experiments and a proper understanding of the soil's chemistry.

In the event, when I arrived there were more pressing problems. The mine-workers and their families on the Copperbelt could afford to buy food imported by rail from the richer lands in the south. The rural communities in the northeast, cultivating the poor soil there, could barely subsist, and with the population's increasing there was need to identify land that could be developed. It became my job to survey soil for that purpose.

Don Mackney, who would later become head of the Soil Survey of England and Wales, had taught me all I knew about soil mapping—how to classify the soil into series, how to draw boundaries between the series in the field, and so on. Classification was somewhat arbitrary, but not especially difficult in the post-glacial English landscape. Mapping soil on the ancient African plateaux was a very different matter. There were no obvious boundaries between one kind of soil and another. Instead, the soil changed gradually in response to the gentle rise and fall of the land, though with local fluctuation superimposed.

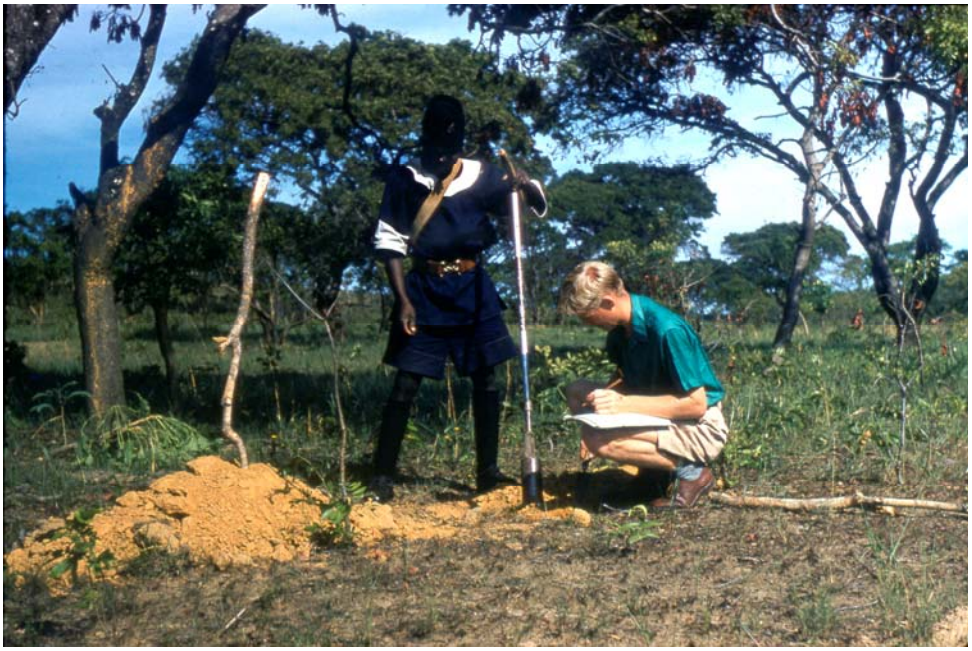


Figure 1 The author at work in the miombo woodland of Zambia.

I was dealing with classic catenas, but that recognition did not solve my problem of dividing them into relatively homogeneous patches for agricultural management and predicting what I should be likely to find at any place in the landscape. I pondered the situation long and hard.

I was no nearer to solving my problem when Philip Beckett and Frank White of Oxford University landed in the Country. The Royal Society of London had sponsored them to study the soil and vegetation in relation to the physiography of the African plateaux. I joined them in the field for part of their stay, and in the evenings we would sit around the table in the rest house, lit by a single paraffin lamp, and discuss the day's observations. We would return to my unsolved problem of prediction time and again, only to determine to find a solution.

Some months later I received a letter from Philip: he had obtained a grant from the British Government to solve the problem in a military context. He wanted a soil scientist to work alongside the Royal Engineers and their civilian counterparts. Was I still interested in predicting soil conditions at unvisited places? Of course I was, and as soon as the various documents had been signed and sealed I headed for Oxford.

The year was 1961. A few engineers had begun to realise that the problem was essentially statistical and were toying with a combination of classical soil maps and prediction statistics based on stratified random sampling in which the classes of the maps were the strata. As far as we knew at the time none of them had tested their own maps in these terms. We should make maps ourselves. Because the context was military we should do so largely by air-photo interpretation and we should call the classes 'land facets' rather than soil series or soil types. We should then test our maps for their effectiveness in (a) diminishing the variance of soil properties within classes and (b) predicting the values of those properties with acceptably small variances. We also tested maps made and sampled by several of our collaborators. We had mixed success. Our map of the Oxford region enabled us to predict the mechanical properties of the soil reasonably well. It predicted relatively poorly the soil's pH and organic matter content, and it was useless for predicting the plant nutrient status of the soil.

Even in the most favourable situations there were substantial residuals for which we could not account. Also, we were still wedded to classification as a way of describing the variation we could see. We had not solved the problem of the catena or any other form of gradual change or trend. If we simply drew boundaries in those situations then the residuals would contain trend. We also recognized that trend surface analysis, then becoming fashionable in geography and petroleum exploration, was unsatisfactory because the residuals were correlated. Further, if there were neither evident trends nor clear boundaries then how were we to describe the variation?

Figure 2 Philip Beckett (right) leading the army's pool of engineering geologists on English farmland.

Enter Heriberto Cuanalo de la Cerda from Mexico. He brought new ideas: time-series analysts have similar problems, and they treat actuality as realizations of stochastic processes to describe fluctations quantitatively in time. Could we not do the same for soil? So we switched our thinking from classical mode and took the wild leap of imagination; we would treat the soil as if it were random against all the tenets of the day! To test the feasibility of this approach he painstakingly described 321 pits at 10-m intervals on a transect across north Oxfordshire, and we wrote programs to compute correlograms from his data and to plot them. We found strong spatial correlation extending to 250 m or more. There were evident boundaries between classes of soil. We removed the class means from the data and discovered that there was still spatial correlation in the residuals. Where were we to go from there? How could this form of analysis lead to prediction? Cuanalo returned to Mexico and I, by now a member of the Soil Survey of England and Wales on the Rothamsted staff, turned my attention to another problem that was taxing my colleagues, namely multivariate classification.

However, one morning in 1972 I received a telephone call from Australia. Gordon Hallsworth, then chief of the CSIRO Division of Soils, was on the line. A young Englishman, John Norris, whom he had recruited to help Bruce Butler quantify soil survey, had died in a road accident, and Gordon wanted someone with the necessary skills to take over the project as soon as possible. Was I free? I negotiated a year's leave of absence from Rothamsted and joined Bruce Butler in Canberra the following January. I re-analysed Norris's soil data on the Southern Tablelands of the Australian Capital Territory but could make little sense of them. Correlation between variables was in general weak. Soil classification scarcely improved the ability to predict.

There seemed to be no common spatial pattern among the many variables that Norris and Butler had recorded, and some variables had no evident spatial pattern at all. This was not how things were supposed to be; it was not what CSIRO's pedologists expected when they first attempted, and failed, to map the soil there. Butler and I asked the questions: (a) on what spatial scales are the individual properties of the soil varying? and (b) can we discover economically what those scales are? This led to our adapting nested random sampling in which each hierarchical level was a fixed distance separating sampling points on the ground. By analysis of variance we could estimate the variance associated with each distance. We later realised that we had rediscovered an innovation of Youden and Mehlich but whose publication in 1937 in the house journal of their research institute had lain unheralded for more than 30 years.

Figure 3 Bruce Butler scanning the Riverina in south east Australia with expert eye.

Nevertheless, we did take the analysis a step further in that we accumulated the components of variance from the shortest distance to the largest and thereby formed crude variograms, the first of any soil properties. We also discovered that the properties we analysed in that exercise did indeed vary on disparate scales and that it was small wonder that the pedologists had largely failed to map the soil by conventional means. At the same time I pressed the analogy with time series into the spectral domain and surveyed a transect across gilgai landscape as a case study. Now the gilgais, typically gentle depressions in plains and widespread in eastern Australia, appear in patterns that seem to have some degree of regularity. These manifested themselves as peaks in the spectra.

These two studies occupied much of my sabbatical year in Australia, but I had still not worked out how to move from the variogram or spectrum to prediction. I was about to depart and was tidying up my office when a total stranger marched in unannounced. The intruder came straight to his point without a moment's delay or even introducing himself: 'They tell me that you are some kind of statistician. Well, what's this kriging?' I had never heard the word, and his brutal introduction put me on the defensive; I played for time. I asked the newcomer who he was and to explain the context, which he did. He was Daniel Sampey, a mining geologist. He told me that a certain Professor Krige had discovered how to optimize the estimation of gold reserves on the Reef in South Africa. He also told me of Georges Matheron, of the theory of regionalized variables and of its application in geostatistics. I let him continue, which he did for about 15 minutes with only the occasional 'mmm' and 'yes I see' in the way of encouragement from me. Then, clearly disappointed that I knew even less than he did, he left as abruptly as he had arrived. His parting shot was that as I was about to return to Britain I should visit Leeds University where mining engineers knew a thing or two.

I shall not forget Daniel Sampey. In those 15 minutes I realised that my problem of spatial prediction of soil conditions at unvisited places had been solved, at least in principle and by miners, and in general terms I understood how. On my return to the Soil Survey I lost no time in contacting Anthony Royle, lecturer in the subject at Leeds, and a week or two later we met. He amplified what Daniel Sampey had told me, and he generously gave me a copy of his lecture notes on the subject and a few references to the literature including Matheron's seminal thesis—in French. My next student was Trevor Burgess, an Oxford mathematician who was looking for a postgraduate position in which he could apply his talents. He was the ideal person, keen and swift to appreciate the problem and its solution. We turned Matheron's equations into algorithms and algorithms into computer code. And in 1980 our first scientific papers appeared, the first to describe for soil scientists the variogram as we know it today and the first to display maps of soil properties made by kriging.

Trevor obtained his doctorate and was followed by Alex McBratney and Margaret Oliver, both of whom made their careers by extending the applications ever more widely and helping to establish geostatistics as an essential strand in modern quantitative soil survey through their writing and teaching.

Someone some day was bound to see in geostatistics the tools that are now proving so effective in soil survey. It was largely by chance that that someone happened to be me. What might I have done had I not read Arthur Grimble's book, had I not learned of the Colonial Office's recruiting drive, had Philip Beckett not ventured into Zambia, had John Norris not met such an early death, and had Daniel Sampey breezed into my office the week after I had left Australia instead of the week before? We shall never know. All we know is how it happened by a combination of opportunity, good fortune and more than a little persistence. Let's give thanks for it.

The Comte de Buffon, an early Pedometrician?

Georges-Louis Leclerc, Comte de Buffon (1707–1788) was a French naturalist, mathematician, biologist, and cosmologist. His early interests were in mathematics, particularly probability. His most celebrated result is in geometrical probability and is known as 'Buffon's needle' (see below). This concerns the probability of a randomly dropped needle intercepting a regular pattern of lines. You may have encountered it in junior school, applying the formula to estimate π by counting the number of times a dropped pencil intercepts two ruled lines.

Buffon translated the work of Stephen Hales, an English physiologist, into French, and this awoke his interest in biological problems. Among other topics, he contributed ideas about evolution and ecology, which influenced later workers such as Darwin.

Buffon also had an interest in soil. This is described in his book *Histoire Naturelle des Minéraux* (1783–1788). He classified soil into three groups: clays, calcareous earths, and vegetable mould (*terre végetalé*). He noted that the layer of vegetable mould is always thicker in virgin lands than in inhabited lands where man and fire annihilate the animal and vegetable kingdom. Vegetable mould is thinner on top of the mountains than in valleys and plains, because it is washed down by rains and deposited downhill.

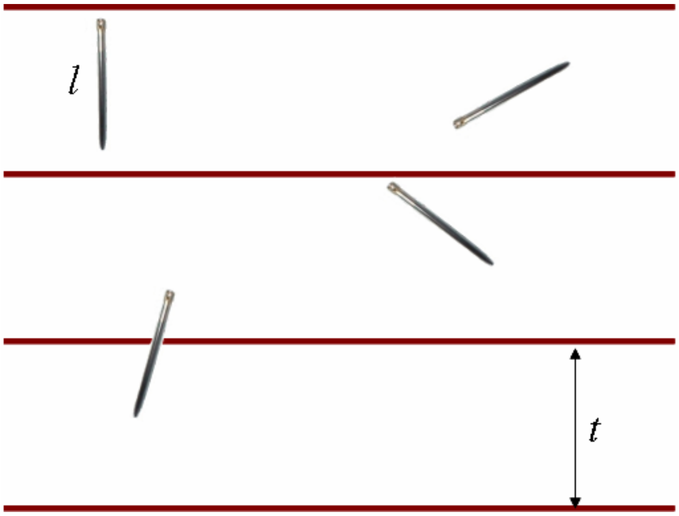
According to Feller *et al*. (2006) he showed remarkable skill at soil profile description. He also conducted a soil survey and reported the variations that he discovered in his book *Histoire Naturelle des Minéraux*:

> *"In 1734, I ordered a plot of about seventy acres to be probed by several auger drills, for I wanted to know how thick the good soil in that place, where I had formerly had a number of trees plated, with satisfactory results. The ground had then been divided into several acres; and the boring being performed at all four angles of each acre, I noted the different depths of soil, the thinnest being of two feet, and the thickest, three feet and a half."*

Feller, C., Blanchart, E., Yaalon, D.H., 2006. Some major scientists (Palissy, Buffon, Thaer, Darwin and Muller) have described soil profiles and developed soil survey techniques before 1883. In: Footprints in the Soil. People and Ideas in Soil History. B.P. Warkentin (ed). Elsevier.

Buffon's Needle

Buffon posed this question in 1733: suppose we have a floor made of parallel strips of wood, each the same width, and we drop a needle onto the floor. What is the probability that the needle will lie across a line between two strips? This is known as Buffon's Needle problem. Our needle is of length l, and we drop it onto a plane with parallel lines distance t apart. Buffon asked what the probability is that the needle will cross a line (where $l < t$).



We consider the position of the centre of the needle, which will be some distance, x, between 0 and $t/2$ from the nearest line. We also consider the acute angle, θ, made between the needle (or its projection) and the line (which will be between 0 and $\pi/2$ radians). We assume that the distribution of x over the interval $[0, t/2]$ is uniform, with probability density $^{2}/_{t}\, dx$, and that it is independent of the distribution of θ over the interval $[0, \pi/2]$ which is also uniform with probability density $^{2}/_{\pi}\, d\theta$.

Now, if the needle is to intercept a line then a quick sketch on the back of an envelope will show you that

$$x \leq \frac{l}{2} \sin \theta.$$

We can therefore evaluate the probability that the needle crosses a line as

$$\begin{aligned} p_{\mathrm{I}} &= \int_0^{\pi/2} \int_0^{\frac{l}{2}\sin\theta} \frac{4}{t\pi} \sin\theta \;\; dx\, d\theta, \\ &= \int_0^{\pi/2} \frac{2l}{t\pi} \sin\theta \;\; d\theta, \\ &= \frac{2l}{t\pi} \left[-\cos\theta\right]_0^{\pi/2} \;=\; \frac{2l}{t\pi}. \end{aligned}$$

Kendal & Moran (1963) state a more general conclusion. If an irregular linear object (e.g. a twisted wire) of length L is randomly dropped onto our plane, then the expected number of intersections of the wire and the lines is $^{2L}/_{t\pi}$, irrespective of the shape of the object.

This allowed the principle of Buffon’s needle to be applied in soil and plant measurement, in particular to estimating root densities and the length of soil cracks. Newman (1966) estimated the length of roots by lying out the roots on a flat surface, and counting the number intersections between the roots and random straight lines.

Ringrose-Voase *et al*. (1996) used the same principle to measure the length of cracks in Vertisols. The cracks are sampled using a transect (that is made of linked semi-circles) across the soil surface. The number of cracks intercepted by the semi-circle is counted, and the length of soil cracks can be estimated.

Kendal, M.G. & Moran, P.A.P. 1963. *Geometrical Probability*. Griffin, London

Newman, E.I. 1966. A method of estimating the total root length in a sample. Journal of Applied Ecology 3, 139–145.

Ringrose-Voase, A.J. & Sanidad, W.B. 1996. A method for measuring the development of surface cracks in soils: application to crack development after lowland rice. Geoderma 71, 245–261

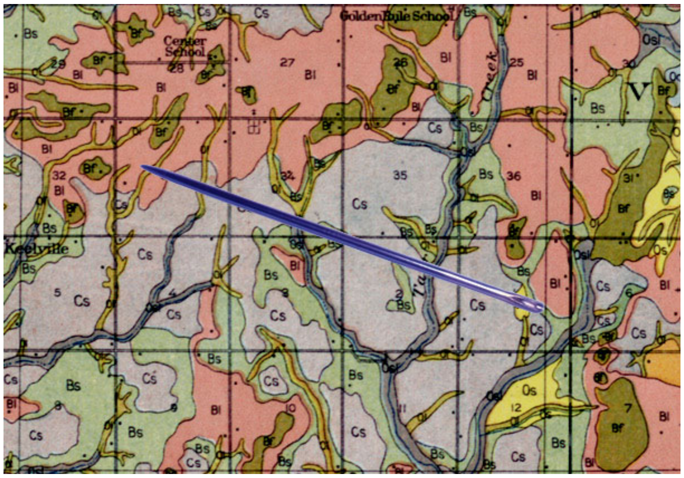
On an 18th Century French Count and Soil Boundaries.

Murray Lark

"... all the work of the crystallographers serves only to demonstrate that there is only variety everywhere where they suppose uniformity ... that in nature there is nothing absolute, nothing perfectly regular".

Histoire Naturelle des Minéraux Georges-Louis Leclerc, Comte de Buffon

Some years ago, while a graduate student, I was quietly musing in the tea room of the Agricultural Science building in Oxford when I was joined by a fellow student, an animal scientist from County Fermanagh in Ireland. As I recall she was studying the genetics of red deer. "What are you thinking about?" she demanded, to which I replied, "I am imagining a large needle. You drop it at random on the landscape, examine a soil profile pit at each end, and then decide whether or not these correspond to the same soil series." She looked at me for a moment. "The stuff you do is weird!" she said.



But I was being entirely truthful. I had just finished reading a paper by Philip Beckett and Stein Bie (Beckett & Bie, 1975) in which they discussed the possibility of a reconnaissance procedure for soil survey. Previous studies on soil survey in England and Australia had shown that survey effort (staff days) could be related to boundary density (length of boundary per unit area of map). Beckett and Bie asked whether you could estimate the boundary density for 'pure' map units for a particular classification by examining pairs of soil profiles separated by a fixed (short) distance. If the profiles belonged to different classes then it was assumed that the line between them intercepted a soil boundary. The proportion of intersections could then be used directly to estimate the density of boundary via the relationship in geometrical probability known as "Buffon's needle" (see above). Beckett and Bie previously had the inspired idea of applying Buffon's relation in order to estimate the boundary densities on real soil maps (Bie & Beckett, 1971). The proposed extension to a field methodology was a bit of lateral thinking.

It was also rather more of a *jeux d'ésprit* than a practical tool. If we assume that every two observations of different soil classes must be separated by a mappable boundary, then we assume that soil map units can, at least in principle, be pure (i.e. correspond entirely to the soil classes with which they are associated). Beckett and coworkers, however, were more conscious than anyone of the distinction between the soil map unit called "Evesham" and the soil profile class called "Evesham". The latter is a class defined on features of the profile. The former is a region of the landscape, defined by the surveyor on features (topography, vegetation, etc.) that are linked by a mental model to the distribution of soils in the landscape, and found to correspond predominantly to the class for which it is named. The fact that inclusions of different classes are found within the Evesham map unit therefore does not necessarily reflect poorly on the skill of the surveyor. It arises inevitably because a soil class and a soil map unit are different, though correlated, kinds of object. If we tried to apply Buffon as suggested by Beckett & Bie (1975) our basic problem is that our point observations are of profile classes, while the objects that we want to describe are map units.

But I don't want to suggest that the Comte de Buffon lead us up a dead end. Far from it. Soil map units are enormously informative (which is one reason that pedometricians have paid considerable attention to the problem of incorporating soil boundaries into predictive models), and so are soil classifications. Thinking about the distinction helps us to understand better the value and the limitations of attempts to classify a continuous medium, and to see that the soil map, with its discrete parcels, need not be discarded because we prefer to think of the variation of the soil as essentially continuous. It is perhaps no coincidence that the Beckett and Bie paper on the boundary density of pure map units was part I in a pair of papers on reconnaissance for soil survey. Part II (Beckett & Bie, 1976), which reported some results from field work in Australia, is probably the first publication in the soils literature to cite Matheron on the variogram.

Bie, S.W. & Beckett, P.H.T. 1971. Quality control in soil survey. II. The costs of soil survey. Journal of Soil Science 22, 453–465.

Beckett, P.H.T. & Bie, S.W. 1975. Reconnaissance for soil survey I. Presurvey estimates of the density of soil boundaries necessary to produce pure mapping units. Journal of Soil Science 26, 144–154.

Beckett, P.H.T. & Bie, S.W. 1976. Reconnaissance for soil survey II. Presurvey estimates of the intricacy of the soil pattern. Journal of Soil Science 27, 101–110.

Best Paper in Pedometrics Award

Jaap de Gruijter and Inakwu Odeh have nominated papers for the Best Paper in Pedometrics awards for 2005 and 2006 respectively. They were asked to consider peer-reviewed papers published in international journals, and to select the five that they considered to be most deserving of the title. We list below the nominations, in alphabetical order by the first author's name.

The awards will be announced at Pedometrics 2007 in Tübingen this August. Unlike previous years we would like the vote to be completed *before* the conference. Margaret Oliver, who chairs the Commission's awards committee, has kindly agreed to collate and report on the vote.

In another development, the journals involved in this vote have kindly agreed that the full text of the papers be made freely available online until the vote is complete. We are grateful for this, which should make it easier for all to participate in this award. If you visit the Pedometrics website at: http://www.pedometrics.org/best_paper_2005_06.asp you will find links to each nominated paper. The abstracts are also reproduced below with the journals' kind permission.

To participate in the award you should:

- Read each paper. This is now possible for everyone!
- For each of the two years, rank all five papers in order of preference. As in previous years, **give rank 5 to the paper which you believe to be the best, rank 4 to the second-best and so on.**
- Email your rankings for the two years to Margaret at bestpaper@pedometrics.org
- **Votes must be received by 15 August 2007.**

I would like to thank Jaap and Odeh for undertaking the considerable task of reading and assessing papers for nomination. It is no mean feat. Thanks also to Margaret, who is looking forward to receiving your votes.

Nominations for 2005

1. Henderson, B.L., E.N. Bui, C.J. Moran, D.A.P. Simon. Australia-wide predictions of soil properties using decision trees. Geoderma, 124 (2005): 383-398

Abstract

This paper describes the construction of Australia-wide soil property predictions from a compiled national soils point database. Those properties considered include pH, organic carbon, total phosphorus, total nitrogen, thickness, texture, and clay content. Many of these soil properties are used directly in environmental process modelling including global climate change models. Models are constructed at the 250-m resolution using decision trees. These relate the soil property to the environment through a suite of environmental predictors at the locations where measurements are observed. These models are then used to extend predictions to the continental extent by applying the rules derived to the exhaustively available environmental predictors. The methodology and performance is described in detail for pH and summarized for other properties. Environmental variables are found to be important predictors, even at the 250-m resolution at which they are available here as they can describe the broad changes in soil property.

2. Jost, G., G.B.M. Heuvelink, A. Papritz. Analysing the space-time distribution of soil water storage of a forest ecosystem using spatio-temporal kriging. Geoderma, 128 (2005): 258-273

Abstract

In forest the soil water balance is strongly influenced by tree species composition. For example, differences in transpiration rate lead to differences in soil water storage (SWS) and differences in canopy interception cause differences in infiltration. To analyse the influence of tree species composition on SWS at the scale of a forest stand, we compare spatio-temporal patterns in vegetation and SWS. Geostatistical space–time models provide a probabilistic framework for mapping SWS from point observations. The accuracy of these models may be improved by incorporating knowledge about the process of evapotranspiration. In this paper we combine a physical-deterministic evapotranspiration model with space–time geostatistical interpolation to predict soil water storage in the upper 30 cm of soil (SWS30) for a 0.5 ha plot in a mixed stand of Norway spruce (*Picea abies* (L.) Karst.) and European beech (*Fagus sylvatica* L.) in Kreisbach, Lower Austria. Soil water storage was measured at 198 locations by permanently installed wave guides. This was repeated 28 times, about every two weeks during the growing seasons of 2000 and 2001. Incorporation of a process-based model in space–time prediction of SWS30 reduced the effect of precipitation on SWS30 predictions prior to precipitation. Spatial patterns of

SWS30 between the permanent wilting point and field capacity depend on the precipitation and drying history, which is affected by vegetation. Early in the growing season spruce starts to transpire markedly, which is common for coniferous trees. During dry periods, spruce reduces transpiration earlier than beech. Overall beech transpires more than spruce during the growing season. The greater transpiration rates of beech are compensated for by greater soil water recharge after precipitation because less rainfall is intercepted. At low water contents near the permanent wilting point SWS30 was spatially quite uniform. This was also the case at water contents nearfield capacity, probably because the soil physical parameters varied little. Space–time interpolation of SWS30 and the prediction of soil water discharge and soil water recharge during periods of drying and rewetting demonstrate the important role of vegetation on the spatial patterns of SWS30.

3. Monestiez, P., J.-S. Bailly, P. Lagacherie, M. Voltz. Geostatistical modelling of spatial processes on directed trees: Application to fluviosol extent. Geoderma, 128 (2005): 179-191

Abstract

This paper shows that geostatistical modelling can be extended to spatial supports such as directed trees and applied to variables spatially structured along a river network. Specific assumptions were necessary and main methods were redefined introducing modifications on metrics, proper variogram estimates and ad hoc drift models. We also proposed a model-based simulation procedure to generate random functions on directed trees. A case study on fluvisol delineation for the Hérault river (South of France) was analyzed. Clear spatial structures were observed and modelled using variogram based on upstream–downstream distance along a hydrographic network. A drift was also modelled as a multiplicative term affecting the fluvisol width versus the cumulated length of the upstream network. The significance of the drift was then assessed conditionally to the former spatial variogram using Monte-Carlo simulations of the spatial observed process on the river network.

4. Saito, H., K. Yoshino, T. Ishida, T. Nagano, W. Sirichuaychoo, A. Jongskul, N. Haraguchi. Geostatistical estimation of tropical peat-soil volume at Bacho, Thailand: impact of spatial support size and censored information. Geoderma, 125 (2005): 235-247

Abstract

The peat-soil volume at the Bacho site in Thailand was estimated using indicator geostatistics. The original peat layer thickness data include two types of censored observations: the physical and measurement limits. To avoid assigning values arbitrarily to them, the indicator approach was used, in which all observations are transformed into either 0 or 1 depending upon the exceedence of any given threshold. In this study, peat-soil thickness values are estimated using blocks with different sizes (i.e., change of support). Indicator kriging is applied to construct conditional cumulative distribution functions (ccdf) defines peat layer thickness at centers of estimation blocks. From the point ccdf obtained, an optimal estimate of peat layer thickness at each block is obtained by taking the mean of the point ccdf. The ccdf value beyond the maximum threshold is modeled by the linear model as it fits well to the original cumulative distribution of data. The choice of the extrapolation model needs to be guided by available information. The total peat-soil volume is estimated simply summing up the volume at each block (optimal thickness×area of the block). The estimated volumes are almost constant when the block size less than 200 m is used, indicating that the mean of the point ccdf at the center of the block can be used as the representative value of the block. When much larger block sizes are used, the ccdf at the center of the block cannot be used to estimate the block value. In such a case, the block ccdf need to be derived using different approaches such as stochastic simulation. The estimated total peat-soil volume within the investigation boundary at the Bacho site is 2.14×107 m3, when the block size smaller than 200 m are used. Using the average organic carbon content value measured at the site, the total organic carbon storage is estimated 1.22×109 kg C.

5. Savelieva, E., V. Demyanov, M. Kanevski, M. Serre, G. Christakos. BME-based uncertainty assessment of the Chernobyl fallout. Geoderma, 128 (2005): 312-324

Abstract

The vast territories that have been radioactively contaminated during the 1986 Chernobyl accident provide a substantial data set of radioactive monitoring data, which can be used for the verification and testing of the different spatial estimation (prediction) methods involved in risk assessment studies. Using the Chernobyl data set for such a purpose is motivated by its heterogeneous spatial structure (the data are characterized by large-scale correlations, short-scale variability, spotty features, etc.). The present work is concerned with the application of the Bayesian Maximum Entropy (BME) method to estimate the extent and the magnitude of the radioactive soil contamination by 137Cs due to the Chernobyl fallout. The powerful BME method allows rigorous incorporation of a wide variety of knowledge bases into the spatial estimation procedure leading to informative contamination maps. Exact measurements (“hard” data) are combined with secondary information on local uncertainties (treated as “soft” data) to generate science-based uncertainty assessment of soil contamination estimates at unsampled locations. BME describes uncertainty in terms of the posterior probability distributions generated across space, whereas no assumption about the underlying distribution is made and non-linear estimators are automatically incorporated. Traditional estimation variances based on the assumption of an underlying Gaussian distribution (analogous, e.g., to the kriging variance) can be derived as a special case of the BME uncertainty analysis. The BME estimates obtained using hard and soft data are compared with the BME estimates obtained using only hard data. The comparison involves both the accuracy of the estimation maps using the exact data and the assessment of the associated uncertainty using repeated measurements. Furthermore, a comparison of the spatial estimation accuracy obtained by the two methods was carried out using a validation data set of hard data. Finally, a separate uncertainty analysis was conducted that evaluated the ability of the posterior probabilities to reproduce the distribution of the raw repeated measurements available in certain populated sites. The analysis provides an illustration of the improvement in mapping accuracy obtained by adding soft data to the existing hard data and, in general, demonstrates that the BME method performs well both in terms of estimation accuracy as well as in terms estimation error assessment, which are both useful features for the Chernobyl fallout study.

Nominations for 2006.

1. Bishop T.F.A., Lark R.M. The geostatistical analysis of experiments at the landscape-scale. Geoderma 133 (2006): 87–106

Abstract

In conventional field experiments inherent variability is managed by design. In all cases the inherent variation is treated as additive random variables (a residual and any block and/or covariate effects). This assumption is generally reasonable in most field experiments where our basic units are plots within a relatively small and uniform region of a field. It is less plausible when we wish to conduct experiments across heterogeneous landscapes, with inherent variation of the soil over a wide range of many variables. In this paper we present a geostatistical approach to the design and analysis of landscape-scale experiments. We no longer regard the treatment response as a fixed effect, but rather as a random variable. Therefore, at any target site we can estimate the response to different treatments and treatment contrasts. This could be done by ordinary kriging, or by cokriging after we model the treatment responses as coregionalized variables. The advantage of cokriging is that contrasts and their confidence limits may be estimated optimally, and are coherent with estimates of the responses (i.e. the difference between two optimal estimated responses is the optimal estimate of the contrast between them). Since only one treatment response can be observed at a particular location we use the pseudo cross-semivariogram [Papritz, A., Kunsch, H.R., Webster, R., 1993. On the pseudo cross-variogram. Mathematical Geology 25, 1015–1026] to model the cross-covariances of the responses. We compared ordinary kriging and three variants of cokriging; standardized ordinary cokriging, ordinary cokriging and the method of Papritz and Fluhler [Papritz, A., Fluhler, H., 1994. Temporal change of spatially autocorrelated soil properties: optimal estimation by cokriging. Geoderma 62, 29–43]. Standardized ordinary cokriging was found to be the best predictor of the treatment contrast and responses under different levels of spatial auto-correlation and structural correlation, and different experimental designs. The results showed that the plots of different treatments should be placed as close together as possible to give the best predictions of treatment contrasts.
A field-scale nitrogen-response experiment was used to illustrate the proposed methods.

2. Follain S., Minasny B., McBratney A. B. Walter C. Simulation of soil thickness evolution in a complex agricultural landscape at fine spatial and temporal scales Geoderma 133 (2006): 71–86

Abstract

Hedgerow networks in the landscape are adapted objects that can be used to study soil redistribution processes within the landscape. In hedged landscapes, water erosion redistributes

soil, but hedges act as barriers to the physical transfers of soil particles. The most systematic effect is the increase in the thickness of A-horizons uphill from the hedges. A field experiment was carried out within an old agricultural area with a high density of hedges. A high resolution digital elevation model and a soil thickness map were created to investigate the effect of hedges on soil reorganization. The aims of this paper are to use this pedological knowledge for a better understanding of process dynamics, to simulate quantitatively the effect of hedgerow network on soil organization and redistribution, and to test different scenarios of land management on soil redistribution dynamics. The simulation uses a mechanistic model where the change in soil thickness over time depends on the transport of soil through a diffusive transport and a water erosion process. We tested the suitability of the model to operate on a DEM with grid size of 1 m and a simulation time of less than 1200 years. We performed the simulations on theoretical and actual DEMs with and without the hedgerow network. The effect of different land use and management scenarios on soil redistribution was tested. Those scenarios were applied on a DEM of real landscape, with the addition and removal of hedge on the DEM. The results suggest that the combination of diffusive transport and water erosion could significantly modify the topography and soil redistribution over a few centuries. The simulations show that hedges modify soil distribution and landforms by favouring deposition in the uphill position and soil erosion in the downhill position in agreement with field observations.

3. Heuvelink G.B.M., Schoorl J.M., Veldkamp A., Pennock D.J. Space–time Kalman filtering of soil redistribution. Geoderma 133 (2006):124–137

Abstract

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 (R2=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.

4. Kuzyakova I.F., Turyabahika F.R. Stahr K. Time series analysis and mixed models for studying the dynamics of net N mineralization in a soil catena at Gondelsheim (S–W Germany). Geoderma 136 (2006): 803–818

Abstract

Net N mineralization rate having very high annual dynamics is one of the basic parameters characterizing the N balance of the soil. The dynamics of the net N mineralization rates, and the effects of soil temperature and moisture on them, were analyzed for four soils: Eroded Haplic Luvisol, Calcaric Regosol, Gleyic–Calcaric Regosol and Eutric Cambisol located at different catena positions in the western part of the Kraichgau (Germany). The net N mineralization rates were measured in situ on unfertilized and N fertilized plots twice a month over a period of 6 years. Statistical analyses were conducted by a combination of the classical Time Series Analysis, particularly Census-I-Decomposition, with repeated-measures ANOVA using PROC MIXED of SAS. These statistical approaches allow to evaluate the seasonal, trend–cyclic and random components of the time series. In addition to the dynamics of soil temperature, soil moisture and net N mineralization rate, the following main characteristics were investigated: least square means of the investigated data series, their standard errors, and seasonal (annual) components of the series. The amplitudes of annual components of the time series were calculated by two methods: 1) as a half of the difference betweenmaximal and minimal values of the seasonal components determined by Time Series Analysis and 2) based on regression coefficients of a cosinefunction with an annual period estimated by the Fourier spectral analysis within the Linear Mixed Models approach. Repeated-measures ANOVA showed significant effects of soil type and location of the soils within the catena on temperature and moisture in 30 cm soil depth. The maximal amplitudes of annual variation of soil temperature and moisture were observed for Calcaric Regosol. This soil was characterized by a maximally pronounced annual cycle of net N mineralization rate, as well as by an increase of mineralization rate after fertilizer application. The annual cycle of net N mineralization rate in Calcaric Regosol was mainly determined by changes of soil temperature, not by the absolute temperature values. However, the long-term trend of net N mineralization rate in Calcaric Regosol followed the trend of soil moisture. The net N mineralization rate and subsequently the total amount of mineralized N increased in the following sequence: Eutric Cambisol<Eroded Haplic Luvisol<Gleyic–Calcaric Regosol<Calcaric Regosol.

5. Parasuraman K., Elshorbagy A., Si B. C. Estimating saturated hydraulic conductivity in spatially variable fields using neural network ensembles. Soil Sci. Soc. Am. J. 70 (2006):1851–1859

Abstract

Modeling contaminant and water flow through soil requires accurate estimates of soil hydraulic properties in field scale. Although artificial neural networks (ANNs) based pedotransfer functions (PTFs) have been successfully adopted in modeling soil hydraulic properties at larger scales (national, continental, and intercontinental), the utility of ANNs in modeling saturated hydraulic conductivity (Ks) at a smaller (field) scale has rarely been reported. Hence, the objectives of this study are (i) to investigate the applicability of neural networks in estimating Ks at field scales, (ii) to compare the performance of the field-scale PTFs with the published neural networks program Rosetta, and (iii) to compare the performance of two different ensemble methods, namely Bagging and Boosting in estimating Ks. Datasets from two distinct sites are considered in the study. The performances of the models were evaluated when only sand, silt, and clay content (SSC) were used as inputs, and when SSC and bulk density rb (SSC1 rb) were used as inputs. For both datasets, the field scale models performed better than Rosetta. The comparison of field-scale ANN models employing bagging and boosting algorithms indicates that the neural network model employing the boosting algorithm results in better generalization by reducing both the bias and variance of the neural network models.

The *h* index

**Budiman Minasny, Alex. McBratney &
Alfred Hartemink**

Introduction

Recently Hirsch (2005) proposed the *h* (or Hirsch) index as an assessment of the research performance of individual scientists. Hirsch defined it as:

> "a scientist has index *h* if *h* of his/her N_p papers have at least *h* citations each, and the other (N_p − *h*) papers have no more than *h* citations each."

Although the paper by Hirsch was published as recently as 2005, it is now being used in several disciplines for ranking or assessing scientists' performance. It is also used as one of the criteria for staff promotion in some departments. The *h* index is a single number that represents both productivity (number of papers) and their impact (number of citations). Here we look at the distribution of the *h* index for pedometrics and pedometricians.

The algorithm to calculate *h* index is as follows: all papers are ranked based on their number of citations, from the most, to the least, cited (See Fig. 1). The paper rank which equals the number of citations is the *h* index. Graphically, as in Fig. 1, the intersection of the 45 degree line with the curve of the number of citations versus the rank gives the *h* index. The total number of citations is the area under the curve.

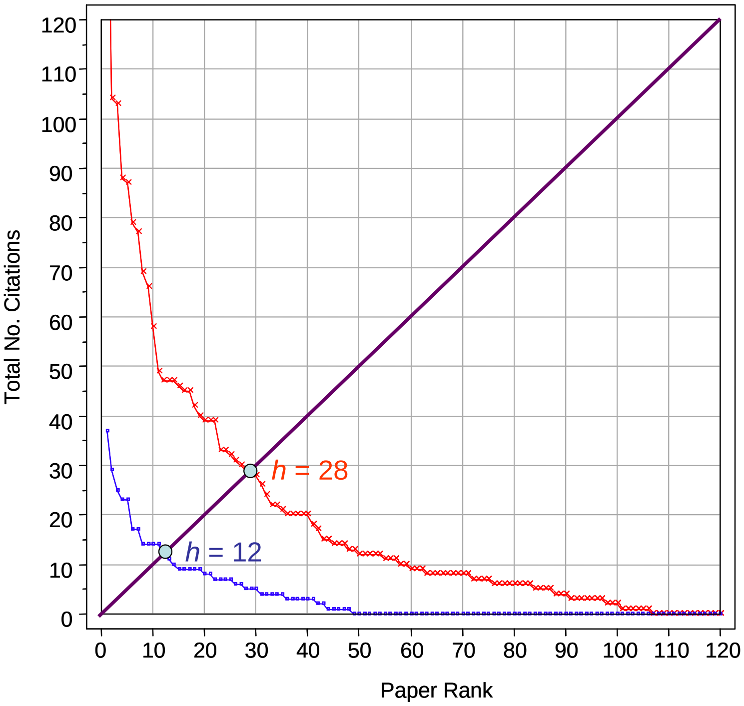


Figure 1. Total no. citations vs. paper rank, the intersect with a 1:1 line is the *h* index.

The distribution of the number of citations (Fig. 1) usually can be modelled as a stretched exponential function (Hirsch, 2005; Laherrere and Sornette, 1998):

$$N_c(y) = N_0 \exp\left[-\left(\frac{y}{y_0}\right)^{\beta}\right] \qquad (1)$$

where $N_c(y)$ is the number of citations of the *y*-th paper (ordered from the most to least cited), N_0 is maximum no. citations, and β, and y_0 are empirical parameters with $\beta \le 1$. When plotted on a semi-log plot it gives a straight line, and in a log-log plot shows curvature. The larger the value of β and y_0, the larger *h* will be. The total no. of citations for N_p papers can be found by:

$$N_{c,tot} = \int_1^{N_p} N_c(y)\,dy \qquad (2)$$

In practice, it is much easier to count the number of citations than doing the integral.

Data synthesis

We selected 35 pedometricians randomly using the ISI web of science database, accessed in November 2006. The following parameters were recorded: the number of papers N_p, total number of citations $N_{c,tot}$, year of the first paper published by the scientist, the average citations per paper ($N_{c,tot} / N_p$), and the *h* index.

The *h* index for the 35 pedometricians ranges form 1 to 32, with a median of 7. The scientific age (no. years since the first paper is published) ranges from 1 to 41 years representing early to mature researchers.

Results and Discussion

Figure 2 shows the relationship between *h* and total no. of citations. *h* increases with the square root of the number citations, following the diffusion or sorptivity process:

$$h = 0.57\sqrt{N_{c,tot}} \ . \qquad (3)$$

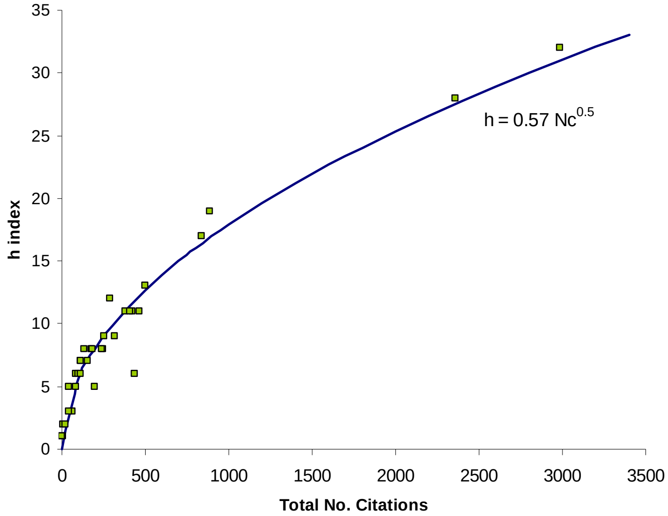


Figure 2. Relationship between total no. citations and *h* index for pedometricians.

We can see that *h* is closely related to the total number of citations. Thus *h* depends on how many citations one can earn in the pedometrics subject. This in part depends on the number of pedometricians.

Another factor that controls *h* is obviously the age of the researcher. Typically *h* increases linearly with time, assuming that a researcher has a constant output of papers and the papers are cited. A linear relation with age is proposed by Hirsch (2005):

$$h = m\, t \qquad (4)$$

where *t* is the "scientific age" of the researcher, and *m* is the impact or productivity of the researcher. As a measure of *t*, it can be approximated by the number of years after the first published paper until the present. The year when the first paper is published usually occurs at the end of the PhD degree (approximately 25-30 years or age). For physics, Hirsch found that $m = 1$ characterised a successful scientist (meaning that after ten years the top 10 paper will be cited more than 10 times), and $m = 2$ is outstanding. The relationship assumes that the researcher has a constant output of *p* papers per year and each paper gets cited *c* times per year.

This "standard" in physics may not be applicable in pedometrics. Fig. 3 shows the relationship between *h* and scientific age *t* for the 35 pedometricians. We found the "average" productivity and impact curve for pedometrics:

$$h = 0.7\, t \qquad (5)$$

This means that on average a pedometrician should get an annual increase of 0.7 in the *h* index. It will take one and a half years for an increase of one *h* unit, assuming a constant output of papers and annual citations.

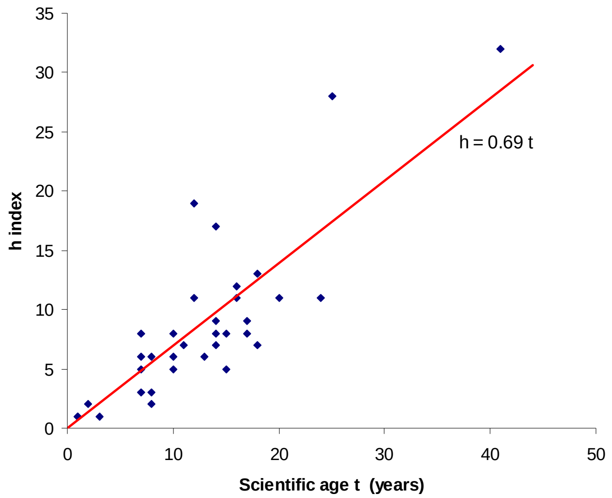


Figure 3. Relationship between scientific age and *h* index. The line represents the average impact curve for pedometrics.

We performed a regression between "scientific age" and the number of papers and average citations per paper. From Figs. 4 & 5 we can deduce that pedometricians publish on average 2 papers per year and each paper is citied 0.75 times per year.

$$N_p = 2.3\,t \qquad (6)$$

$$N_c/N_p = 0.75\,t \qquad (7)$$

Although some authors deemed the average no. of citations is better than other indices (Lehmann et al., 2005, 2006), it could be a bit deceptive. Most of the time, the top papers will be cited more frequently and the rest may not be cited at all. Most people have a highly skewed citation pattern.

Clearly, the average *h* index in pedometrics and soil science is lower than major science disciplines like physics or chemistry. The highest *h* index in physics about 110, and in biology is an unimaginable 190 (See: http://en.wikipedia.org/wiki/Hirsch_number). The *h* index is strongly related to the square root of the total number of citations. Pedometrics is a young and expanding area of research, but the number of researchers interested is still small. Compared with a larger dataset that we analysed (about 200 soil scientists) we found that the average relationship in pedometrics (Eq. 5) is the same as the average in soil science.

Based on Eq. (5) you can set your benchmark of the *h* index. You can use this as your argument for promotion, that is if your *h* index is similar to or larger than the average.

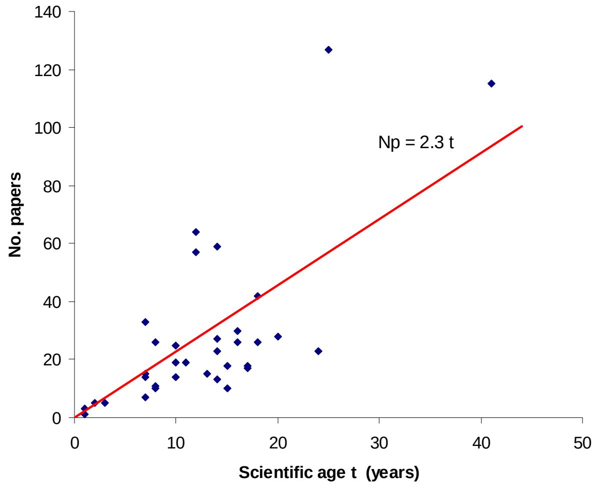


Figure 4. Number of papers as a function of time. Pedometricians on average publish 2 papers a year.

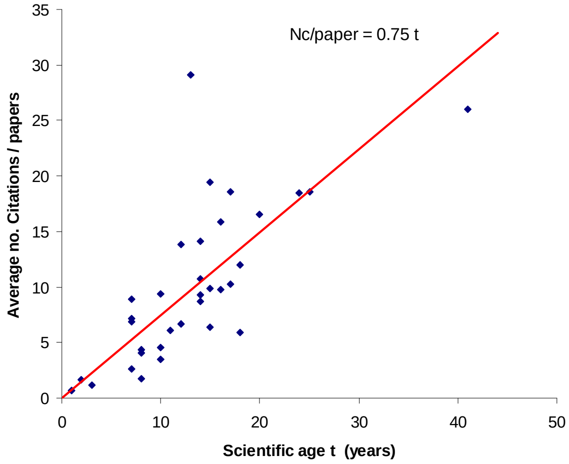


Figure 5. Average no. citations per paper as a function of time. Pedometrics paper on average get cited 0.75 time per year.

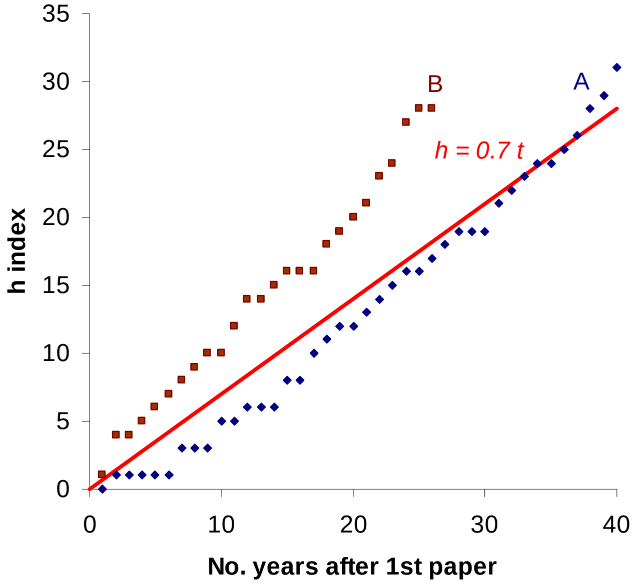


Figure 6. *h* index as a function of time for two pedometricians.

To see the trend of *h* index with time, we calculated the *h* index for two pedometricians: A and B (Fig. 6). A is a senior pedometrician and his first paper was published in the mid 1960's. The *h* index for A appears to be below the average line, this is because the *h* index is not linear with time, rather there is an initial lag of take-up of the subject (about 10 years). The *h* index seems to be increasing more recently. Pedometrics is still new at that time and requires some time for the topic to be accepted. Meanwhile the *h* index for B is increasing linearly with time, and above the average line. B started publishing in early 1980s and it appears now that pedometrics are well received.

Realistically, there is no single index that can capture everything, echoes of Philip (1974, p.268). We think that combinations of no. papers, average no. citations, and *h* index can give a good indication of your performance. Equations (5), (6), and (7) should give you a standard to compare.

If you don't have access to ISI, you can use Google scholar as a database. The webpage from University of Århus Denmark calculates the *h* and *m* indices from Google scholar:
http://www.brics.dk/~mis/hnumber.html
The software from Harzing, "Publish or Perish" also does the same thing:
http://www.harzing.com/resources.htm.

References

Ball, P., 2005. Index aims for fair ranking of scientists. Nature 436, 900.

Hirsch, J. E., 2005. An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America 102, 16569–16572. DOI: 10.1073/pnas.0507655102

Laherrere, J., Sornette, D., 1998. Stretched exponential distributions in Nature and Economy: "Fat tails" with characteristic scales, European Physical Journal B 2, 525-539. (http://xxx.lanl.gov/abs/cond-mat/9801293)

Lehmann, S., Jackson, A.D., Lautrup, B.E., 2005. Measures and Mismeasures of Scientific Quality http://arxiv.org/PS_cache/physics/pdf/0512/0512238.pdf

Lehmann, S., Jackson, A.D., Lautrup, B.E., 2006. Measures for measures. Nature 444, 1003-1004 http://www.nature.com/nature/journal/v444/n7122/full/4441003a.html

Philip, J.R., 1974. Fifty years of progress in soil physics. Geoderma 12, 265-280.

Spatial variability of soil carbon

Sasha Kravchenko

Soil organic matter is probably the most important soil constituent that makes soil to be a rather unique place. The place seems to live by its own laws, the laws that one would think are the standard laws of chemistry and physics. But the infinite complexity of the medium where they operate, the soil, makes the comprehensive understanding of their specific actions and interactions and the deterministic modeling, which depends on such an understanding, to be a still far away sci-fi. On a non-optimistic accord we are not much closer to the comprehensive deterministic models of soil processes on relatively large scales than we were 50 years ago, and, if somewhat more pessimistically, we are as close to it as Dokuchaev was, traveling in his horse cart in search of Russian Chernozem. However, optimistically, we have arguably the next best thing, that is quantitative tools for characterizing the large (as well as small) scale variability and complexity and employing the characterization results via stochastic modeling.

As part of historical and current agricultural activities, humans subject soil to a variety of land uses and land managements. Of particular interest to me became a question of what those different land management practices change in not just the soil property average values, but in spatially varying details, where, i.e., in the details, as we know, the "devil is". Specifically, I wanted to look at long-term (several decades) effects of different land uses on development of site-specific soil spatial patterns, especially patterns in soil organic matter. Frankly, in the beginning my primary driving force was of sheer curiosity – do different land management practices add a twist to the actions of soil forming factors, and if so, what is the size of that addition, i.e. will it become noticeable after just a couple of decades? Of course, there is a lot of practical importance to these questions as well and to the possibility of more reliable large-scale assessments of soil organic matter under different land use and land management scenarios that answers of these questions would bring. It is especially so, given the need for accurate estimations of soil C stocks, soil contribution to global C cycling, and their impact on atmospheric accumulations of CO_2. The amount of C stored in soils has been estimated to be twice that of the atmosphere (Schimel, 1995), while soil and atmospheric C are strongly linked.

The Long Term Ecological Research (LTER) site at Kellogg Biological Station (KBS) in Michigan (http://www.kbs.msu.edu/lter/) presented an excellent opportunity to begin with getting answers to these questions, that is, to study the effects of different land management practices on spatial variability of soil C. Naturally, my first choice of a tool box was the quantitative tools of spatial variability characterization, of which geostatistics was the one I have tried so far.

One of the many great features of the KBS LTER site is that it has a large number of different land use and agricultural management treatments in a replicated setting (Fig.1). LTER experimental plots are fairly large (1-ha), which is certainly not big enough to assess variability patterns on a scale of a watershed, but sufficiently large to approximate variability on a scale of a typical field. The KBS LTER has been established in 1988 and a wealth of soil information has been collected from it over the years including a very well designed and thought of 1988 baseline soil sample collection.

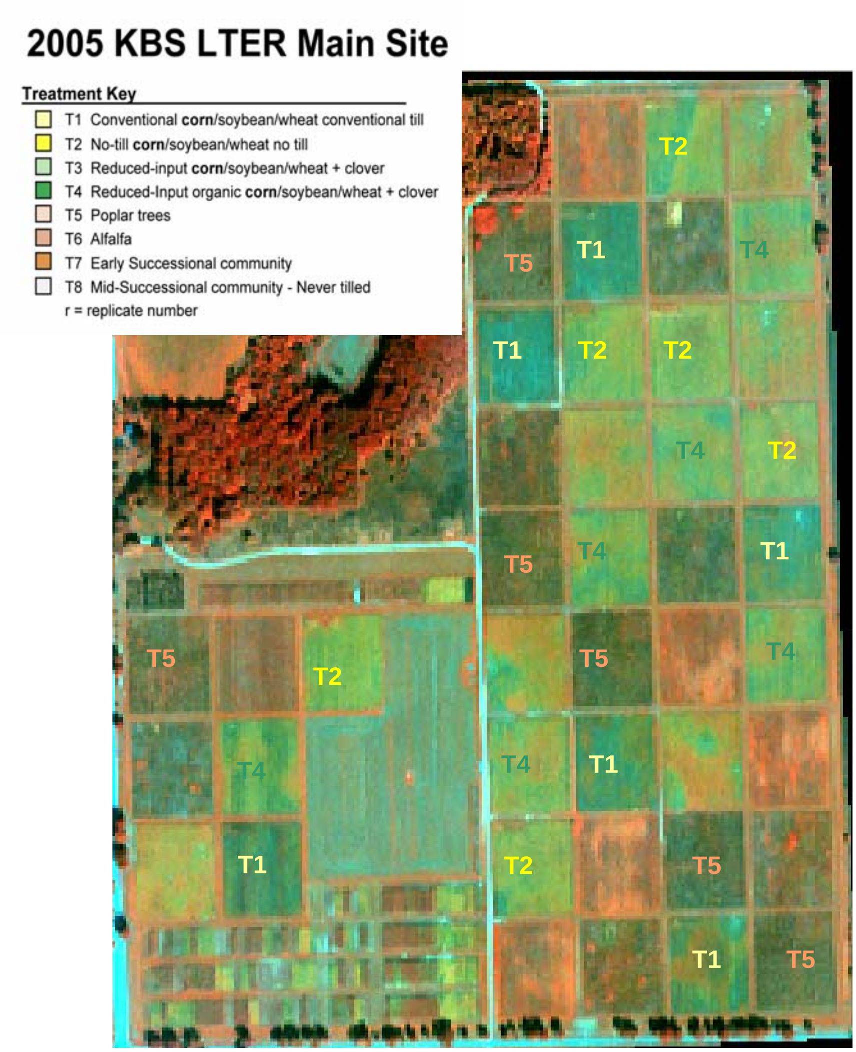


Figure 1. Layout of the KBS LTER main site, Hickory Corners, MI (from Subramanian et al., 2006).

Thus, we (my research group) set out to collect ~2,400 soil samples from 6 replications of the four LTER treatments. We looked at three agronomic management practices, namely chisel plowing with conventional levels of chemical inputs (T1), no-till with conventional chemical inputs (T2), and organic-based zero chemical input systems with a winter leguminous cover crop (T4), as well as a perennial biomass – poplar trees treatment (T5). The sample collection scheme was designed to enable future geostatistical analyses, particularly spatial variability description via variogram structural analysis.

The results were quite revealing in many respects. First of all, we indeed observed noticeable differences in the spatial patterns of total soil C under different land management practices (Fig. 2). Soil C from no-till, organic management, and poplar plantations exhibited much more pronounced spatial structures than the conventional tillage. Since no such differences in spatial patterns were evident from the analyses of 1988 data it seems that these patterns have indeed developed since 1988 following the transition to different land managements. The soil forming factors, specifically relief and parent material, were certainly at work at this scale adding a differential component to the overall effects of different land management practices on soil C averages and playing a major role in formation of these spatial patterns (Kravchenko et al., 2006).

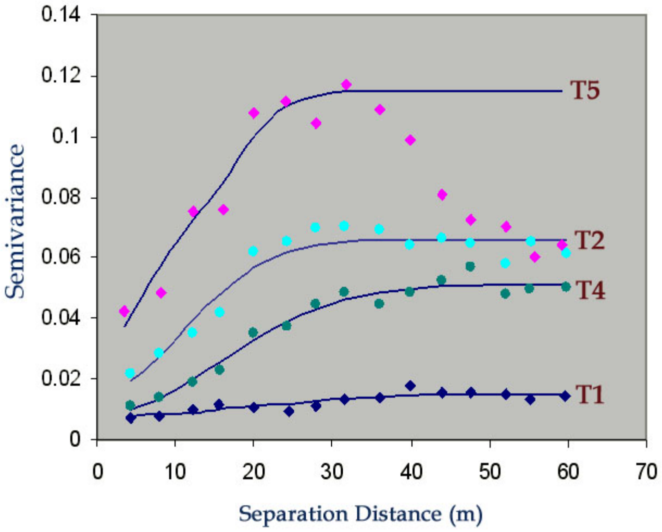


Figure 2. Sample variograms and variogram models for total C data (0-5 cm depth) in chisel plowing with conventional levels of chemical inputs (T1), no-till with conventional chemical inputs (T2), organic-based zero chemical input systems with a winter leguminous cover crop (T4), and perennial biomass – poplar trees (T5) treatments from KBS LTER, MI experiment.

It appears that reduction in soil disturbance brought by no-till or by conversion to poplars has led to more pronounced influence of site specific variations in factors affecting soil C storage, including but not limited to soil texture, aggregation, moisture and temperature regimes.
Likewise, replacement of uniform fertilizer applications of conventional management practice with cover crops in organic management as well as conversion to poplars have lead to greater spatial variability of biomass inputs.

As a personal disclosure I would say that I greatly enjoyed conducting this study and analyzing the results. It seemed that the textbook info on soil formation has suddenly come to life with those unpronounceable (c,o,r,p,t) actually operating right here in front of me. Given the number of years passed since the last soils course I have taken, this revelation probably should have occurred much earlier, but I have “better later than never” in my defense.

What is next? We will continue with analyses of the observed differences in spatial patterns using a variety of other spatial tools attempting to get yet a better insight in the site-specific interactions among soil forming factors and land managements. Also we will strive to incorporate these findings in large scale modeling efforts in order to improve large scale assessments and predictions of soil C via stochastic modeling tools. However, investigation of the specific deterministic physical, chemical, and biological mechanisms that led to formation of these spatial patterns also carries a great appeal and is of great interest to me. So attempts to move a step or two further on a road to comprehensive understanding of these mechanisms and their deterministic modeling will probably be invariably present on the “things to do” list.

References

Kravchenko, A.N., G.P. Robertson, X.Hao, and D.G. Bullock. 2006. Management practice effects on surface total carbon: Differences in spatial variability patterns. *Agronomy J.* 98: 1559-1568.

Schimel, D.C. 1995. Terrestrial ecosystems and the carbon cycle. *Global Change Biology*. 1:77-91.

Subramanian, S. K., A.N. Kravchenko, and G.P. Robertson. 2006. Are poplar plantations a better alternative to no-till management in carbon sequestration for Michigan producers? Presented at the *Annual Meeting of Soil Science Society of America*, Nov. 12-16, Indianapolis, IN.

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FRACTAL? MULTIFRACTAL? NO!!! THEN WHAT?

Ana Tarquis

When Murray asked me to write about fractals and pedometrics I was very happy to do it, that was one month ago. But now that I have to do it I am feeling less sure. Is this because of my horrible English or that I don't know what to say that hasn't been said before? I will try in a very informal way to do it and I will only put the minimum references to understand this *story*, otherwise more than half of this ***Pedometron*** issue will be full of references to fractal and multifractal applications.

The processes which determine vegetation, soil and other surface characteristics are very nonlinear; they involve interacting structures from planetary to millimeter scales. So soils exhibit considerable spatial variability that must be quantified by statistics.

Most soil data are obtained from small samples: cores, monoliths, or small field plots, yet the goal is to reconstruct soil properties across fields or watersheds or to predict physical properties of pore surfaces and structure of pore space. The representation of processes and properties at a scale different from the one at which observations and property measurements are made, is a constant problem. Because the spatial variability is an intrinsic property, its change with scale presents substantial interest and has long been the subject of intensive research.

In the last twenty-five years an understanding of these strong resolution-dependencies has started to emerge, and systematic techniques are now available for analyzing and modelling such behaviour. F. *Hausdorff* (1919) introduced the term *fractal* dimension in the sense of a non integer dimension. Consequently, a set that can be assigned a fractal dimension is called a fractal set. One can determine the fractal dimension of the set by observing optimal covering systems of fractal sets with decreasing diameters. Motivated by the fractal geometry of sets (*Mandelbrot*, 1982), and the development of cascade models in turbulence, the origin of this behaviour has been traced to nonlinear dynamical mechanisms which repeat scale after scale from large to small scales.

Numerous scientists use derivatives of this concept, so inevitably the term "*fractal structure*" is used with different meanings. It either denotes the fractal set itself, or the generating system of the fractal set, where the generating system is based on a suitable construction rule which usually works inductively from one generation level to the next. These mechanisms have become an important source of scaling laws in soils.

Looking at the properties of fractal sets more generally, they can be considered as boundary sets that connect (or divide) neighboured systems. A mathematician might say that a Mandelbrot set is the locus of points, C, on the complex plane for which the series $Z_{n+1} = Z_n \cdot Z_n + C$, where $Z_0 = (0,0)$ is bounded by a circle of radius two, centered on the origin. But most soil scientists aren't mathematicians and they will say that it's a pretty picture. And also that it's a mathematical wonder that we can appreciate, and to some extent understand, even if we don't understand the above definition.

One of the interesting things about the Mandelbrot set is that the most complex object ever seen is generated by a very simple formula that will be applied again to obtain a new value for Z until the absolute value of Z is greater than two, or until our counter expires. If $|Z|$ (absolute value of *Z*) ever exceeds two, and then it will very quickly head off towards infinity which means that the point is not in the Mandelbrot set. These points are typically assigned a colour based on how many iterations were done before $|Z|$ exceeded two. If $|Z|$ doesn't exceed two after a large number of iterations, then we give up and assume that the initial point is in the Mandelbrot set. These points are coloured in blue (see Figure 1). The blue, barnacle covered pear is the Mandelbrot set proper, all the bands of colour outside of it helps to expose the detail of the Mandelbrot set itself.

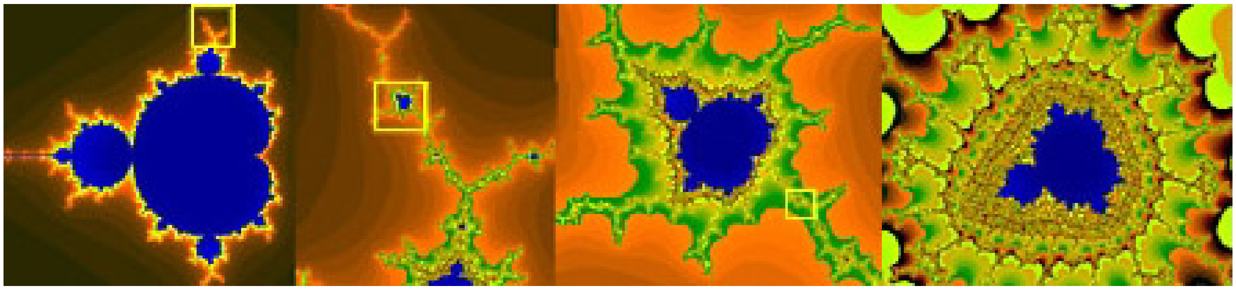

Figure 1. Mandelbrot set. Obtained from *Wikipedia, the free encyclopedia*.

Looking at Figure 1 is easy to understand that the applications of fractal geometry became very popular because its capacity to relate features of natural objects observed at different scales through simple rules.

The construction rules (generating system) of a set may depend on the generation level. Construction rules, which are independent of the generation level, are called self-similar and the resulting fractal set is also called a self-similar set. A more precise definition of self-similar can be found in Hutchinson (1981). Mathematicians created a lot of self-similar fractal sets (*Peitgen* and *Saupe*, 1988). One of the most common fractal sets known in soil science is the Sierpinski carpet. This set is created by the simple rule of removing the central square from a block of black pixels (Figure 2a) and repeating this rule for the subsets of the image (Figure 2b an c).

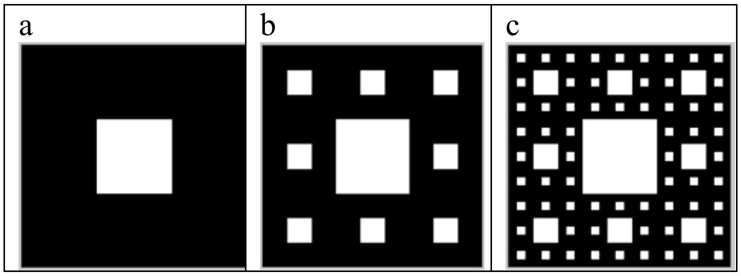

Figure 2. The first three steps in the Sierpinski carpet.

If a set is given in a binary image, one can always measure its fractal dimension (see Figure 3). Several methods estimate the fractal dimension in the given range of magnification limited by the resolution of the digital image. An common method of this type is the box-counting method (BC). This method uses a regression along the range of possible magnifications in the image (*Falconer*, 1994). In the BC method the number of boxes of a regular grid with boxes of side length δ, intersecting the set of interest ($N(\delta)$), are counted. The logarithm of this number is plotted versus $\log(\delta)$ in a so-called "log-log-plot" or “bi-log-plot”. In case of self-similar sets the graph has globally a constant slope which is directly related to the fractal dimension (*D*):

$$D = \lim_{\delta \to 0} \frac{\log(N(\delta))}{\log(\delta)} \qquad [1]$$

In the example that we have put (Figure 3) *D* is 1.893 (fractal). Fractal dimension has often been applied as a parameter of complexity, related to, for example, surface roughness, or for classifying textures or line patterns. Fractal dimension can be estimated statistically, if the pattern is known to be self-similar.

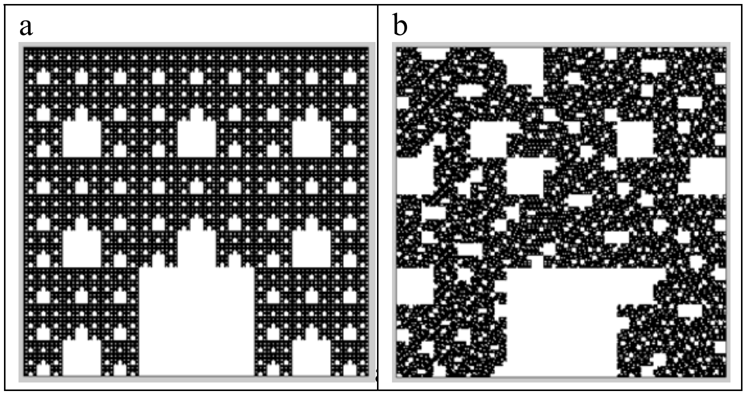

Figure 3. Fractal set created by 5 iterations in a deterministic (a) or randomly (b) method. Both have a fractal dimension of 1.893 .

We call these fractals *uniform* because if we calculate *D* locally we find that it does not vary. But this is a very restrictive requirement. Non-uniform fractals can be defined where we permit local fluctuation in pixel density. This leads us to the idea of multifractals (Evertsz and Mandelbrot, 1992), which have recently been applied in soil science. How can we explain this idea?

Let's assume a line, over which a total density is distributed. At the first scale we divide the line in two and divide the density between the left and right fragments in the ratio p_1, p_2. If we keep these proportions in all subsequent subdivisions then the overall density is preserved, and we have a particular cascade model (see Figure 4).

If we extend this *game* to the plane and express density (or another measure) in that plane in grey levels we obtain images such as Figure 5 that often resemble the type of statistical variability that soil scientist have to handle.

The essential difference between the images in the first line (fig. 5 a and b, multifract1) and the second one (fig. 5 c and d, multifract2) is that the set of probabilities used are more different in the second one creating a more erratic distribution of grey tones in space. We can see very clear the different pattern from Figure 3b (fractal) to Figure5b (multifract1) and Figure 5d (multifract2) but it is necessary to quantify these differences so we can evaluate the different complexities of these distributions.

One of the most common calculations done is the generalized fractal dimension (D_q). In order to execute this *multifractal analysis* we need to base the calculation on the grey levels (density of black pixels) of the images and modify Equation [1]. We again consider grid box of size δ covering the image. The measure of the ith box ($\mu_i(\delta)$) covering the image it will be the density of black pixels. We now perform the sum over all boxes to yield the function (partition function)

$$\chi(q,\delta)=\sum_{i=1}^{n(\delta)}(\mu_i)^q \quad , \qquad [2]$$

where $n(\delta)$ is the number of boxes covering the image that at least has one black pixel. The exponent *q* (mass exponent) it is any real number, positive and negative.

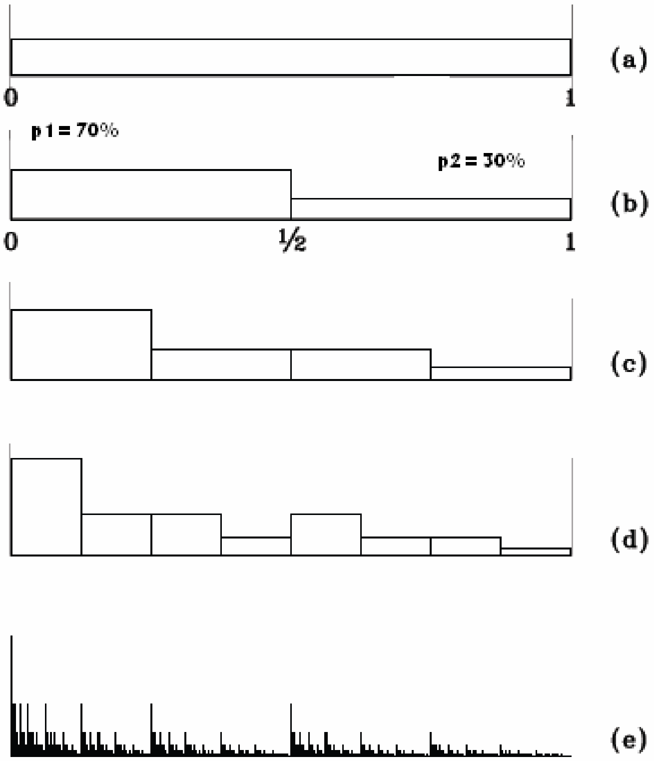

Figure 4. Cascade model distributes a measure in a line. We used two probabilities in this case and the measure can be, for example, density.

Commonly speaking, *q* stretches the original measure to create a *cartoon*. When *q* is positive the result is that the larger values of $\mu_i(\delta)$ are exaggerated and the small values of $\mu_i(\delta)$ are diminished further. With negative values of *q* the converse happens, it is for this reason that we say that *q* creates a *cartoon*. When *q* is 1 we have the original measure studied and when *q* is zero the partition function is simply the number of boxes that cover the space where at least one black pixel exists, in other words $N(\delta)$.

For a multifractal measure this function will have scaling properties, namely

$$\chi(q,\delta)\sim\delta^{\tau(q)} \qquad [3]$$

where $\tau(q)$ is a nonlinear function of *q* (*Feder*, 1989). For each *q*, $\tau(q)$ may be obtained as the slope of a log-log plot of $\chi(q,\delta)$ against δ (similarly that with Equation [1]). A generalized dimension function D_q is then derived as (*Hentschel* and *Procaccia*, 1983):

$$D_q = \tau(q)/(1-q) \qquad [4]$$

for $q \neq 1$. The case D_1 the indetermination is resolved by L'Hôpital's rule. Figure 6 shows us D_q versus q for our three examples.

It is evident that the more complex the distributions the wider the range of values of D_q, particularly for negative exponents *q*. For a fractal distribution there is only one D_q value and the line is constant. The introduction of a multifractal model has apparently accounted for many deviations from the fractal scale dependence, or mono-fractal situation.

Up to here we have the *good news*, now for the less good news. In all the literature on soils the part of the curve where most interesting variations are seen between different cases ($q \leq 0$) is where the uncertainty in the estimate is greatest. It is interesting to see how often people avoid putting error bars on this type of curves, or similar ones, and only report how large the R^2 is. Many people will say that the R^2 increase when we have a bi-log plot, and this is true.

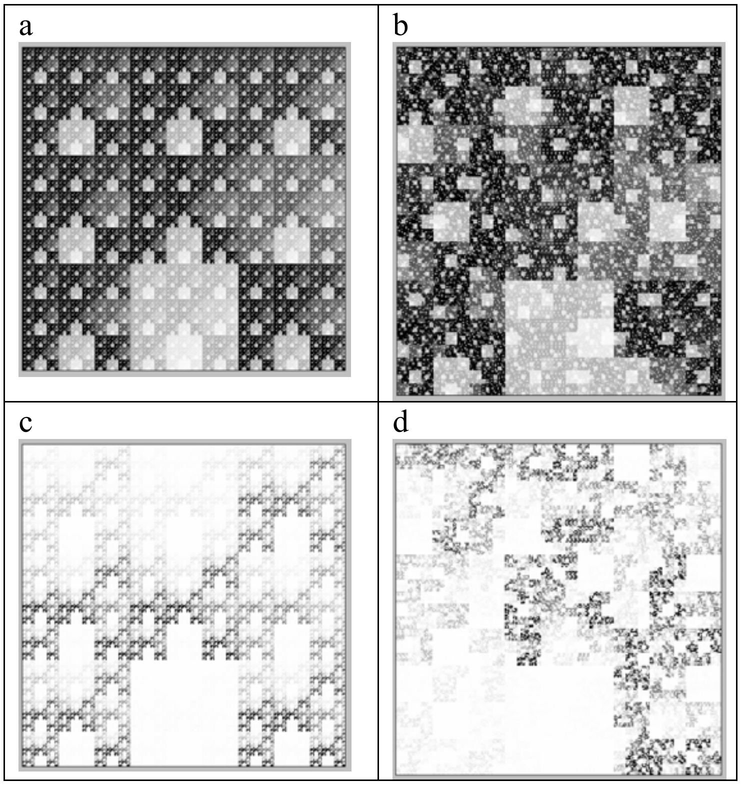

Figure 5. Simulations of two multifractals self affine cascade models (a and b, c and d). Right column the sets are random and left deterministic.

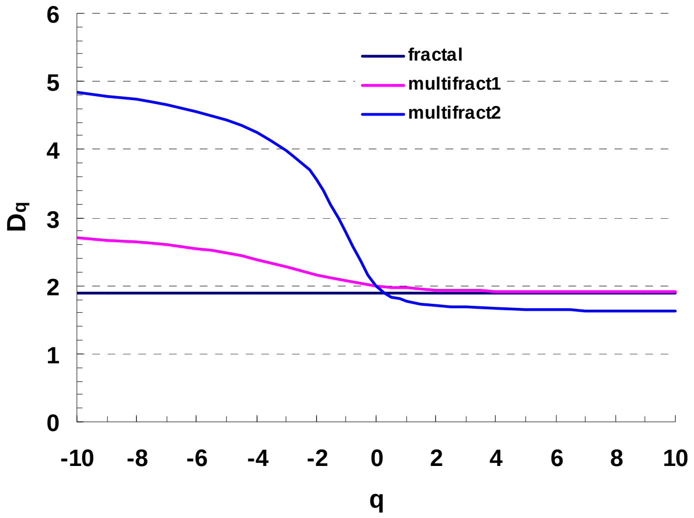

Figure 6. Generalized dimensions of the distributions showed in Figures 2 and 4.

The box-counting method is the most common one used, but there is much literature pointing out that is not the best method to apply in many real cases. Step by step this has been included in the soil science literature but much slower than in other areas.

A large percentage of the works presented are describing and understanding situations with this type of tool. Now it is the moment to push on further in using these fractal dimensions, or parameters derived from them, into modelling fields to reduce errors or *simplify* them.

Despite being undoubtedly useful, the multifractal model is still just a model. As scientist have got more experience of applying these techniques, it has became clear that *true* fractal or *true* multifractal behaviour are not so common in soils. There are cases where we can find a weak fractal/multifractal behaviour and the reasons could be several: few data available, low resolution in the images or not the adequate model to test. In this last case a compact representation of the information about changes in variability with scale is needed no matter whether particular scale-dependence models are or are not applicable.

Paralleling to this revolution in our understanding of the consequences of wide range scaling, is the generalization of the notion of scale itself to encompass systems which are scaling but highly anisotropic achieving the concept of "generalized scale invariance" (GSI) (*Schertzer and Lovejoy*, 1985). This concept is beginning to be applied and still is not so popular in soil science area.

Fractals and multifractals still need to be better understood. A huge effort has been made by many scientists applying these concepts and progress has been made. I believe that still there is a long way to go in this direction and more flexible tools need to be designed and incorporate to adapt to the soil scientists' demands.

RECOMMENDED WEB PAGES TO VISIT

http://en.wikipedia.org/wiki/Fractals
http://math.rice.edu/~lanius/frac/index.html
http://library.thinkquest.org/26242/full/ap/ap.html
http://spanky.triumf.ca/www/fractint/fractint.html
http://kluge.in-chemnitz.de/documents/fractal/node2.html
http://www.physics.mcgill.ca/~gang/multifrac/index.htm
http://complex.inria.fr/cgi-bin/twiki/view/Complex/WebHome

BOOKS

Fractals in Soil Science by P. Baveye (Editor), J. Y. Parlange (Editor), B. A. Stewart (Editor). CRC press.

Fractal in Soil Science by Y. Pachepsky (Editor), J.W. Crawford (Editor), W.J. Rawls (Editor). Elsevier press

Scaling Methods in Soil Physics by Yakov Pachepsky (Editor), David E. Radcliffe (Editor), H. Magdi Selim (Editor). CRC press

Physical Nonequilibrium in Soils by H. Magdi Selim (Editor), Liwang Ma (Editor), Hussein Magd Eldin Selim (Editor). CRC press

REFERENCES

Evertsz, C.J.G., Mandelbrot, B.B., 1992. In Chaos and Fractals: New Frontiers of Science, Peitgen, H., Jurgens, H. and Saupe Springer-Verlag D., Eds., New York, 921.

Falconer, K. 1985. The Geometry of Fractal Sets. Cambridge UP

Feder, J. 1989. Fractals, Plenum press, New York.

Hentschel, H.G.E. and I. Procaccia, 1983. The infinite number of generalized dimensions of fractals and strange attractors Physica D: Nonlinear Phenomena, Volume 8, Issue 3, p. 435-444.

Hutchinson, J.E. 1981. Fractal and self-similarity. Indiana Univ. Math. J.

Lovejoy, S. and D. Schertzer 1985. Generalized Scale Invariance in the Atmosphere and Fractal Models of Rain. Water Resources Research, Vol. 21, No. 8, p 1233-1240.

Mandelbrot, BB. 1982. The fractal geometry of Nature. WH Freeman&Company, San Francisco, CA.

Saupe, D. and H.O. Peitgen. 1988. The Science of Fractal Images. Springer, New York

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Pedometrics 2007

Pedometrics 2007 will take place at the Institute of Geography in Tübingen, Germany. The conference covers all major topics of pedometrical research and application. It comprises geostatistics, the research fields of the related working group on digital soil mapping, proximal soil sensing, as well as soil fractals, wavelets and spatial accuracy.

We welcome all soil scientists, soil surveyors, soil geographers, environmental scientists and engineers, GIS specialists, geostatisticians, statisticians, and mathematicians to join the conference and exchange their knowledge.

A Pre-Conference Workshop on Uncertainty Propagation Analysis will be held by Gerard B.M. Heuvelink and James D. Brown. A Field trip introducing the soilscapes and the famous vineyards of Baden-Wurttemberg follows the conference.

Important dates

Abstract submission deadline	1 April 2007
Notification of acceptance	15 May 2007
Early Registration deadline	1 June 2007
Pre-Conference Workshop	25-26 August 2007
Pedometrics 2007 Conference	27-29 August 2007
Post-Conference Field Trip	30 August 2007

Conference Venue

Tübingen is located in south-west Germany. Its contemporary appearance is characterized by 20000 students living in a comparatively small city of 85000, which combines the flair of a lovingly restored medieval centre of town with the colourful bustle and typical atmosphere of a young and cosmopolitan students' town. The University, with almost 10000 employees, is the biggest employer of Southern Württemberg and has a budget of about EUR 650 million. The Institute of Geography (IGT) is part of the Faculty of Geosciences and was founded in 1897. About 800 students are educated at present accompanied by 6 full professors and 45 employees.

Pre-Conference Workshop details

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.

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. 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.

Further information

Further information including an online abstract submission form is provided at www.pedometrics.de

Looking forward to seeing you in Tübingen
Thorsten Behrens, Volker Hennings and Thomas Scholten

Conferences & Workshops Reports

Workshop on Modelling of Pedogenesis

Christian Walter & Budiman Minasny

An international workshop on *modelling of pedogenesis* was organized in Orléans (France) in October 2006 by researchers from INRA (S. Cornu, G. Richard, A. Samouelian) and CNRS (A. Bruand). The background of this congress was to consider the long term evolution of soils under human impact and global change: to be able to predict soil evolution in the future, pedogenesis processes need to be more thoroughfully understood in combination with short time dynamics. Modelling approaches are necessary to combine processes and to integrate them in time and space.

Sixty researchers from nine countries (Algeria, Australia, Brazil, Canada, France, Germany, Iran, and United States) attended the workshop: almost half of the participants were soil scientists, but a large panel of disciplines was represented (applied mathematics, geochemistry, geography, geology, mineralogy, hydrology).

The workshop was divided into two sessions, considering modelling approaches over long or short time scales. This division probably meant for the time scale of soil formation, but can be interpreted differently: for geologists, the long time scale is billion of years, and for hydrologists 100 years is a long time.

Modelling pedogenesis can be interpreted in various meanings by different people. Two broad categories we can identify are:
- to model soil formation, starting from a bedrock, what processes that can produce a soil with its properties.
- modelling changes in soil properties (or processes) in the soil. Soil is already in place, it is modelling physical, chemical and biological processes that influence the development of soil.

It seems the second view was stronger in this workshop.

Geochemists are interested in the chemical weathering of minerals and rocks. But they usually treat soil as a medium for chemical reactions. Soil physicists and hydrologists viewed it as the change in physical and chemical compositions as water and solute is moving through the soil. The way to model it is to combine soil-water transport, solute, heat, and chemical speciation/reaction models.
Pedologists are interested in the weathering of parent materials to produce soil materials and to be able to explain the processes that result in field observations. Spatial and temporal scales varied by different modellers. Some consider weathering from the time of Rodinia, while some argue they need hour and daily time steps to capture the pedological processes.

One of the topics brought up in the final discussion is: Do we need to take into account all processes for pedogenesis?
Some view it that soil is too complex and to consider all processes are impossible. So maybe modelling pedogenesis is a waste of time. Others view it that you need to consider the big picture, model the main or dominant processes, and if there are some episodic events you can further make it more detail.

Some of the themes that were lacking are: no geomorphologist was represented, and very little data on soil formation (rate of weathering, age of the soil) are available. Geomorphologists have made very good model for landscape evolution and they also have started to include soil in their models.

The conclusions we can draw from this workshop is that there are already abundant of models that can describe processes and transformation in the soil: physical, chemical. But there are only a few that describe the actual formation of soil.

We can model the soil and soil processes of now and see what is going to happen. We might call this predictive pedology. This is a useful pursuit especially with climate change and land-use pressures. Here time scales of decades and centuries are relevant for humanity (and its survival). And we should certainly do some of that, but not as a one dimensional soil profile model we must include the landscape (lateral processes).

The real challenge for pedometrics is to be able to model soil development *ab initio*. (Not the absolute beginning, I don't think we have to model the big bang). It's too challenging for most, so many will dismiss it as irrelevant, it's not rocket science, but it's more difficult than that.

Upcoming Events

Pedometrics 2007. 27-30 August 2007. Tubingen, Germany.
http://www.pedometrics.de

Pedofract 2007. International Workshop on Scale Dependence in Soil and Hydrologic Systems. El barco de Avila, Spain, 3-6 July 2007.
http://www.etsia.upm.es/gruposinv/pedofract2007/index.html

18th annual meeting of the International Environmetrics Society. TIES, 16-20 August 2007. Mikulov, Czech Republic.
http://www.math.muni.cz/ties2007/

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

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

Looking for: Articles, photos, information about your work, theses, upcoming events, pictures, art works, poems, etc. Send to: vchair@pedometrics.org.

The International Symposium on Terrain Analysis and Digital Terrain Mapping TADTM 2006

Peter A. Shary
Russian Academy of Sciences
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The International Symposium on Terrain Analysis and Digital Terrain Mapping (TADTM 2006, http://www.tadtm2006.net/) held November 23-25, 2006 in Nanjing, China, has demonstrated essential new advances both in various approaches to digital terrain analysis and mapping, and in theoretical research, in part, in geomorphometry as a science of quantitative land surface analysis.

Topics of TADTM2006 covered a wide spectrum of topics, from digital soil and vegetation mapping, to hydrological modelling and airborne technologies for producing LiDAR and other large-scale Digital Elevation Models with reduced noise from vegetation, but it contained also new studies on geomorphometry, its current state-of-the-art, interrelationships between topographic attributes, segmentation of land surface onto landforms, thermal regime of slopes description, and unsolved tasks of geomorphometry.

Soil scientists frequently use topographic attributes and terrain segmentation onto landforms or landform types, and we know that quantitative description of topography is of great importance for studies of soil spatial variability. Phenomena like statistical predictability of some landforms and duplication of topographic attributes with different physical meaning put new questions:

- If proportions of areas occupied by such landforms are predictable for any terrain, how to use them in predictive soil mapping?
- Are soil types and other taxa also predictable, or are they always terrain-specific?
- What are rules for selecting interdependent topographic attributes that have different physical meaning?

George Miliaresis with his Chinese counterpart.

Unsolved tasks of geomorphometry may also significantly influence current possibilities of quantitative soil spatial variability analysis. For example,

- Quantitative description of relative position in slope profiles needs further studies and currently cannot be considered as satisfactory.
- We can describe closed depressions, but current quantitative description of open depressions should be considered as not satisfactory.

New results from digital terrain modeling and geomorphometry may appear of essential interest for soil scientists.

Hands-on geostatistics “Merging GIS and Spatial Statistics”

Tomislav Hengl

The training course held at Facolta di Agraria in Napoli in period 29 January to 3 Febraury 2007 under auspices of the Commission 1.5 Pedometrics of the IUSS, University of Napoli (SISS, SIPE), and the Institute for Environment (Joint Research Centre). It was an intensive 5-days course with balanced combination of theoretical and practical training, aimed at helping young researcher find their way in the combined used of GIS and geostatistical tools. It gathered 30 PhD students, post-doctoral researchers and specialists from various European universities and research organizations. The course focused on use of remote sensing-based and DEM-based predictors for improving prediction of soil variables.

The first day was purely theoretical, second, third and fourth day were a combination of theoretical lectures and practical training and the last day was organized as a workshop where each participant was able to pose technical and theoretical questions to the lecturers and the course participants. We started by introducing each other to course participants. We then inverted the course a bit a distributed a test-your-knowledge-of-geostatistics exercise that consisted of 20 questions. These were all, more all less, simple logical questions that can be solved with some intuition and without big computations. The answers to questions were provided day-by-day, as soon as some topic became actual. In the second part of the first day, key concepts of geostatistics, such as spatial autocorrelation, semi/co-variance, variogram, kriging and kriging variance, were introduced; after that concepts of regression analysis (correlation, GLMs, GLS estimation, prediction error) and, finally, the target technique of the course – regression-kriging – was elaborated in detail.

The second day was dedicated to remote sensing data sources that can be used within the regression-kriging framework. A review of remote sensing system and images was first given including the practical tips on how to browse and obtain remote sensing images. The concept of grid/support size and their connection with scale and complexity of target features was clarified and main applications of geostatistics for remote sensing reviewed. We demonstrated how can geostatistical techniques be combined with remote sensing: to filter the missing pixels, analyze noise in remote sensing images and use them as covariates in the spatial prediction. The objective of the first exercise was to compare ordinary kriging and regression-kriging and evaluate how much do the predictions improve if additional auxiliary information is used (LANDSAT bands and geological map).

On the third day of the course, **Victor Olaya** provided an extensive overview of the field of geomorphometry including an overview of the techniques that can be used to build or obtain DEMs and extract DEM derivatives in SAGA GIS. Victor specifically suggested which algorithms to choose and how to interpret various land surface parameters and objects derived out of DEMs. The course participants then tested running land surface analysis in SAGA and ILWIS. The objective of the second exercise was to compare the prediction models derived using DEMs of two different sources: 100 m

SRTM DEM and the 25 m DEM derived from topo maps.

On the fourth day, **Edzer Pebesma** made an introduction to the statistical computing environment R and emphasized advantages and disadvantages of using R. Edzer was definitivly the best choice for this task as he was closely involved with the design and development of 'spatial' packages in R. He is also the author of the gstat package, probably still the richest geostatistical package in the world. Edzer gave us many tips'n'tricks on how to start working with R, how to create, debug and distribute R scripts and what are the benefits and dangers of data processing automation. We then run an exercise where ordinary kriging with large dataset (2937 observations) was compared with regression-kriging with a much smaller dataset (300 points) but with all possible auxiliary maps including remote sensing bands, DEM derivatives and geological map. The objective of this exercise was to evaluate influence of sample size on the quality of final predictions and discuss dangers of data processing automation. The fifth day of the course was organized as a workshop where each participant got a chance to present his/her work and ask his/her colleagues for help with the data processing. Here many interesting issues were raised, so that also we, the lecturers, got to learn about the field from our colleagues.

The participants have received basic training in software packages and the most important techniques and applications connected with use of geostatistics jointly with remote sensing and geomorphometry have been explained and elaborated. As an output of the final training day, we managed to produce a R script that automates both fitting of regression models and variograms and spatial predictions and simulations.

Finally, I should also mention that it was a great pleasure to work with this group. Self-motivation to master the presented techniques and actively continue using these software packages was overwhelming. I am probably not objective enough to judge about how successful the course was, but I can at least mention some observations on how to improve the course. Number one issue raised was that the it should be longer (e.g. two weeks). The first week would then be organized with a bit less of intensity, while the second week the participants should be able to process (under supervision of the trainers) their own datasets. Many participants had prepared and brought with them their datasets, but there was simply not enough time for course trainers to get deeper into each case study. So now that we know how to improve the course, the only remaining issue is where and when should we put the next one.

A proof of a significant correlation between geostatistics and music: Victor, Edzer and other course participants doing a jam session during the course dinner.

Vacant Position

Graduate Assistantship (Ph.D. or M.S.) – Soil Science –pedology/ soil physics

Job Description: A motivated student is sought to pursue a Ph.D. or M.S. in soil science/soil physics in the Soil & Crop Sciences Department at Texas A&M University. The candidate will be part of research program that is working to improve the ability to spatially and temporally quantify soil properties across landscapes and to improve understanding of water transport processes affected by the variation of these soil properties. For example, the hydrology of a watershed would be better estimated if portable soil mapping equipment could collect high spatial resolution information on soil physical properties. One such portable instrument is a visible and near infrared diffuse reflectance (VNIR-DRS) spectrometer. The research project will include work on developing methodology using a VNIR-DRS for creating a Texas soil spectral library, collecting in-situ field measurements for mapping site-specific shrink-swell potentials and soil pedons, and developing a probe to insert the VNIR-DRS optical sensor into the ground..

Deadline to apply: Spring 2007

Requirements: Applicants must have a strong interest in exploring statistical techniques as applied to spectroscopy and in developing new sensing methodologies. Training in soil science, hydrology, agricultural engineering, geosciences, or a related discipline is needed. Demonstrated excellence in technical, oral, written, and interpersonal communication skills is preferred. Consideration of candidates will start immediately and the assistantship may start as early as Spring 2007. Applications will be accepted until a qualified candidate is appointed. Application documents include: 1) One-page letter of interest, 2) curriculum vitae, including GRE scores, TOEFL score (if applicable), 3) name, address, and phone number of three professional references and 4) transcripts. Application for admission to graduate studies at Texas A&M is made on-line at http://admissions.tamu.edu/graduate/ All application materials go to the Office of Graduate Admissions.

Contact person: Dr. Cristine Morgan (cmorgan@ag.tamu.edu)

Graduate Assistantship (Ph.D. or M.S.) – Soil Science – soil physics/ hydropedology

Job Description: A motivated student is sought to pursue a Ph.D. or M.S. in hydropedology in the Soil & Crop Sciences Department at Texas A&M University. The candidate will be part of research program that is working to improve the ability to spatially and temporally quantify soil properties across watersheds and to improve understanding of water transport processes affected by the variation of these soil properties. The project is funded by the USDA NRCS; the goal of the project is to improve the accuracy of the hydrologic response of watershed management models by 1) developing a reliable method to model soil cracking patterns across watersheds using readily measurable soil properties, and 2) quantifying the effects of soil cracking at different scales on landscape hydrology. As a part of this program, the candidate will collect field measurements of soil cracking under different management conditions and use these measurements to improve a current soil-water model that simulates water movement into the soil profile and across the landscape.

Deadline to apply: 30/03/2007

Requirements: Applicants must have a strong interest in fundamental process-oriented research and should have training in soil science, hydrology, geosciences, or a related discipline. Demonstrated excellence in technical, oral, written, and interpersonal communication skills is preferred. Consideration of candidates will start immediately and the assistantship may start as early as Spring 2007.

Contact person: Dr. Cristine Morgan (cmorgan@ag.tamu.edu)

Pedometrician Profile

Lubos Boruvka
Professor of Soil Science, Czech University of Life Sciences in Prague (formerly Czech University of Agriculture), Czech Republic

How did you first become interested in soil science?
My parents worked in agriculture, so I got close to soil and land very early. On grammar school I prepared a small study concerning soil taxation and land management for a local agricultural company. However, really strongly interested in soil science I became during my Ph.D. studies.

How were you introduced to pedometrics?
I was lucky to do my Ph.D. on a department with a long tradition of using advanced statistical methods in soil assessment. Former head of the department, Professor Lubomir Pavel, applied factor analysis and other multivariate methods on soil data already in 1970s and 1980s. In 1994 I participated on a statistical and geostatistical course organised by European Commission in Slovakia. This course was led by Margaret Oliver and Richard Webster and there, thanks to these two nice people, I found out what geostatistics is about and I started to be interested in it. Later, I have learned also some other methods and approaches and during conferences and workshops I got into contact with the community of pedometricians.

What recent paper in pedometrics has caught your attention and why?
It is hard to name just one. I would mention three papers, though there should be several more papers.

B. Minasny, A.B. McBratney (2006) Mechanistic soil-landscape modelling as an approach to developing pedogenetic classifications. Geoderma 133, 137-149.
The attempt to describe the whole soil formation process by a model sounds crazy, but the authors provided very serious, promising and interesting results.

A. McBratney, B. Minasny, R. Viscarra Rossel (2006) Spectral soil analysis and inference systems: A powerful combination for solving the soil data crisis. Geoderma 136, 272-278.
In contrast, this paper shows a practical example of soil inference system. The path from spectral measurements, via basic soil properties estimation, to deriving soil properties using pedotransfer functions, including error assessment, nicely illustrates the soil inference system as the basis for digital soil mapping.

G. Jost, G.B.M Heuvelink, A. Papritz (2005) Analysing the space-time distribution of soil water storage of a forest ecosystem using spatio-temporal kriging. Geoderma 128, 258-273.
Including time dimension in soil characteristics assessment becomes more and more important and this paper does it really well.

What problem in pedometrics are you thinking about at the moment?
I have two main problems in my mind. The first one concerns the correlations between soil characteristics and auxiliary data and consequent development of useful *scorpan* functions. The second is the heterogeneity of forest soils as these soils are strongly variable even at very short distances and we need to describe them in our studies on soil acidification with a reasonable rate of simplification.

What big problem would you like pedometricians to tackle over the next 10 years?
Creation of digital soil maps for different purposes with sufficiently fine resolution and acceptable accuracy. That means collecting enough data and developing and applying reliable *scorpan* models.

Non-Pedometrician Profile

Guy Kirk
Professor of Soil Systems in the National Soil Resources Institute (NSRI) at Cranfield University in England

How did you first become interested in soil science?

Via a friend of my father’s called John Coulter, who was a soil scientist at the World Bank. He had soil maps on the wall of his living room. I was inspired by the idea of applying physics, chemistry and biology to solve practical problems. At the time, almost 30 years ago, the big practical problems were to do with feeding the world and agriculture, rather than the environment. I did an undergraduate degree in chemistry and soil science at Newcastle University, and then a doctorate and post-doctorate in soil science at Oxford University, before going to work as a soil chemist at the International Rice Research Institute in the Philippines.

What are the most important current developments in your area of soil science?

My area is soil biogeochemistry and modelling. There is a huge demand for better data and models of soils from other environmental sciences. This is across all scales from the local to the global. It is being driven by the explosion in availability of data across scales, from geo-spatial sciences at one end and molecular sciences at the other, combined with developments in modelling and e-science. This means there is a great opportunity for re-positioning soil science in the mainstream of environmental and Earth system sciences, and pedometrics should be at the forefront of this.

Has pedometrics made an important contribution in your area of soil science?

Not yet. Though I’d say much of soil science has its origins in pedology and soil mapping and therefore in pedometrics in a broad sense.

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

To help make quantitative knowledge and understanding of soils more accessible to other environmental sciences. The demand is for high-resolution spatial information and models of soil processes to link to higher-order models of environmental systems. Dealing with scaling issues, non-linearity in models, error propagation and so forth will be central to this.