Pedometron

Chair: Budiman Minasny

Vice Chair: Lin Yang

Editor: Jing Liu

From the Chair

Dear Colleagues

It is a pleasure to present Issue 39 of Pedometron.

This year has been a busy and also a rough ride, and some said that it opens a period of uncertainty.

Maybe it is time for pedometricians to tackle more uncertainty, as Claude Shannon once said, "Information is the resolution of uncertainty". Thus Pedometrics will keep working to resolve this issue.

The Pedometrics commission continues with the annual Best Paper award nomination. Please read the nominated 2015 papers, and vote for it. As a result of the meeting in Cordoba last year, we now officially has the Margaret Oliver Award for early-carreer pedometricians. Nomination is now open.

We will be celebrating 25 years of Pedometrics in 2017. The first Pedometrics conference was held on September 1-3, 1992 at Wageningen. And the first official publication was published as a Special Issue of Geoderma (1994, Vol. 62, Nos. 1-3: 1-326). Pedometrics was established as a provisional working group of the ISSS in 1988.

I hope to see you all next year in this exciting meeting. The organising committee promises for an exhilarating adventure.

Sydney, November 2016

Budiman Minasny

Pedometrics 2017

Dear colleague,

From **26 June to 1 July 2017** the [Pedometrics conference](#) will be held in Wageningen, the Netherlands. Pedometrics is a branch of soil science dedicated to the application of mathematical and statistical methods for the study of the distribution and genesis of soils. The 2017 conference marks the occasion of 25 years of Pedometrics. After touring the globe we will return to Wageningen, where the first Pedometrics conference was held in 1992.

Pedometrics 2017 is organised by the Pedometrics Commission of the International Union of Soil Science and its Working Groups: Digital Soil Mapping, Digital Soil Morphometrics, Modelling of Soil and Landscape Evolution, Proximal Soil Sensing and Soil Monitoring.

We are delighted that we have been given the opportunity to host Pedometrics 2017 and hope that you will join us in this memorable and festive event. It will be an excellent opportunity to present and discuss your work and learn about recent developments in quantitative soil science.

Please note that the call for abstracts and call for workshop proposals are given below.

For further information please contact info@pedometrics2017.org.

Call for abstracts

Abstracts for oral and poster presentations are invited on all aspects of Pedometrics. The abstract submission closes on **1 February 2017**. We will inform you on acceptance of your abstract by **15 March 2017**.

- All abstracts must be written in English and may not exceed **400 words**.

- Individuals can submit multiple abstracts but cannot have more than one oral presentation.

- Abstracts must be submitted through the [Conference Administration Tool](#) which is accessed through the [conference website](#). Instructions to create author accounts are outlined therein.

After the conference authors will be invited to submit an extended manuscript to the Pedometrics 2017 special issues.

Call for workshops

The organising Committee is soliciting proposals for pre-conference workshops that will be organised on Monday 26 June 2017. The call for workshop proposals is open until **1 November 2016**. For more information, see [here](#).

The 7ᵗʰ Digital Soil Mapping Conference

by John Triantafilis

The 7th Digital Soil Mapping Conference was held at the University of Aarhus and hosted by Senior Scientist Mogens H. Greve and post-doctoral fellows and post-graduate students from the Institute of Agroecology at the Research Centre Foulum.

The Workshop was held over four days and included several invited key notes addresses by Jens Dr Hesselbjerg Christensen (Climate Modelling), Professor Lars Arge (Flood-risk Screening) and Professor Eyal Ben Dor (Image Spectroscopy) .

The Workshop also had several key themes. On day 1 these centered on two sessions focussed on Digital Soil Mapping of SOC either side of the lunch break and on Digital Soil Mapping in general after the afternoon coffee break.

One presentation worth noting was that DSM might pay dividends if the work being conducted by a consortium from Australia (Prof Budiman Minasny – Usyd) and Indonesia can successfully employ this approach to win the "Million dollar challenge to map peatlands"?

On day 2 the focussed switched to and DSM of large areas and also the uncertainty associated with the maps, data and other aspects of modelling. The work presented also touched on the application of machine learning, remote sensing data, monitoring schemes and proximal data to model and map heavy-metal contamination, soil organic matter and soil properties of all descriptions.

The quote of the day belonged to Philippe Lagacherie and when he "lost the toss" and therefore had to present a paper on behalf of his team. Despite losing the toss Philippe rest assured we thought you gave a winning account of yourself and the scientific merit of the paper!

After two days of intense but rewarding workshop proceedings it was time for a well-earned break from proceedings. Whilst the clouds loomed low

and ominously, they cleared soon after the start of the scheduled Day 3 Field Trip to Lyngdal Plantage, AU-Foulum and Hestehaven Kaløvig.

The highlights of the day were clearly the magnificently fabulous exemplar of a Podzol in a small forest clearing in Lyngdal Plantage and including;

O – horizon rich in decaying organic matter laden with mosses and liverworts;

A – horizons including a mineral horizon coloured with aforementioned O material and an elluviated A2 or E horizon;

Bhs – horizon coloured with chelated iron compounds and following a quite irregular or tongued pattern along the entire exposure.

Pure and simple this was as per advertised and lived up to expectations. As a soil it classifies out as a Fabusol and as a work of art it is up there with the best!

The contact with the C horizon was also more than apparent with much discussion about the processes of fingering and preferential flow well discussed and critiqued.

On day 4 the workshop continued with presentations focussing on remote sensing and soil spectroscopy applications in DSM and at various scales. Applications in DSM in places such as Ethiopia, Denmark, Hungary and China are worth mentioning.

The take home message here was that not only in developing countries as well as countries large and small that DSM methods are slowly but reassuringly being taken up by soil scientists and that the challenge of providing the necessary layers to the specifications of the DSM Consortium are being delivered…from the bottom-up!

In closing this small overview it is important to recognise the fabulous work of Team Greve for the behind the scenes work they carried out before, during and after the Workshop. Congratulations on providing a fabulous conference venue, proceeding and program of dinners, lunches and cultural activities.

As a participant I found the atmosphere provided a platform for excellent discussions to take place and a fabulous forum to seek collaboration with other scientists and groups. I look forward to exploring these and am looking forward to the 25ᵗʰ Anniversary of Pedometrics in Wageningen in 2017 and DSM 2018 in Chile!

The 7th Digital Soil Mapping Conference
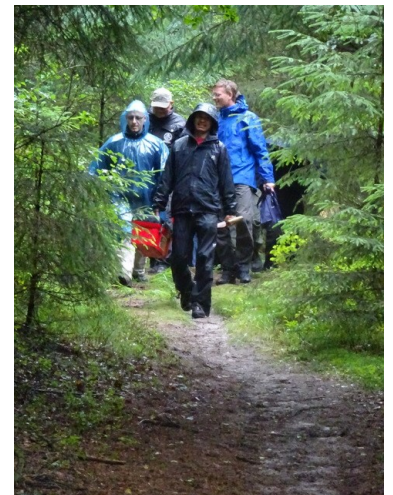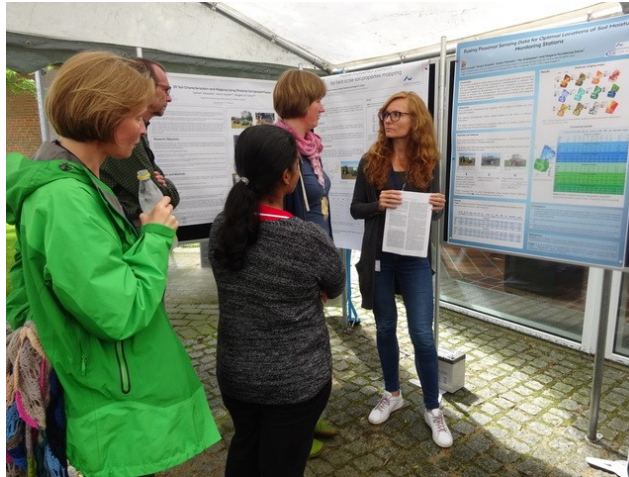
ΠΕΔΟ METRICS

25 WAGENINGEN 2017

Key dates

Submission of pre-conference workshop proposals
1 November, 2016

Abstract submission deadline
1 February, 2017

Early-bird conference registration
1 April, 2017

Submission of special issue manuscripts
1 October, 2017

Come celebrate 25 years of pedometrics with us!

Pedometrics 2017 will be a joint conference of the IUSS Pedometrics Commission and five of its Working Groups:

**Digital Soil Mapping
Digital Soil Morphometrics
Modelling of Soil & Landscape Evolution
Proximal Soil Sensing
Soil Monitoring**

Please join us in Wageningen, The Netherlands!

26 June – 1 July, 2017

Come share and learn about the latest developments in the field and join the festive 25th anniversary of pedometrics.

Stay up to date at
www.pedometrics2017.org

An interview with **Laura Poggio**
Chair of the IUSS WG on Digital Soil Mapping

How did you become interested in soil science?

I became interested in soil science during my university degree. I always saw soil as central part of environment. I had the chance to investigate further the relationships between soils and environment (and people) during the Masters thesis and the PhD.

How were you introduced to digital soil mapping?

I always liked map, soils and computers, DSM seemed to be a good combination. When I moved to Aberdeen I had the chance to start "playing" with it. I was hooked and I tried to dig further into it.

What problems in DSM are you working on at the moment?

I am working on including additional satellite covariates, on the use of Bayesian methods and the use of generated results in further soil assessment.

What is the next technical and scientific challenge for DSM?

I think there are technical challenges in developing methods that can be applied to large datasets (including modelling of spatial autocorrelation) and scientific challenges in using these data in various applications jointly with other fields (climate science, ecology, ecosystem science, and socio-economics). I think it is also important to find approaches to use at best the existing and legacy data.

What is your vision for the DSM WG for the next 4 years?

To facilitate the sharing of approaches and results pertinent to DSM.

Laura Poggio is a research scientist at The James Hutton Institute (Aberdeen, Scotland, UK). Laura has a background in forestry and environmental sciences. Her PhD involved the development of a simplified land-use modelling method for the assessment of the risk of heavy metal polluted soil towards human health, and evaluating the influence of planning measures on this risk. The major focus her current work is the implications of soil and climate interactions for adaptation to climate change.

News Update on GlobalSoilMap

The GlobalsoilMap project's ultimate aim is to produce a harmonized high-resolution (3 arc-second-3 arc-second) spatial soil information of selected soil properties and their uncertainties for the entire globe (1). For tier one products, the uncertainty is defined as the 90% prediction interval. The list of required soil properties is limited to those found essential for addressing key global issues.

The GlobalSoilMap project was formalized in 2010 under a Consortium Agreement signed by representatives of eleven organizations. The first GlobalSoilMap conference took place in Orléans (France) in 2013, followed by a management committee meeting. Three other meetings took place in Jeju (Korea, June 2014), Ottawa (Canada, November 2015) and Aarhus (Denmark, June 2016). GlobalSoilMap progress was reviewed. The most advanced countries are Australia and USA, but there are also some significant advances in Oceanian countries, Canada, South America, China, Africa and Europe. Participants agreed that both bottom-up and top-down products should be produced and harmonized, and that where possible, bottom-up approaches should be preferred.

The addition of new soil properties was discussed and agreed upon in Aarhus, which includes O layer thickness and time stamp. The specifications of GlobalSoilMap products will be updated by the end of 2016.

The first GlobalSoilMap Consortium Agreement ended in 2015. A new Consortium Agreement is in preparation and will be open to all national agencies, institutions and universities willing to achieve GlobalSoilMap products or to contribute to GlobalSoilMap developments.

The establishment of a GlobalSoilMap Working Group (WG) has been proposed to the IUSS and will be discussed during the IUSS inter-congress meeting (Rio de Janeiro, November 2016). Pierre Roudier (Landcare Research, NZ) and Zamir Libohova (USDA, USA) are proposed as chairman and secretary of this WG. This IUSS GlobalSoilMap WG will be open to individuals and will be a product oriented WG, not a methodology one.

The next GlobalSoilMap conference will be held in Moscow, July 4-6, 2017.

Dominique Arrouays

Dominique.Arrouays@orleans.inra.fr

Reference

Arrouays D., Grundy M. G., Hartemink A. E., Hempel J. W., Heuvelink G.B.M., Hong S.Y., Lagacherie P., Lelyk, G., McBratney A. B., McKenzie, N. J. Mendonça-Santos M.D., Minasny B., Montanarella L., Odeh, I. O. A., Sanchez P. A., Thompson J. A., Zhang G. L. 2014. GlobalSoilMap: towards a fine-resolution global grid of soil properties. *Advances in Agronomy*, 125, 93-134.

GlobalSoilMap
Conference 2017
Moscow, Russia
4-6 of July, 2017

The conference continues the discussion initiated at the meetings of the Consortium of GlobalSoilMap in Orleans, France (2013) and Ottawa, Canada (2015).

The main topics of the Conference will include:

- Advances of GlobalSoilMap.net project

- The developments in Digital Soil Mapping theory and methods

- Sources of data for digital soil mapping (legacy data, remote sensing, field data)

- Regional/National case studies

IMPORTANT DATES:

1 of September 2016 – registration and abstract submission open
31 of December 2016 – abstract submission closes
15 of February 2017 – decision on the acceptance of abstracts
15 of April 2017 – early bird registration fee deadline
4 of July 2017 – the conference starts.

VENUE, ACCOMODATION AND VISAS

The venue of the conference will be the campus of the PFUR in Moscow, Russian Federation. Accommodation in the hotels in the vicinity of the venue will be facilitated by the Organizing Committee . Most international participants would need visas to enter Russia.

More information at:

www.esoil.ru/globalsoilmap2017

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Margaret Oliver Award for Early-career Pedometricians Call for Nominations 2017

The Pedometrics Commission of the International Union of Soil Sciences (IUSS) is pleased to introduce a new award, which is intended to recognize up-and-coming talent in pedometrics. The award is named for Margaret Oliver, in recognition of her outstanding commitment to the promotion and encouragement of pedometricians in the early stages of their careers as well as her overall service to pedometrics. The award will be given at each biennial meeting of the Pedometrics Commission; the first award will be at Pedometrics 2017, 26-June – 01-July 2017 in Wageningen (NL) (http://www.pedometrics2017.org).

Requirements and eligibility for the award of the Margaret Oliver award:

Nominees must have:

1) received a PhD degree or equivalent no longer than 5 years before the nomination deadline of 30-November-2016; that is, the award must be after 01-December-2011

2) made high-quality contributions to pedometrics, as evidenced by published work, conference presentations, workshops, field guides, etc.

3) at the time of the award be active in pedometrics and with a prospect of so continuing

"Pedometrics" is broadly defined as the application of mathematics or statistics in soil science.

Nominations procedure

1) Nominations for the Margaret Oliver Award should be made by a colleague or colleagues who know the person's work well -- these do not have to be IUSS members or active in pedometrics. The proposer(s) should submit the following on behalf of their nominee:

   a) a supporting letter signed by the proposer(s) explaining why this nominee should be awarded the Margaret Oliver Award, with respect to the conditions outlined in the section "requirements and eligibility", above;

   b) a curriculum vitae that gives one or more the following, always showing clear relevance to pedometrics:

      i. publications (journal, book, popular…);

      ii. positions held;

      iii. research undertaken;

      iv. education of others;

      v. teaching courses developed;

      vi. leadership and management of research projects;

      vii. service (broadly defined) to the pedometrics community.

2) Nominations should be sent before 01-December-2016 to the Chairman of the Pedometrics award committee: D G Rossiter at david.rossiter@wur.nl or dgr2@cornell.edu, with the subject line "Oliver Award 2017"

3) The nominations will be evaluated by the award committee:

    David G. Rossiter (ISRIC-World Soil Information (NL), Cornell University (USA), Nanjing Normal University (PRC).

    Sabine Grunwald (University of Florida, USA)

    Alex McBratney (University of Sydney, Australia)

    Margaret Oliver (University of Reading, UK)

    Lin Yang (Chinese Academy of Sciences, State Key Laboratory of Resource and Environmental Information Systems, PRC)

This committee was appointed by the IUSS Pedometrics Commission advisory board in January 2014 and serves until the next World Soil Congress in 2018.

More on Soil Science Journal's Impact Factor

By Budiman Minasny and
Alex McBratney

In June this year, Thomson & Reuter released its journal Impact Factors for 2015. Editors of journals are enthusiastic to share their journal's impact factor, while most of us have a hate-love relationship with it. The journal impact factor was conceptualised in the 1960s and has been around for more than 40 years, and it is still being used as a major measure of any particular journal's quality. We are encouraged to submit our papers to journals with high impact factors. It is even used to demonstrate researchers' achievements.

Ivan Oransky from Stat News wrote that impact factor "is a bit like a corrupt bureaucrat: overly powerful, largely incompetent, and widely feared."

As we know, a journal's impact factor for a particular year is calculated from the average number of times that a journal's articles is cited over the previous 2 years. For example *Soil Biology and Biochemistry* currently has an impact factor of 4.152 which is interpreted as the journal's articles have an average citation of 4. However, a high impact factor journal does not imply that *all* its papers have high citation numbers. We have covered this here and here.

The calculation is done by Thomson Reuters, and not in a very transparent way. A journal's impact factor can be manipulated in various ways, including editorials with lots of self citations, editors' coercive citations, citation cartels, etc.

Recently, a paper published in the bioRXiv preprint examined the citation distribution of some high impact factor journals. The researchers looked at the citation statistics of 11 journals (including *Science* and *Nature*), and they found that their citation distributions are so
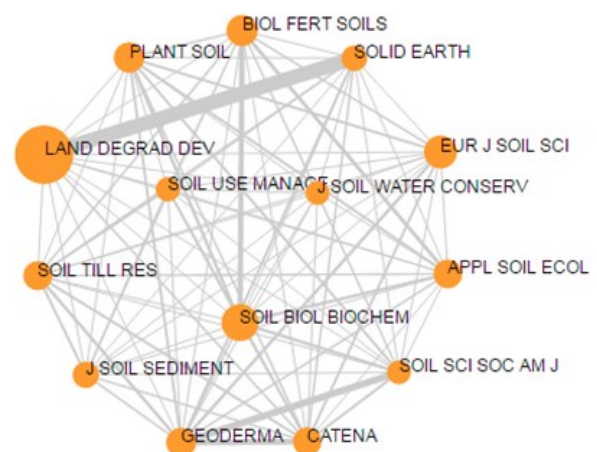
Figure 1. Citation network of selected soil science journals from Thompson Reuters' web of science.

skewed that up to 75% of the articles in any journal had smaller citations than the journal's impact factor. One way of expressing this is:- the impact factor of a journal has no impact on citations of its individual papers. Even *Science* and *Nature* discussed this preprint, and talked about the misuse of impact factors. The authors of the paper (Larivière *et al.*) proposed that journals should generate their citation distributions as a move to greater transparency. In addition, one should (re)focus attention on individual pieces of work. *Nature* suggested the two-year median, Google Scholar has its h5 index, the h-index for articles published in a journal the last 5 years. And there are also other indices.

In this article, we look at the impact factor and citations in soil science journals. We take the top 15 soil science journals according to the 2015 impact factor published by Thomson Reuters (**Figure 1**). The impact factor for a journal in 2015 was calculated by dividing the number of articles the journal has published over the past 2 years (2013 and 2014) with the number of times those articles were cited in 2015. For each journal, we downloaded the number of papers they published in 2013 and 2014 and the number of citations the papers received in 2015. We used Scopus, another database, for this analysis to check for consistency.

We fitted a gamma distribution to the citation data, with a probability density function:

$$f(x; \alpha, \beta) = \frac{\beta^\alpha \, x^{\alpha-1} e^{-x\beta}}{\Gamma(\alpha)}$$

where α is the shape and β is the rate parameter ($\alpha, \beta > 0$).
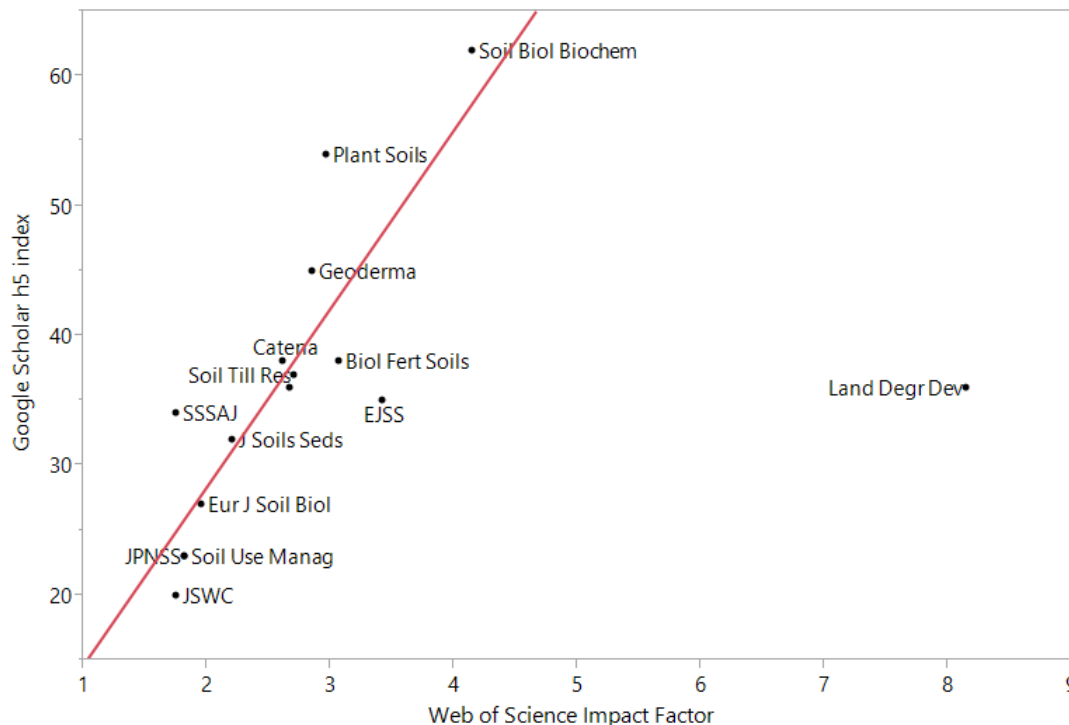
Figure 2. The relationship between a journal's impact factor (IF) and its h index.

In soil science, most journals have impact factors around 1 to 3. The IF calculated using the Scopus database is also comparable with IF calculated from Web of Science, except for Land Degradation & Development (Table 1). We also compared impact factor with Google Scholar's h5 index (from June 2016). In a previous article, we found that the h5 index is quite a robust measure of citations. The impact factor of a journal mostly correlates well with its h5 index except for Land Degradation and Development (**Figure 2**).

We further examined the journal's citation distribution. **Figure 3** shows examples of 4 journals with their histogram and fitted gamma distribution (red lines).

Land Degradation and Development

IF = 8.145

Figure 3a

Soil Biology and Biochemistry

IF = 4.152
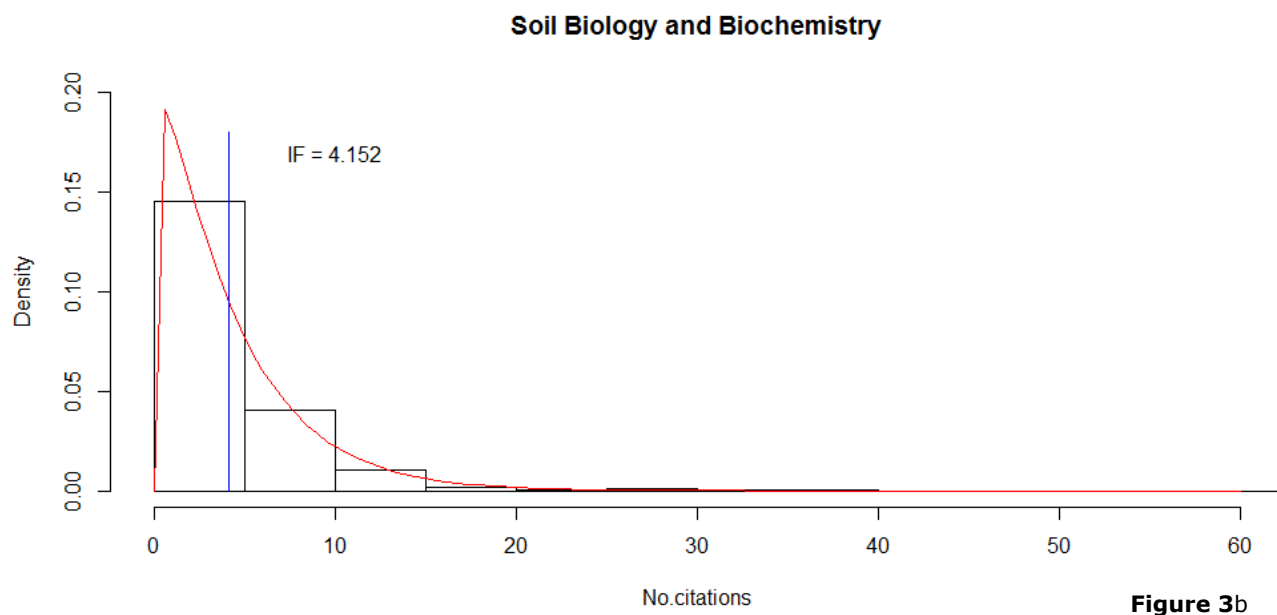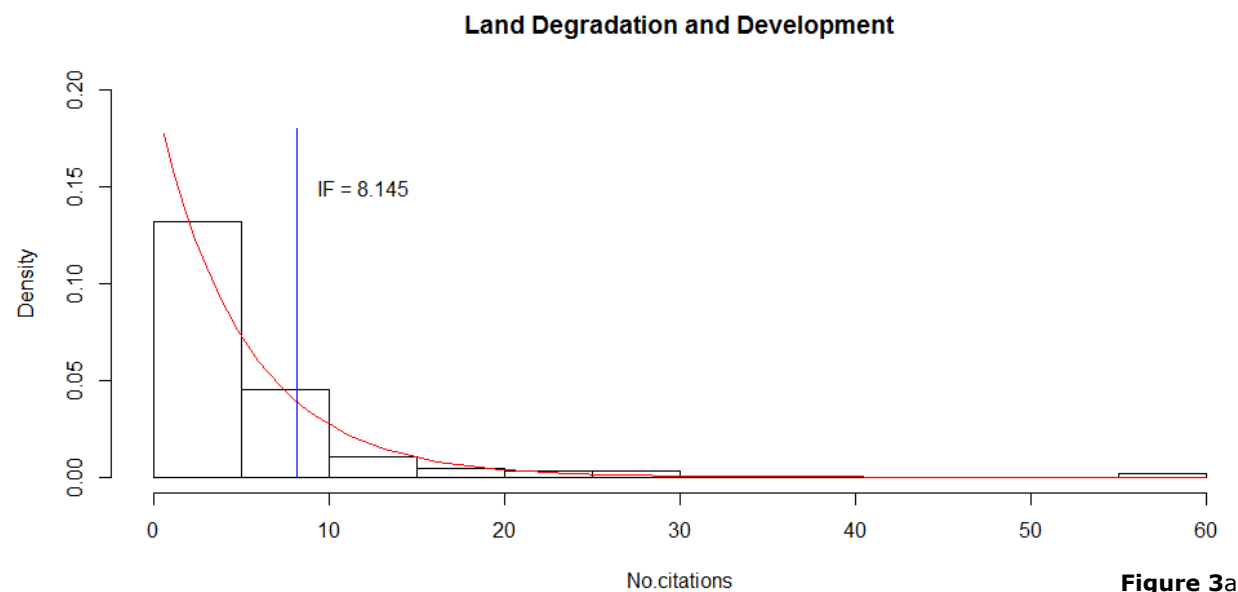
Figure 3b

European Journal Soil Science
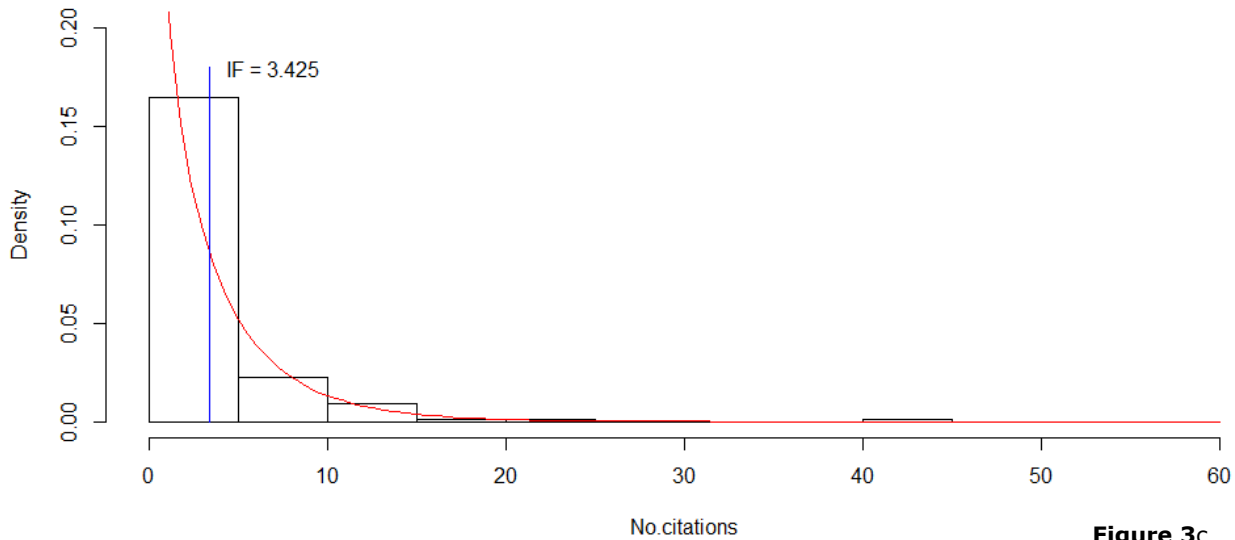
Figure 3c

Geoderma

Figure 3d

Figure 3. Examples of 4 journals with their histogram and fitted gamma distribution (red lines)

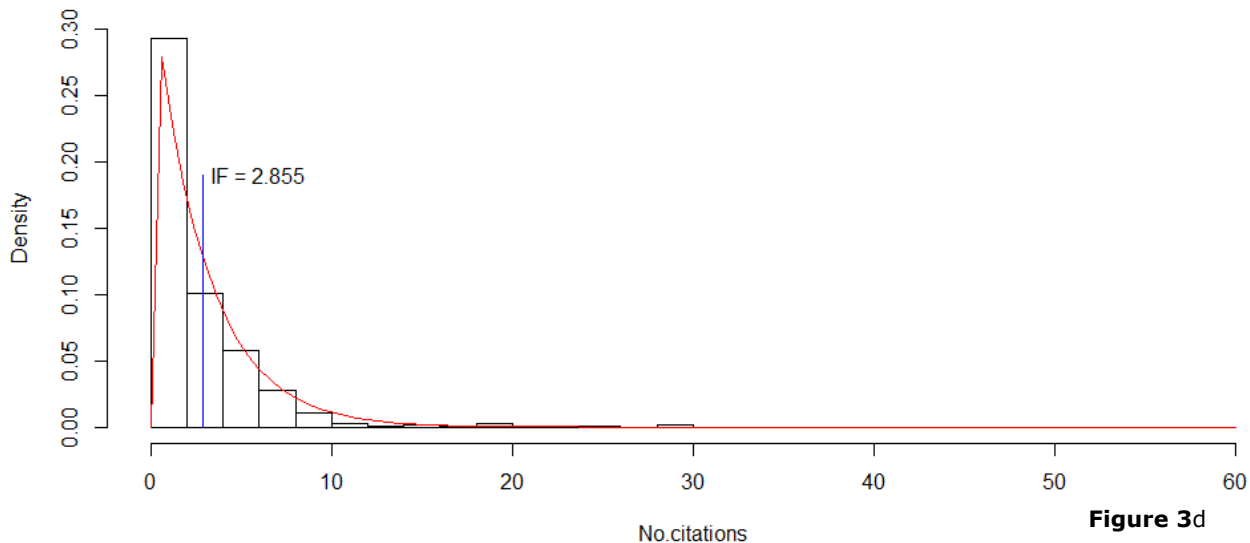**Figure 4** shows the journal's impact factor and the percentage of papers that are higher than the reported IF. We included few high impact journals from the study by Larivière et al. (2016) as a comparison. Most soil journals with modest impact factor (1 to 3), 35-45% of their papers have citations greater than its published impact factor. Soil science journal with the highest impact factor (Land Degradation and Development) only 16% of its papers have citations higher than its IF. It is evident that high impact journals were mostly dominated by few highly cited papers and a high proportion of them still have low citations.

So as you as you probably figured out, the IF of a journal is not going to predict the citation of your paper. This topic has been repeatedly discussed every year, however IF seems to remain and is still used in job applications and promotions, but we all need to realise it's the citations of individual papers that actually counts. A more useful indicator is how the citation

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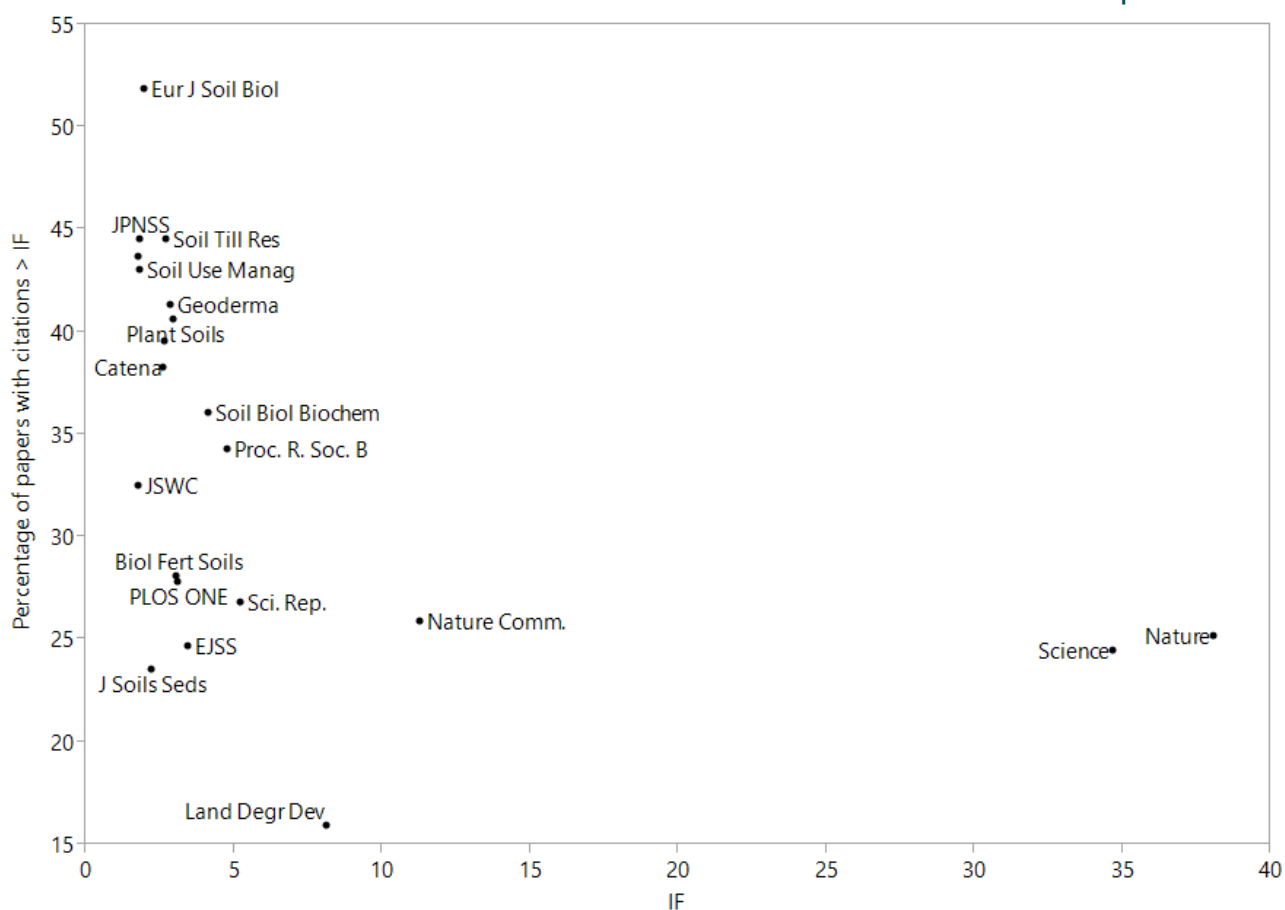
Figure 4. 2015 Journal's impact factor (IF) and percentage of its paper with citations higher than its IF.

of a paper compared to the others of the same field of study. The following is the quantiles of citation for the 15 journals mentioned in **Table 1.** One can compare the citation of a paper 2 years after it has been published. To calculate a Relative Citation Index (RCI) for a paper, place the citation of that paper in the following percentiles. It shows 22% of paper has zero citation, and the median of citation for a paper is 2. For example a paper published in 2013 has 7 citations in 2015, thus it is on the top 10 percentile of citation. Or the top 1% citation papers have at least 15 citations, 2 years after it has been published.

Percentile	20%	25%	40%	50%	60%	70%	80%	85%	90%	95%	99%	100%
Citation	0	1	1	2	2	3	4	5	6	9	15	79

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Table 1 shows the journal and its impact factor and other parameters.

Journal	2015 Impact Factor	No. papers (2013-2014)	Total citations (2015)	IF calculated from Scopus	Median citation	h index (2015)
Land Degradation and Development	8.145	132	710	5.379	4	12
Soil Biology and Biochemistry	4.152	784	3330	4.247	3	15
European Journal of Soil Science	3.425	170	534	3.141	2	11
Biology and Fertility of Soils	3.069	288	751	2.608	2	9
Plant and Soil	2.969	1033	2868	2.776	2	15
Geoderma	2.855	711	2062	2.900	2	11
Soil and Tillage Research	2.709	265	791	2.985	2	10
Applied Soil Ecology	2.67	341	924	2.710	2	10
Catena	2.612	483	1338	2.770	2	12
Journal of Soils and Sediments	2.206	454	817	1.800	1	8
Soil Use and Management	1.823	151	264	1.748	1	6
European Journal of Soil Biology	1.951	162	345	2.130	2	6
Journal of Plant Nutrition and Soil Science	1.816	202	388	1.921	1	7
Journal of Soil and Water Conservation	1.752	163	215	1.319	1	5
Soil Science Society of America Journal	1.752	453	836	1.845	1	9

Journal	% papers with no citation	% papers with Citation >IF	Citation Mode	α (shape)	β (rate)	Cumulative Probability of IF	Google h5 index
Land Degradation and Development	12.1	15.9	1	0.989	0.196	0.800	36
Soil Biology and Biochemistry	11.5	36.1	1	1.120	0.264	0.617	62
European Journal of Soil Science	27.6	24.7	0	0.678	0.229	0.702	35
Biology and Fertility of Soils	23.6	28.1	0	1.001	0.360	0.668	38
Plant and Soil	22.5	40.7	0	0.977	0.355	0.661	54
Geoderma	18.7	41.4	1	1.003	0.344	0.625	45
Soil and Tillage Research	15.8	44.5	1	1.069	0.351	0.584	37
Applied Soil Ecology	18.5	39.6	1	1.032	0.374	0.618	36
Catena	20.7	38.3	1	0.946	0.342	0.616	38
Journal of Soils and Sediments	31.1	23.6	0	0.898	0.491	0.704	32
Soil Use and Management	30.5	43.0	0	0.885	0.475	0.633	23
European Journal of Soil Biology	24.1	51.9	1	1.008	0.438	0.571	27
Journal of Plant Nutrition and Soil Science	28.2	44.6	0	0.900	0.456	0.610	23
Journal of Soil and Water Conservation	41.1	32.5	0	0.736	0.511	0.712	20
Soil Science Society of America Journal	33.8	43.7	0	0.837	0.453	0.626	34
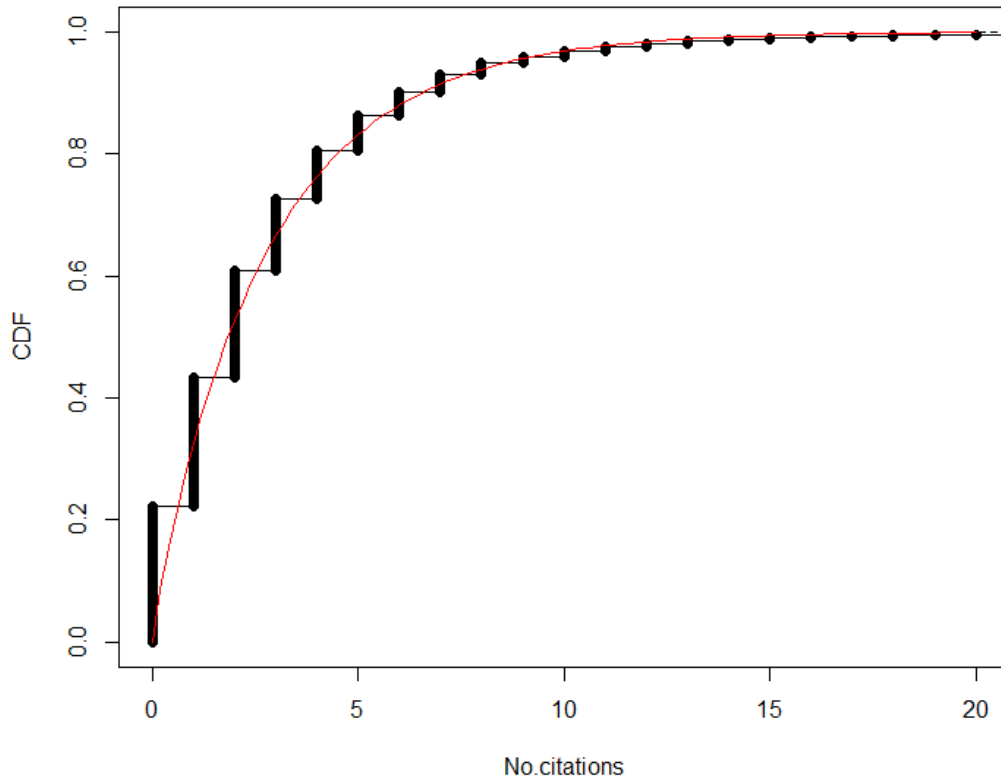
Figure 5. CDF of citation of 15 soil science papers. The citation is from year 2015 from papers published in the previous 2 years.

Alternatively use **Figure 5**, which shows the CDF of citation for the 15 journals. The gamma distribution shape parameter a is 0.9015 and rate $\beta = 0.325$.

Reference:

Larivière, V., Kiermer, V., MacCallum, C.J., McNutt, M., Patterson, M., Pulverer, B., Swaminathan, S., Taylor, S. and Curry, S., 2016. A simple proposal for the publication of journal citation distributions. *bioRxiv*, p.062109.

Can citizen science assist digital soil mapping?

By David G. Rossiter, Jing Liu, Steve Carlisle, A-Xing Zhu

This article summarizes the main points from our recent paper "Can citizen science assist digital soil mapping?" Geoderma, 259-260, 71–80. http://doi.org/10.1016/j.geoderma.2015.05.006

Before you consider our concepts, please be clear that we have ourselves not undertaken any of the projects proposed in the paper. Our purpose was to stimulate the discussion on the possibilities, so that active digital soil mappers can consider how, in their specific social and soil mapping context, a successful citizen science initiative might be undertaken. As you will see, we believe that citizen science projects are quite context-dependent. Since our article was published, an excellent soil survey example has appeared: **Thomas, M., et al. (2016). Mobilising citizen scientists to monitor rapidly changing acid sulfate soils. Transactions of the Royal Society of South Australia***, 1–17.*

http://doi.org/10.1080/03721426.2016.1203141

The essential element of citizen science is the participation of non-specialists in scientific research. The citizen acts as an observer or experimenter within structures established by a project run by professional scientists. The recent explosion in citizen science projects is due to the development of enabling technology, exemplified by the spatially-enabled "smart" phone with mapping applications and its supporting networks including the GPS system, as well as the increasing engagement of non-specialists in what were once specialist domains (e.g., encyclopedias, book reviews, travel advice). Citizen science projects typically have two purposes: (1) to amplify scientific research; and (2) to build citizen support for, and understanding of, science.

The role that citizen science may have in soil science is twofold: (1) involving citizens in observing soils and their landscapes, and thus building a wider citizen appreciation of soil geography; and and (2) increasing the density and geographic spread of observations to improve mapping accuracy. The primary beneficiary of incorporating citizen science in DSM would be the professional mapper using digital information to produce or enhance maps of soil properties or types. The secondary beneficiary would be the citizen scientist, who would benefit from an enhanced map, and may be better able to participate in policy debates related to the soil resource. Current initiatives in citizen soil science include the OPAL Soil and Earthworm Survey, GLOBE, and mySoil. However, none of them are specifically aimed at DSM.

In the paper, we identified the types of citizens who might be motivated to contribute to such initiatives; the forms of potential contributions by those citizens; the potential ways to use citizen-contributed data in using citizen data; and the challenges. We also proposed some potential initiatives to incorporate citizen science with DSM.

The nine groups of citizens who might contribute useful information for DSM include: (1) consulting or research soil scientists and agronomists, who are familiar with existing soil survey protocols and products; (2) farmers/land managers, who are familiar with their portion of the landscape and aware of the value of up-to-date soil maps; (3) civil engineers and others involved in construction, who are routinely views the subsoil, via road cuts, surface mining, and excavations for basements and foundations (**Fig 1**); (4) gardeners who have an intimate relation with the soil but in a small, generally intensively managed area; (5) outdoor activities, including hikers, birdwatchers, and geocachers, who routinely use tracking GPS to record their traverses; (6) sport hunters who are traverse rough areas of difficult access and intimately know the surface properties (such as vegetation type, rocks and slopes) over a large area; (7) school teachers who want to motivate their students to apply proper measurement technique and scientific methods. They and their students can be trained in data collection and reporting techniques; (8) "greens" who have an emotional and political affinity for natural areas, low-impact agriculture, locally-produced foods and similar lifestyle choices. They are often active in field activities and can be motivated by the effect of their contributions on their "green" cause; (9) "organizers" who have a psychological need to live in an organized

Fig. 1 Soil profile description and sampling at an excavation for building foundation, HeDong neighborhood, LinYi City, Shandong Province, China (34.996N 118.48E).
Note the good view of the horizontal and vertical spatial variability of the horizons.

world. In a DSM context, these people would find an anomaly in soil map, they would feel a compulsive need to correct it. They might also be attracted to projects that organize and harmonize information.

The information provided by citizens could be direct observations of soil properties, observations of soil-related covariables, and georeferenced photographs. Such information could be in the form of tacit knowledge, opportunistic or protocol-guided new information, information from precision agriculture, and physical samples submitted for analysis. Rural communities, including farmers and land managers, have built up tacit knowledge of their soil resources through long-time working on the land. They can be asked to make a sketch map or annotate air photos, and provide local descriptions that can be ground-truthed to correlate with the standard mapping legend. In addition to tacit knowledge, modern citizens often make quick observations according to opportunity (**Fig. 1**). They may photograph remarkable land features as they traverse the landscape for other purposes. Citizen scientists can also cover the landscape more densely and purposefully following a data collection protocol prepared by a professional soil scientist. However, a suitable protocol for non-specialists should be easy (which also means the measurements may not be precise), safe (which means that the citizen cannot be asked to traverse dangerous terrain or dig pits), and reliable (which means that the observations must be well-documented and subjected to quality control).

The information contributed by citizens can be used in both previously-mapped areas, with good knowledge of the soils but relatively sparse ground truth, and unmapped areas where the range of soils is not known. In previously-mapped areas, citizen-contributed information can assist to improve the level of details of legacy maps. For example, the citizen may may help identify the contrasting minor soils ("inclusions") that form bodies of soil too small to map at the design scale of the soil map. For unmapped areas, observations contributed by citizens can be used to calibrate DSM models, or validate/evaluate the products of DSM models.

A key issue of using citizen-contributed information in digital soil mapping is how to integrate observations from citizens and those from the professionals. Observations made by citizens can be surficial (photos, landscape description, surface features), subsurface (cuts, profiles), field measurements (e.g., with a simple pH kit), output of on-the-go sensors on agricultural machinery, or even simple laboratory measurements. Measurements and observations made by citizens are expected to be more general, using less precise instrumentation and field keys than would be used by a trained surveyor. Free-text descriptions and sketches are expected to use layman's language and naïve observation. This variety of observation types immediately raises two questions: (1) how can the credibility of citizen-supplied observations be assessed? and (2) how can imprecise observations be combined with professionally-provided observations? An obvious check is how well new observations fit an existing soil landscape model used for DSM. Another check is the comparison between the observation and a prediction based on existing maps. The resultant mapping uncertainty should also be considered and quantified when using citizen-contributed information.

In the paper we proposed possible initiatives for citizen science to assist DSM, how to over-come the limitations of the existing initiatives, and how to address the problems associated with citizen provided information. In countries with well-organized soil survey (such as the USA), it should be possible to start a citizen program to further enrich the existing knowledge and to correct mapping errors. For countries with internet-accessible interactive soil surveys, a feedback loop could be incorporated to allow registered users to comment on the current digital soil map. This way, discrepancies with existing maps observed in the field by citizen map users could be geographically indexed to the map and sent back digitally. The new infor-mation would be reviewed by a staff soil scientist from the relevant local office, and evaluat-ed for rejection, immediate incorporation, or field check (as shown in Fig. 2 and Fig. 3). If enough citizens can be engaged for longer periods and regularly repeat visit to the same sites, it opens up possibilities for making real-time digital soil maps with DSM.
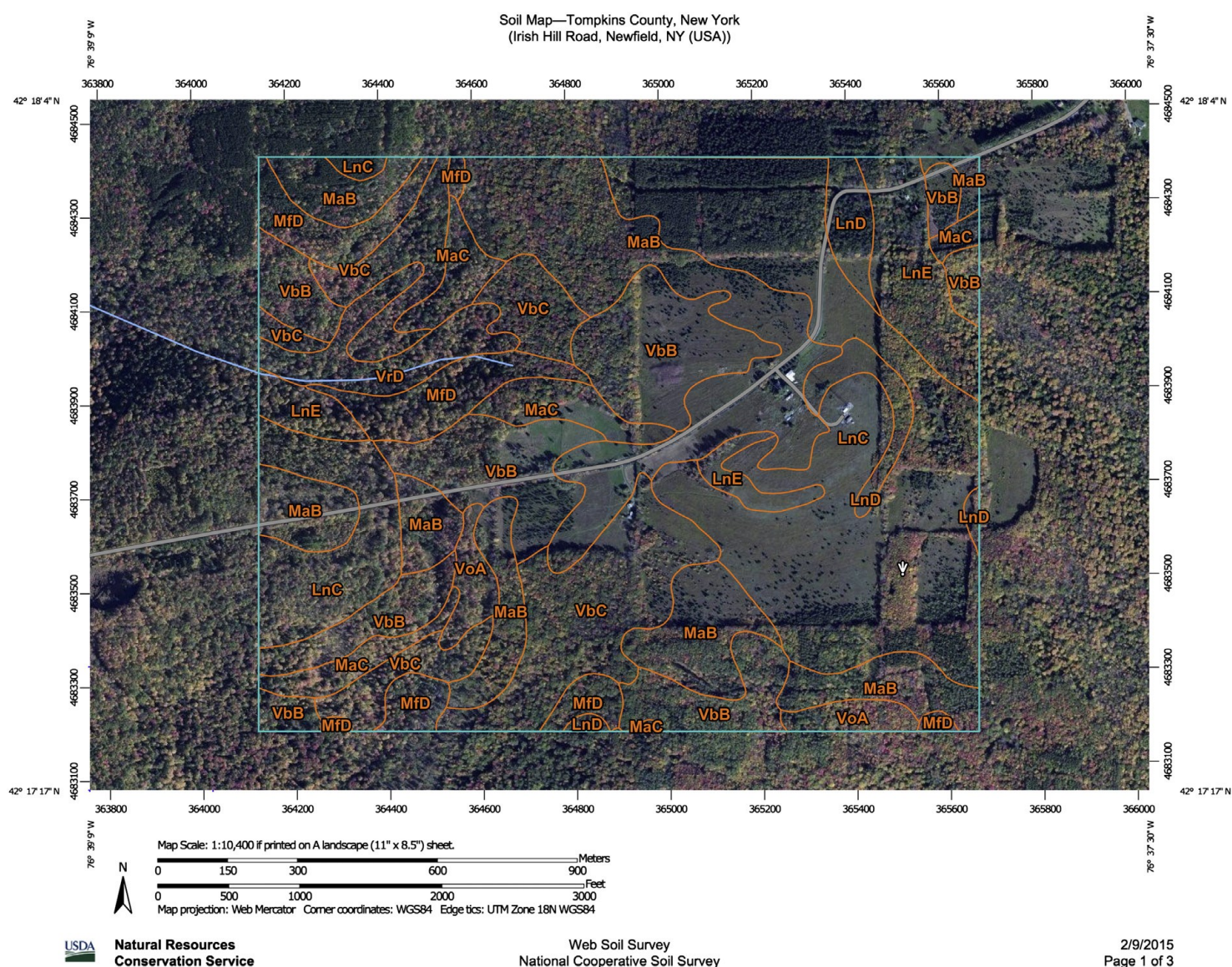
Fig. 2 Portion of Web Soil Survey map
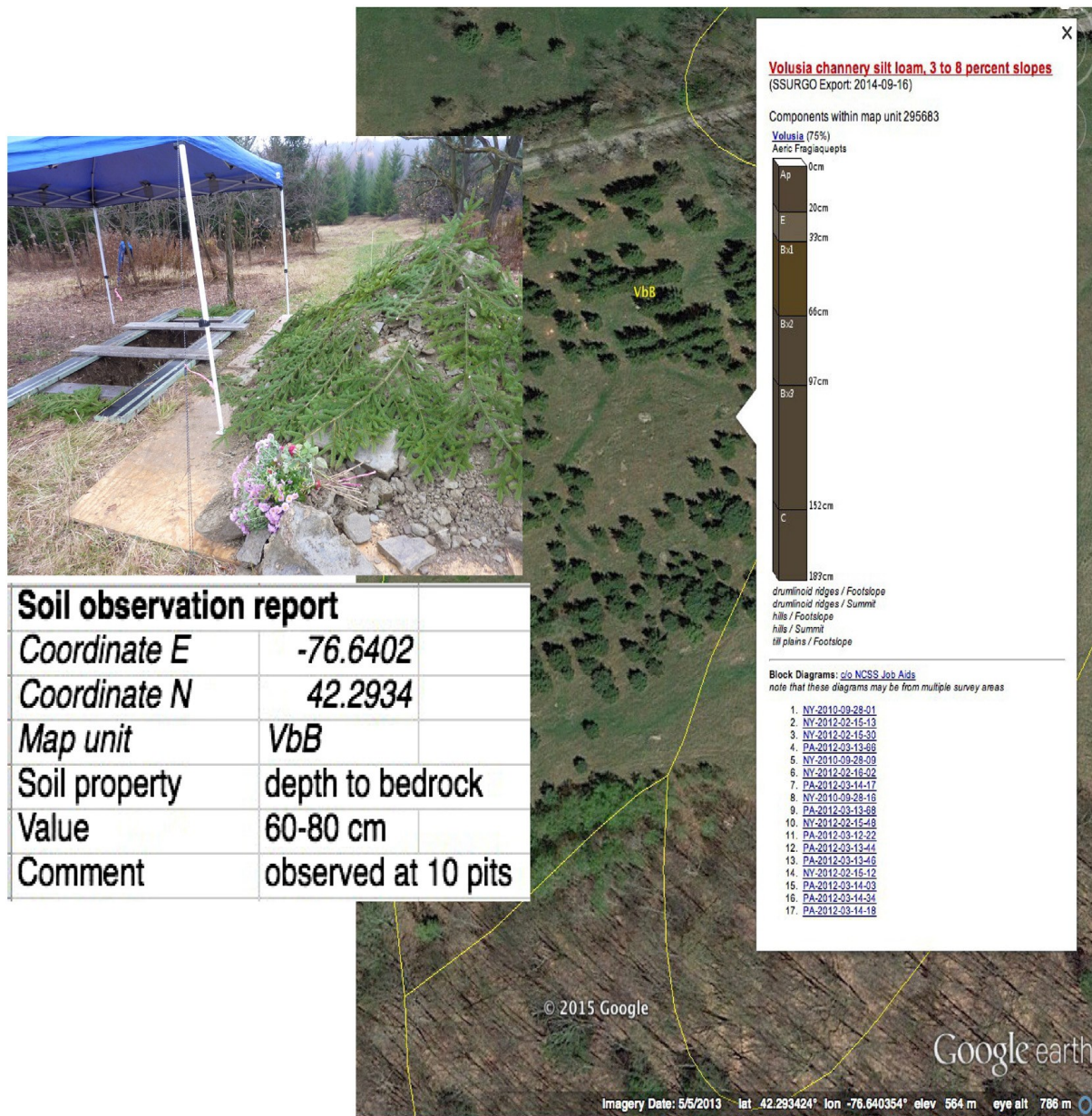
Fig. 3 Hypothetical user comments on Web Soil Survey via the Soil Web interface

In other countries the organizers of the citizen science project would first need to publicize their mapping objective and explain what will be done with provided information, so that citizens can see their contributions in the enhanced database and the soil maps. There should also be some effort to familiarize the non-specialist citizens with soil survey products and their benefits. Observation protocols used to guide citizens must be easy and straightforward, but also needs to make sure the collected data by citizens are reliable and usable.

The introduction of citizen science tools to aid DSM would raise a number of research and technical challenges, including:

1. how to compile easy protocols and field guides which encourage broad participation;

2. what tools can best match citizens' landscape perception and allow reliable data capture;

3. what quality control and evaluation mechanisms are appropriate to the type of citizen and information they provide;

4. how to judge and account for observer bias in both geographic and feature spaces;

5. how to integrate data of heterogeneous nature (e.g., type and precision of observation) and quality;

6. how to use data of limited representativeness in mapping;

7. how to quantify the uncertainty of information provided unsystematically;

8. how to stimulate adaptive sampling in contentious areas (with contradictory information).

In addition, there are also many social obstacles in incorporating citizen science in DSM. A major obstacle is the general public's low awareness of the soil resource, compared to more easily appreciated resources such as vegetation, air and water. Citizen soil science usually requires fieldwork, which seems more difficult compared to other projects.

Citizen science has captured the imagination of millions worldwide, and has stimulated active participation in a wide variety of projects in many fields. Soil science has had a very minor part of this, for several reasons: (1) soil is not "attractive" in the same way as birds, plants, or stars; and soil maps are even less known than soil in general; (2) soil is not easily visible in the same way as the atmosphere or biosphere; (3) citizens have little knowledge of soil science, compared to sciences with wide popularity such as medicine, astronomy or even cosmology; and (4) soil observations require field work. So to design a citizen science project to aid DSM will require (1) a clear description of what additional information for DSM can be easily and safely provided by a non-specialists; (2) the identification of citizen groups that would be in a position to provide these; (3) a strong publicity campaign, with appropriate materials and perhaps training opportunities; (4) protocols for data collection and submission by the citizens; and (5) protocols for dealing with citizen-submitted information, to make it useful for DSM.

Though facing those challenges, we cannot ignore the potential benefits. It is clear that citizen-provided information can accelerate and improve DSM projects. The benefits may go beyond the immediate aim of improving soil maps. In the longer term citizen soil science may enhance the "connectivity" between soil and citizens as defined by McBratney et al. (2014): "whether the person who is responsible for the soil in any given piece of land has the right knowledge and resources to manage the soil according to its capability".

Do any Pedometron readers have experience with citizen science to assist DSM?

Citation:

McBratney, A., Field, D.J., Koch, A., 2014. The dimensions of soil security. *Geoderma* 213, 203–213.

Challenges in establishing digital maps of soil organic carbon in Madagascar

By Nandrianina Ramifehiarivo[1] (ranandrianina@hotmail.fr) , Michel Brossard[2], Herintsitohaina Razakamanarivo[1]

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- **Soil in Madagascar**

Madagascar is an island located in Eastern Africa (Fig.1) in the Indian Ocean (area of 587,000 km², between 11°57 and 25°29 S and 43°14 and 50°27 E) with a tropical climate characterized by a variety of vegetative cover: Forest, shrub fallow, agricultural land, bare land, mangroves… (Fig.2 respectively (a) to (e)). The geomorphology roughly consists of three parallel longitudinal zones: central highland, humid coastal strip in the east, and zone of low highland and plains in the west. Dominant soil types are Ferralsols (Ferralitic soil) and Ferric Luvisols (Ferruginous soil) covering over 46% and 28 % of national area respectively (Fig.1).

It is an island where its natural resources present a richness not only in the biodiversity of flora and fauna but also in terms of soil. This soil resource has an important place given that more than 80% of Malagasy people live in rural area where agricultural activities are performed on different landscapes (Forest, Coast, plains, shrubland). Nevertheless, due to the unsustainable agricultural practices (slash and burn, imbalance fertilization…), add to the spectacular erosion phenomena, Malagasy soil undergoes a considerable pressure. This makes us focus on soil inventory and mapping.
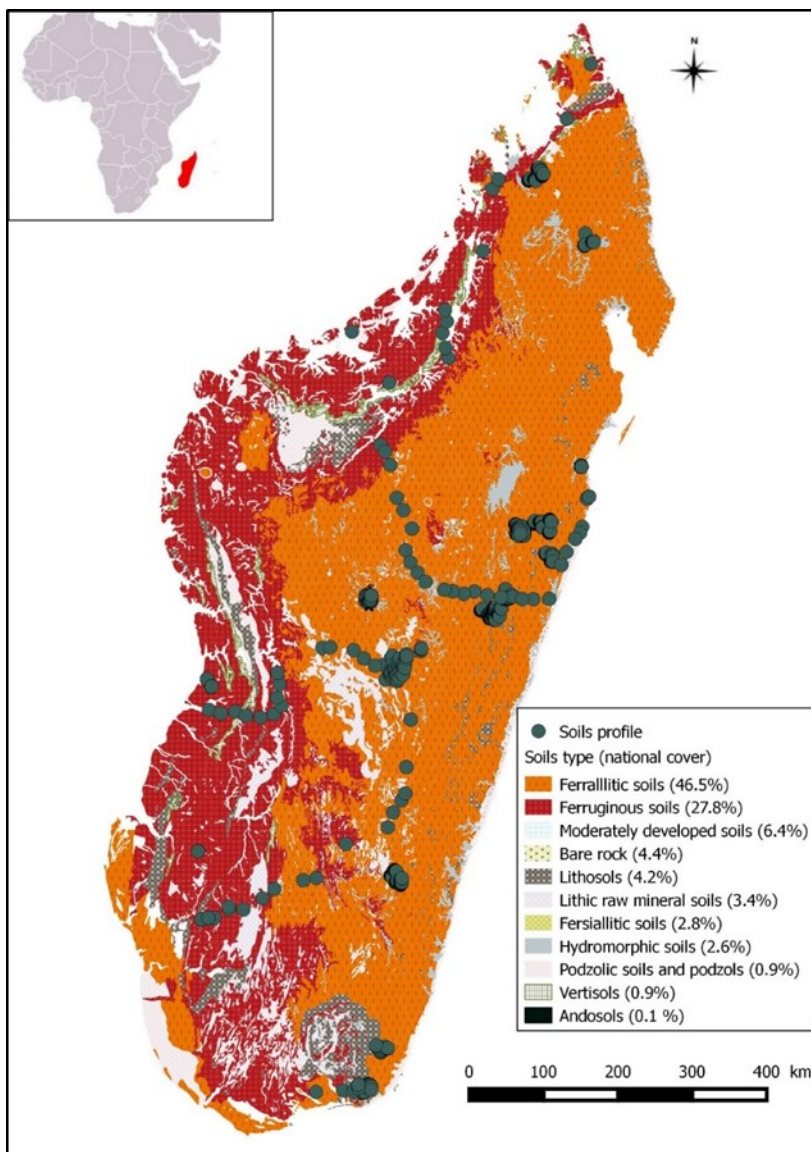
Fig. 1. Soil distribution in Madagascar (Delenne and Pelletier, 1981) with location of soil profiles studies on 2010 to 2015 (n = 1,993)

- **The history of soil survey**

Soil research in Madagascar included three major periods (Feller et al., 2010):

- before 1970, French researchers from Office of Scientific Research in Overseas Territories (ORSTOM) particularly worked on the identification of existing soil types, their classification following the French Commission of Soil Science and Soil Mapping (CPCS, 1967)), their spatial distribution in some coastal area of interest, and the study of pedogenesis.

- between 1970-1994 : during which Malagasy researchers from the National Agricultural Research Institute (FOFIFA) and French researchers from ORSTOM have done many works in applied pedology and large-scale mapping of soil type (1 :10,000 to 1 :200,000) for irrigation, fertilization studies and land development.

- and from 1994 : where other overseas researchers (British, Japanese…) joined the Malagasy researchers from FOFIFA and Laboratory of RadioIsotopes (LRI) of University of Antananarivo, and French researchers from the Institute of Research for Development (IRD, formerly called ORSTOM), in soil survey in the framework of climate change mitigation and adaptation, food security, biodiversity conservation, and land degradation.

Maps of 1:200,000 only cover 20% of the national area and the remaining larger-scale studies don't cover more than 2% of the territory.   Nevertheless, Soil Organic Carbon (SOC) as the main content of soil organic matter was always considered. Actually, knowledge of the size, the temporal and spatial distribution of SOC sequestration provides a good understanding of the ecosystem carbon balance. This last contribute to a better policy decision making and implementation of a sustainable crop production, and also a sustainable natural resource management.

- **A national database as a main output of soil surveys**

Following the different works of the three above-mentioned periods, a national georeferenced soil and environmental database named VALSOL-Madagascar was established, which contains soil maps and soil data information from soil surveys. This database, updated during the last 5 years by LRI and IRD teams recorded soil information by profile (soil profile (Fig.2 (f) to (i)), including geographical location, physical and chemical soil properties such as soil thickness, soil organic carbon content, bulk density, clay, silt, and sand content, pH (47 properties), …. (Beaudou and Le Martret, 2004).

Now, this database contains 770 soil profiles information carried out by the research during the ORSTOM period and 3,122 soil profiles collected during the third period.

- **Mapping of Soil Organic Carbon**

Many efforts were made in order to acquire good knowledge of the spatial distribution of SOC; they included field works (Fig.2j) all along the big island, and laboratory works (Fig.2 (l) to (o)). This last combines conventional methods with chemical analysis using several reagents and also alternative methods corresponding to the Infrared Spectroscopy (the near- and mid-infrared spectroscopies (Fig.2k) ones). All this allow the establishment of Soil Or-

ganic Carbon stocks (SOCs) map at different levels according to the needs of scientists and policy makers (Fig.2). Few attempts were undertaken in SOCs mapping at different level: local, regional and national. At local level, there is the research carried out by Razakamanarivo et al. (2011) on SOCs mapping for the first 30 cm depth in eucalyptus plantations (30 m resolution) in the central highlands of Madagascar by using the gradient boosting model (n = 41 soil profiles). At the national level, Grinand et al. (2009) has produced a SOCs map for the 30 cm depth (1,000 m of resolution) according to VALSOL-Madagascar which gathered SOCs data collected before 1979 (n = 279 soil profiles), by using average values of soil-vegetation units. This study was the first evaluation of organic carbon resource in Madagascar in order to assess its future trend in climate and land use change. At regional level, SOCs mapping of eastern humid ecoregion was done in 2014 (www.perr-fh-mada.net/) by using an updated database (n = 733 soil profiles) of VALSOL-Madagascar at 0 to 30 cm depth (30 m resolution) to the reference level of the greenhouse gas (GHG) emissions from deforestation within this ecoregion (using the Random Forests Approach). Despite these studies, SOCs mapping approaches in Madagascar still need to be developed in order to reduce uncertainty regarding the accuracy of the map. This main uncertainty is often related to sample small size and sample plot location, under-sampled locations, errors generated from laboratory analysis and land cover mapping from remote sensing, modelling errors, … . My ongoing research focuses on this problem of accuracy.

- **Towards a digital map of soil carbon at the national level**

In 2015, VALSOL-Madagascar was updated. My main work consists in the capitalisation of these data and producing maps with a minimum of uncertainty at the national level by using easy-to-access covariates in time and in space. The first results showed that the most recent soil inventory (n= 1,993 soil profiles (**Fig.1**) sampled between 2010-2015) with using the Random Forests approach gave a good prediction (R^2 = 0.59 and a RMSE = 25.81 MgC.ha^{-1} on an external validation dataset (n=358)). The model is influenced by elevation, temperature and vegetation data. The SOCs map ranged (**Fig.3**) from 28.3 to 197.6 MgC.ha^{-1} on 30 cm of depth. The total SOCs was 4,137 ± 1,214 TgC with coefficient of variation (CV) of 29%. In spite of this first success, there were some gaps in regions with lithic raw mineral soils because of the lack of our SOCs database and 3.4 % of the area was not predicted. The new national map produced with my model has improved the accuracy of the prediction: (i) in resolution, from the 1km² resolution m for Grinand et al. (2009) to 30 m × 30m in the new digital map (case of county of Didy in **Fig. 4**) and (ii) in value by also decreasing the CV of the maps (66% for Grinand et al. (2009)). Although the accuracy of the map is updated, the next step of my PhD will concern the decrease of uncertainty by testing additional relevant covariates derived from remote sensing dataset.

- **Conclusions**

More than one century of soil studies allowed the IRD and LRI team to achieve the actual stage of spatial distribution of SOC in Madagascar. The use of DSM approach during the last
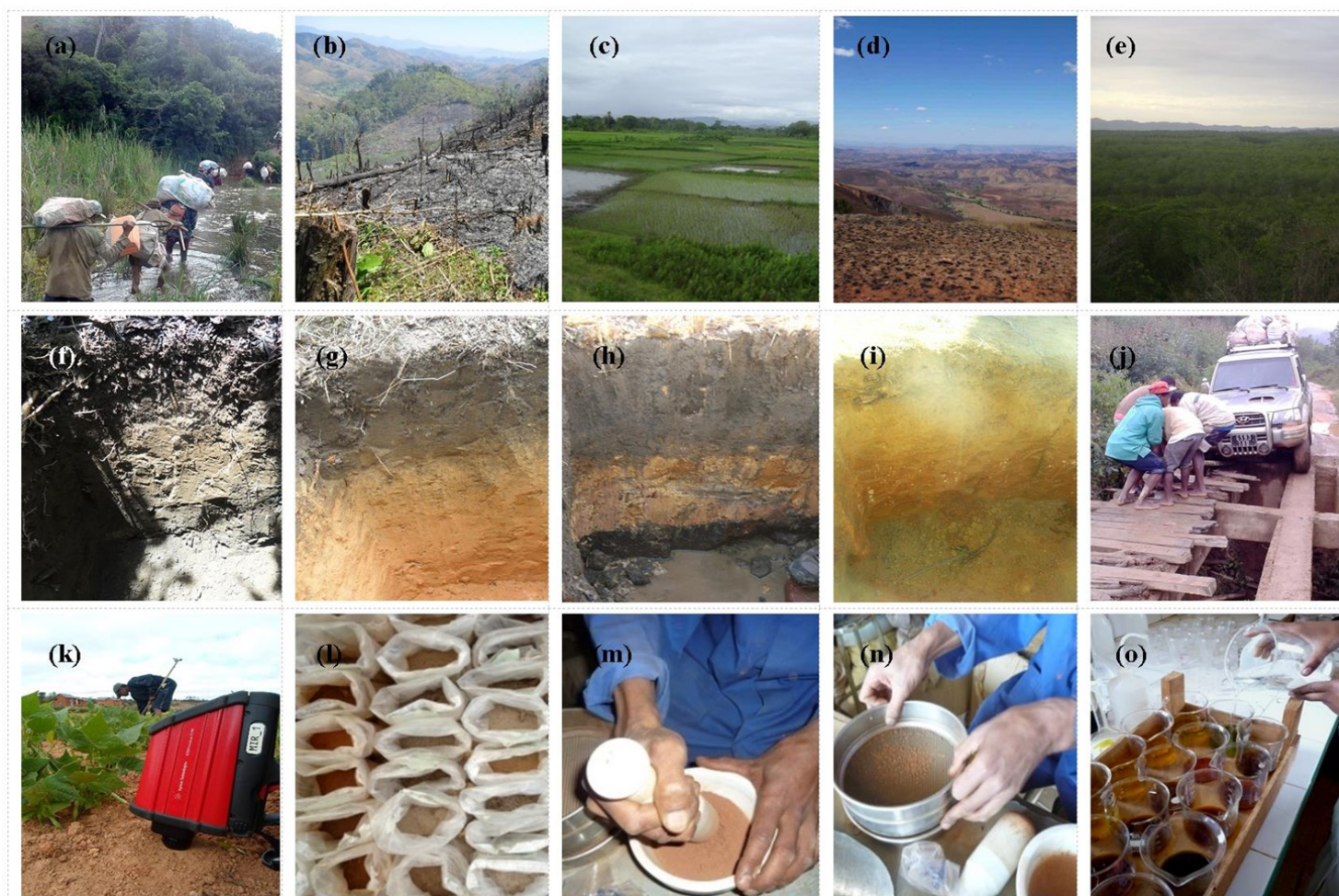
Fig.2.Challenge in soil sampling for agronomical and environmental research

**(Photos N. Ramifehiarivo, N. Ramboatiana, M. Razafindrakoto, A. Rina, N. Rakotovao)**

5 years revolutionized the soil research, but much remains to do for achieving efficient national soil research goals in terms of : soil sampling, capacity building in modelling, in data mining and analysing library of spectral data, in producing more interactive maps for the users (mapping of nitrogen and phosphorus for agronomic purposes) and the governments. Despite these studies, soil inventory is far from complete, because of access difficulties on the field work and the relative large size of the country, therefore, networking and advising are always welcome.

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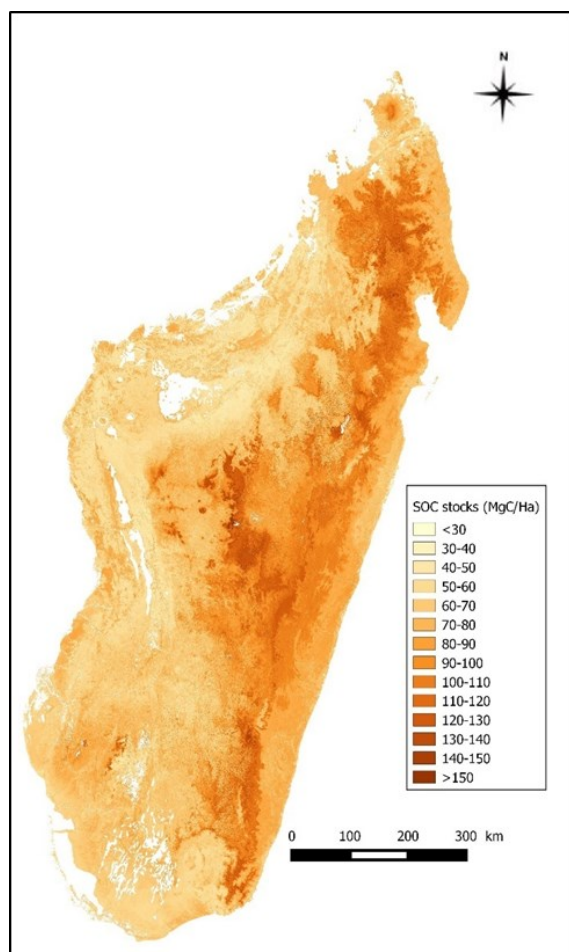
Fig.3. SOCs (MgC.ha⁻¹) distribution map at national scale for the first 30cm soil layer based (2015)
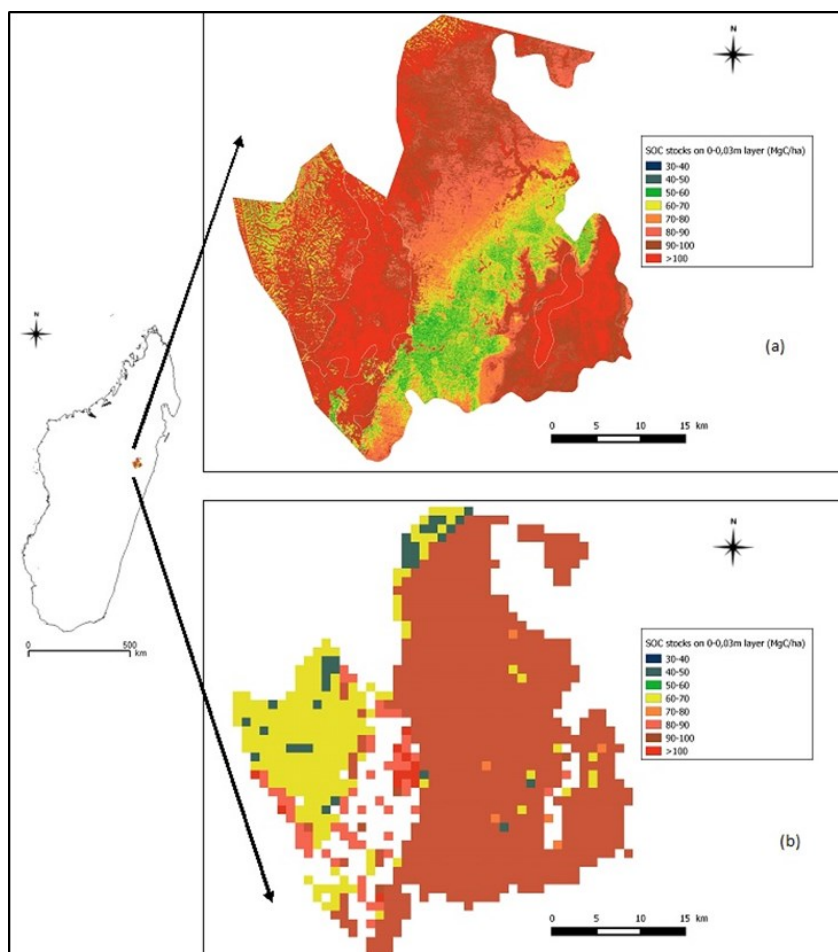
Fig.4. Comparison of SOCs map for the first 30 cm layer in the county of Didy according the new national map (30m ×3 0 m of resolution) (a) and the national map by Grinand et al. (2009) (1km² of resolution) (b)

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Ramifehiarivo Nandrianina is a PhD student at the Laboratory of RadioIsotopes (LRI) of the University of Antananarivo (http://www.laboradioisotopes.com/), Madagascar. His research interests are: soil science, DSM, remote sensing, agronomy and Environment.

Herintsitohaina Razakamanarivo and Michel Brossard are Nandrianina's supervisors and they have closely followed the history of soil survey in Madagascar. Three of them are working closely with other IRD UMR Eco&Sols members, UMR Espace-dev, FTM, ETC-Terra Madagascar and Conservation International Madagascar.

Comment traduire «le Clavier sphérique»?

By Murray Lark
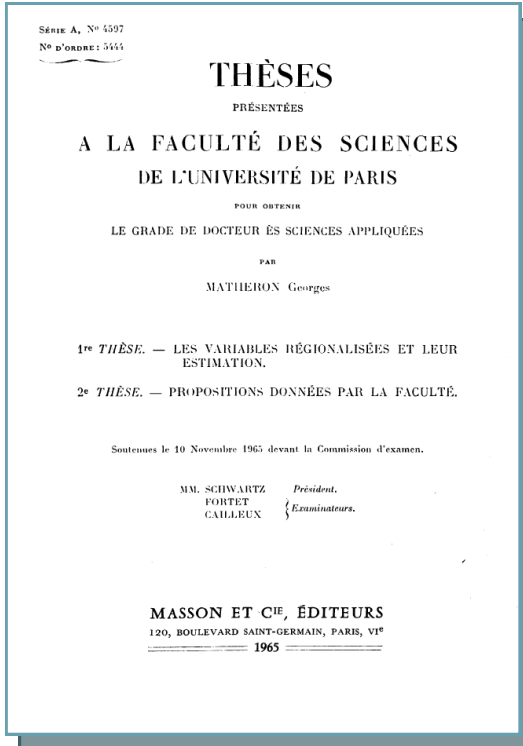
One of the most interesting geostatistical resources on the web is the catalogue of publications at the Centre de Géostatistique of the Ecole des Mines in Paris. There you can find PDFs of articles by luminaries such as Georges Matheron written in the 1950s, alongside the centre's most recent output. The link to the site is here http://cg.ensmp.fr/bibliotheque/cgi-bin/public/bibli_index.cgi

It was while browsing through this resource that I came upon a curious linguistic question. One of the foundational documents in geostatistics is Matheron's thesis from 1965: *Les variables régionalisées et leur estimation: une application de la théorie des fonctions aléatoires aux sciences de la nature*, regionalized variables and their estimation, an application of the theory of random functions to natural sciences. Chapter 1, *Le symbolisme Transitif*, sets out the general concepts of random fields with five principal sections or *paragraphes.* In section 3, Matheron introduces the idea of the operation of grading (*montée*) for passing from a random variable in n to $n-1$ dimensions. One can think of this as the process of finding the variogram in $n-1$ dimensions for a uniform regularization of a random field in n dimensions consider, as an example, a 2-D plane in which the value at location $Z_2(\mathbf{x}_1, \mathbf{x}_2)$ is the mean of a 3-D random field $Z_3(\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3)$ with $\mathbf{x}_1$ and $\mathbf{x}_2$ fixed and $\mathbf{x}_3$ taking all values in $R,$ the domain of interest i.e.

$$Z_2(\mathbf{x}_1, \mathbf{x}_2) = \int_{\mathbf{x}_3 \in R} Z_3(\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3)$$

The summary of section 4 (page 17 of the thesis) then *donne le formalisme de la montée pour les covariogrammes isotropes (claviers).* i.e. it gives the formalism of grading for isotropic variograms, but how to translate the word in brackets? The translation of *montée* as 'grading' is found, for example, in Journel's and Huijbregts's well-known textbook of 1978, but there is no equivalent to the mysterious *clavier*.

Chapter 2 continued the development, it is entitled *Exemples de claviers isotropes*, and section 5 (page 56) is devoted to *le clavier sphérique*. Most French dictionaries that I consult give only one translation for *clavier* and that is 'keyboard', denoting either a musical keyboard or a keyboard for an *ordinateur* such as the one on which I am typing this. In fact if you Google 'clavier spherique' you will find some curious examples of spherical keyboards, but those are clearly not what Matheron had in mind.

> Le paragraphe 4 donne le formalisme de la montée pour les covariogrammes isotropes (claviers). Un peu plus difficile que les 3 premiers, il est indispensable pour comprendre le phénomène essentiel de la régularisation à la montée. Après avoir mentionné les anomalies possibles dûes à un effet rectangulaire, on définit montées et descentes par la transformation de Fourier-Hankel (1,4,6), puis, directement, par une convolution (1,4,18).

When I first read the document I consulted with Dick Webster, a non-native French-speaking geo-statistician (who also appears in the list of authors in the Centre de Géostatistique's catalogue). He was unable to help, and offered to contact some of his former colleagues at Fontainbleau, but none of them were able to shed any light. However, some further digging has suggested that the word has sometimes been translated as "scheme". In a conference paper by Mardia (2007), for example, the author refers to exponential, spherical and Matérn schemes, and the word appears in some later English language articles by Matheron himself, but not specifically in relation to the *montée* (grading) process.

Google gave me a further clue, with a citation of a paper by Gneiting (2002) who, discussing compact correlation functions and their grading, points the reader to some of the earlier pages of Chilès and Delfiner (1999) which relates Matheron's distinctive *montée* term to the radon transform (page 72). Gneiting, infuriatingly, quotes Matheron directly the *clavier sphérique* (no English translation offered) is a set of functions which include the spherical but also the cubic and penta models (see page 84 of Chilès and Delfiner, 1999). Now here we are getting somewhere, because the cubic model is a grading of the pentaspherical model from its natural five dimensions to 2, and the penta model is a grading of an equivalent model from an initial seven dimensions. Further, when we leaf back a few pages in Chilès and Delfiner (1999) we find that they define the spherical model in very general terms. In most geostatistical parlance the spherical correlation with distance parameter *a* over lag *h* is the proportion of the joint volume of two spheres (3D) each of radius *a* and with centres *h* apart which is in the overlap between them. For Chilès and Delfiner (1999) spherical applies to the 2D and 1D case as well (i.e. the circular and linear-with-sill models). It would seem, then, that the *clavier sphérique* comprises the spherical correlation functions in this broad sense, and their gradings by the Radon transform.

But the linguistic problem remains, at the very least I want to know why a word that normally translates as "keyboard" can be rendered as "scheme" I continued to look in dictionaries. A few years ago I found *Le Petit Robert* published in 1977 by the *Société du Nouveau Littré* under the editorship of A. Rey and J. Rey-Debut. These give a secondary meaning of *clavier* as an extension of the sense of keyboard to the musical stave, but indicate that it is not restricted to this literal interpretation but could also be used in an expression such as *clavier des sentiments*, which we might render in English as "emotional range". The online Larousse, similarly, quotes *gamme* as a synonym, which we might translate as "gamut" in English denoting a musical scale or, more generally, a set of artistic resources which have some ordered structure to them: not just a hotch-potch but perhaps a spectrum. However, we don't want to complicate matters by using the word "spectrum" since that suggests the frequency domain whereas correlation/covariance/variogram

functions are all specifically in the space or time domain.

Perhaps, then, Gneiting (2002) was justified in not looking for an English equivalent but rather retaining Matheron's original French. By the *clavier sphérique* we mean the "variety", "family", "gamut" or perhaps "suite" of covariance functions obtainable from the geometrical construction outlined above in some number of dimensions, and by using the radon transform to reduce a function to a smaller number of dimensions. The *clavier sphérique* has a certain unity of construction and so of properties (the compact support), but also shows a structured variety in its behaviour (e.g. the abruptness with which the correlation goes to zero at the range). Reflection on the linguistic challenge of translating the (ever linguistically resourceful) Matheron into English can remind us of the beauty of the apparatus that he developed. It is just a pity that the *clavier sphérique* has such troublesome likelihood functions!

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Pedometricians' Favourite Equations

Xiao-Lin Sun (Sun Yat-Sen University)

When I was asked if I have a favourite equation to share with the Pedometrics community, I was excited. After some days of thinking, I recognize the Matérn function is my favourite equation,

$$F(h) = \frac{1}{2^{v-1}\Gamma(v)} \left(\frac{h}{r}\right)^v K_v\left(\frac{h}{r}\right)$$

where h represents the separation distance, v is the smoothness parameter, Γ is the gamma function, r is the distance parameter and K_v is the modified Bessel function of order v. I rarely use other functions to model the variogram after my first time of using the function. This is because the function releases me from working hard to choose one of a few common functions such as spherical and exponential. With a smoothness parameter ranging from 0 to infinity, this function is more general for application than the others.

Brendan Malone (The University of Sydney)

I particularly enjoy the Mahalanobis distance equation. Firstly, the word Mahalanobis has certain prosody to it that I enjoy (although I continually bumble over the pronunciation and misspell it in my writing). Mostly though, I often use distance measurements to gauge how similar different objects are to one another. This could be a taxonomic distance between soils, or it could be the allocation of an object to a class, or it may be the identification of soil-landscape homologues. Distance estimations and specifically the squared Mahalanobis distance is your friend in these and many more similar situations.

The Mahalanobis distance was introduced by P. C. Mahalanobis in 1936 (https://en.wikipedia.org/wiki/Prasanta_Chandra_Mahalanobis). Formally, it is a measure of the distance between a point P and a distribution D (or could be another point). This distance is zero if P is at the mean of D, and grows as P moves away from the mean. The Mahalanobis distance is unitless and scale-invariant, and can be used in both single and multidimensional contexts. In general, if $\vec{x} = [x_1,\ x_1, ..., x_p]^T$ and $\vec{y} = [y_1,\ y_1, ..., y_p]^T$ are multivariate data-points (or observations or records or cases) drawn from a set of p variables with a $p \times p$ covariance matrix S, then the Mahalanobis distance d_m between them is defined as:

$$d_m(\vec{x} - \vec{y}) = \sqrt{(\vec{x} - \vec{y})^T S^{-1} (\vec{x} - \vec{y})}$$

I like to think the Mahalanobis distance is a generalized distance measure that takes account of the correlations of a dataset. This is particularly handy in geospatial soil science applications that often deal with correlated multivariate information data sources. In any case, if the covariance matrix is the identity matrix, the Mahalanobis distance reduces to the Euclidean distance. In fact the Mahalanobis distance corresponds to standard Euclidean distance in the transformed space. If the covariance matrix is diagonal, then the resulting distance measure is called a normalized Euclidean distance.

Ben Marchant (British Geological Survey)

My favourite equation has to be Fisher's Equation. When he wasn't developing analysis of variance or maximum likelihood estimation Sir Ronald Aylmer Fisher found time to suggest a model for the spatial spread of a favoured gene into a population. It is written (in dimensionless units):

$$\frac{\partial u}{\partial t} = u(1-u) + \frac{\partial^2 u}{\partial x^2},$$

where $u(x,t)$ is the population of the favoured gene at position x and time t. Thus, the gene undergoes logistic growth and diffusion.

This model is very popular amongst mathematical biologists because all sensible initial conditions evolve to waves that have a fixed shape and advance at a constant speed. Also, standard undergraduate mathematics techniques can be used to determine that speed. Variants of Fisher's Equation have been used to model wound healing, the spread of cancer and the invasion of countless species into different environments. Most importantly however, these equations provided me with enough material to complete undergraduate, masters and doctoral projects without ever having to study anything more complicated such as computational fluid dynamics and the Navier-Stokes Equations.

What Does the Shannon Equation Really Mean?

By Brian Murphy[1]

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Pedometron always provides interesting and challenging reading and it was pleasing to see the short article on Pedometricians' Favourite Equations in Pedometron 38, page 25. The equation for Shannon's entropy suggested by Ana M Tarquis especially interested me. Dr Tarquis emphasises the importance and utility of the Shannon equation:

$$H = -\sum_{i=1}^{M} P_i \log_2 P_i$$

mainly for its use as a measure of diversity and heterogeneity including biodiversity and pedodiversity. The Shannon statistic is seen as a measure of randomness and entropy within systems. I would like to support and enhance Dr Tarquis' emphasis on the importance of this equation for soil science.

While this use of the Shannon equation is useful for the purposes outlined by Dr Tarquis, I would like to draw attention to the intent and purpose of the equation as defined in Shannon's original 1948 paper.

"The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages. (Source: Shannon 1948, p1)"

The definition and description of the Shannon equation in Shannon's original paper implies a considerably broader application and meaning beyond that suggested by Dr Tarquis. I admit I came across the Shannon Equation in 1974 at a lecture on human communication at the University of New England in Armidale in New South Wales and have been intrigued and wondered about its meaning and implications for a long time.

The Shannon equation is intended to measure the number and effectiveness that messages are communicated. Hence the Shannon equation is potentially even more powerful and important than suggested by Dr Tarquis. It can be used to measure the information and message carrying capacity of a set of data. The set of data may be the mean and standard deviation of polygon of a soil map or some other data set.

The difficulty in applying the equation with Shannon's original intention is identifying the messages to which it refers in any system. In a Morse Code system (for which Shannon's equation was originally developed and hence the binary system based on log to the base 2), the messages are strings of letters which them become words. The Shannon Equation can be complex in its application and can appear in different forms depending on the context in which it is applied.

In a soil system, a reasonable assumption is that the messages will refer to the state of the soil for particular purposes or uses and the physical and conceptual entities around interpretation tables for soil data would be a logical system to identify messages about soils. Note that this may not simply refer to the raw soil data, but potentially may also be based on the interpretations made on the soil data. The messages need to identify the state of the soil condition in a particular context (soil pH, ESP, EC, clay content, etc.). Expected messages are:" the soil is in good condition", "the soil is in poor condition", "soils are acidic requiring lime amelioration", or "soils are not acidic".

Applying the Shannon Equation in this way has several potential advantages for soil science.

1. It can provide a mathematically based estimate of the amount of information included in a soil map of an area. The estimate of the amount of information can be based on specific soil properties that are considered important for land management or environmental management. This will be a more realistic estimate of the amount of information available than one based on the use of means, standard errors or coefficients of variation of soil properties alone.

2. This approach to the measurement of soil information can provide a link between the numerous sources of used for interpreting soil data (e.g. Peverill et al. 1999; Sanchez et al. 2003; Hazelton and Murphy 2007; USDA 2015) and the mathematical measurement of information levels and uncertainty in soils. This can only be seen as useful for the practical application of soil science.

3. This approach to the measurement of soil information can also add a new perspective to the meaning of uncertainty in soil mapping by the emplacement of a land management or environmental management interpretation on the level of uncertainty. It enables statements to be made such as:

   a. There are no sodic surface soils in this map unit.

   b. Acidic surface soils are common in this map unit, recommend testing.

   c. Swelling clays are widespread in this map unit.

4. It may partially clarify the apparent hiatus that currently exists between traditional pedological soil mapping and digital mapping. It is possible that the measurement of soil information in this way may indicate that many older soil maps (admittedly not all) are also very useful for predicting soil properties based on analysis using an assessment of available soil information.

I have previously discussed and provided an example of the application of the Shannon equation in this way (Murphy 2014). Note that for soils, the information system may not necessarily be a binary system as it does not have to use the dot/dash mechanism employed for Morse Code. The base of the log will depend on the number of states that a soil property may have in the information system, which will often be more than 2.

Shannon's information equation is indeed a fascinating and important equation and many thanks to Dr Tarquis for emphasising its importance.

Reference:

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D G Rossiter, Chairman Pedometrics Awards Committee
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Both the 2015 and 2016 awards will be presented at Pedometrics 2017 (25th anniversary of the first Pedometrics conference) in Wageningen (NL) 26 June- 1 July 2017; you are encouraged to attend (see information at http://www.pedometrics2017.org).

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Please rank the papers in the "instant runoff" system: first choice, second choice, etc. up till the last paper you are willing to vote for, i.e., the last paper that you think would deserve the award. Votes should then be sent to me from a traceable e-mail address (to prevent over-voting). I will apply the instant runoff system to determine the winner. A co-author may not vote for her/his own paper(s), but may vote for any paper(s) where s/he is not a co-author.

The papers are listed here in order of DOI.

1   Lark, R. M., & Knights, K. V. (2015). The implicit loss function for errors in soil information. Geoderma, 251–252, 24–32. http://doi.org/10.1016/j.geoderma.2015.03.014
2   Brus, D. J. (2015). Balanced sampling: A versatile sampling approach for statistical soil surveys. Geoderma, 253, 111–121. http://doi.org/10.1016/j.geoderma.2015.04.009
3   Orton, T. G., Pringle, M. J., & Bishop, T. F. A. (2016). A one-step approach for modelling and mapping soil properties based on profile data sampled over varying depth intervals. Geoderma, 262, 174–186. http://doi.org/10.1016/j.geoderma.2015.08.013
4   Gasch, C. K., Hengl, T., Gräler, B., Meyer, H., Magney, T. S., & Brown, D. J. (2015). Spatio-temporal interpolation of soil water, temperature, and electrical conductivity in 3D + T: The Cook Agronomy Farm data set.Spatial Statistics, 14, Part A, 70–90. http://doi.org/10.1016/j.spasta.2015.04.001
5   De Gruijter, J. J., Minasny, B., & McBratney, A. B. (2015). Optimizing stratification and allocation for design-based estimation of spatial means using predictions with error. Journal of Survey Statistics and Methodology, 3, 19–42. http://doi.org/10.1093/jssam/smu024