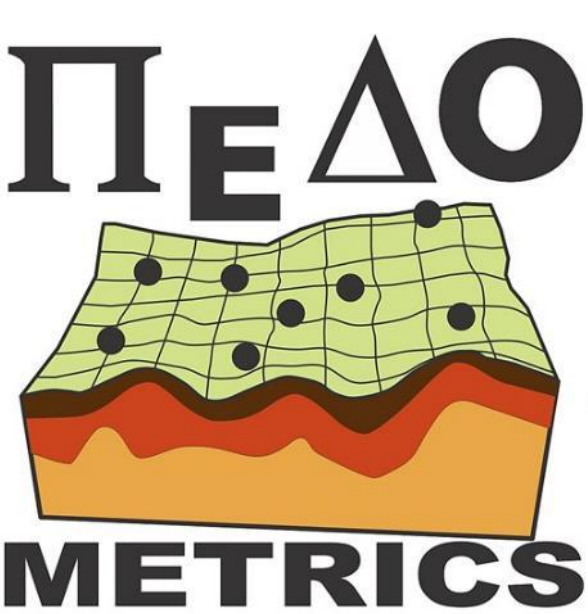

Commission 1.5 of the IUSS presents

PEDOMETRICS 2019

ABSTRACT BOOK

June 2-6, 2019

UNIVERSITY of GUELPH

ORGANIZED BY

Ministry of Agriculture,
Food and Rural Affairs

Agriculture and
Agri-Food Canada

Agriculture et
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PLATINUM CATEGORY

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Fostering collaboration with provincial and federal agencies and research organizations, the International Union of Soil Sciences will host 13th Pedometrics conference of Commission 1.5. Pedometrics 2019 conference will be held on June 2-6, 2019, at the University of Guelph, Guelph, Ontario in collaboration with Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and Agriculture and Agri-Food Canada (AAFC). The main objective on this conference is to identify and prioritize knowledge gaps related to the fundamental similarities and/or dissimilarities between the measurements and methods, scale mis-match, and utilization and incorporation of the information in understanding and developing process-based ecosystem models that are believed to contribute towards sustainable ecosystem.

The commission will host different sessions of the conference along with the responsibility of selecting appropriate abstracts for that session. This publication is a compilation of selected abstracts from the response to the call for abstracts to present at Pedometrics 2019.

Compiled and designed by Local Organizing Committee of the conference.

Available online from 30 May 2019.

Pedometrics 2019
At
University of Guelph
50 Stone Rd E, Guelph, Ontario, Canada
Web: http://www.pedometrics2019.com

LOCAL ORGANIZING COMMITTEE

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Associate Professor, University of Guelph, Canada

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Assistant Professor, University of Guelph, Canada

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Sytze de Bruin - Wageningen University, the Netherlands

Titia Mulder - Wageningen University, the Netherlands

Tom Bishop - the University of Sydney, Australia

Tom Orton - University of Queensland, Australia

Tomislav Hengl - OpenGeoHub, the Netherlands

Xiaoyuan Geng - Agriculture and Agri-Food Canada, Canada

Zamir Libohova - USDA-NRCS-National Soil Survey Center, USA

Zhou Shi - Zhejiang University, China

PROGRAM DETAILS

Sunday, June 2nd	
8:30 – 9:00	**Arrival and Set up for Workshop**
9:00 – 17:00	**Pre-conference Workshop** ***(THRN 1307)***
16:00 – 20:00	**Registration** ***(Peter Clark Hall)***
18:00 – 21:00	**Welcome Reception** ***(Peter Clark Hall)***
	18:00- Opening mixture with food and drink
	19:00- Welcome remarks by the conference Chair- Asim Biswas

Monday, June 3rd		
7:30 – 8:30	**Breakfast** ***(Peter Clark Hall)***	
8:30 – 10:00	**Opening Ceremony and Plenary** ***(Peter Clark Hall)***	
	8:30- Welcome speech by the conference Chair- Asim Biswas	
	8:35- Welcome speech by Vice-President (Research)- Malcolm Campbell	
	8:40- Welcome speech by RDT Director (A), AAFC- Antonet Svircev	
	8:45- Welcome speech by Assistant Deputy Minister, OMAFRA- Debra Sikora	
	8:50- Welcome speech by Pedometrics Chair- Titia Mulder	
	9:00- Plenary 1- Dominique Arrouays, INRA, France	
	9:25- Plenary 2- David Lobb, University of Winnipeg, Manitoba, Canada	
	9:50- Discussion/ QA	
10:00 – 10:30	**Coffee Break** ***(Peter Clark Hall)***	
	Session 1A Oral Presentations (Peter Clark Hall)	***Session 4A Oral Presentations (THRN 1200)***
10:30 – 10:50	Title: Digital Soil Mapping and Laws of Geography Presenter: A-Xing Zhu Authors: A-Xing Zhu, Jing Liu	Title: Comparison of soil organic carbon maps of France using global and national soil databases Presenter: Songchao Chen Authors: Songchao Chen, Vera Latitia Mulder, Gerard Heuvelink, Laura Poggio, Manuel Martin, Nicolas Saby, Christian Walter, Dominique Arrouays
10:50 – 11:00	Title: Mapping soil properties in the Canadian managed forest with limited data: comparison of spatial and non-spatial statistical approaches Presenter: Julien Beguin	Title: Efforts towards a national scale, fine resolution grid of soil pH for New Zealand Presenter: Pierre Roudier Authors: Pierre Roudier, Anne-Gaelle

	Authors: Julien Beguin, Geir-Arne Fuglstad, Nicolas Mansuy, David Paré	Ausseil, James McCarthy, Nathan Odgers, Sarah Richardson
11:00 – 11:10	Title: Extrapolation of a structural equation model from one region to another Presenter: Marcos E. Angelini Authors: Marcos E. Angelini, Bas Kempen, Gerard Heuvelink, Arnaud Temme, Michel Ransom	Title: Integrated data mining for national scale probabilistic digital mapping of soil thickness (Australian Case Study) Presenter: Brendan Malone Authors: Brendan Malone, Ross Searle
11:10 – 11:20	Title: Sampling design for large-scale soil mapping based on MaxVol algorithm and Simulated annealing Presenter: Anna Petrovskaia Authors: Anna Petrovskaia, Gleb Ryzhakov, Ivan Oseledets	Title: Comparison between conventional and digital soil mapping approaches for mapping soil hydrological classes in Scotland Presenter: Zisis Gagkas Authors: Zisis Gagkas, Zisis Gagkas, Allan Lilly, Nikki Baggaley
11:20 – 11:30	Title: Geospatial Data Modelling by Integrating Sensor-Fused Data in Agricultural Field Management Presenter: Md Saifuzzaman Authors: Md Saifuzzaman, Viacheslav Adamchuk, Asim Biswas, Shiv Prasher, Nicole Rabe	Title: An evaluation of the predictive power of a soil map from western Nigeria Presenter: Fasina Abayomi Sunday Authors: Fasina Abayomi Sunday
11:30 – 11:40	Title: Limited spatial transferability of the relationships between kriging variance and soil sampling spacing in some grasslands of Ireland and its implication for sampling design Presenter: Xiaolin Sun Authors: Xiaolin Sun	Title: Supporting Enhanced Forest Resource Inventories using Machine Learning for High-Resolution Digital Soil Mapping Presenter: Christopher Blackford Authors: Christopher Blackford, Brandon Heung, Kara Webster
11:40 – 11:50	Title: A Novel Latent Variable Approach for Factorial Modeling of Soil Carbon in Florida Presenter: Sabine Grunwald Authors: Setyono Hari Adi, Sabine Grunwald	Title: Mapping functional soil properties of the McMurdo Dry Valleys, Antarctica Presenter: Pierre Roudier Authors: Pierre Roudier, Fraser Morgan
11:50 – 12:00	**Discussion**	
12:00 – 13:00	**Lunch *(Peter Clark Hall)***	

	Session 1B Oral Presentations (Peter Clark Hall)	*Session 4B Oral Presentations (THRN 1200)*
13:00 - 13:20	Title: Ensemble machine learning as a generic framework for soil data science Presenter: Tomislav Hengl Authors: Tomislav Hengl, Madlene Nussbaum	Title: New Field Research Paradigms in the Digital Agriculture Era Presenter: Harold van Es Authors: Harold van Es
13:20 - 13:30	Title: Machine learning in soil research: Model tuning by differential evolution Presenter: Mareike Ließ Authors: Mareike Ließ, Anika Gebauer, Monja Ellinger, Victor Brito Gomez	Title: A Bayesian Belief network to operationalize the concepts of Soil Quality and Health Presenter: Ron Corstanje Authors: Ron Corstanje, Kirsty Hassall, Joanna Zawadzka, JIm Harris, Alice Milne, Andy Whitmore
13:30 - 13:40	Title: Developing an interpretable machine learning method for digital soil mapping Presenter: Feng Liu Authors: Feng Liu, Ganlin Zhang	Title: Progress on application of soil infrared spectroscopy in agricultural and environmental management in developing countries and remaining challenges Presenter: Keith Shepherd Authors: Keith Shepherd
13:40 - 13:50	Title: Evaluating the Accuracy of Machine Learning Based Digital Soil Mapping Models for Multiple Categories of Environmental Variables in an Agricultural Landscape Presenter: Siddhartho S Paul Authors: Siddhartho S Paul, Nicholas Coops, Mark Johnson, Maja Krzic, Sean Smukler	Title: Minimum detectable difference: using composites or using NIR spectroscopy? Presenter: Cesar Guerrero Authors: Romina Lorenzetti, Romina Lorenzetti
13:50 - 14:00	Title: Transfer learning to localise a continental soil vis-NIR calibration mode Presenter: Jose Padarian Authors: Jose Padarian, Budiman Minasny, Alex McBratney	Title: Mapping soil organic carbon content using crop phenology parameters extracted from NDVI time series data Presenter: Lin Yang Authors: Lin Yang, XiangLin He
14:00 - 14:10	Title: Oblique coordinates as covariates for digital soil mapping Presenter: Anders Bjorn Miller	Title: Developing a crop suitability assessment framework for underutilised crops Presenter: Ebrahim Jahanshiri Authors: Ebrahim Jahanshiri, Tengku Adhwa

	Authors: Anders Bjorn Miller, Amelie Beucher, Nastaran Pouladi, Mogens Humlekrog Greve	Syaherah Tengku Mohd Suhairi, Nur Marahaini Mohd Nizar, Ayman Salama
14:10 - 14:20	Title: Three-dimensional modelling and mapping of soil constraints, combining machine learning and geostatistical methods Presenter: Thomas Orton Authors: Thomas Orton, Neal Menzies, Yash Dang	Title: A Government-funded Program of Applied Pedometrics to Stimulate Agricultural Growth in Tasmania, Australia Presenter: Darren Kidd Authors: Darren Kidd, Mathew Webb, Budiman Minasny, Brendan Malone, Alex McBratney
14:20-14:30	**Discussion**	
14:30 – 15:00	**Coffee Break *(Peter Clark Hall)***	
15:00 – 15:20	Title: Accounting for conditional bias in digital soil mapping with proximal soil sensing data Presenter: Gerard Heuvelink Authors: Gerard Heuvelink, Laura Poggio, Alexandre Wadoux	Title: The importance of soil for global ecosystem modelling Presenter: Vera Leatitia Mulder Authors: Vera Leatitia Mulder, Alexandre Wadoux
15:20 – 15:30	Title: Mapping soil salinity in three-dimensions using EM38 and EM34 data and inversion modelling Presenter: John Triantafilis Authors: Jie Wang, Jie Wang, John Triantafilis	Title: Soil, climate and native tree species in Great Britain Presenter: Laura Poggio Authors: Laura Poggio, Alessandro Gimona, Enrico Simonetti, Alison Hester
15:30 – 15:40	Title: Using Neural Networks to Predict SOM of Moist Samples by VisNIR Spectroscopy Presenter: Changkun Wang Authors: Changkun Wang, Xianzhang Pan	Title: Multi-method soil carbon assessment in the Peruvian Central Andes Presenter: Sabine Grunwald Authors: Carla Gavilan, Sabine Grunwald
15:40 – 15:50	Title: Temporal harmonization of a national dataset for spatial prediction of soil organic carbon Presenter: Guillermo Federico Olmedo Authors: Guillermo Federico Olmedo, Marcos Angelini, Guillermo Schulz, Dario Rodriguez, Miguel Taboada, Carla Pascale, Dardo Escobar, Mario Guevara,	Title: Parameter optimisation of a multi-level unsaturated water balance model Presenter: Niranjan Wimalathunge Authors: Niranjan Wimalathunge, Niranjan Wimalathunge, Thomas Bishop

	Gerard Heuvelink, Juan Colazo, Juan Gaitan	
15:50 – 16:00	Title: The effects of grinding on spectral information in the mid-infrared Presenter: Anne Neuser Authors: Anne Neuser, Jannis Heil, Rolf Neuser, Bernd Marschner, Britta Stumpe	Title: Monitoring soil moisture using observations from multiple spatial supports. Presenter: James Patrick Moloney Authors: James Patrick Moloney, Thomas Bishop, Dan Pagendam, Ross Searle
16:00 – 16:10	Title: Delineating soil horizons using digital images Presenter: Yakun Zhang Authors: Yakun Zhang, Alfred Hartemink	Title: Is it possible for a soil physics lab not only to perform analyzes but also to add recommendations on soil management? Presenter: Rubismar Stolf Authors: Rubismar Stolf
16:10 – 16:20	Title: Can we adequately predict particle size distribution from MIR spectral signature? Presenter: Tegbaru Bellete Authors: Tegbaru Bellete, Hailu Shiferaw	Title: Is anyone using the results of pedometrics applications? In Australia the answer is yes. Presenter: Ross Searle Authors: Ross Searle, Linda Gregory, David Freebairn, Tim MClelland, Geoff Downes
16:20 – 16:30	**Discussion**	
16:30 – 18:00	***Poster Presentations (Peter Clark Hall)***	
Poster 1	Title: Field scale digital soil mapping of clay using ancillary data and common models Presenter: Maryem Arshad Authors: Maryem Arshad, Maryem Arshad, Nan Li, Lawrence Di Bella, John Triantafilis	
Poster 2	Title: Prediction of Soil Hydrologic Properties On Sodic and Saline Soils Presenter: Hans Klopp Authors: Hans Klopp, Will Bleam, Francisco Arriaga	
Poster 3	Title: Depth Function Analysis for Soil Cores across Middlesex County Presenter: Sarah Lepp Authors: Sarah Lepp, Asim Biswas, Daniel Saurette	
Poster 4	Title: Error assessment of Soil Organic Carbon Pools from incubation to spatial predictions in managed landscapes of Midwest United States Presenter: Kabindra Adhikari Authors: Zamir Libohova, Phillip Owens, Kabindra Adhikari, Diane Scott	
Poster 5	Title: Model building for spectrometric functions of soil organic carbon Presenter: Mareike Ließ Authors: Monja Ellinger	

Poster 6	Title: Mapping clay and soil organic matter contents for fields without samples using electrical conductivity and aerial imagery Presenter: Anders Bjorn Moller Authors: Anders Bjorn Moller, Amelie Beucher, Nastaran Pouladi, Mogens Humlekrog Greve
Poster 7	Title: Prediction of physicochemical soil parameter on spectra of sieved soil samples Presenter: Anne Neuser Authors: Anne Neuser, Jannis Heil, Britta Stumpe
Poster 8	Title: Using deep learning for Digital Soil Mapping Presenter: Jose Padarian Authors: Jose Padarian
Poster 9	Title: Surprisingly high variation of soil map diversity in country-wide study of flood-affected areas using the high-density legacy data Presenter: Jan Skala Authors: Jan Skala,
Poster 10	Title: Quantitative soil quality indices for benchmark soils in Taiwan Presenter: Tai-Hsiang Huang Authors: Shyh-Wei Chen, Shyh-Wei Chen, Tai-Hsiang Huang, Yun-Jie Lai, Yi-Ting Lee, Shen-De Chen, Chia-Hsing Lee, Ming-Yang Syue, Zueng-Sang Chen, Zeng-Yei Hseu
Poster 11	Title: Delineating soil horizons using pXRF and vis-NIR Presenter: Yakun Zhang Authors: Yakun Zhang, Alfred Hartemink
Poster 12	Title: Soil Information Integration for Agroecological Intensification policy development in Indonesia Presenter: Sabine Grunwald Authors: Setyono Hari Adi, Sabine Grunwald, Stefan Gerber, Walter Bowen, Denis Valle
Poster 13	Title: Accumulation rates and chronologies from depth profiles of 210Pb in sediments of northern Beibu Gulf, South China Sea Presenter: Jing Guo Authors: Jing Guo, Yinghui Wang, Ozeas Costa Jr.
Poster 14	Title: Digital Soil Mapping Using Remote Sensing Derived Products and Machine Learning Algorithm: The Case of the Upper Awash Sub Basin, Ethiopia. Presenter: Ashenafi Ali Abduljelil Authors: Ashenafi Ali Abduljelil, Berhan Gessese Aweke, Tulu Besha Bedada
Poster 15	Title: Pedometric techniques for detailed soil class mapping using topsoil reflectance data Presenter: Marilusa Pinto Coelho Lacerda Authors: Marilusa Pinto Coelho Lacerda, Raul Poppiel, Jose Dematte, Manuel Oliveira Jr, Bruna Gallo, Jose Safanelli

Poster 16	Title: Identifying microplastic in soil using NIR spectrometer and deep learning Presenter: Wartini Ng Authors: Budiman Minasny, Wartini Ng, Alex McBratney
Poster 17	Title: A first survey of glomalin related soil protein using digital soil mapping in France Presenter: Wartini Ng Authors: Nicolas Saby, Siobhan Staunton, Cisse Gaoussou, Wartini Ng, Budiman Minasny, Songchao Chen, Dominique Arrouays, Herve Quiquampoix
Poster 18	Title: Soil erosion risk and SOC-balance based on remote sensing data for bioenergy purposes Presenter: Bruna Gallo Authors: Bruna Gallo, Paulo Magalhaes, Jose Dematte, Walter Cervi, Raul Poppiel, Jose Safanelli
Poster 19	Title: Modeling of Soil Temperature Based on Soil and Environmental Characteristics in Cold Season Presenter: Solmaz Fathololoumi Authors: Solmaz Fathololoumi, Ali Reza Vaezi, Seyed Kazem Alavipanah, Asim Biswas
Poster 20	Title: Predictive modelling and digital soil mapping of microbial community diversity and soil organic matter properties in Atlantic Canada. Presenter: Sheldon Hann Authors: Louis-Pierre Comeau
Poster 21	Title: Characterizing Soil Hydromorphism in Riparian Zones by Magnetic Susceptibility Presenter: Komathy Prapagar Authors: Komathy Prapagar, Richard Heck, Naresh Thevathasan
Poster 22	Title: Use of Terrestrial Laser Scanner to estimate waste volume of iron ore in fluvial terraces Presenter: Marcio Rocha Francelino Authors: Eliana dos Elizabet dos Santos, Marcio Rocha Francelino, Elpidio Inacio Fernandes Filho, Carlos Ernesto Goncalves Reynaud Schaefer, Felipe Carvalho Santana
Poster 23	Title: Monitoring agricultural land use change trend using remote sensing and GIS-based approach Presenter: Zohreh Alijani Authors: Zohreh Alijani, Asim Biswas
Poster 24	Title: Scale dependency of environmental variables on soil organic carbon prediction across the conterminous USA Presenter: Kabindra Adhikari Authors: Kabindra Adhikari, Umakant Mishra, Phillip Owens, Skye Wills, Zamir Libohova, David Miller

Poster 25	Title: In-Situ Characterization of Soil Properties and Horizon Separations to depth using Vis-NIR Spectroscopy Presenter: Rebecca-Jo Vestergaard Authors: Rebecca-Jo Vestergaard, Doug Aspinall, Songchao Chen, Adam Gillespie, Vischeslav Adamchuck, Asim Biswas
Poster 26	Title: Mapping of soil thickness in mountainous, upland and hilly area of Japan using small-catchment-scale and regional-scale sampling data Presenter: Naoyuki Yamashita Authors: Naoyuki Yamashita, Yasuhiro Ohnuki
Poster 27	Title: Evaluation of Global Soil Moisture Predictions based on Remote Sensing and Digital Terrain Analysis Presenter: Mario Guevara Authors: Mario Guevara
Poster 28	Title: A Row Detection Algorithm for Paddy Rice Seedling Based on Convolutional Neural Network Presenter: Shaomin Lin Authors: Shaomin Lin, Long Qi, Asim Biswas
18:00 – 19:00	**Industry Sponsored Session *(Peter Clark Hall)*** 1800- Opening Remarks- Adam Gillespie 1805- Malvern Panalytical- Robert Cocciardi 1815- DualEM- Rick Taylor 1825- Korechi and SoilOptix- Sougata Pahari and Ryan Eyre 1840- Spectral Evolution- Joseph Mayr 1850- Terraplus- Claude Meunier
19:00 – 22:00	**Conference Dinner and Award Ceremony *(Science Complex Atrium)***
Tuesday, June 4th Field Trip to Niagara Falls	
7:30 – 8:00	**Breakfast (*Peter Clark Hall*) and Boarding**
8:00 – 9:30	**Travel to Field Site**
9:30 – 12:00	**Field Visit at Hipple Farm** 09:30: Field Trip Overview 09:35: Welcome to Hipple Farms—Larry and David Hipple 09:50: Geology of Niagara Region—John Menzies, Brock University 10:05: Soil of Niagara Region—Daniel Saurette 10:20: Proximal Soil Sensing of Hipple Farms—Asim Biswas 10:30: Digital Soil Mapping of Hipple Farms—Daniel Saurette 10:45: Soil Profile (1 of 2)

	11:15: Soil Profile (2 of 2) 11:45: Proximal Sensing and Automation Demo—Soil Optix and Korechi	
12:00 – 13:00	**Lunch at Hipple Farm (onsite)**	
13:00 – 14:00	**Travel to Niagara Falls**	
14:00 – 17:30	**Recreation Visit to Niagara Falls, 'Hornblower Niagara Cruise' visit**	
17:30 – 18:30	**Travel to Winery**	
18:30 – 19:30	**Winery tour, and wine testing (Hernder Estate Winery)**	
19:30-21:00	**Dinner (Hernder Estate Winery)**	
21:00 – 22:30	**Travel back to Guelph**	
Wednesday, June 5th		
7:30 – 8:30	**Breakfast (*Peter Clark Hall*)**	
8:30 – 10:00	**Plenary *(Peter Clark Hall)*** 8:30- Updates from GSM- Dominique Arrouays, France 8:35- Updates from DSM- Laura Poggio, The Netherlands 8:40- Updates from Digital Soil Morphometrics- Alfred Hartemink 8:45- Updates from PSS- Zhou Shi 8:50- Updates from soil monitoring- Tom Bishop 9:00- Plenary 3- Alain Houde, AAFC, Ottawa 9:25- Plenary 4- Ross Kelly, OMAFRA, Guelph 9:50- Discussion/ QA	
10:00 – 10:30	***Coffee Break (Peter Clark Hall)***	
	Session 3A Oral Presentations (Peter Clark Hall)	***Session 2A Oral Presentations (THRN 1200)***
10:30 – 10:50	Title: Generating interpreted digital soils data products for agriculture and planning - experiences from Queensland, Australia Presenter: Lauren O'Brien Authors: Lauren O'Brien, Daniel Brough, Ben Harms	Title: Low-cost portable near-infrared sensors for rapid analysis of soil Presenter: Budiman Minasny Authors: Budiman Minasny, Yijia Tang, Edward Jones
10:50 – 11:00	Title: Comparing traditional and digital soil mapping at a district scale using residual maximum likelihood analysis Presenter: Ehsan Zare Authors: Ehsan Zare	Title: Development of a low-cost NIR spectrometer for proximal soil sensing in low resource settings Presenter: Matthew D Keller Authors: Matthew D Keller, James Stafford, Wenbo Wang, Benjamin Wilson

11:00 – 11:10	Title: Multielement geochemical modelling for differences in topsoil pollution along the environmental gradient near the coal fields Presenter: Skala Jan Authors: Skala Jan	Title: Comparison and complementarity of color, VIS, NIR, MID and LIBS spectroscopic methods for soil analysis Presenter: Marie-Christine Marmette Authors: Marie-Christine Marmette, Marie-Christine Marmette, Viacheslav Adamchuk
11:10 – 11:20	Title: Comparison of pedotransfer functions to determine soil bulk density with limited data at a regional scale in the Thompson-Okanagan region, BC Presenter: Jin Zhang Authors: Jin Zhang, Margaret Schmidt, Chuck Bulmer, Anders Knudby, Brandon Heung	Title: Maximizing Utility of the VisNIR-Mounted Penetrometer Presenter: Sarah Hetrick Authors: Sarah Hetrick, Cristine Morgan, Katrina Hutchinson
11:20 – 11:30	Title: A new quantitative model for soil formation based on soil water flow Presenter: Tom Vanwalleghem Authors: Tom Vanwalleghem	Title: Prediction of Soil Organic Carbon Based on In-Situ Vis-NIR Spectroscopy in Poyang Lake Wetland of China Presenter: Hong-Yi Li Authors: Hong-Yi Li, Mao-Tong Zhai, Hang-yu Peng, Zhou Shi
11:30 – 11:40	Title: Tea Bag Index (TBI): as a promising quantitative approach for analysing SOM dynamic and increasing soil connectivity via citizen science Presenter: Vanessa Pino Authors: Vanessa Pino, Kanika Singh, Alex McBratney, Damien Field	Title: The use of vis-NIR and pedotransfer functions to predict moisture storage in sandy soils Presenter: Jenifer L Yost Authors: Jenifer L Yost, Alfred Hartemink
11:40 – 11:50	Title: Automated soil core scanning for high resolution carbon analysis down a soil profile? full inversion tillage case study Presenter: Matteo Poggio Authors: Matteo Poggio, Roberto Calvelo Pereira, Michael Blaschek, Carolyn Hedley, Mike Hedley, Mike Beare, Sam McNally	Title: Actual evapotranspiration and crop coefficient for tropical lowland rice: Eddy Covariance approach Presenter: Sumanta Chatterjee Authors: Sumanta Chatterjee
11:50 – 12:00	**Discussion**	
12:00 – 13:00	**Lunch *(Peter Clark Hall)***	

	Session 3B Oral Presentations (Peter Clark Hall)	*Session 2B Oral Presentations (THRN 1200)*
13:00 - 13:20	Title: Digital pedology? studying soil profiles Presenter: Alfred Hartemink Authors: Alfred Hartemink, Yakun Zhang, Jingyi Huang	Title: Advances in modelling and mapping of global soil information Presenter: Laura Poggio Authors: Laura Poggio, Luis Moreira de Sousa, Gerard Heuvelink, Bas Kempen, Zhanguo Bai, Ulan Turdukulov, Maria Ruiperez-Gonzalez, Eloi Ribeiro, Niels Batjes, Rik van den Bosch
13:20 - 13:30	Title: Colour Features and Visible-Range Spectral Imaging for Soil Organic Carbon Assessment Presenter: Asa Gholizadeh Authors: Asa Gholizadeh, Mohammdmehdi Saberioon, Raphael Viscarra Rossel, Lubos Boruvka	Title: Digital mapping of soil organic carbon in an alluvial plain area of the Terai region of Nepal Presenter: Sushil Lamichhane Authors: Sushil Lamichhane, Lalit Kumar, Kabindra Adhikari
13:30 - 13:40	Title: Surface and undersurface soil drainage inference by sensors located 800 km from the target Presenter: Jose A. M. Dematte Authors: Nelida Elizabet Quinonez Silvero, Rodnei Rizzo, Wanderson de Sousa Mendes, Jose Lucas Safanelli, Merylin Taynara Accorsi Amorim, Julia de Souza Vieira, Benito Bonfatti	Title: Quantification and mapping of soil properties on a profile wall using digital photography Presenter: Jannis Heil Authors: Jannis Heil, Bernd Marschner, Britta Stumpe
13:40 - 13:50	Title: Using Field Data and Airborne LiDAR-acquired Digital Elevation Data to Model Depth to Bedrock at a High Resolution Presenter: Babak Kasraei Authors: Babak Kasraei, Chuck Bulmer, Margaret Schmidt, Brandon Heung	Title: SLAKES Smartphone Application for Aggregate Stability Differentiates Between Different Management Practices Presenter: Kade D. Flynn Authors: Kade D. Flynn, Dianna Bagnall, Cristine Morgan
13:50 - 14:00	Title: Exploring relationships between remotely sensed thermal imagery, EM data, crop yield, and soil texture Presenter: Adam Gillespie	Title: Development of a methodical approach for the detection of soil microbial activity using infrared thermography Presenter: Katharina Schwarz

	Authors: Adam Gillespie, Daniel Saurette, Asim Biswas, Tony Balkwill, John Sulik	Authors: Katharina Schwarz, Bernd Marschner, Britta Stumpe
14:00 - 14:10	Title: Quantification of organic matter and moisture content in soil using cell-phone-based computer vision techniques Presenter: Perry Taneja Authors: Perry Taneja, Asim Biswas, Prasad Daggupati	Title: Mapping cation exchange capacity using a quasi-3d joint-inversion of EM38 and EM31 data Presenter: Dongxue Zhao Authors: Dongxue Zhao, Xueyu Zhao, Tibet Khongnawang, Maryem Arshad, John Triantafilis
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18:00 – 19:00	**Round Table Discussion: Precision Agriculture Research Needs from the Grower and Service Provider Perspective** 18:05- Introduction and discussion structure- Adam Gillespie and Bronwynne Wilton 18:05- Views and Updates of Growers, Growers Association, Industries, Government agencies, researchers 18:30- Discussion 18:55- Wrap up

Thursday, June 6th

7:30 – 8:30	**Breakfast *(Peter Clark Hall)***
8:30 – 10:00	**Award lectures *(Peter Clark Hall)*** 8:30-9:10: Richard Webster Medal lecture: Murray Lark, University of Nottingham, UK 9:10-9:50: Margaret Oliver Prize lecture: Titia Mulder, Wageningen University, The Netherlands 9:50-10:00: Discussion/QA
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11:00 – 11:10	Title: Uncertainty guided sampling optimizes the application of legacy data for soil class mapping	Title: Predicting Soil Properties in 3D: Should Depth be a Covariate? Presenter: Alex McBratney

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11:30 – 11:40	Title: Identifying the spatial drivers and scale-specific variations of soil carbon fractions in a montane natural forest ecosystem in Sri Lanka Presenter: Asim Biswas Authors: Kumari Rajapaksha	Title: Volumetric mapping of soil organic carbon and soil water content with electrical conductivity data Presenter: Tobias Rentschler Authors: Tobias Rentschler, Mario Ahner, Thorsten Behrens, Philipp Gries, Peter Kuhn, Ulrike Werban, Thomas Scholten, Karsten Schmidt
11:40 – 11:50	Title: Exploring how proximal soil sensors account for spatial variability and the effect of scale to optimise soil property estimates in UK precision agriculture Presenter: Jonathan Holland Authors: Jonathan Holland, James Taylor, Benjamin Marchant	Title: Are existing digital maps of soil organic carbon consistent and of equal quality? Presenter: Lemercier Blandine Authors: Amelin Julien, Blandine Lemercier, Yosra Ellili, Vincent Sebastien, Didier Michot, Christian Walter
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	Presenter: Alexandre Wadoux Authors: Alexandre Wadoux, Dick Brus, Gerard Heuvelink	Presenter: Hu Authors: Hu, Hocine Bourenane, Thomas Opitz, Ben Marchant, Dominique Arrouays, Blandine Lemercier, Nicolas Saby
12:00 – 12:10	Title: Disaggregation of legacy soil survey maps in the agricultural region of Saskatchewan using DSMART Presenter: Jeremy Kiss Authors: Jeremy Kiss, Angela Bedard-Haughn	Title: Developing digital soil mapping methodologies for remote areas of the Northern Territory, Australia Presenter: Kaitlyn Andrews Authors: Kaitlyn Andrews, Jonathan Burgess, Jason Hill
12:10 – 12:20	Title: Determining an optimal mathematical model, sample size and ancillary data to map exchangeable calcium and magnesium at the field level Presenter: Nan Li Authors: Nan Li, Maryem Arshad, Michael Sefton	Title: Fussy learning: reducing the fuzziness in legacy soil map disaggregation Presenter: Craig Liddicoat Authors: Craig Liddicoat
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A Mechanistic Model to Predict Soil Texture, in Piracicaba, Brazil

Presenting author: Benito R. Bonfatti
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Authors: Benito R. Bonfatti, Jose Dematte, Nelida Silvero, Wanderson Mendes, Jose Safanelli, Rodnei Rizzo

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: mechanistic models, soil texture, SYSI, mARM3D

Abstract: Mechanistic models are known to used physical theories and techniques derived from the environment study and observations. When applied to soil science, can be useful to understand the soil genesis and to support soil properties prediction and mapping. Mechanistic models use different methods to soil properties prediction, less dependent on soil sampling, when compared to empirical models, which needs a sufficient amount of data, sometimes difficult to be available. Furthermore, mechanistic models deal with the dynamics of pedogenesis, taking in account the geomorphic and pedogenesis evolution. Hence, the soil prediction is not time dependent, allowing to understand the evolution processes and to link with environmental changes. This work aimed to develop a mechanistic model to predict soil texture on the 20 cm soil depth, in Piracicaba city, S?o Paulo State, Brazil. The model of soil prediction was elaborated based on the pedogenesis evolution model mARM3D and the landscape evolution model SIBERIA, which here was implemented in the Python programming language. A landscape evolution model was used initially, to predict erosion and deposition to the whole study area, based on a DEM and precipitation data. An initial grading with a range of particle size was used to pedogenesis evolution model, in which each particle size underwent changes during transport and weathering. The erosion/deposition values from the landscape evolution model were used to determine what particle size would be removed from the soil located on each pixel, based on hydrologic parameters and particle diameter. The technique used in mARM3D is based on transition matrix, herein elaborate to erosion and weathering. A reduce number of sample data was used to model calibration. Weathering functions was used to break symmetrically the particles at each iteration. We assumed that the sand fractions were formed of quartz, undergoing transport by erosion but not broken by weathering. To determine the initial quartz content, we used reflectance information from the orbital images of exposed soils, elaborated as a SYSI image, which used several orbital images varying temporally. The process iterates by year and we considered the iteration evolving up to 100,000 years. Results showed that sand content on soil is strongly dependent of initial grading size condition. Silt content evolves to clay through the time. Clay tends to increase with time, but is limited by the sand (quartz) content on the initial grading of particle size. The evaluation of soil texture prediction was better for places where deposition does not occur. The results depend strongly of the original condition, derived from the parent material. The use of orbital processed image SYSI proved to be an important auxiliary tool during the determination of the sand content in the initial grading of particle size. Overall the technique showed promising to predict soil texture, based on how soil and landscape evolve and using reduce number of sample data.

A New Quantitative Model for Soil Formation Based on Soil Water Flow

Presenting author: Tom Vanwalleghem
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Authors: Tom Vanwalleghem

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: critical zone, soil formation model, soil water dynamics

Abstract: Interest in modelling pedogenesis has increased greatly over the past few years, with the emergence of detailed pedon-scale models (e.g. Soilgen) on the one hand and landscape-scale models (e.g. marm3D, MILESD, LORICA) on the other. Pore water chemistry and chemical weathering is not (well) represented in the latter and needs to be improved in order to adequately model the evolution of soils and of the critical zone. Here, we present a new landscape-scale model, MILESD2, which takes into account the spatial variability of soil water and associated element fluxes. The model takes into account physical and chemical weathering, bioturbation, clay migration and neoformation and erosion processes. Soil production from bedrock is modeled directly as a function of percolation. We show that this approach leads to similar results as the classical empiric approach based on cosmogenic nuclides, with a humped soil production function. The model is then used to explain the vertical and lateral distribution of key soil properties a test area in Southern Spain. We evaluate soil depth, particle size distribution and rock fragment abundance, soil carbon stock and chemical depletion fraction.

A Novel Latent Variable Approach for Factorial Modeling of Soil Carbon in Florida

Presenting author: Sabine Grunwald
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Authors: Setyono Hari Adi, Sabine Grunwald

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: soil environmental modeling, soil carbon, latent variable modeling, regression model

Abstract: Soil-environmental correlation has been extensively studied as a cost-effective method for regional-scale soil attribute modeling. However, the limitations of commonly used statistical methods in soil-factorial modeling entail multicollinearity in Bigdata soil-factorial prediction data and mixed type of (categorical and continuous) soil-environmental variables. Both of these shortcomings were addressed resulting in a new soil-factorial modeling approach. The objective of this study was to develop a novel statistical technique for factorial modeling of topsoil soil total (TC), organic (SOC), recalcitrant (RC), moderately-available (MC), and hot-water extractable carbon (HC) in Florida. We present a two-step regression technique combining linear regressions (i.e., Ridge Regression RR and Bayesian Linear Regression) and latent variable models (i.e., Partial Least Squares Regression PLSR and Sparse Bayesian Infinite Factor SBIF) for the integration of mixed type soil-environmental datasets. Results of this research showed the new technique capabilities to derive acceptable models for TC, SOC, RC, and MC predictions (R2>0.65; residual prediction deviation, RPD>1.6), but fair for HC prediction (R2=0.6; RPD=1.6). This novel method substantially improved TC, SOC, and MC prediction accuracies compared with standard PLSR and RR methods. In conclusion, the new modeling approach that incorporates categorical along with continuous soil-environmental predictor variables in latent variable models has profound potential to improve soil predictions in other regions.

A Row Detection Algorithm for Paddy Rice Seedling Based on Convolutional Neural Network

Presenting author: Shaomin Lin
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Authors: Shaomin Lin, Long Qi

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: Row detection, Computer vision, Paddy filed, Rice seedlings, Convolutional Neural Network

Abstract: The rice seedling rows distribution status in the paddy which seriously concern to the further paddy filed management with efficient agricultural mechanization. However, the laborious and inaccurate manual operation make the transplanter difficult to transplant the rice seedling rows in a straight line. This paper proposes a row central line detection algorithm to improve the accuracy for transplanter navigation system based on computer vision. The proposed algorithm seeks to detect and locate the rice seedlings with an trained convolutional neural network, extract the target row with hierarchical agglomerative clustering and fit the crops in target row with linear least squares. The proposed algorithm was observed to have excellent performance experimentally in various rated setting grades hill space of transplanter with strong illumination robustness in paddy environment condition. The results showed that the RMSE of algorithm in this study for detect the target rice seedling row's central line angle was less than 1° and initial point was less than 6.58 pixels (14.22mm).

An Evaluation of the Predictive Power of a Soil Map from Western Nigeria

Presenting author: Fasina Abayomi Sunday
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Authors: Fasina Abayomi Sunday

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Soil map, predictive power, South Western Nigeria

Abstract: The purity of a soil map of a 100 ha farm at Idoffa in Ogun State was evaluated using some established criteria purity was found to be 67.12%, F-tests showed that 15 out of 19 soil properties studied were effective and significant (P<0.05) in separating the mapping units. Based on intra-class correlation co-efficient, six properties namely colour, structure, consistence, gravel clay and exchangeable Mg were fairly well predicted (P<0.05>). High relative variance value (0.21-1.04) were obtained for all the properties, indicating high variability. Results obtained in this study indicated that the soil map has a moderate to high predictive value in spite of the variability imposed on the land as a result of present land use (grazing) and inherent parent material.

Accounting for Conditional Bias in Digital Soil Mapping with Proximal Soil Sensing Data

Presenting author: Gerard Heuvelink
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Authors: Gerard Heuvelink, Laura Poggio, Alexandre Wadoux

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: digital soil mapping, measurement error, proximal soil sensing, conditional bias, prediction error variance

Abstract: Digital soil mapping takes pride in quantification of the uncertainty associated with spatial predictions of soil properties and soil type. The main sources of uncertainty included are poor predictive power of covariates and model parameter estimation error. However, there is another important source of uncertainty that has long been ignored. This is the measurement error in the soil observations that are used to calibrate the model and used to condition predictions to observations. Measurement uncertainty can be substantial, particularly when the soil is observed indirectly, such as in proximal soil sensing. In this presentation we show how measurement uncertainty can be included in regression kriging of soil properties. The methodology builds on existing techniques developed for kriging, which essentially boil down to adding the measurement error variance to the diagonal of the kriging matrix. We extend this technique by also taking into account that the measurement error may be negatively correlated with the soil property. This "conditional bias" effect may be strong in a case where the soil observations are derived using proximal soil sensing. In such case the measurement error is effectively a smoothing error caused by predicting the soil property from a multivariate spectral signal, using techniques such as partial least squares regression. We show that ignoring the conditional bias effect may significantly underestimate the prediction error variance. We illustrate the methodology with a case study on mapping soil texture for Germany using the LUCAS soil dataset and commonly available environmental covariates.

Can We Adequately Predict Particle Size Distribution from MIR Spectral Signature?

Presenting author: Tegbaru Bellete
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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: LDPSD, MIR, Prediction, Calgon,

Abstract: Laser diffraction particle size distribution (LDPSD) and Mid-infrared spectroscopy (MIR) is currently being introduced in the Ethiopian Soil Information System (EthioSIS) project with the aim of predicting soil properties on a large amount (>100 000) of soil samples. Handling large numbers of soil samples requires efficient processing and analysis methods of soils. Two hundred and ninety three soil samples were randomly selected from this EthioSIS data archive with the aim of predicting soil particle size distribution from MIR spectral data and evaluate their complementarity. All the soil samples were analyzed using HORIBA-Partica (LA-950V2) laser scattering particle size distribution analyzer to determine particle size distribution. The soil samples screened through 2 mm sieve was run in a wet mode using 1% sodium hexametaphosphate (Calgon) solution as dispersing agent. The files were then converted to sand, silt and clay, and reported on a volume basis (%) using the R programming language. The average reading of four records taken from continuous agitation of the particles was considered as final data for the particle size distribution. All the 293 soil samples were also scanned with duplicates of spectral signature using a Bruker-TENSOR 27 with the HTS-XT accessory. The spectra were captured using diffuse reflectance mode the MIR region (4,000 ? 600 cm-1). A Partial Least Squares Regression (PLSR) model created with 40% calibration and 60% out of the box validation datasets were used to predict clay, silt and sand contents. The results showed that the PLSR model didn't fit well for the three particle sizes (R2 = 0.15, rmse = 0.23 for sand, R2 = 0.15, rmse = 0.19 for clay and R2 = 0.16, rmse = 0.2 for silt contents) and very poorly validated; data transformation couldn't improve the model performance too. Therefore, the complementarity of laser scattering particle size distribution and MIR spectral dataset requires further research.

Delineating Soil Horizons Using Digital Images

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Authors: Yakun Zhang, Alfred Hartemink

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: CIE L*a*b*, HSV, local entropy, k-means clustering, tortuosity

Abstract: Here we present a novel way to assess soil horizons, their boundaries, and purity using the image of a Spodosol. Four horizons were identified and delineated in the field: O horizon (not measured), E horizon (0-30 cm), Bhs1 horizon (30-70 cm), and C horizon (70-95 cm). The boundary between E and Bhs1 was described as diffuse and irregular, whereas the boundary between Bhs1 and C was described as gradual and wavy. A soil profile image in JPEG format was taken using a digital camera. Soil color (CIE L*a*b* color) and image texture (local range, local standard deviation, and local entropy) features were extracted from the image, and k-means clustering was used to segment the soil profile. The number of clusters k was tested using field delineated horizons. Then k-1 boundaries were extracted from the lower boundary of each of the k-1 clusters in order to study the boundary features. Boundary features (distinctness, tortuosity, mean curvature, and topography) and horizon features (thickness and purity) were calculated. The CIE L*a*b* color and image texture distinguished three horizons in which the image texture separated the subsoil into a coarse-textured Bhs1 horizon with gravels and a smoother C horizon. The E horizon had the highest purity of 0.92, whereas the Bhs1 had the lowest purity of 0.59. The calculated distinctness of the boundaries was the same as field-delineated boundaries, whereas the topography of the boundaries changed. Tortuosity and mean curvature were used to assess the waviness of horizon boundaries. The method of automated soil horizonation is robust and yields quantitative metrics on horizon purity and boundaries.

Delineating Soil Horizons Using pXRF and vis-NIR

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: proximal soil sensors, soil horizons, clustering, CIE L*a*b* color

Abstract: In this study, we evaluate the use of vis-NIR and pXRF for delineating soil horizons and how these are affected by soil moisture in a Mollisol (A, Ab, E, and Bt) of south-central Wisconsin. The soil profile was scanned in the field (moist) and soil samples were taken that were scanned in the laboratory (dry). The CIE L*a*b* color was extracted from the vis-NIR spectra, and the weathering indices (Ruxton ratio, sesquioxide ratio, calcium/titanium ratio, and silica-titanium index) were calculated from the pXRF data. It was found that soil moisture decreased L*, a*, and b* color coordinates and the elemental concentrations. Soil moisture had little effect on the vertical distribution of the CIE L*a*b* color and pXRF measurements. Moisture effects can be partly reduced by calculating weathering indices. The color variables (a* and b*), and calcium/titanium ratio distinguished A horizons (Ap, A2, and Ab), whereas the Ruxton ratio and sesquioxide ratio distinguished E, Bt1, and Bt2 horizons. The CIE L*a*b* color and pXRF data were excellent variables for delineating soil horizons, and the measurements on moist soil samples performed better than those measured on dry soil samples.

Depth Function Analysis for Soil Cores across Middlesex County

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Presentation Type: Poster

Session 1: Developments in Pedometrics 1: Mathematical and methodological

Keywords: Depth functions, modeling, splines, polynomial regression, sigmoid model

Abstract: Soil depth varies drastically both in large scale (farm fields) and small-scale areas (counties/provinces) as well as across various land use types. To accurately represent soil attributes across an area, standard depths within a soil core must first be calculated to allow three-dimensional mapping. The transformation of variable soil horizons into comparable and mappable depths can be either continuous depths which increment via centimeter, or discrete depths. For the purposes of this investigation, six standard depths (0 - 5 cm, 5 - 15 cm, 15 - 30 cm, 30 - 60 cm, 60 - 100 cm, 100 - 200 cm) will be used. Along with soil depth variability across an area, soil properties within a soil column can display significant variation. To transform variable soil horizons into standard depths, different depths functions are available. The most common and relied on depth function to determine variation of soil properties at different depths is the equal area quadratic spline. This study explores and compares the following depth functions on 1331 soil cores collected in Middlesex County in the 1980?s: the equal area quadratic spline, the 3rd order polynomial regression function, the sigmoid model, the exponential decay function, and four different kriging functions. The comparison of depth functions is crucial for each soil property because different depth functions may be more suitable for different soil properties. This study will determine which depth functions are more appropriate for different soil properties, different soil types, and different land use types. The study expands the soil cores available in Middlesex County out to the WISE Soil Property Database to explore most appropriate depth functions for each land use type nationally and globally.

Developing an Interpretable Machine Learning Method for Digital Soil Mapping

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: machine learning, soil prediction, environmental similarity

Abstract: Machine learning techniques have achieved success of prediction accuracy in quite a few digital soil mapping applications. However, the prediction from these techniques are usually difficult to interpret. The lack of interpretability is not good for advancing our understanding on the relationships between soil and landscapes. To address this issue, this study developed a new machine learning method which not only has good prediction performance but also strong interpretability. Our idea is to integrate individual cognitive inference with team decision making. The former is to mimic soil experts' way of thinking when investigating soil and landscapes in an area. The mimicking is performed through soil prediction based on environmental similarity. The latter is mimic team's way of thinking when making a decision. This mimicking is performed using ensemble strategy. The method was tested in two study areas. One is the Heihe River basin located in northwestern China, with 298 soil sampling sites, and another is the Anhui province of eastern China, with 150 soil sampling sites. Environmental covariates used in this study include mean annual air temperature, annual precipitation, parent materials, elevation, aspect, slope gradient, profile curvature, planform curvature, MrVBF, TWI, NDVI, and remote sensing images. The targeted soil variables are silt content, CaCO3 content and soil groups for the Heihe River basin and SOM and soil pH for the Anhui province. The proposed method was evaluated through the comparisons with conventional similarity-based prediction method and frequently used random forest method. Leave-one-out cross validation was used to calculate prediction accuracy. The results showed that the prediction accuracy of our method is at the same level with (slightly better) that of random forest. Both our method and random forest are much better than conventional similarity-based prediction method in terms of prediction accuracy. More importantly, in addition to a soil prediction value at a geographical location, our method directly output uncertainty information of the prediction and also quantitative information of contribution of every soil samples to the prediction at this location. This makes it easy to interpret and trace the prediction at any location. We concluded that the proposed method can be an alternative to current machine learning techniques.

Digital Mapping of Soil Organic Carbon in an Alluvial Plain Area of the Terai Region of Nepal

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Pedometrics; Quantile Regression Forests, Random forests; Regression kriging; Uncertainty

Abstract: Soil organic carbon (SOC) of top 20cm was predicted and mapped at 30m resolution in an alluvial area of the Sarlahi district in Nepal. The study area lies in a warm, sub-tropical region and is intensively cultivated. It has been reported that SOC concentration in this region has been depleted to alarmingly low levels; however, no documented work on the mapping of SOC has been found. We compared the performance of the Stepwise Multiple Linear Regression Kriging (RK) and Random Forest (RF) techniques for mapping SOC. Point SOC observations (n = 526) were randomly split into training and validation sets as 70% and 30% respectively. Box-cox transformation was carried out with the lambda value of 0.5 to achieve normal distribution of SOC point data. Environmental covariates of SOC were selected following the SCORPAN framework of digital soil mapping and it included terrain attributes derived from a digital surface model of ALOS World 3D?30m, bioclimatic variables of WorldClim Version2, Landsat based long-term vegetation indices, land-use and world reference base soil map. The sensitivity of the model to available data and the model uncertainty based on the probability distribution function for each pixel was combined to portray the total uncertainty using quantile regression forest technique. SOC was further calculated according to soil and land use units. We found that RF performed better than RK as evidenced by more favourable error statistics. Validation R2 was 0.34 and 0.32, whereas calibration R2 was 0.87 and 0.79, respectively, for RF and RK techniques. These figures are in line with similar studies in other areas. Highest mean SOC content, i.e. 15.23 g kg-1, was found in the forests of Calcaric Phaeozems. Mean SOC content of cultivated lands ranged from 8 g kg-1 in Calcaric Fluvisols to 11.04 g kg-1 in Eutric Gleysols. Lowest mean SOC content of 6.31 g kg-1 was found in the barren lands of Calcaric Fluvisols. The map showing the spatial distribution of SOC could guide the efforts to prioritize the activities to raise the level of SOC content in the study area.

Digital Soil Mapping and Laws of Geography

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: digital soil mapping; First Law of Geography; Third Law of Geography; spatial prediction; organic matter content

Abstract: Current digital soil mapping methods are based on either the First Law of Geography or the statistical principle or the combination of these two. This paper first examines utilities of the existing Laws of Geography and the statistical principles in digital soil mapping and then presents a new thinking about prediction of soil spatial variation based on a different geographic principle (one may refer to it as the Third Law of Geography) which focuses on the similarity of geographic configuration of locations. Under this principle, prediction of soil spatial variation can be made on the basis of the similarity of geographic configurations between a sample and a prediction point. This allows the representativeness of a single sample to be used in prediction, in contrast to an explicit relationship from a sample set. A case study in predicting spatial variation of soil organic matter content was used to compare the prediction based on the new principle with those based on the First Law and the statistical principle. It is concluded that spatial prediction based on the new principle does not require samples to be of specific size nor to be of a particular spatial distribution to achieve a high quality prediction. The prediction uncertainty associated with spatial prediction based on the new principle is more indicative to quality of the prediction, thus more effective in allocating error reduction efforts. These properties are particularly important to digital soil mapping in geospatial big data science where more than often sample sets are not as representative as expected.

Ensemble Machine Learning as a Generic Framework for Soil Data Science

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: ensemble machine learning, SuperLearner, random forest, Support Vector Machine, automated mapping

Abstract: The the ensemble machine learning (EML), based on the SuperLearner framework described by Polley and Van Der Laan (2010), is applicable for various soil data science problems, and especially for generating spatial predictions of soil variables. By incorporating distances and spatial connectivity into modeling, we have produce a complete framework for geostatistical mapping (Hengl et al. 2018). In this paper we further extend single-learner methods to ensemble of applicable learners (EML). The results show that EML helps increase the mapping accuracy. The remaining issues is fast and reliable estimate of prediction error i.e. prediction intervals. We introduce an efficient error-decomposition to estimating prediction error using model stacks with at least 3-5+ learners. The error-decomposition method includes three main steps: (1) estimate RMSE separately per learner using repeated CV with re-fitting, (2) estimate mean weighted predictions and variance of the model stack, (3) determine the remaining static components of the error, and (4) scale variances to match the global measures of accuracy. Results indicate that the error-decomposition is applicable to general spatial prediction problems and is significantly less computational than Quantile Regression RF or similar.

Error Assessment of Soil Organic Carbon Pools from Incubation to Spatial Predictions in Managed Landscapes of Midwest United States

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: soil incubation, digital soil mapping, soil carbon modeling

Abstract: The development of the markets for carbon credit accounting purposes requires an accurate assessment of errors by different evaluation methods. Most of the carbon credit accounting methodologies for soils are based on evaluation of total carbon and CO2 evolution. However, studies describe the presence of different soil organic carbon (SOC) pools with different mean resident time (MRT) and resistance to mineralization, one of the major process of SOC loss. The objective of this presentation is to (i) evaluate the size of errors associated with different SOC pools determined at point locations and predicted at different spatial scales; and (ii) their implication for carbon credit accounting purposes. Soil samples from the 0-25 cm surface layer along 10-point transects capturing key soil slope positions in dominant geomorphology units were collected and analyzed for total SOC prior and after a 2-year incubation period. Soil samples were divided in three replicates for SOC determination and CO2 measurement from incubation day 3, 7, 10, 14, 21, 28, 60, 90, 180, 365 and 730. The data was used to determine various SOC pools (mineralizable, labile, active, metabolic and structural). The MRT was determined from the slope coefficients of CO2 evolution over time. Overall, depressions stored twice as much (72 Mg C ha-1 6.8) compared to summits and side slopes (33 Mg C ha-1 1.2). Also, more SOC was mineralized from depressions (1.4 Mg C ha-1 0.05) compared to summits and side slopes (0.8 Mg ha-1 0.04). However, relative to total SOC, soils on summits and side slopes mineralized about 2.7% C compared to 1.9% for the depressions. Error size for mineralized SOC (ug g soil-1) was variable between replicates and days of incubation and increased overall with time. Similar trend was observed going from the most dynamic SOC pools (mineralizable, labile, and active) to less dynamic (metabolic and structural). However, the opposite was true for mineralized SOC rate (ug g soil hr-1), with error size decreasing over time of incubation. The distribution of total and mineralized SOC was highly and positively correlated with topographic wetness index (r = 0.91) while the SOC stability was negatively correlated. However, the strength of relationships for the mineralized SOC decreased over time. Temporal variability and error size associated with SOC stocks and stability significantly influenced spatial predictions at multiple scales. Considering space-time interactions of SOC stocks is beneficial for modeling community globally and management of SOC at finer scale.

Extrapolation of a Structural Equation Model from One Region to Another

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: model transportability; structural equation modelling; digital soil mapping; pedometrics; Argentinian pampas

Abstract: Theoretically, two different regions with similar soil-forming factors should develop similar soil conditions. However, when this finding has been used to extrapolate a digital soil mapping (DSM) model from one area to another it usually performs very poorly. This might be a consequence of the type of models used in DSM, which generally are empirical. Since structural equation modelling (SEM) is a semi-mechanistic technique that can explicitly include expert knowledge, we think that SEM models are more suitable than purely empirical models in DSM. The objective of this study was therefore to investigate the goodness to apply SEM for model extrapolation by comparing different model settings. We took a SEM model developed for the Argentinian Pampas from a previous study and applied it in the Great Plains of the United States, a region that is similar in term of lithology and climate. We predicted clay, organic carbon, and cation exchange capacity for three major horizons: A, B, and C. In term of accuracy, the results showed that extrapolation, in strict sense, had poor performance. However, by using SEM, it was possible to apply different extrapolation setting which gave us more insights to identify the issues related to this practice. One of them was that those system relationships that we could support very well (relations among soil properties) showed consistent and equal behaviour in both study areas, while the problems persisted in the relations between proxies of the soil-forming factors and soil properties. For this reason we concluded that a deeper understanding of indicators of soil-forming factors could strengthen conceptual models for extrapolating DSM models. Also, we found that improving local predictions in one area by using empirical data harms the predictive power of the model for extrapolating it to another area. Therefore, knowledge-based links between system variables are more effective than data-driven links.

Field Scale Digital Soil Mapping of Clay Using Ancillary Data and Common Models

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: clay, ancillary data, digital soil mapping, prediction error

Abstract: Owing to its small (< 2 µm) size and large surface area; the clay fraction confers storage of nutrients, retention of water and formation of stable aggregates than sand and silt; playing a substantial role in maintaining soil quality and health. Herein, we aim to determine which ancillary data can be coupled through various models with limited laboratory data and create digital soil maps (DSM) of clay across a sugarcane field and at various depths, including topsoil (0-0.3 m), subsurface (0.3-0.6 m), and subsoil (0.9-1.2 m) clay. We first consider either in combination or alone the use of elevation, gamma-ray (γ-ray) and electromagnetic (EM) ancillary data using either regression kriging (RK), linear mixed model (LMM) or a Bayesian model; Integrated Nested Laplace Approximation (INLA) combined with Stochastic Partial Differential Equation (SPDE). We use these models to predict clay and associated error. We evaluate model performance at different depths, with the final aim to compare prediction efficiency by calculating the mean square prediction error (MSPE). The log likelihood and Akaike information criterion (AIC) showed that RK and LMM fitted better with ancillary data in combination, while Deviance information criterion (DIC) showed equivocal results for INLA-SPDE. Generally, model performance decreased with increasing depth as evidenced by root mean square error (RMSE), mean error (ME), correlation coefficient (R2) and concordance (Lin's). DSM of predicted clay were consistent with that of measured clay while prediction error was largest where clay was large (RK) or at field edges (LMM and INLA-SPDE). Considering MSPE, model performance followed the order of LMM>INLA-SPDE>RK.

Is it Possible for a Soil Physics Lab Not Only to Perform Analyzes but also to Add Recommendations on Soil Management?

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: PTF, soil management, degree of compaction

Abstract: When a soil sample is sent to a soil chemistry lab the result is generally accompanied by a fertilizer dose recommendation that sustains a million dollar economy in the agricultural world. Is it possible to do the same in soil physics laboratory? This possibility is discussed with 10 examples of use of pedo-transfer-functions, considering two input data measured by the laboratory: granulometric analysis and bulk density. Estimated variables: macroporosity, microporosity, total porosity, bulk-density equivalent to Macro=0.10 m m-3, relative bulk density, soil organic carbon, particle density, maximum bulk density, and Clay in function Sand content.

Limited Spatial Transferability of the Relationships between Kriging Variance and Soil Sampling Spacing in Some Grasslands of Ireland and its Implication for Sampling Design

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Spatial variability, soil mapping, kriging variance, soil sampling, spatial transferability

Abstract: Sampling plays an important role in acquiring precise soil information required in modern agricultural production world-wide, which determines both the cost and quality of final soil mapping products. For sampling design, it has been proposed to transfer the relationships between kriging variance and sampling grid spacing from an area with existing information to other areas with similar soil forming environments. However, this approach is challenged in practice due to two problems: (1) different population variograms among similar areas, and (2) sampling errors in estimated variograms. This study evaluated the effects of these two problems on transferability of the relationships between kriging variance and sampling grid spacing, using spatial data simulated with three variograms and soil samples collected in four grasslands of Ireland within similar soil forming environments. Results showed that variograms suggested by different samples collected with the same grid spacing in the same or similar areas were different, leading to a range of mean kriging variance (MKV) for each grid spacing. With increasing grid spacing, the variation of MKV for a grid spacing increased and deviated more and more away from the MKV generated using the population variograms. As a result, spatial transferability of the relationships between kriging variance and grid spacing for sampling design was limited.

Machine learning in soil research: Model tuning by differential evolution

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: pedotransfer function; machine learning; optimisation; differential evolution; parameter tuning

Abstract: Machine learning algorithms are well-suited for computing non-linear problems and fitting complex composite functions. Accordingly, there are many applications in Pedometrics research. Soil water retention data are often scarce. Spatial prediction on a landscape scale may therefore require the use of pedotransfer functions (PTFs) to increase the input dataset. Machine learning algorithms are typically involved in both, soil regionalisation at plot and landscape scale and the development of PTFs. In that effect, each machine learning model must be adapted to the respective dataset and research context. This makes parameter tuning a crucial point. In this line, we compare the commonly used grid search with optimisation by the differential evolution algorithm. The PTF development for the prediction of soil water retention in two tropical mountain regions of different soil landscapes should serve as an example of application. Results confirm the high potential of the differential evolution algorithm for tuning machine learning models.

Mapping Cation Exchange Capacity Using a Quasi-3d Joint-Inversion of EM38 and EM31 Data

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: Digital soil mapping; cation exchange capacity; fertility; electromagnetic inversion; alluvial clay plains;

Abstract: The cation exchange capacity (CEC, cmol(+)/kg) is a measure of soil's capacity to attract and exchange cations (Ca2+, Mg2+, K+, Na+). The CEC therefore provides farmers with information about soil nutritional retention and buffering capacity, potential response to amelioration where structure is compromised by high sodium and soil structural stability. Therefore, accurate spatial information on CEC is needed. However, it is expensive to collect CEC data across a heterogenous field and at different depths. Although geostatistical methods (e.g. kriging and cokriging) have been used to map spatial distribution of laboratory measured CEC, this approach still requires a large number of soil samples to define the spatial autocorrelation. An alternative is to use electromagnetic (EM) induction data, which can more quickly and cheaply develop spatial dense datasets to map CEC. Because EM instruments measured apparent soil electrical conductivity (ECa mS/m) which could be coupled to CEC through linear regression (LR). However, these LRs were depth-specific or considered average CEC; leading to loss of information at specific depths. Recently, a universal LR has been developed between estimates of true electrical conductivity (σ mS/m) inverted from ECa data, and soil properties at various depths, to provide soil information within a soil profile.

However, using this approach to invert combined EM38 and EM31 ECa to predict CEC at various depths has seldom been discussed. In this study, we firstly explore if separate LR models could be established between ECa, from root-zone measuring EM38 or vadose-zone sensing EM31 in horizontal (ECah) or vertical (ECav) modes, and topsoil (0-0.3 m), subsurface (0.3-0.6 m), subsoil (0.6-0.9 m) and deeper subsoil (0.9-2.1 m) CEC, across a field in the south-east of Australia. Secondly, we compare this approach with a universal LR between estimates of ? and CEC at various depths. We estimate ? by inverting ECa from either alone or in combination EM38 and EM31, using inversion modelling software (EM4Soil) capable of quasi-3dimensional (q-3d) and joint-inversion. We also consider various parameters to get the best ?, including EM38 height (i.e. 0.2 or 0.4 m), forward modelling (cumulative function [CF] or full-solution [FS]), inversion algorithm (S1 or S2), number of iterations and damping factor (?). In addition, a leave-one-out-cross-validation (LOOCV) is used to test the calibration models.

In terms of performance of separate LR models, the correlation (R2 > 0.60) was largest between EM38 ECah at a height of 0.2 m and deeper subsoil (0.9-2.1 m) CEC. However, the LRs were unsatisfactory for CEC calibration in the topsoil (0.31), subsurface (0.37) and subsoil (0.52). In comparison, a universal LR between ? and CEC at various depths was well correlated (0.72), when both EM38 (0.2 m) and EM31 ECa in both modes, were inverted using a forward model (CF), inversion algorithm (S2) and small damping factor (? = 0.03). The calibrations tested using a cross-validation, showed CEC prediction was precise (RMSE - 2.44 cmol(+)/kg), unbiased (ME - 0.11 cmol(+)/kg) with good concordance (Lin's - 0.81). To improve areal prediction, closer spaced transects need to be collected, while improved vertical resolution of CEC prediction we recommend DUALEM-421 ECa data be acquired.

Mapping Clay and Soil Organic Matter Contents for Fields without Samples Using Electrical Conductivity and Aerial Imagery

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: EC, clay, SOM, soil color, downscaling

Abstract: Several studies have shown that the apparent electrical conductivity (ECa) has a high correlation with the clay content of the soil. At the same time, bare soil imagery is highly useful for predicting soil organic matter (SOM) contents. However, both the ECa and the soil color are subject to spatial and temporal variations, for example due to variations in soil moisture. Therefore, models using EC and bare soil imagery need local samples for calibration in order to provide accurate predictions.

As an alternative, we propose a method using soil maps at regional or national extent and soil observations from other fields. All fields have ECa measurements from a DUALEM sensor and soil brightness from aerial imagery. The method establishes generalized relationships between the measured soil properties and ECa measurements and soil brightness using the observations from other fields. It then adjusts the predictions from this relationship, using a national map of soil properties.

We tested the method for predictions of topsoil clay and SOM contents at five agricultural fields in Denmark, using cross-validation between the fields. The method predicted clay contents with a higher accuracy than the national map for fields with clay contents higher than 10%. The method also predicted SOM contents with a higher accuracy than the national map, although nonlinear relationships between SOM and soil brightness lead to errors in some areas. However, the method had a lower accuracy than models trained from local observations for all fields.

Our study shows that it is possible to use ECa measurements and bare soil imagery to improve upon predictions of soil properties from regional and national maps. The method is mostly useful for providing preliminary estimates of soil properties for planning sampling strategies and fieldwork.

Mapping Soil Properties in the Canadian Managed Forest with Limited Data: Comparison of Spatial and Non-Spatial Statistical Approaches

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Spatial autocorrelation, Bayesian analyses, Machine-learning, Geostatistic, Cross-validation

Abstract: With more data available, better soil pit location and faster computers, digital soil mapping (DSM) products are becoming more and more available and their accuracy is improving. This revolution greatly facilitates the use of soil variables into modelling and into the assessment of ecosystem functions or vulnerabilities because maps of soil properties are now becoming available as well as that of the uncertainties of predictions. Predicting soil properties in a forest environment is however generally difficult due to the low density of available soil data and to the limitations in the availability of co-variables. For these reasons it is important to make the best use of the available data. In the development of most DSM products, only one (or a few) statistical methods have been used and spatial autocorrelation is often not considered. We tested several statistical methods on the same dataset covering the whole Canadian managed forest. Methods included parametric methods, non-parametric methods of machine learning (Knn, Random forest, boosted regression trees, cubist) and a Bayesian approximation method (INLA), and we tested the effect of including or not a spatial component. The choice of a statistical method had a great impact on the quality of the predictions but the optimal method varied with soil properties, indicating a benefit of testing several approaches. Inclusion of a spatial component greatly improved the predictions in most cases. A possible explanation for this effect is that the processes driving a soil properties, and therefore predictors may vary regionally.

Mapping Soil Salinity in Three-Dimensions Using EM38 and EM34 Data and Inversion Modelling

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: EM38, EM34, inversion modelling, salinity, DSM

Abstract: In irrigated areas the specter of soil salinisation is ever-present. Information about the areal distribution of salt is necessary to assist policy analysts. To map salt, or soil electrical conductivity of a saturated soil paste extract (ECe, dS m-1), we demonstrate how electromagnetic (EM) induction data from a reconnaissance survey of EM38 and EM34 instruments can be used with EM inversion software (EM4Soil). This is because the collected apparent electrical conductivity (ECa, mS m-1) can be inverted to estimate true electrical conductivity (σ, mS m-1) and correlated with ECe. In the first instance, a quasi-two dimensional (Q-2D) model was used along a single pseudo-transect. A linear regression (LR) between σ and ECe was generated from 7 soil sample locations to a depth of 12 m; ECe = -0.054 + 0.012?? (R2 = 0.71). From the inversion of interpolated EM38 and EM34 ECa across 40,000 ha, a quasi-three dimensional (Q-3D) model was used to predict ECe. The model was validated using 37 soil sample locations. The agreement between measured and predicted ECe was good (Lin's concordance = 0.85). We conclude the approach provides useful information on a reconnaissance scale and indicates where more detailed information may be collected to confirm areas of moderate salinity. To better predict areal ECe, more ECa data could be collected and on a smaller grid spacing (than 0.5 km and 1 km in irrigated and dryland areas, respectively). To improve resolving depth of ECe we recommend including ECa from EM31 or a DUALEM-421 instrument.

Model building for spectrometric functions of soil organic carbon

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: soil organic carbon, Vis-NIR reflectance spectrometry, Partial least square regression

Abstract: Model building for spectrometric functions of soil organic carbon

Soil organic carbon (SOC) plays a major role concerning soil functionality. Vis-NIR reflectance spectrometry is a non-destructive fast methodology that is often applied jointly with SOC dry combustion analysis to increase the available dataset. It involves a model building process. The precise documentation of the measurement protocol and this model building process is important in order to understand the provided performance measure and to allow for comparison. For this study, 100 soil samples were collected at a long-term field experiment in central Germany by two different sampling designs. Regression models were built using partial least square regression (PLSR). In order to build robust models, resampling was used for the model tuning and validation procedure. Various aspects that influence the obtained error metrics are analysed and discussed.

Multielement Geochemical Modelling for Differences in Topsoil Pollution along the Environmental Gradient near the Coal Fields

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Session 1: Developments in Pedometrics 1: Mathematical and methodological
Presentation Type: Oral
Keywords: Trace elements, compositional analysis, soil contamination

Abstract: The Czech Republic belongs to the countries with a long-term industrial history that is especially true along the Czech - Saxony border, where the industrial growth was led by mining activities in the opencast coal fields and historical polymetallic mining districts. An interference of various pollution sources was reported in the broad region of the Ore Mountains with the proven symptoms in soil environment. We expected some differences in geochemical signatures between the mountainous unit, central basin with the coal fields and the surrounding agricultural part of the basin. In order to interpret these differences, the topsoil sampling was conducted in transects from the mountainous region to the basin and various extraction procedures were employed to properly distinguish between the geochemical signatures:

a) The total extraction of soil trace elements using the acid mixture (HF, HClO4, HNO3).
b) The partial 2M HNO3 extraction that has a potential to reflect the associated pollution risk to the ecosystem more accurately than the total contents as the elements present in the residual fraction are not potentially bioavailable and mobile
c) The sequential extraction procedure for selected trace element using the Wenzel?s extraction scheme (Wenzel et al., 2001).

The statistical processing of multi-element geochemical data is further complicated by the closure problem and possible spurious correlations (Aitchison, 1986). In statistics and mathematical geosciences, the log-ratio approach is being evolved to overcome these pitfalls of compositional analyses. In order to interpret and visualise the regional variability of geochemical domains we proceeded in the following steps.

a) The subcompositional analysis was done to define those subcompositions of trace elements that may retain within the subcompositional data as much as possible of the variability in the entire composition and that have potential to record the geochemical differences along the transects.
b) Principal component analysis (PCA) adapted to compositions was employed to understand the compositional variability.
c) Based on centred log-ratio (clr) transformation the topsoil geochemical data were modelled using discriminant function analysis that highlight the differences in geochemical compositions between landscape units along the transect.
d) In the last step, the subcompositions selected within the explanatory analysis were employed to spatially delineate the zones with distinct geochemical characteristics of surficial soils.

For these purposes, the univariate ilr-coordinates were calculated and then spatially interpolated using the IDW interpolation technique. The resulting spatial information for a 3-part subcompostions were mapped using the colour composite method.

The results of discriminant analysis showed that As, Be, Pb, Ni discriminated well the geochemical patterns between the landscape units. However there were proved strong differences between the mountainous and basin units and the differences between the central industrial basin and its agricultural margins were not significant. The discrimination functions showed very similar results for both extractions. Since As and Be were proved to be distinctive trace elements discriminating the geochemical zoning within the region, we explored their geochemical position using the sequential extraction procedure at chosen sites.

Oblique Coordinates as Covariates for Digital Soil Mapping

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Random Forest, RFsp, kriging, SOM, geographic space

Abstract: The inclusion of an explicit spatial component into decision tree predictions for digital soil mapping remains a challenge. Studies have shown that x and y coordinates as covariates results in unrealistic orthogonal artefacts in the resulting maps (Hengl et al., 2018, Nussbaum et al., 2018). Hengl et al. (2018) instead proposed the use of buffer distances to the training points as covariates, referred to as Spatial Random Forest (RFsp). A disadvantage of RFsp is that it requires the calculation of buffer distances to every observation in the training data. RFsp therefore becomes computationally expensive with large datasets.

As an alternative, we propose several sets of coordinates at oblique angles as covariates for Random Forest predictions of soil properties. We test this approach for the prediction of soil organic matter (SOM) in a densely sampled agricultural field in Denmark. A previous study showed that kriging was the most accurate prediction technique for this field, yielding more accurate results than Random Forest and Cubist models with kriged residuals.

The use of oblique coordinates effectively eliminated orthogonal artefacts from the output maps. Moreover, even with a small number of oblique coordinates, the predictions were on par with the predictions previously obtained with kriging. Moreover, using the oblique coordinates in conjunction with covariates derived from a DEM and proximal and remote sensors further increased accuracy. In effect, the use of oblique coordinates makes Random Forest the most accurate method for predicting SOM in this field.

Oblique coordinates are a likely candidate for a generic implementation of a spatial component for Random Forest models in digital soil mapping. It eliminates orthogonal artefacts from the predictions, is computationally efficient and highly accurate. Furthermore, it may be useful for data with a high degree of anisotropy and variable spatial relationships.

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Prediction of Physicochemical Soil Parameter on Spectra of Sieved Soil Samples

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: Diffuse reflection spectroscopy, MIR, PLS-regression, soil sample preparation

Abstract: Structural and small-scale heterogeneity of soils is often neglected in soil analyses. Generally, the soil is dried and finely ground before spectral measurement to avoid reflections of surface water films and minimize the intra- and inter-particle variability, respectively. Additionally, the sample surface is levelled to a plain surface for an ideal reflection. However, these sample preparation techniques are limited to disturbed samples only. Thus, a potential DRIFT mapping of undisturbed soil samples requires an adjusted calibration to allow an accurate prediction of soil properties.

In this study, we developed a method for calibrating DRIFT spectra collected from sieved soil samples (< 2 mm), as a first approximation for undisturbed soil samples, against several soil surface parameters. Therefore, we recorded the DRIFT spectra of both soil samples, ground and sieved, of 120 chemically well-characterized soils from the Ruhr-area, Germany. In preliminary experiments, we found that spectra of sieved and ground samples significantly differed in specific spectral regions representing covering of soil matrix particles like clay minerals, as well as organic matter. Spectra of both types, ground and sieved, were calibrated against different physio-chemical soil properties, such as texture, CEC, organic carbon, pH, or several oxides. It can be assumed that the prediction of surface-related soil parameters was superior using sieved soil spectra, as grinding alters the natural surface structure of the soil. We found that the R2 of PLS-calibration of texture, Al, pH, and CEC were between 81.41 and 97.55 in both cases (ground and sieved), whereby Sand and Silt had higher R2 for the sieved samples. It appears that the use of sieved soil sample spectra for the prediction of several soil parameters is of high potential.

In a further step, micro topography effects on spectra quality from disturbed as well as undisturbed soil samples will be evaluated. Thus, a digital elevation model (DEM) will be constructed using close-range digital photogrammetry to correct these topography effects of the DRIFT mapping data from undisturbed soil samples.

The introduced method has the potential of imaging soil parameters on a microscale that can help considerably in locating and understanding soil processes on a small scale.

Prediction of Soil Hydrologic Properties on Sodic and Saline Soils

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: Soil sodicity, soil hydrology, soil physical property

Abstract: Soil hydrologic properties are important in the transport of solutes in soils. Too high of a percentage of sodium in the soil solution at low salinity levels in known to decrease the saturated hydraulic conductivity of soils. Saturated hydraulic conductivity and water retention was measured on soil textures ranging between sandy loam and clay. Water retention curves were fit with the van Genuchten equation. Pedotranfer functions made to predict soil water retention and saturated hydraulic conductivity and compared to the McNeal 1968 Model and Rosetta parameters. Pedotransfer funtions were able to predict soil water content within 30 % of the measured average soil value of the property in the verification data. The RMSE of the developed pedotransfer function to predict saturated hydraulic conductivity was 25. 1 cm/day which was reduced from 27. 5 cm/day using the Rosetta function and 31.7 cm/day using the McNeal 1968 Hydaulic conductivity model.

Prediction of Soil Organic Carbon Based on In-Situ Vis-NIR Spectroscopy in Poyang Lake Wetland of China

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: Soil organic carbon (SOC), In situ vis-NIR spectroscopy, PLSR, SVM

Abstract: Visible and near infrared (vis-NIR) spectroscopy, especially in-situ spectroscopy, of soil has proved to be accurate, cheap and robust for survey of soil properties. To test its potential, there were 246 samples were selected from 68 profiles in Poyang Lake Basin, Jiangxi Province, China. Fresh soil cores were scanned by an ASD vis−NIR spectrometer with wavelength range from 350 to 2500 nm. Then, Soil samples were air-dried, ground and passed through a 2 mm sieve. They were then scanned by an ASD vis−NIR spectrometer again. Scanned spectra were first cut at both ends to leave them from 400 nm to 2450 nm for removing noise. The spectra were transformed into absorbance by log (1/R) (R is the reflectance), and Savitzky-Golay(S-G) smoothing. Soil Organic Carbon (SOC) was measured on soil samples to build calibration models and also to validate the models' accuracy. On the basis of the ratio of prediction deviation (RPD), which is standard deviation (SD) of prediction divided by the root mean square error (RMSE) of prediction, the accuracy of leave-one-out cross-validation of the Partial Least Square (PLSR) and Support Vector Machines Regression (SVMR) SOC models with in situ vis-NIR spectroscopy were classified fair performance (RPD=1.60), and good (RPD=2.07) respectively, while the PLSR and SVMR SOC models were classified good performance (RPD=3.10), and good (RPD=3.61) respectively with indoor vis-NIR spectroscopy. For eliminating the influence of soil water contents, PLSR and SVMR with a direct standardization (DS), External Parameter Orthogonalization (EPO), Piecewise Direct Standardization (PDS), and Generalized Least Squares Weighting (GLSW) algorithms were used to build the prediction model for SOC. It was shows that the RPDs of PLSR models are 1.53, 1.71, 1.83, and 1.66, respectively. And the RPDs of the SVMR models are 1.93, 2.10, 2.39, and 2.34, respectively. The SVMR with PDS prediction model has the highest precision with a RPD of 2.39. However, the water elimination models seem didn't improvement the precision much good enough. So, we assessed the influence of prediction precision with the other spectral data pre-treatment method, which is without S-G smoothing. It was show that the RPDs of PLRS and SVMR models with in situ vis-NIR spectroscopy without taking water elimination into account are improved to 2.61 and 2.26, respectively. The model's RPD of PLSR with DS algorithm is 2.66, while the PRD of SVMR with DS algorithm is decreased to 1.55. The model's RPD of PLSR with PDS algorithm is 2.38, while the PRD of SVMR with PDS algorithm is 2.2. It was show it was not necessary to taking water elimination model into account at the field scale in the Poyang Lake Basin. This study is encouraging for the application of vis−NIR survey of SOC.

Sampling Design for Large-Scale Soil Mapping Based on MaxVol Algorithm and Simulated Annealing

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: digital soil mapping, sampling design, clustering

Abstract: Spatial soil sampling is an internal part of a soil survey aimed at creating a soil map. This step dramatically affects the quality and accuracy of a map, as well as the cost of a survey. An optimal layout of soil sampling points should contain as minimum points as possible, and at the same time, it should capture the sufficient variability of soil cover. In most cases, especially on a large scale, soil variability is closely related to elevation. Usually, soil experts predict the best places for collecting soil samples based on relief parameters. We propose to do it fully automatically by combining different elevation features of a particular site and performing the MaxVol algorithm (https://pythonhosted.org/maxvolpy) to choose sample points.

Our sampling design consists of a three-step procedure. On the first step, several morphometric land-surface parameters are derived from the digital elevation model (DEM). The result is several images of the same size and resolution as DEM, consists of pixels with the values of particular parameters. The images are stacked together and supplemented with two coordinate layers.

At the end of the first step, a matrix of land-surface parameters is created. On the second step, we perform a clustering procedure using the DBSCAN algorithm along with some technique of dimensionality reduction (t-SNE or UMAP) as a preparatory step. The result is an image of the site, segmented based on land-surface features. Optimal hyperparameters for the algorithms of this step are obtained by the simulated annealing optimization method. Clustering result is added to the matrix of land-surface parameters as a layer. This step significantly improves the sampling quality.

On the third step, we use the MaxVol algorithm to find points, which are the most appropriate for sample locations. MaxVol is an algorithm for obtaining submatrices of maximum volume. The volume of a general tall rectangular matrix is defined as a square root of the determinant of the product of the transpose matrix on itself. In other words, MaxVol selects rows of the given matrix, which are in some sense most different from each other in terms of elevation characteristics. Therefore, MaxVol captures the main differences in the field, like experts in soil science do.

Field data for testing our sampling design were collected in 2013-2016 during detailed mapping of the soil cover in the virgin forest-steppe of the Central Russian Upland. The source materials include a DEM with a resolution of 2.5 m and soil data consist of 157 soil descriptions (Kozlov et al, 2017). The size of the test site is about 40 ha. Existing information was used for creating a digital soil map of the site. Quality of sampling design was measured by the accuracy of prediction based on selected points. Proposed approach outperforms conditional Latin Hypercube (cLHS) sampling. On the test site, the quality of our sample design exceeds the quality of cLHS by 10-2%.

Temporal Harmonization of a National Dataset for Spatial Prediction of Soil Organic Carbon

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: digital soil mapping, soil organic carbon, quantile regression forest, data harmonization, space-time modeling

Abstract: Mapping and monitoring of soil organic carbon (SOC) stocks have become highly relevant issues because of the contribution of SOC stocks to the global carbon cycle and climate change. Many studies have spatially predicted SOC at local, regional and global scales using digital soil mapping techniques. Most of these maps are based on SOC data collected over long periods of time. However, using data from a long period leads to uncertainty of SOC predictions. Digital soil mapping approaches typically ignore the measurement time of SOC observations, even though it is known that SOC dynamics can be substantial. The main goal of this study was to spatially predict the SOC stock for Argentina for the year 2015, while accounting for SOC dynamics. We applied a year-specific harmonization of the SOC stock at point locations using the IPCC Tier 2 approach and consecutively estimated SOC stock for 2015 at 1 km resolution. First, we standardized the SOC stock at 0--30 cm depth for 5,073 soil samples. Second, we estimated the IPCC change factors for all local administrative units. Third, we estimated the impact of each factor at the sample point level for the year 2015. Finally, we spatially predicted SOC stock and applied an uncertainty analysis using quantile regression forest and sensitivity analysis. We show that including temporal harmonization slightly improved the prediction. Further developments should consider the impact of soil erosion on SOC lost within the approach.

The Effects of Grinding on Spectral Information in the Mid-Infrared

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Diffuse reflectance spectroscopy, Mid-infrared spectroscopy, Scatter correction, Soil sample preparation, Scanning electron microscopy

Abstract: Conventional wet-chemistry analysis methods of soil properties are destructive and not suitable to get information of soil physicochemical parameters at a high spatial resolution. Thus, structural or small-scale heterogeneity of soils is often neglected in these analyses albeit it has a big impact on soil processes, functions, and quality. Diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy in the mid-infrared range (MIR) has become an established analytical tool for quantitative and qualitative analysis of soil samples. Generally, soil is dried and ground before spectral measurement to avoid reflections and minimize particle variability. During preparation, it is likely, that grinding breaks up soil aggregates and alters the surface structure, and consequently, the spectral information received.

In this study, we developed a method to compare spectra of sieved soil samples (< 2mm), as first approximation for undisturbed soil samples, to spectra of ground soils. As sample particle size accounts for the majority of the variance between spectra due to light scattering effects, interpretation of sieved soil spectra requires precise pre-processing methods. Therefore, spectral information of the two variants (ground and sieved) obtained from the 240 topsoil samples were collected, corrected by using standard normal variate (SNV), and compared statistically. Clustering of ground spectra with k-means allowed a more precise spectral characterization within similar groups. We found that in addition to scattering effects caused by particle size, organic or clay material coatings on the mineral soil matrix in the sieved soil samples caused differences between the two spectral data sets. Scanning electron microscopy (SEM) showed that chemical surface composition of the same soil sample detected by the MIR beam was different after grinding and/or grinding exposed formerly coated silicate surfaces. DRIFT spectroscopy in the MIR has potential to be applied on undisturbed soil samples, but it requires careful spectra interpretation.

In a further step, several PLS regressions on ground soil samples will be conducted to validate the potential of predicting physicochemical parameters on sieved-only soil samples.

Transfer Learning to Localise a Continental Soil Vis-NIR Calibration Mode

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Convolutional Neural Networks; regionalisation; domain adaptation

Abstract: The rapid development in NIR and information technologies saw the development of various initiatives that have generated large scale databases of soil spectroscopy globally. Models generated within a specific spectral or geographical domain should be carefully used in other contexts since they may lose their validity. This includes the application of a global, continental or national spectral libraries to local areas or regions. Both, global and local models are valuable and, ideally, we would like to transfer some of the rules learnt by the more general global models to a local domain. In machine learning, the process of sharing intra-domain information is known as transfer learning. This paper aims to describe and evaluate the effectiveness of transfer learning to 'localise' a general soil spectral model. The transfer process consists on, first, training a model with a big volume of data covering a diverse group of cases. Second, some layers of the trained neural network are used to build a local model, which is fine-tuned by using a smaller amount of local data. We demonstrated this method using the LUCAS database, a European dataset, comprising spectral data from 21 countries. For each country, we generated three models: a) Global, with data from all except the country of interest; b) Local, with data from the country; and c) Transfer, pre-trained as the Global model and fine-tuned with data from the country. The results showed that the Transfer model can lower the error (expressed as RMSE) 91% of the cases, with a mean reduction of RMSE: 10.5, 11.8, 12.0 and 11.5% for organic carbon, cation exchange capacity, clay content and pH, respectively. This paper demonstrates the usefulness of transfer learning for soil spectroscopy, which will enhance the use of global spectral libraries for local application.

Using Deep Learning for Digital Soil Mapping

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Poster

Keywords: DSM, contextual information, machine learning

Abstract: Digital soil mapping has been widely used as a cost-effective method for generating soil maps. However, current DSM data representation rarely incorporates contextual information of the landscape. DSM models are usually calibrated using point observations intersected with spatially corresponding point covariates. Here, we demonstrate the use of the convolutional neural network model that incorporates contextual information surrounding an observation to significantly improve the prediction accuracy over conventional DSM models. We describe a convolutional neural network (CNN) model that takes inputs as images of covariates and explores spatial contextual information by finding non-linear local spatial relationships of neighbouring pixels. Unique features of the proposed model include: input represented as 3D stack of images, data augmentation to reduce overfitting, and simultaneously predicting multiple outputs. Using a soil mapping example in Chile, the CNN model was trained to simultaneously predict soil organic carbon at multiples depths across the country. The results showed the CNN model reduced the error by 30% compared with conventional techniques that only used point information of covariates. In the example of country-wide mapping at 100 m resolution, the neighbourhood size from 3 to 9 pixels is more effective than at a point location and larger neighbourhood sizes. In addition, the CNN model produces less prediction uncertainty and it is able to predict soil carbon at deeper soil layers more accurately. Because the CNN model takes covariate represented as images, it offers a simple and effective framework for future DSM models.

Using Neural Networks to Predict SOM of Moist Samples by VisNIR Spectroscopy

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: Shallow neural network; Convolutional neural network; SOM prediction; Moisture effects; VisNIR

Abstract: Visible and near-infrared (VisNIR) reflectance spectroscopy has been successfully used to predict soil organic matter (SOM). However, soil spectra can be significantly altered by moisture, usually causing a negative effect on the prediction accuracy when moisture levels of calibration samples cannot span those of samples to be predicted. This limits in-situ prediction of SOM due to the large spatial and temporal variability of moisture in the fields. In this study, we used neural networks to predict SOM of soils with various moisture levels, in order to explore the feasibility of building a calibration model with high prediction accuracy for moist soil samples.

Soil reflectance spectra covering 350 to 2500 nm was measured in the laboratory for 117 samples collected in Fengqiu County, China, each with varying moisture levels from air-dried to saturated conditions, with a result of 2661 spectra. All the spectra were randomly divided into calibration (n = 1863) and validation sets (n = 798). Shallow neural network (SNN) and one-dimensional convolutional neural network (1D-CNN) were used for calibrating, respectively. Besides, partial least squares regression (PLSR) was used as the benchmark. The SNN architecture had only one hidden layer with 10 nodes, and the 1D-CNN architecture was composed of four convolutional layers and the number of filter kernel was set to 32, 64, 128, and 256.

The prediction accuracy was best for SNN model (R2 = 0.92 and RPD = 3.62), followed by 1D-CNN model (R2 = 0.91 and RPD = 3.17) and PLSR model (R2 = 0.86 and RPD = 2.74). These results were highly satisfactory and even better than those (R2 = 0.84 and RPD = 2.44) obtained by using only air-dried soil samples calibrated by PLSR model (n = 117; 78 for calibration and 39 for validation), indicating that high accuracy of SOM prediction by VisNIR could be obtained by neural networks. Neural networks can provide better prediction results than linear models such as PLSR when a large number of samples is available. Compared with SNN, 1D-CNN needs more samples to train. The number of samples here might be not enough for 1D-CNN model although it was better for predicting SOM than PLSR model. The study can be a reference for building a calibration model free of moisture effects for predicting SOM and provide new ideas for related research.

Session 2

3-D Soil Structure Scans Show Effect of Management

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: Soil Structure, 3-D Scanning

Abstract: Dryland agriculture depends on the capture and storage of rain for its existence. Promoting soil conservation in such areas, therefore, hinges on the ability of management practices to provide additional water to crops. Modeling the impacts of tillage practices on soil volumetric water content is critical to choosing management practices, but numeric representations of soil structure are not available as model input. Models use soil texture alone to determine soil physical parameters, but it is soil structure that management effects.

A field study in the middle and lower Brazos River watershed of Texas collected 3-D scans of soil pits in conventional, no-till, and perennial systems in Texas Vertisols. Novel algorithms were developed to extract soil structure parameters from the scans. Descriptions of soil structure and measurements of bulk density, aggregate stability, and saturated hydraulic conductivity were recorded for each site to ensure that the new soil structure parameters were representing real and reasonable difference in soil properties.

The newly developed soil structure parameters successfully showed the effects of the three different land managements measured. Measured soil physical properties showed intuitive relationships with soil structure parameters.

This crucial advance provides the foundation for incorporating soil structure and the effects tillage into hydrology models. Such models can be used to relate changes in management practices to soil functions and ultimately to a metric that is clearly and directly valuable to land managers soil water.

A Comparative of Different Digital Soil Mapping Approaches for Modelling Various Soil Taxonomic Levels in Arid and Semiarid Area

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Digital soil mapping, Covariates, Data mining, Soil classes

Abstract: The information about spatial distribution of soils is needed for managing of soil resources and their application for environmental modeling. The aim of present study compares different digital soil mapping approaches to produce the categorical maps of soil types at various taxonomic levels in part of Qazvin plain lands.

In total, 61 observation profiles were selected by stratified random sampling method and digged with a mean distance of 750 meters. Then, soil samples were taken from all genetic horizons based on soil survey manual. Three digital soil mapping approaches including random forest (RF), boosting decision tree (BRT), and Multinomial logistic regression (MLR) were used for soil-landscape modelling relations at different soil taxonomy levels (order, suborder, great group, sub group and family level). The primary and secondary derivatives of digital elevation model and Landsat 8 satellite image with spatial resolution of 30 m were used as covariates. Mean decrease accuracy (MDE) and mean decrease Gini (MDG) indices were used to determine the relative importance of environmental variables in modelling. In order to determine the accuracy and validity of spatial predictive results, overall accuracy (OA) and Kappa index were used. Then 80% of observation were used for training and 20% of them for modelling validation.

Based on MDE and MDG at all of categorical level, Standard height and Catchment area had the highest important but Mid-slop position and Modified catchment had the lowest important on taxonomic levels of order, suborder, subgroup and the great group and family respectively in soil landscape modelling in compartment with other environmental variables. The soil classification showed that Inceptisols, Aridisols and Entisols are the dominate soil class at the order categorical level. Validation results indicate that RF, BRT and MLR models exhibited similar performance and produced similar distributions at the order taxonomy, but in other taxonomic levels (suborder up to family), RF model had the highest OA and Kappa index, respectively, Kappa index values according to RF from order up to family were obtained 1, 0.85, 0.72, 0.65 and 0.60.

Finally, the RF model as a known machine learning method can extract the spatial relationship between environmental covariate and soil type variables in to predict the soil classes if the proper environmental covariates were chosen in the spatial modeling process.

A European Mid-Infrared Spectra Library: A Useful Tool for Precision Farming Applications

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: proximal soil sensing, partial least squares regression, soil heterogeneity, LUCAS topsoil survey

Abstract: Information on soils at high spatial resolution is a bottleneck for precision farming applications. In contrast to time-consuming conventional soil analyses, mid infrared spectroscopy (MIRS) is a rapid and high throughput measurement technique which allows deriving numerous soil properties at high quality. Thus, MIRS is potentially useful for precision farming applications. The derivation of soil properties from MIR spectra requires model calibration with conventionally measured soil properties. Most precedent projects aimed at building libraries at national or even smaller scale. However, for precision farming, small variation in soil properties at field scale must be detectable. Previous studies revealed that limited transferability between different scales hampers a more broad use of MIRS in precision farming. Within our BonaRes-I4S study, our aim is to minimize this drawback. Our spectra library consists of thousands of already conventionally analyzed topsoil samples including 1014 arable topsoil samples from the European LUCAS survey in Germany and the BeNeLux countries and 445 samples from the State Agency for Agriculture, Environment and Rural Areas of Schleswig-Holstein (Germany). In-field heterogeneity of soil properties at different arable fields from all over Germany was captured in high spatial resolution to test the performance of our MIRS library for predicting parameters of interest for precision farming applications.

Our hypotheses are: (A) It is possible to calibrate prediction models for a large number of soil properties based on the MIR spectra of the spectra library. (B) These prediction models are suitable to characterize the in-field heterogeneity of different soil properties on arable fields with respect to precision farming applications. (C) Available soil maps at small to medium scale (e.g. soil type, soil parent material) can be used for regionally clustering the calibration dataset to improve the applicability in precision farming applications.

Actual Evapotranspiration and Crop Coefficient for Tropical Lowland Rice: Eddy Covariance Approach

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: actual evapotranspiration, eddy covariance, lowland rice, crop coefficient, reference evapotranpiration

Abstract: For better irrigation scheduling and accurate application of required irrigation water measurement of actual evapotranspiration is essential. Eddy covariance (EC) method is extensively used as a direct method to measure actual ET (ETa). A field study was conducted in two consecutive years (2015 and 2016) to estimate ET and crop coefficient (Kc) of tropical lowland rice. Energy balance components and daily weather variables were measured at the agro-met observatory and an EC system in dry season (DS), dry fallow (DF), wet season (WS) and wet fallow (WF). Rice was grown in dry season (January-May) and wet season (July-November) following two fallow periods. During dry seasons ETa and Kc values were higher as compared to wet season ETa and Kc. Mean growing season ETa rates for dry seasons rice were 2.86 and 3.32 mm d-1, whereas, these were 2.31 and 2.24 mm d-1 during wet seasons in both the years. The magnitude of ETa increased with the progress of both cropping seasons and was found minimum during the fallow periods. To compare the ETo and Kc values, four methods namely Food and Agriculture Organization- Penman-Monteith (FAO-PM), Hargreaves and Samani (HS) method, Mahringer (MG) method and Pan evaporation (Epan) method were used. Out of all these methods of estimating ETo, FAO-PM method was the best representative of ETo for this region. Realistic estimates of Kc were found during the dry season as compared to wet season. The FAO-PM and Epan method provided better estimates of Kc values than the other methods. Eddy covariance method could be used in estimating ETa and Kc of lowland rice in the tropical region of eastern India

An Improved Thermo-TDR Sensor for Monitoring Soil Thermal Properties, Water Content, and Porosity

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: thermo-TDR, water content, thermal properties, porosity

Abstract: Soil temperature, water content, thermal properties, and porosity are important parameters for describing the coupled transfer of heat and water in non-rigid soils. The thermo-time domain reflectometry (thermo-TDR) technique is a valuable tool for in situ monitoring soil water content, thermal properties, bulk density, porosity and air-filled porosity in the vadose zone. In this study, we introduced a new sensor design for monitoring soil water content, thermal properties, and porosity with a larger sensing volume and greater accuracy. The new thermo-TDR sensor had an outer diameter of 2.38 mm for the heating needle, an outer diameter of 2.0 mm for the heating sensing needle, a length of 70 mm and a spacing of 10 mm between the heater and sensing needles. Laboratory experiments on the repacked and intact soil columns with different textures and water content were conducted to evaluate the performance of the new sensor. Experimental tests showed that the sensing volume of the new sensor was almost three times than that of the conventional sensor. TDR determined water content showed a root mean square error (RMSE) of 0.01 m3 m-3, much less than those reported with the conventional sensors. With considering finite properties of the sensor needles, soil thermal property results from the heat pulse method agreed well with the modelled ones. Comparing to the previous version, overestimation errors in soil heat capacity at lower water content were reduced significantly. Soil bulk density, porosity, and air-filled porosity derived from the thermos-TDR results were consistent with values determined gravimetrically. We concluded that the new thermo-TDR sensor provide a viable option for monitoring soil temperature, water content, thermal properties, and porosity in situ.

Automated Soil Core Scanning for High Resolution Carbon Analysis Down a Soil Profile: Full Inversion Tillage Case Study

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: soil spectroscopy, soil carbon stratification, inversion tillage, precision agriculture

Abstract: Continuous pasture soils develop a high degree of soil organic carbon (SOC) stratification, which concentrates SOC sequestration near the soil surface. Where strong vertical stratification of SOC can be identified, pasture renewal with full inversion tillage (FIT) through deep ploughing has the potential to accelerate C sequestration by creating a deeper topsoil. For example, recent studies suggest that transferring C-rich topsoil to the subsoil and unsaturated subsoil to the new pasture root zone increases the SOC pool. An increased number of soil profile samples are required to identify the degree of SOC stratification and the feasibility of pasture renewal with FIT. For agricultural contractors to act in a timely manner, soil sampling and C analysis needs to be rapid. For this purpose, we have investigated the use of an automated multi-sensing platform to scan intact cores at field conditions at high depth interval resolution. The sensing platform combines a visible near-infrared (VisNIR) spectrophotometer, a γ-ray densitometer and a charged coupled device (CCD) camera using a method designed and developed by researchers from CSIRO, Australia with our contribution. The sensor platform allows simultaneous determination of several soil properties: the γ-ray densitometer provides estimations of bulk density and the VisNIR spectrophotometer can predict soil properties such as organic carbon, clay content and pH.

To evaluate the platforms efficiency in estimating SOC stratification, we scanned 81 soil cores, collected from 2 trial sites, where the effects of different tillage practices were being evaluated. Entire soil cores were extracted to 40 or 60 cm depth and analysed at 1.6 cm increment from 0 to 30 cm depth, 2.5 cm increment from 30 to 40 cm and 5 cm increment from 40 to 60 cm. Spectral and γ-ray attenuation data were simultaneously recorded for each scan depth. Following spectral data collection, the cores were cut into 5 cm increments between 0-30 cm, 10 cm increments for 30-40 cm depth and 20 cm increment for 40-60 cm depth and analysed for bulk density and SOC to develop calibration models for SOC stocks. Spectra were transformed into absorbance values. First order derivative of the spectra was calculated from Savitzky-Golay algorithms. Approximately half of the dataset generated was randomly selected and used as a model calibration. We used Partial Least Square (PLS) regression to predict volumetric water content and percentage of organic carbon from the spectra, γ-rays attenuation data and volumetric water content estimation were implemented into Beer's law equation for bulk density prediction. Finally soil carbon stocks were computed from the bulk density and organic carbon estimations. Preliminary results on a dataset portion indicate accurate prediction models for bulk density with root mean squared error (RMSE) of 0.12 g/cm3 and R2 = 0.74, satisfactory level of accuracy for volumetric water content and SOC with RMSE equal to 0.05 cm3/cm3 and 1.58%, and R2 equal to 0.46 and 0.71, respectively. Some degradation in the estimation accuracy, indication of error propagation, is reported for SOC stocks, with RMSE equal to 1.56 Mg/m3 and R2 equal to 0.49.

Our results advance the development of proximal sensing techniques to rapidly estimate soil carbon content and stratification with the depth resolution required to identify the feasibility of pasture renewal with FIT to enhance soil carbon storage.

Comparison and Complementarity of Color, VIS, NIR, MID and LIBS Spectroscopic Methods for Soil Analysis

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: Soil spectroscopy, Mid-infrared spectroscopy, Visible spectroscopy, Near-infrared spectroscopy, LIBS

Abstract: Spectroscopy has the capability to predict certain physical and chemical soil properties. Hence, it is a promising avenue to complement traditional laboratory analysis which can be costly and time-consuming. In this research, the performance and the complementarity of eight instruments in the prediction of soil properties are studied. A total of 798 air dried and compressed soil samples representing different agro-climatic conditions across Quebec (Canada) were analyzed using these instruments with various resolutions that use four different optical techniques. Visible spectra were collected using a sensor from Hamamatsu Photonics (Hamamatsu, Japan) covering 350 - 850 nm. VIS-NIR spectra of all soil samples were collected using a laboratory setup with a field spectrometer operating in the range from 350 - 2200 nm (P4000, Veris Technologies, Salina, Kansas, USA) and the ASD FieldSpec? 4 Standard-Res Spectroradiometer (Malvern Panalytical Ltd, Malvern, United Kingdom) operating from 350 - 2 500 nm. MID spectra were collected using a custom and portable DRIFT spectrometer with a spectral range of 5500 - 11000 nm and an Excalibur HE FTS 3 100 (Varian, Melbourne, Australia) with ATR-FTIR covering a spectral range from 2 500 - 17000 nm. Color data were collected with an EZO-RGB TM color sensor from Atlas Scientific LLC (Long Island City, New York, USA) and the RGB data from a Dino-Lite Edge 3.0 AM73915MZT, a digital microscope from AnMo Electronics Corporation (New Taipei, Taiwan). Finally, LIBS data from Logiag (Quebec, Canada) were also analyzed. Prediction performances of each instrument were first assessed, followed by combinations of optical instruments, and, finally, complementarity of optical instruments with LIBS data. Results were produced using partial least squares regression (PLSR) and support vector machine modeling (SVM). The outcomes from each combination of soil property (extractable P, K, Ca, Mg, Al, SOM and CEC), data calibration method and instrument were assessed in terms of measurement reproducibility and prediction error.

Determination of Ba, Cr, and Pb Elemental Composition in Cerrado Soils from Piaui State, Brazil Using Multiple Spectrometric Methods

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Environmental mapping

Abstract: Traditionally, a high number of discrete samples are needed to successfully map soil attributes. In order to reduce the cost and effort needed for this type of sampling, many researchers are turning to field devices, such as XRF portable spectrometers, which can produce fast and relatively accurate soil attribute maps. This study focuses on the concentrations of Ba, Cr and Pb in environmental soil samples and will assess if X-Ray Fluorescence (XRF) is able to produce similar values to that of a more traditional method, namely nitric acid digestion of the soil samples followed by elemental analysis using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). We used both methods to analyze 25 samples of soil horizons from 6 discrete profiles from natural Cerrado soils in the southern portion of Piau? State. Ba, Cr and Pb concentrations in these samples were initially measured using a portable, non-destructive Energy Dispersive XRF analyzer. These results were then compared with the concentrations of these elements on the same samples after nitric acid digestion using an automated microwave digestion system and elemental content determination by an ICP-OES, according to the EPA method 3051. The results of these analyses suggest that the sedimentary nature of the parent material is responsible for the low concentrations of the studied elements. Ba concentrations varied between 24.0 and 350.0 mg kg-1, using the XRF (mean of 106.9 mg kg-1), and between 0.97 and 94.64 mg kg-1 using the ICP-OES (mean of 22.1 mg kg-1). Cr concentrations varied between 4.1 and 55.0 mg kg-1, using the XRF (mean of 18.9 mg kg-1), and between 1.79 and 38.15 mg kg-1 using the ICP-OES (mean of 11.7 mg kg-1). Pb concentrations varied between 4.8 and 34.0 mg kg-1, using the XRF (mean of 10.8 mg kg-1), and between 0.71 and 14.28 mg kg-1 using the ICP-OES (mean of 4.2 mg kg-1). For all samples in all profiles, the XRF provided higher Ba, Cr, and Pb values than the ICP-OES. The Tukey HSD test also suggest that the Ba, Cr, and Pb concentrations provided by the XRF are significantly different than those from the ICP-OES. For Ba, the difference between the arithmetic mean provided by both methods was more that 350%. This happened probably because the XRF is able to capture the elemental composition independent of the mineral to which the element belongs, while the nitric acid digestion is not able to extract the elements (Ba, Cr, and Pb) that are bound within silicate minerals. These results suggest that, for these particular soils of the Brazilian Cerrado, the use of XRF spectroscopy will provide a more accurate account of the total elemental composition of Ba, Cr, and Pb in the samples, while the ICP-OES will provide a more accurate account of the available ions in the soil.

Development of a Low-Cost NIR Spectrometer for Proximal Soil Sensing in Low Resource Settings

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: spectroscopy, near infrared, NIR, proximal soil sensing, sub Saharan Africa

Abstract: Numerous spectroscopic modalities have been explored for proximal soil sensing (PSS). The capabilities of techniques like near infrared (NIR) and mid infrared (MIR) reflectance spectroscopy have been well documented in the literature. Although MIR may provide better prediction performance over a broader range of soil characteristics than NIR, there are many advantages to using NIR for PSS in the field, particularly in low resource environments. These advantages include a smaller impact from remnant soil moisture and no requirement to finely grind the sample. In the context of aiding smallholder farmers in the developing world, both techniques have historically been cost prohibitive, but recent advancements toward smaller and cheaper hardware in the NIR range could enable its widespread use in low resource settings.

We recently designed and tested a NIR spectroscopic device with these goals in mind. It is based on an initial commercial version of a low-cost MEMS spectral detection chip operating in the NIR, or alternatively short wave infrared (SWIR) region from approximately 1300 to 2500 nm. Custom optics, electronics, and mechanical designs were created to produce a complete handheld system capable of operation in the lab or in the field. Initial lab testing indicated excellent reproducibility both within and among five different devices. We have verified desired performance (e.g. acceptable signal to noise ratio for target integration times, spectral features equivalent to lab-grade devices, etc.) for a diverse set of soil samples, as well as other agricultural samples including plant tissue, fertilizers, and manures. We have also developed a custom Android mobile app to accompany the devices in upcoming field testing, which will validate their performance in realistic settings in sub-Saharan Africa. Results from this field testing and implications for future development will be presented.

Development of a Methodical Approach for the Detection of Soil Microbial Activity Using Infrared Thermography

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: Infrared thermography, microbial activity dynamics, spatio-temporal approach, microscale

Abstract: The detection of soil microbial activity on the microscale in a high spatial and temporal resolution is highly important with regard to a more profound process understanding. In this context, non-invasive approaches are not established so far due to methodical, instrumental, and analytical challenges. New techniques and approaches need to be developed to gain more information about spatial microbial dynamics, especially in undisturbed soil samples. This information helps to evaluate the dynamics and spatial dependencies in soil fertility, soil carbon loss, and soil contamination.

In this study, passive infrared thermography (IRT) was used and evaluated, filling the requirements for a non-invasive and non-contact technique, which can be used in a high spatial and temporal resolution on the microscale. Surface temperature-based information of soil samples are detected, and variations in the temperature evolution give information about soil microbial activity on soil surfaces. The infrared thermography technique was used because microbial activity produces heat due to mineralization. Here, an approach for measuring the substrate-induced increase of soil microbial activity is developed. Therefore, three dried topsoil samples and two dried subsoil samples, varying in their soil biological properties, were used. For the pre-incubation (one week), the soils were rewetted to 45% water holding capacity and placed in an air-proof box to avoid soil drying. After pre-incubation, different approaches were tested to develop an optimal measurement setup for the detection of soil microbial activity: Airproof box with and without adjusted relative humidity (80% and 95%); soil samples covered with IRT-transparent PP-/PE-foil and uncovered samples; varying glucose concentrations; varying glucose application. For the processing and comparability of the obtained temperature data, a statistical approach was developed.

After pre-incubation, the surface temperature of the prepared soil samples was monitored minutely over one week using a high definition IRT camera. The dynamics in the temperature evolution over one week were evaluated regarding the strength of temperature increase induced by soil microbial activity. Additionally, microbial soil respiration was detected using a respirometer to relate the respiration rates to the temperature increases. Thus, a temperature increase of 0.1 K induced by microbial activity can be detected. In conclusion, the most promising approach is to use shielded (airproof box or foil) conditions regarding ambient environmental influences and relative humidity < 90%.

Digital Mapping of Soil Classes in Low Relief Lands under Sample- Based Fuzzy Logic at Different Taxonomic Levels in Part of Dry and Semi-Arid Lands of Qazvin Plain of Iran

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: fuzzy logic, low relief, uncertainty, geomorphometry, digital soil mapping

Abstract: Survey and digital mapping of soils in areas with low relief intensity due to low variability of soil forming factors especially topographic factor is a challenge in soil-landscape modeling. On the other hand, in the plain areas, the boundaries of the soil map units have been continuously and without distinctive boundary changes and we have to use logic other than the Boolean logic for soil mapping. The objective of this study was to provide a digital map of soil classes at different levels of taxonomic by using appropriate geomorphometric variables and fuzzy logic to maintain the continuous variability of soil map with area of 16,600 hectares. The study area has a moisture regime of dry xeric Bordered with weak Aridic and thermic temperature regime. Based on the geomorphologic map, more than 89 percent of the area is formed by the plain and piedmont landscapes. 61 profiles were collected using stratified randomize sampling method and from genetic horizons, sampling was carried out. Based on physicochemical and morphological data, the soils were classified based on the key to taxonomic 2014 at Family Level. Based on the Mean decrease accuracy (MDE) and mean reduction Gini (MDG) indices in R-version 3.5.1 and the expert's opinion of the region, geomorphometric variables extracted from a digital elevation model with a spatial resolution of 30 meters including diffuse insolation, standardized height, catchment area, valley depth and multiresolution valley bottom flatness (mrvbf) had the highest impact on the occurrence of soils at different levels of taxonomy. Fuzzy Soil Classes map Using sample-based and with defining the default membership functions for each variable related to the position of different soil classes, ArcSIE software was developed and the final map of the spatial distribution of soil classes using the Hardening Module And assigning a soil class with the highest degree of fuzzy membership per pixel of combining fuzzy maps of soil classes at different levels using 61 soil profiles in the first stage and secondly using 70% of the data as training and 30% of the data Validation using error matrix and based on overall accuracy and index Kappa was verified And uncertainty maps of ignorance and exaggerating the maps produced by the hardening process were also studied. The results showed that the soils were classified into three order (Entisols, Inceptisols and Aridisols) and six suborders (Calcids, Cambids, Gypsids, Salids, Xerepts and Orthents) and 7 great groups and12 subgroups, and 23 soil families class. Overall accuracy at different levels of order, suborder, great group, subgroup and soil family was 100,100, 100,100, 96.7%, and kappa index 96.4% at family level in the first stage of modeling. The results of the uncertainty of ignorance and exaggeration at the family level and for the first stage of modeling were obtained from 0 to 0.64 and 0 to 1, So that the amount of ignorance uncertainty of in the southern regions of the maps is the highest due to the diversity of soil classes and the high degree of membership associated with each soil class And in the northern region of map due to the less diversity of soil classes and the higher purity of the soil map units, they have the lowest. The results of exaggerated uncertainty indicate that in the northern regions of the area where the diversity of classes is less or have a less number of profiles is the highest and in the southern regions, the amount of uncertainty is lowest

Identification of the Best Spectrometric Method for Determination of Ca, K, and Zn Elemental Composition in Tropical Soils

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Soil mapping, Nutrients, XRF, ICP-OES, Brazilian Cerrado soil

Abstract: Portable spectrometers are providing a cost-effective way to generate relatively accurate soil maps in short time frames. This is particularly important in places with very little information that are experiencing rapid agricultural development, like the Brazilian Cerrado region. This study aims to produce a methods comparison that measures the closeness of agreement between the values from two conventional analytical techniques used for determination of elemental composition in environmental soil samples, namely the non-destructive Energy Dispersive X-Ray Fluorescence (EDXRF) and nitric acid digestion followed by analysis using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Soil samples were collected from 6 discrete soil profiles within a 40-km transect of natural, undisturbed Cerrado soils from Piau? State, Brazil.Soil samples from all horizons were collected in each profile, totaling 25 samples. Elemental concentrations decreased following the sequence K > Ca > Zn. The overall low concentration of these elements was expected, given the sedimentary nature of the parent material. K concentrations varied between 63.0 and 8752.0 mg kg-1, using the XRF (mean of 1560 mg kg-1), and between 6.3 and 1569.0 mg kg-1 using the ICP-OES (mean of 198.9 mg kg-1). Ca concentrations varied between 31.0 and 902.0 mg kg-1, using the XRF (mean of 244.6 mg kg-1), and between 1.1 and 1085.0 mg kg-1 using the ICP-OES (mean of 137.9 mg kg-1). These values are likely associated with the presence of feldspars in these soils, especially in profiles 1 and 2. This may also explain why the XRF produced concentration values for all elements that are higher than those from the ICP-OES, since it is well known that nitric acid digestion does not thoroughly extracts elements that are bound within silicate minerals. Zn concentrations varied between 5.8 and 106.0 mg kg-1, using the XRF (mean of 17.18 mg kg-1), and between 0.84 and 12.90 mg kg-1 using the ICP-OES (mean of 2.78 mg kg-1). The Zn in our samples have both organic and mineral origins, and some may be allocated in calamine or hemimorphite from the sand and silt fractions. This also explain the large difference in the concentration of this element between the XRF and the ICP-OES analyses. These results suggest that soils from the study area have low natural concentrations of Ca, K and Zn and that XRF spectrometry is more accurate representation of the total elemental distribution of these species compared to nitric acid digestion followed by ICP-OES analysis. Nevertheless, XRF should not be used for recommendation of fertilizer application, since it does not provide the fraction of these elements that are readily available.

Influence of Different Forms of Soil Samples Preparation on the Qualitative Performance Of X-Ray Fluorescence

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: instrumental multielement analysis; reflectance peaks of elements, loose powder, pastille, soil granulometry

Abstract: X-ray fluorescence is a non-destructive analytical technique used for identification and quantification of elements in the sample by dispersing energy K? and Ka or L? and L?. This analysis is simple, fast and there is not generating toxic waste to the environment. X-Ray Fluorescence has been used in research within soil science as a powerful tool in the analytical determination of several elements. However, the sample preparation can influence the results directly. In this context, the objective of this study was compare different soil sample preparation and scanning methods in qualitative performance of x-ray fluorescence for detection of Fe, Ti, Si and Al. Seven soils were selected and submitted to different forms of preparation: 1. air-dried soil; 2. air-dried soil and sieved at 0.074 mm; 3. dried soil in stove and sieved at 0.074 mm; 4. sand sieved at 0,074 mm; 5. silt sieved at 0,074 mm; 6. clay sieved at 0,074 mm; 7. silt and clay sieved at 0,074 mm. The sample scanning methods used were loose powder and pastille. The samples were analyzed by the portable X-ray fluorescence spectrometer (pXRF). The reflection peaks for Fe, Ti, Si and Al were compared qualitatively between the seven different types of preparation and two forms of scanning. For statistical analysis, a randomized block design was used in a Factorial scheme (7 x 2), seven preparation forms and two scanning methods were the factors and the seven soils represent the blocks. Normality was verified by the Shapiro-Wilk test ($p < 0.1$). To compare the reflection peaks of the elements, t and Wilcoxon tests were used, paired for normal and normal conditions, respectively (p ? 0.05). The other forms of preparation of the samples were analyzed by F test (p ? 0.05) and then by Tukey test (p ? 0.05). It is concluded that the 200 mesh sieving process resulted in higher peak intensity for the samples in the form of loose powder. Therefore, the granulometry and fraction analyzed directly influence the observed results. The air dried samples presented higher peak intensity for Al, Ti and Fe than those dried in a stove, indicating that drying in stove is an alternative for improving the results. The peak intensity of the Al, Fe and Ti elements were lower in samples containing only sand. The samples prepared in the form of loose powder presented higher peak intensity of reflectance for Al and Si compared to those prepared in pastille. The use of loose powder samples is indicated because of the quality the results, ease of preparation, handling and storage.

Low-Cost Portable Near-Infrared Sensors for Rapid Analysis of Soil

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: infrared spectroscopy, MEMS

Abstract: Near infrared spectroscopy has been proposed as a rapid and cost-effective method for soil analysis. The main constraint in the real-world application of the NIR technology is the cost of the instrument. The full-range visible-near-infrared spectrometers working in the 350-2500 nm wavelength are commonly used in research, but the cost of such spectrometers is relatively high. Portable and miniaturized spectrometers are now available as off-the-shelf products.

This study evaluated the feasibility of these low-cost, miniaturized instruments for rapid soil analysis by analyzing various soil properties (total carbon, clay, sand, and silt content, cation exchange capacity, pH, exchangeable Na, Ca, K, and Mg). A total of 392 soil samples from the wheat-sheep belt of southern New South Wales and northern Victoria were used in this study. The study compared two research-grade Vis-NIR spectrometers (350-2500 nm) and two minituarised NIR spectrometers (900-1700 nm and 1350 -2500 nm). Cubist regression tree and Partial Least Squares Regression (PLSR) were used to build calibration models. The results showed that both modelling procedures are reliable for estimating soil properties.

As expected, the research-grade spectrometers provided the best prediction accuracies. Considering the prediction accuracy and cost, the miniaturized spectrometers also perform well. Results from the 1350-2500 nm spectrometer provided a comparable accuracy with the Vis-NIR spectrometers in predicting soil pH, CEC and exchangeable Ca and Mg. The portable instrument produced a slightly less accurate prediction of total carbon, sand, and clay.

This study demonstrates the potential of miniaturized spectrometers as cheaper instruments in soil analysis.

Mapping Soil CO2-C Exchange in Two Different Vegetation Communities in Stansbury Peninsula, Maritime Antarctica.

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Ecossistem Respiration, Net Ecosssitem Exchange, Gross primary Production

Abstract: Carbon dynamics (soil CO2-C exchange) and soil attributes vary considerably in ice-free areas of maritime Antarctica, especially due to differences on vegetation cover, relief, plani-altimetry, hydromorphic conditions, as well as biological activity. Thus, variables directly related to vegetation communities distribution/characteristics and soil attributes, such as organic carbon, soil temperature and moisture, may be used as sensitive indicators of the climate change impacts in ice-free areas in maritime Antarctica. The objective of this work was to map soil CO2-C exchange, soil temperature and moisture in two different vegetation communities in maritime Antarctica. The study was carried out at Stansbury Peninsula, Nelson Island. In February 2018, two different vegetation communities were selected, and a regular 40-point (5 x 8 m) grid, with a separation distance of 1 m was installed. The vegetation community 1(site 1) is a moss-carpet community, predominantly colonized by Saniona unicata (Hedw.) Loeske); and vegetation community 2 (site 2) is predominantly composed by Usnea aurantiaco-atra (Jacq.) Bory and Deschampsia antarctica Desv. Soil was sampled at different soil layers (up to 20 cm depth) to determine soil organic carbon. Ecosystem respiration (ER), net ecosystem CO2 exchange (NEE), gross primary production (GPP) were determined by measuring CO2 fluxes in situ with a closed automatic chamber system (LI-COR Biosciences, Lincoln, NE, USA). Measurements occurred over the course of two days (14th and 15th February) during daylight hours at each site. Soil CO2-C emissions at each grid point were based on a single measurements over 1.5 min. Soil moisture and temperature were also measured using temperature and moisture probes at the same time of soil CO2-C exchange at each grid point. Descriptive and spatial analyses of data were performed in software R. Results indicated that ER ranged from 0.05 to 3.34 µmol CO2 m-2 s-1 in the studied sites. Mean ER was observed to be two times higher in site 1. The highest CO2 sink strength was observed in Site 1 (net uptake of 0.57 µmol CO2 m-2 s-1), coupled with greater soil organic carbon (4.56 dag.kg-?). On the other hand, the lowest CO2 sink strength occurred in Site 2 (net uptake of 0.25 µmol CO2 m-2 s-1). There is a significant negative correlation between NEE and SM, indicating the potential of hydromorphic site on the soil organic carbon storage. Spatial analysis indicates that area 1 is more homogenous (greater range values) than site 2, with spatial correlation between thematic maps of the variables measured. In warmer days, ER increase and NEE reduces. However, even with an increase of 1.95◦C, site 1 still continues storing more carbon during the two days of measurements. This soil temperature increase resulted in 0.41 µmol CO2 m-2 s-1 being released to the atmosphere. ST and SM are directly related to the spatial variability of CO2 exchange.

Maximizing Utility of the VisNIR-Mounted Penetrometer

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: VisNIR, spectroscopy

Abstract: A soil penetrometer mounted with visible and near-infrared reflectance spectroscopy (VisNIR) is a tool that can perform soil profile characterization without the costs, labor, and time associated with soil coring and wet laboratory analyses. When a VisNIR penetrometer is pushed into a soil, continuous measurements of soil properties are created. These measurements can include noisy predictions from natural, small-scale variability. Also, variable soil moisture contents at the time of measurement must be accounted for when making predictions of soil properties. The overall goal of this research is to investigate ways to maximize utility of VisNIR penetrometer profile scans. Specifically, we investigate the effect of averaging soil spectra with depth. We also compare methods to predict soil properties, specifically percent clay content, from field-moist, intact VisNIR scans. Two methods for prediction are used: (1) External Parameter Orthogonalization (EPO) using a dried-ground spectra library, and (2) using an intact, variable-moisture calibration set.

A total of 61 soil cores were collected from Burleson (fine, smectic, thermal, Udic Haplustert), Davilla (Fine-loamy, siliceous, superactive, thermic Udic Haplustalf), and Wilson (fine, smectic, thermic, Oxyaquick Vertic Haplustalf) series-mapped soils in Central Texas. Spectra were collected from cores scanned at variable field moistures and uniform moisture. Predictions of soil clay content were made by transforming soil spectra using EPO and predicting with the Texas State Soil Library (TSSL). Alternatively, an intact dry and intact field-moist data set from 6 other areas of central Texas soils were used to create prediction models. Secondly, spectra were averaged from (1) two scans of the same core, (2) from two different cores in the same location, and (3) by horizon. The TSSL was subsampled using principal component analysis and partial least squares regression models were calibrated using the subsampled library. The model was validated with the 61 Texas soil core spectra. Prediction accuracies will be discussed.

Mineralogy of Soils with Low Clay Activity, as a Regulator of Weathering Dynamics, Detected by Spectral Sensing

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Soil spectroscopy; Surface reflectance; Continuum remove; Derivative spectra

Abstract: Quantifications using spectra has been focused mainly on texture and nutrients. On the other hand, it is the mineralogy that regulates their dynamics in soils. Diffuse reflectance spectroscopy, is a quick, low-cost, nondestructive, and environmental clean technique that can be used to characterize clay mineral composition. We purpose the use of pure spectral libraries and identify mineralogy in soils with low clay activity, based on laboratory (350-2500 nm) topsoil spectra, as to relate it with pedogenesis. Thirty-four samples (0-0.20 m) of Ferralsols, Plinthosols, Regosols, and Cambisols profiles were collected from Central Brazil. These tropical soils developed over predominantly low-grade metamorphic pelitic rocks. Soil samples were ground, air-dried, and passed through a 2 mm screen prior to laboratory analysis. We scanned soil samples in a dark room using a FieldSpec Pro sensor (350-2500 nm). We processed topsoil spectra (TS) by removing the continuous spectrum (CR), and by applying the second derivative (SD) of the Kubelka-Munk (K-M) function using smoothing procedure (Savitzky-Golay). These data transformation allow more specific identification of small and nearby lying absorption features, and make them comparable to other spectra. We checked the mineral occurrences with previous works on mineralogy in the studied region, performed by XRD, and we confirmed the absorption features with those of the pure spectra obtained from the USGS library. Thus, the absorption features were visually identified in the transformed spectra. Then were parameterized by using the amplitude of selected bands in the K-M SD spectra, once they are approximate to the mineral concentrations of the soil. The CR showed six absorption features associated with Fe and Ti oxides in the VIS-NIR range (350-1100 nm), like goethite (at 420, 485, and 950 nm), hematite (at 530 and 885 nm), and Rutile (at 546 and 2305 nm). SWIR range (1100-2500 nm) was related to the presence of water, sesquioxides and aluminosilicate clay minerals, like gibbsite at 1450 and 2265 nm, and kaolinite (1:1) at 1394, 1412, 1908, and 2160 nm and 2205 nm (deeper absorption). Chlorite (2:1) presented a single absorption at 2385 nm. Illite (2:1) presented absorption attribute at 1908, 1412, and 2350 nm. Thus, all soils are kaolinitic, with a large amount of sesquioxides and traces of illite, chlorite, and rutile, where 2:1 clay minerals occur in younger soils or in silt and sand fractions, agreeing to works performed by XRD in soils of the same region of Brazil. The K-M SD revealed 7 well-separated bands amplitude in the VIS (AGt and AHt) and SWIR (AKt, AGb, ARt, AIl, and ACh) regions, indicating predominant iron oxides content (goethite+hematite) in the soils, with exception of Haplic Plinthosol. The kaolinite content was low to intermediate with smaller amounts of gibbsite. We identified trace of rutile and 2:1 clay minerals (illite+chlorite). The presence of 2:1 clay minerals in the more weathered soils (Ferralsols) may occur due to it resistance in the silt and sand fractions derived from the parent material. K-M SD bands amplitude for hematite (AHt) was related to redder soils (hue of 10 R), and for goethite (AGt) to Munsell color about 7.5 YR. The CR and SD K-M processing applied to TS based on spectral libraries enabled to investigate the soil mineralogy which was linked to soil color, weathering and pedogenesis processes.

On-the-Go Gamma-Ray Spectrometry: Highly Resolved Texture Information for Soil Mapping, Precision Farming, and Field Experimentation

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: on-the-go data, proximal soil sensing, soil heterogeneity

Abstract: Proximal gamma spectrometry has emerged to be a capable mobile sensing technique to provide soil information, in particular on topsoil texture. Applying appropriate computational methods such as support vector machines (SVM) enables calibration of site-independent prediction models that provide soil texture information which is valid for different parent materials. Since soil mapping and in particular precision agriculture applications require high resolution soil information, on-the-go gamma data (i.e., recorded from a vehicle while moving onwards) are of special interest. However, on-the-go measurements yield enormous data amounts but require rapid (pre-) processing while travelling over the field. This is due to the significant noise when spectra are recorded at the common frequency of 1 Hz. In this respect, a simple online approach to process on-the-go data was tested. In a first step, we calibrated site-independent prediction models for sand, silt, and clay. Next, a moving window approach was applied to smooth on-the-go data, which were subsequently introduced into the prediction models. The resulting predictions were presented by means of soil maps to show up three different possibilities of application. First, soil mapping over the area of a whole farm is demonstrated. Second, in-field variability is recorded for precision farming applications. Third, use of gamma recordings to produce large scale information for field experimentation (i.e., plot experiments) is demonstrated.

Physical-Chemical Lixisols Characterization Using the Lidar Sensor

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: remote sensing, backscatter, soil properties.

Abstract: New technologies that make it possible to obtain information on soil properties faster and less expensive have been researched, such as the use of LiDAR (Light Detection and Ranging). Due to its characteristics the sensor has been mostly applied to obtain terrain models. However, these sensors produce not only spatialized point clouds, but also amplitude and reflectance (backscatter) levels of their targets, so far this potential has not been explored as a possible methodology for the characterization of some soil properties. It is in the literature studies exploring the reflectance of LiDAR only for determination of gravel, sand and soil moisture. In view of this, the aim of the present study was to evaluate the physical and chemical characterization of a soil profile from the terrestrial laser scanner use (LST). For this, a Lixisols profile was segmented into ten layers, each with a thickness of 10 cm, which were subdivided into two sections (left side - A and right side - B). Then, the profile scanning was performed using the LST model VZ 1000, from RIEGL, which operates in the infrared (1064 nm). The LST was positioned at three different distances from the soil profile to perform the scans (p1 = 1 m, p2 = 2m and p3 = 3m). At each distance scanning was performed with four different intensities (70, 100, 150 and 300 kHz). Subsequently, the RiscanPRO 2.1 software was used for point cloud processing and for the extraction of the mean amplitude and reflectance data of each sampling unit of the profile. The soil of each unit was collected for the determination of moisture, the contents of the elements P, K, Ca and Mg and the granulometry (fine and coarse sand, silt and clay). A similar correlation was observed between soil properties and LiDAR data at different scanning distances and intensities. Therefore, the effect of the distance between target and sensor, and the different frequencies of the bundles, in this case, do not demonstrate to have significant effect in the prediction, being necessary to use only one of the variables to predict the attributes of the profile. The correlations between the soil attributes and the laser data were negative for the moisture content and the clay fraction and positive for the other properties. The coefficients of determination of the adjusted quadratic models ranged from 0.06 to 0.98, where the lowest values for phosphorus (0.06) and silt fraction (0.58) were highlighted, while the highest values were obtained for magnesium (0.98), soil moisture (0.94) and for the coarse sand and clay fractions (0.92). Therefore, the data obtained using the LST can predict, from a correlation, the physical-chemical attributes studied in the Lixisols profile. However, to consolidate the methodology, it is necessary to perform evaluations with other soil classes.

Quantification and Mapping of Soil Properties on a Profile Wall Using Digital Photography

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: Soil color, Digital photography, Soil mapping, Soil organic carbon, Digital soil morphometrics

Abstract: There is a growing interest in the accurate estimation and mapping of soil properties at different scales. While this has already been extensively studied on a larger, ecosystem or landscape scale, the micro-scale is still not very well understood. The measurement of soil properties is often time-intensive, expensive, and does not allow for a high resolution that is necessary to understand soil processes at this fine scale. Here, proximal soil sensing with imaging and spectroscopic methods can help to gain information on the micro-scale. One parameter that is commonly documented in soil surveys is soil color because it is easy to obtain and includes information about soil organic and mineral composition. With modern-day digital photography there is a cost effective and simple way to record color information at a very high spatial resolution. In this study, we demonstrate different calibration models for soil organic carbon (SOC) and total Fe content based on the color information retrieved from digital photography. For this, we sampled a soil profile wall of a Luvisol in the Lower Rhine region, Germany. The site was an extensively used grassland. We took 50 samples (each sample representing a homogenous color) plus 3 additional microplate scale excavations from the profile wall. The 50 samples were sieved and ground and investigated for SOC, N, (amorphous and crystalline) Fe, and pH. Those samples were our calibration samples for the subsequent modelling that was used to map SOC and Fe on the soil excavations. Since soil color changes drastically after grinding, photographs of sieved and ground soil samples were taken in the laboratory under standardized conditions using daylight lighting units with diffusing covers for even lighting. Photographs were recorded with a full-frame 50 MP DSLR camera (Canon EOS 5DS) with a 50 mm prime lens in RAW format. A reference color chart was included in every picture for white balance, color, and brightness correction. After correction, the RGB color tristimuli for each sample was obtained from 200x200 pixel regions of interest. The RGB values were transformed into CIE color spaces for further analysis. We looked at different prediction methods from (multiple) linear regression to more advanced machine learning algorithms such as random forest and artificial neural networks to find the mathematically best model. In a first bivariate linear regression, the R variable showed the highest R2adj (0.91) for SOC and the CIE v* variable the highest R2adj for Fe (0.64) for ground soil samples. When color was obtained from sieved samples R2adj was lower 0.76 (CIE v*) and 0.56 (CIE a*) for SOC and Fe, respectively. Multiple linear regression models using full color spaces could improve those predictions to R2adj of 0.92 (SOC) and 0.77 (Fe) for ground samples and R2adj of 0.85 (SOC) and 0.70 (Fe) for sieved samples. From the best derived pedotransfer functions for SOC and Fe content we predicted the respective contents for the three excavated microplate samples. In a last step, we compared the results of the predictive modeling to the prediction of the soil parameters using MIR spectra as a more sophisticated spectroscopy method. We found that properly calibrated digital photos could predict SOC similarly well as MIR spectra. Soil color derived from digital photography is a cost-effective method that has the potential to map the distribution of at least SOC on a small to micro-scale.

Spatial-Temporal Analysis of Soil Water Storage and Deep Drainage under Irrigated Potatoes in the Central Sands of Wisconsin, USA

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: sandy soils, irrigation, hydraulic conductivity, potato yield, evapotranspiration

Abstract: Knowledge of soil water storage and deep drainage is important for improving irrigation efficiency, maximizing crop water use, and understanding groundwater table fluctuation. This is particularly important in sandy soils that depend on irrigation to produce crop yield. In sandy soils under potato in the Wisconsin Central Sand Plains, soil water storage using tension probes was measured in three irrigation zones over the 2014 and 2015 growing seasons. Soil water storage was estimated across a 78 ha field using apparent electrical conductivity maps. Deep drainage was estimated using the Richards' equation and Hydrus-1D software. It was found that soil water storage ranged from 82 to 118 mm in the top 0.45 m in three irrigation zones in 2014, and from 71 to 97 mm in 2015. Rainfall and irrigation was 387 and 269 mm in 2014, and 328 and 281 mm in 2015. Estimated deep drainage was uniform in three irrigation zones, and ranged from 222 to 244 mm in 2014, and from 167 to 180 mm in 2015. A negative correlation was found between soil water storage and potato yields possibly due to over-irrigation. The methods used in this study can be applied to improve irrigation and water use efficiency.

Sentinel-2A Time-Series for Digital Soils Mapping Using Topsoil Reflectance and Spectral Mixture Models

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Spectroscopy, temporal series, Sentinel-2, Soil Survey, Remote Sensing.

Abstract: In-depth knowledge about soil resource is indispensable to conservation actions. However, pedological maps at appropriate scales are scarce in developing countries such as Brazil. Digital Soil Mapping Techniques (DSM) are interesting alternatives considering time gain, cost minimization and lower waste generation when we compared to traditional soil mapping methods. Thus, the objective of this work was to evaluate a short Sentinel-2A (S-2A) time-series for digital soils mapping using topsoil reflectance and spectral mixture models (MESMA). The study area has about 152 Km2, it is located in Central Brazil and developed over metasedimentary rocks. We collected 19 representative soil profiles using toposequence method and we performed field morphological descriptions. The soil samples were air-dried, ground and sieved using 2-mm mesh for physical, chemical and spectroscopic analyzes. We classified the soils up the third categorical level of the World Reference Base for Soil Resources (WRB - FAO/ UN). We performed spectral readings on topsoil samples using a FieldSpec Pro spectrometer, from 350 to 2500 nm. The mineralogy was checked by the Morphological Interpretation of Reflectance Spectrum (MIRS). We grouped similar soils using topsoil spectra in clustering analysis by Euclidian distance module of single linkage by means of R software. We calculated the mean curve into each group that represented the soils of the study area. After we reissued to the S-2A bands (VNIR-SWIR) to obtain the endmembers. Then, we acquired a surface reflectance time-series of 16 S-2A images (Level 2A) from 2015 to 2018 during the dry season. We calculated and applied two spectral indexes (NDVI and MIDII) to mask bare soil areas in the time-series that were used to calculate the median reflectance which produced a Synthetic Soil Image (SYSI). For soil class mapping purpose, we used as inputs data the laboratory endmembers and the SYSI to apply the Multiple Endmember Spectral Mixture Analysis (MESMA) method. We elaborated the soil map legend by adding the mean topsoil color of the clustered soils to each endmember (soil class). We validated the digital soil map (DSM) using Kappa index calculated from 70 field-visited sites distributed on a regular grid of 1.0 x 0.9 Km. The profiles were distributed in 6 soil classes and organized as: Dystric Rhodic Ferralsol (FR-ro.dy I, FR-ro.dy II, FR-ro.dy III); two Dystric Xanthic Ferralsol (FR-xa.dy I, FR-xa.dy II); one Petroplinthic Xanthic Ferralsol (FR-xa.pp); two Dystric Petric Plinthosol (PT-pt.dy I, PT-pt.dy II); one Dystric Haplic Plinthosol (PT-ha.dy) and two Dystric Clayic Regosol (RG-ce.dy I, RG-ce.dy). The MIRS showed features of Fe oxides such as goethite (480 and 950 nm) and hematite (530 and 850 nm), kaolinite (1,400 and 2,205 nm), gibbsite (2,265 nm), 2:1 clay mineral, and water adsorbed on the particle surface (1,400 and 1,900 nm). The topsoil spectra clustered the soils into 11 groups which had as main attribute the topsoil color. The SYSI achieved 41.7% of bare soil area coverage and presented very similar spectra to the endmembers. MESMA modeled 98.7% of the SYSI with low global RMSE of 0.81% and high global fraction of 60%. MESMA-derived Digital Soil Map reached a Kappa coefficient of 0.73, indicating a good agreement with the field-verification sites. Thus, we evaluated that the short S-2A time-series has potential for digital soils mapping using topsoil reflectance and spectral mixture models (MESMA).

SLAKES Smartphone Application for Aggregate Stability Differentiates Between Different Management Practices

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Oral

Keywords: Aggregate Stability, soil management

Abstract: Measurements of soil condition that can be simply implemented by farm mangers or scientists are ideal for quantifying and comparing soil condition. Quantified soil condition ratings can inform managers and scientists on effective soil management practices and identify regions where poor soil condition is jeopardizing the environment and soil productivity. However, many current methods for quantifying a rating of soil health are complicated, time consuming, and require specialized equipment-especially the measure of aggregate stability. SLAKES is a new application that runs on an Android smartphone and uses the built-in camera along with image recognition software to quantify aggregate stability through a simple experiment. The experiment requires three pea-sized soil aggregates, a petri dish of water, and an Android smartphone running the SLAKES application. The application takes a reference image of the aggregates before dispersion then images the aggregates as they disperse for ten minutes. A non-linear Gompertz function, characterized by three coefficients, is fit to the dissolution data and one of the coefficients is displayed as the on-screen stability rating. A text file of the aggregate dissolution over time can be downloaded from the smartphone. SLAKES, along with the Cornell Wet Aggregate Stability Test, was used to measure the aggregate stability of seven conventional, seven no-till, and eight perennial fields under agricultural production to test the methods sensitivity to different management practices. All 22 sites were on Vertisols, Typic Haplusterts. These results showed SLAKES was better able to differentiate between management practices than the Cornell method, which was only able to differentiate between conventional tillage and perennial managements at a low significance. SLAKES proved to be a legitimate method for quantifying aggregate stability based on slaking, and we estimate that a SLAKES measurement costs less than 1 USD per sample. This makes SLAKES a viable and inexpensive method for quantifying aggregate stability for anyone with a portable electronic device.

Soil Attributes Survey Using X-Ray Spectrometry: Comparison of Aerogeophysical Data with Soil Use and Occupation Map

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: XRF, gamma spectrometry, magnetometry, thermofluorescence.

Abstract: X-ray fluorescence (XRF) is a technique that has been used for soil analysis, being a dynamic and extremely proficient tool for the quantitative and qualitative determination of the presence of chemical elements in several types of samples of biological, industrial interest, geological and environmental. The basic principle of X-Ray Fluorescence Spectrometry is to use a large energy to excite the atoms, causing the electron to be removed from the atom, and another atom at a higher energy level to replace it by releasing an energy in the form of a photon with spectrum in the X-ray range. Knowledge of the geophysical characteristics of the study area compared to the map of land use and occupation can help to understand the dynamics of the environment; and these data correlated to those obtained by means of thermofluorescence can improve this study allowing the correlation of this data with many other variables. The study area was a microbasin located in the southeastern region of Brazil. The maps of land use and occupation were created through of automated classification (Random Forest algorithm). Gamma spectrometry data were obtained through national company of mineral resources (CPRM). For XRF analysis, 100 points were collected at two depths and the total macro and microelements were determined. In relation to the geophysical data, the study area presented low levels of K, a fact that may be associated with the source material. The forest regions were those that presented milder temperatures in the region while rocky outcropping showed the maximum. Four main components were able to explain the overall variation in data from x-ray analysis. Ten variables presented non-linear correlation values above 0.8. The use and occupation of the soil was correlated with the geophysical and temperature data. In relation to aerogeophysical data, high correlation with altitude and low correlation with data obtained by x-ray analysis were found.

Spatial Distribution of Top-Soil Properties and Thermal Behaviour of the Permafrost Active Layer via Satellite Images in Byers Peninsula, Marine Antarctica

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: satellite images; PLRS models; ADS spectra; color indexes

Abstract: In Antarctic periglacial areas the thermal soil regime undergoes rapid changes in response to annual or long term climatic oscillations. Soil properties as color or mineralogy of the parent material could be related to the soil thermal behavior. The main objective of this experiment was to find a remote sensing method to monitoring top-soil properties and thermal behavior of the active layer of permafrost in the beginning of snow cover melting. From a WoldView-2 image of Byers Peninsula, six color spectral Indexes were calculated: Ferric ion (Fe3+) = RED/GREEN; HUE= arctg ((2R-GREEN-BLUE/30.5)* (GREEN-BLUE)); IR550= 550-1; IR700= 700-1; Missa Soil Brightness Index (MSBI) = 0,404 GREEN-0,039 RED- 0,505Pan+0,762NIR; I/O (OXIDE) = RED/BLUE. Soils of Limnopolar lake watershed in Byers peninsula were sampled and several soil properties as pH, electrical conductivity, total organic carbon, texture, organic carbon, density and sequential extraction of Fe and Mn (F1: exchangeable fraction, F2: carbonate fraction, F3: amorphous ox hydroxides, F4: Fe ox hydroxides and associated Mn, F5: crystalline Fe ox, and organic Fe and Mn) were analysed. NIR spectra (ASD) of soils samples were taken. The color of soils was measured using a colorimetric device to validate the soil color obtained via spectral indexes. The ASD soil spectra were resampled to the spectral bands of WorldView-2 and the indexes of color with the resampled bands were calculated. We calculated the correlation between soil properties and resampled ASD bands and color indexes calculated with resampled ASD bands, as well as the correlation between WorldView-2 bands and color indexes calculated with WorldView-2 bands. Spectral bands Blue (479 nm), Yellow (608 nm) or Red (659 nm) and spectral indexes Hue, Ferric ion (Fe3); IR 550 or IR700 are highly correlated (R2 > 0,5) to soil properties as texture, organic carbon and ferric oxides. Finally, PLSR models of soil properties and spectral bands and color indexes were performed. Crossvalidation of Sand; Fe and Soil Organic Matter PLSR models indicate that were suitable to be regionalized via satellite image to Byers Peninsula.The preliminary results show that there exists a relation between the thermal behavior of the permafrost active layer and the values of the color indices.

The Potential of Active and Passive Infrared Thermography for Identifying Soil Physical and Biological Parameters

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Infrared thermography, soil moisture calibration, microbial activity dynamics, spatio-temporal approach, microscale

Abstract: Spatio-temporal analyses of soil physical and biological properties of soil samples are important for a better process understanding and deeper insights into soil property dynamics. Up to now, there is a gap of non-invasive approaches analyzing these properties combined on the microscale in a high resolution based on methodical limitations. Such approaches are important for the evaluation of physical and biological heterogeneity of soil samples.

Passive and active infrared thermography (IRT) are evaluated in this study. These techniques enable a non-invasive and non-contact evaluation of surface temperature-based information of the soil surface. Active IRT is used to detect and calibrate soil moisture contents and soil surface structure based on the specific heat capacity of soil samples varying with moisture contents and structural differences, like soil density. Passive IRT is able to monitor soil microbial activity due to heat production at increased mineralization rates.

A pool of 51 soil samples was used for the experimental approach, which are varying in chemical, physical, and biological properties. The soil material was rewetted to 16 different moisture contents. To reduce soil drying, the experiments were conducted in an air-proof glove box with an ambient relative humidity of 92% obtained by a saturated sodium chloride solution and a ventilation system. Immediately after rewetting, the soil surface temperature was recorded minutely using the passive IRT procedure and hourly using the active IRT approach at a spatial resolution of 0.283 mm per pixel. To validate the passive IRT measurements, the surface temperature of ?-irradiation sterilized soil material was also detected, which are expected to be microbial inactive.

The active IRT measurements were reliable in determining the soil surface moisture contents in consequence of the changing specific heat capacity at varying water contents. About 88% of the mean temperature amplitude calculated from the active IRT values can be explained by the mean volumetric contents of the soil samples, which is a good approximation for relative differences in the spatial and temporal distribution of water contents. Qualitative variations of the soil surface structure can be evaluated as well by calculating the phase image of the active IRT values.

Using the passive IRT approach for the detection of microbial activity, temperature increases up to 0.5 K can be detected for the non-sterile samples. In the sterile samples, rewetting did not result in heat production. Thus, the temperature increase can be linked to increased mineralization rates of soil microorganisms by adding water to the dry soil samples, which is the commonly observed ?Birch?-CO2-pulse.

In conclusion, IRT is a promising technique for monitoring soil surface processes, since IRT techniques allow studying moisture and microbial activity of intact soil structures.

The Use of Vis-NIR and Pedotransfer Functions to Predict Moisture Storage in Sandy Soils

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: soil organic carbon, available water capacity, vis-NIR spectroscopy, pedotransfer functions, soil texture

Abstract: Quantifying soil water storage is important for plant growth and agricultural production. This is particularly important in sandy soils since they are widely cultivated and prone to drought. We investigated the effect of soil organic carbon (SOC), soil texture, and gravel content on soil moisture characteristics in sandy soils. Soil moisture characteristics were analyzed using standard soil physical characterization as well as visible-near infrared (vis-NIR) spectroscopy and pedotransfer functions (PTFs). Volumetric water content (-10, -33, -1500 kPa) and available water capacity (AWC) increased by 0.01 to 0.02 m3/m3 with a 2% increase in silt plus clay content. Available water capacity increased by about 0.05 m3/m3 with a 1% increase in SOC. A 5% increase in gravel in the subsoil decreased the volumetric water content of the soil by 0.01 m3/m3. Predictions of volumetric water contents and AWC by vis-NIR were the best when using a random forest model. Pedotransfer functions for AWC predictions performed best when sand, silt, clay, bulk density, and SOC were included. Soil water storage ranged from 44 to 65 mm in the top 50 cm. At mean evapotranspiration (4.2 mm/day), irrigation requirements were reduced by 6 days in the sandy soils that have larger SOC and silt contents in the topsoil. These soils are sandy throughout but have subtle differences in particle size distribution, SOC concentrations and gravel content. These differences affect soil moisture storage considerably. Soil management practices that increase the SOC contents in these sandy soils favor moisture storage and tend to reduce irrigation requirements.

Session 3

A First Survey of Glomalin Related Soil Protein using Digital Soil Mapping in France

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: soil, glomalin, DSM, protein, carbon sequestration, carbon dynamics, fungal tracer

Abstract: Organic matter plays essential roles in soil, including climate change mitigation and adaptation, and carbon sequestration or food security. Total Soil Carbon content alone is insufficient to predict the dynamics of organic matter. An operationally defined fraction of soil organic matter known as glomalin or glomalin related soil protein, GRSP, obtained by autoclaving soil in citrate solution, is assumed reputed thought to be of fungal origin, very stable and responsible for enhanced soil physical stability.

In this work, we produced a first extensive spatial survey of GRSP at the French territory level. To achieve this goal, we first measured GRSP on a selection of 200 sites representing mostly cropland, grassland and woodland land uses from the 2200 sites of the French National Soil Monitoring network (RMQS). This selection was done on the basis of organic matter content. In addition to this, we calibrated a predictive function based on either pedological data and on MIRS data to estimate the GRSP on the remaining RMQS sites. Lastly, we implemented a digital soil mapping approach involving a regression kriging model using with environmental covariates. The cross validation of the predictive MIRS yielded to a reasonable accuracy (R?> 0.8). The first results revealed a strong effect of the land use effect that appears to be led by organic carbon content.

Adding Climatic and Terrain with Spectral Data to Improve Soil Classification

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: climate, terrain, Vis-NIR-MIR spectroscopy, proximal sensor, pedometrics.

Abstract: Predicting soil classes from spectroscopy data is a challenging task and has not yet presented satisfactory results. Even with the incorporation of different sensor types, spectral range and modelling approaches, it became challenging to improve the prediction performance. Defining new alternatives to improve soil classification prediction is necessary in order to detect what spectrum data cannot express. This study aims to improve the soil classification prediction by combining soil spectra with climatic and terrain data. The study was conducted in a vast and heterogeneous area, encompassing three regions of Brazil: Southeast, Central-West and Northeast. At total 1570 samples from 382 soil profiles were used. Three model approaches were applied to predict soil classes: linear discriminant analysis (LDA), support vector machine (SVM) and random forest (RF), all using cross validation (fold =10). LDA presented lowest performance in both Vis-NIR and MIR data, with overall accuracy (OA) of 0.76 and 0.65, respectively. Adding climatic and terrain attributes to LDA model presented a small effect on the increase in accuracy. When using only Vis-NIR and MIR spectra, SVM model presented better performance than LDA (OA of 0.80 and 0.74, respectively). Adding climate and terrain variables to SVM modelling, OA raised to 0.88 for Vis-NIR and 0.84 for MIR. The RF model with only Vis-NIR data had OA of 0.79. When climatic and terrain variables where added to RF, the OA improved to 0.94 (a 15% increase). Same increase was found applying MIR and MIR spectra plus climate and terrain data (OA of 0.78 and 0.93, respectively). In the best model (RF/Vis-NIR+climate+terrain), Arenosol, Ferralsol, Lixisol, Luvisol and Planosol classes obtained accuracies higher than 0.90 (0.96, 0.96, 0.95, 1.00, and 0.97, respectively). These classes were predicted with high precision, when combining spectral with climatic and terrain data. Climate and terrain information improved the model's accuracy in 50% for Gleysol, 38% for Nitosol, and 36% for Cambisol. Comparing the classification techniques, models applying decision trees (RF) presented the best performance. Comparing the use of Vis-NIR and MIR data, both had similar prediction performance. Generally, most misclassification was found between the classes: Ferralsol-Nitisol-Lixisol, Planosol-Arenosol, and Regosol-Ferralsol-Nitisol. Adding up the climatic and terrain information enhanced prediction of all the soil classes. Soil water balance, annual evapotranspiration, annual precipitation were the variables that presented more than 95% of importance in the classification model. The annual temperature was an important information for Gleysols and Koppen classification was important for Nitosols. The minimum temperature presented high importance in the classes of Regosol, Nitosol, Cambisol. In the terrain variables, channel network and altitude above channel network presented high importance. The elevation was important for Gleysols, aspect and valley depth for Nitosols, and LS factor and slope for Planosol. The climatic and terrain variables were mainly responsible for increasing the accuracy of Gleysol, Nitosol, and Cambisol classes. Climate variables presented higher relevance in the soil classification model comparing with those of terrain.

Advances in Modelling and Mapping of Global Soil Information

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: quality assessment, cross-validation, uncertainty, quantile regression forests, SoilGrids

Abstract: Soil information is fundamental for a large range of global applications, such as studies on food security, land degradation, sustainable management, water resources, hydrology, climate change and ecological conservation. In order to address these diverse needs, it is important to provide free, consistent, easily accessible and standardized soil information. SoilGrids is a global product that fulfils two main goals: 1) it is a source of consistent soil information to support global modelling, and 2) it provides complementary information to support regional and national soil information products in data-poor areas. This presentation will highlight methodological and geo-computational improvements and updates for modelling and mapping of global soil information of GlobalSoilMap consortium. The modelling approach is based on state-of-the-art statistical and geo-statistical approaches, including machine learning. The developed procedures will be transparent and reproducible at all stages. The set of input data was expanded and all data were standardized. The set of covariates used was critically revised. A solid quality control procedure was implemented in the production process and final maps to check for both technical issues and pedological meaning of the results. The cross-validation procedure was improved so that it takes into account bias caused by spatial differences in sampling density at different depths. We will quantify location-specific uncertainty at global level by computing 90% prediction interval limits. The whole process is based on FOSS4G software and implemented for High Performance Computing settings.

Application of Fuzzy Logic for Fine-Scale Soil Mapping: A Case Study in Thailand

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Keywords: Fuzzy logic, defuzzification, digital soil mapping, topographic wetness index, uncertainties and validation

Abstract: Conventional soil survey methods are labor intensive and prohibitively expensive considering the area to be covered. Unfortunately, the current soil survey products are not adequate, either categorically or cartographically, and cannot be easily downscaled for its application at farm-level. On the other hand soil is a continuous variable and does not have abrupt boundaries in nature. One soil type can change gradually to become another class. This creates problem in delineating soil boundaries due to overlapping of classes, resulting in low mapping accuracy especially in conventional soil survey works. In this situation fuzzy logic can be useful. In classification using fuzzy logic a pixel may have multiple class membership and the one with the highest membership gets the class label. The main objective of the study is to assess the usefulness of fuzzy logic in increasing efficiency in soil mapping. The study was conducted in Lomsak, Phetchabun province in Thailand. An expert system is used whereby rule-based reasoning is applied for mapping soils in which the soil-landscape relationship is taken into account. Litholgy and terrain parameters were used as predictor variables for mapping 17 soil series and topsoil texture in a complex landscape. The accuracies of the fuzzy logic derived soil map and that of conventional soil map are tested using a set of validation data. The results show that a soil series map generated by fuzzy logic has an overall accuracy of 67%, the highest accuracy is found in Ct series (88 %) and the lowest in So series (57%). Two topsoil texture classes giving the highest accuracy (greater than 80%) are silty clay (sic) and slightly gravelly clay loam (sgcl), with an overall accuracy about of 65%. The lowest accuracy was found in clay loam (cl, 53% accuracy). The accuracy of the soil map prepared by conventional method shows an overall accuracy of 13%, which shows that application of fuzzy logic improves the quality of soil maps. It has also the potential for reducing inconsistency and costs associated with the traditional soil mapping processes as mapping can be carried out with a relatively low density of soil samples. The research results can be thus used to support soil survey works in complex landscapes at sub-watershed scale.

Are Existing Digital Maps of Soil Organic Carbon Consistent and of Equal Quality?

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Soil Organic Carbon, Quality of prediction, Comparison of digital soil mapping

Abstract: Facing the increasing demand in soil information, digital soil mapping approaches (DSM) are developed and new soil maps are delivered to address environmental, agronomical, land management issues at global and local scales. Several DSM initiatives led to multiple soil maps, without post-hoc evaluation of the consistency and quality of the results. This step seems crucial to appreciate the suitability of digital soil maps for operational soil and environment management.

The aim of this work was to provide a comparative and critical analysis of available digital soil maps of soil organic carbon (SOC) produced for various spatial extents and resolutions. We compared soil maps extracted from (i) SoilGrids global maps at 250m resolution, (ii) European maps at 90m resolution produced by the European Soil Data Center (ESDAC), (iii) national maps at 90m resolution (French contribution to GlobalSoilMap program) and (iv) regional maps at 50m resolution (Sols de Bretagne program). All these soil maps were compared in Brittany (France) covering an area of 27,200 km^2. In order to assess the quality of these various SOC maps, we used for independent validation 135 soil profiles sampled in 2017 at three soil depths (5-15 cm, 30-60 cm, 60-100 cm) in Ille-et-Vilaine department (6755 km?) located in the eastern part of Brittany. Similarities and differences between maps were quantified according to the soil parental material (18 classes).

Considering the 5-15cm soil layer, the coefficient of determination R between predicted SOC map and measured SOC achieved 0.13, 0.04, 0.03 and slope coefficient were 0.22, -0.02 and -0.01 for 'Sol de Bretagne', SoilGrids, and 'France' soil maps, respectively. Regarding the overall distribution of values for the 5-15cm layer, SoilGrids data recorded higher soil organic carbon predictions, then French national maps, and even lower values were predicted by Sols de Bretagne. However, these differences were not significant. 'Sols de Bretagne' data exhibited the largest range of values with a skewness equal to 15 whereas it was 2.5 and 0.6 for SoilGrids and French national maps respectively for the 5-15cm layer. Concerning SOC content profiles according to depth, “Sol de Bretagne” data showed a sharp decrease between depths 15-30cm (median 20g.kg-1) and 30-60cm (median 10g.kg-1) whereas SoilGrids and 'France' data revealed a regular decrease of SOC content with depth. Similarities between maps varied according to soil parent material, e.g. for soils developed on silt, SOC from “Sols de Bretagne” was significantly higher than SoilGrids considering the soil layer 0-20cm whereas on the soils developed from igneous rocks, SOC from “Sols de Bretagne” was significantly equal to SoilGrids.

Overall, these preliminary results may be explained by the integration of fine territory features in the regional prediction models, which can be captured at fine resolution and were not discriminated at larger scales such as the silty soils in northwestern Brittany (France). The comparative analysis of the digital maps is ongoing for other soil properties.

Assessment Spatio-Temporal Variation of Topsoil Ph in France Using INLA-SPDE

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Soil pH; France, SpatialSpatio-temporal variation; INLA-SPDE

Abstract: Soils contribute to many ecosystem services, and the quantitative assessment and mapping of the state and evolution of soils and their properties is a crucial task. Specifically, it is essential to get information on spatial-temporal variation of soil properties. This need is recognized both by the scientific community through projects such as GlobalSoilMap, and by international organizations and policymakers such as UNEP, FAO or the European Commission. However, currently there are only few examples of soil mapping that explicitly integrate the time dimension into statistical models. This lack of information on temporal variation is an important impediment for using the GlobalSoilMap grid in many environmental studies.

In this work, we proposed a Bayesian hierarchical space-time model to predict spatial-temporal variation of soil properties. We used a mixed-effects model including linear relationships with spatial covariates and spatially and temporally correlated residuals. The model involves a Gaussian Field with Mat?rn covariance function and a space-varying time trend. This model is considerably more general than the standard geostatistical model but can be estimated for many thousands of observations on a standard personal computer by utilising the integrated nested Laplace approximation (INLA) in combination with the stochastic partial differential equation (SPDE) approach.

We tested this approach on more than one million soil pH observations of agricultural topsoil in France from 1996 to 2014. The results showed that soil pH in France significantly increased over the French territory from 1996 to 2014.They also revealed different temporal trends, depending on the considered region. . Further analysis will be conducted to incorporate into the model the different known drivers, e.g. management policy, certain soil properties such as CaCO3 content, land use change or climate change. Our results can provide crucial information for soil management, and are a valuable contribution to develop sustainable soil management systems.

Colour Features and Visible-Range Spectral Imaging for Soil Organic Carbon Assessment

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Soil organic carbon; Soil colour; Colour indices; Digital camera; Spectral VIS imaging.

Abstract: Colour appears to be a useful proxy for determining some characteristics of soil including Soil Organic Carbon (SOC) as a crucial parameter of soil quality. In order to expand the single (point spectrometry) domain into a spatial-cognitive (image spectrometry) domain, this study investigated the utility of the low-cost digital camera and free Sentinel-2 data in VIS range, compared to common reflectance spectroscopy, to estimate SOC using soil colour indices and colour spaces as covariates. It was shown that applying a colour index was preferable to using simple colour spaces. The study found that a number of colour indices, followed by colour spaces and the RGB bands, provided the highest correlations with SOC and were considered useful enough to derive SOC from digital camera image. Regarding to correlation of SOC and extracted Sentinel-2 bands, highest correlation was found between SOC with B4 (650-680 nm). Predictions of SOC content using digital camera was comparable, or even better than, those obtained using reflectance spectra. The RGB camera results were also more accurate than those attained using Sentinel-2 data; however, reduction in accuracy of Sentinel-2 results may be offset by the extensive geographical coverage and more frequent revisit characteristic of satellite observation. The SOC maps also confirmed that digital camera was able to detect SOC more precisely than the other applied techniques in this study. Then as a digital camera easily operates and obtains data using a simple treatment without the complex processing of spectral data, it can be used as an alternative promising tool for providing fast and inexpensive estimation of SOC contents.

Comparing Approaches to Predicting Soil Organic Carbon for Provincial Soil Map Updates in Peterborough County, Ontario: Keene Case Study

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: soil organic carbon, predictive digital soil mapping, legacy soil map updates, Cubist, random forest

Abstract: Soil organic carbon levels across Canadian agricultural lands mostly show an increasing trend from 1980 to 2011; however, the opposite is true for the eastern provinces, including Ontario, due mostly to a transition away from hayland and pasture towards annual crops. In response to this trend and the need to increase the resilience of agricultural soils, Ontario developed the Agricultural Soil Health and Conservation Strategy, with the broad goal of preserving and improving the health of Ontario?s soils for improved crop growth, water and nutrient retention and climate change adaptation. Under the strategy, Soil Data and Mapping is identified as a main pillar, including the need to modernize soil maps and inventory methods. This provides the premise for the Keene Pilot Study, a 10,000-hectare area within the Peterborough County soil survey sampled, to develop a workflow and test methods to develop predictive soil maps of continuous soil properties and categorical soil classes. The focus of this presentation will be predictive modelling of soil organic carbon, given its importance as an indicator of soil health. Two main approaches have been proposed for predictive digital soil mapping, including three-dimensional (3D) regression kriging, which combine a regression model with kriging of the prediction residuals in 3D, or development of regression, or trend, models for harmonized soil layers in 2D and kriging of the residuals, these 2D layers then being stacked to create the third dimension. We will compare these approaches in the Keene Pilot area by assessing model calibration and validation using a number of machine learning models (e.g. Cubist, random forest), and review their suitability for predictive mapping in the larger Peterborough County. The resulting maps will also be assessed for their suitability of informing soil mapping updates of the provincial soil maps. To date, results of preliminary predictive modelling have yielded encouraging results using the Cubist model with average RMSE of 7.6%, average concordance of 0.73 and average bias of -0.4 across the 0-5, 5-15, 15-30, 30-60 and 60-100cm depths.

Combining Multi-Temporal Satellite Images and Terrain Attributes to Perform a Digital Map of Soil Classes at the Southeastern Brazil

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Soil classes; Digital soil mapping; Landsat 5 satellite; Bare-soil composite image.

Abstract: The soil plays a major role in the provision of ecosystem services, such as, food production, climate regulation and carbon fixation. Due to soils high spatiotemporal variability, it is essential to consider the specificities of each location before establishing a management strategy. Efforts have been devoted to reduce the time and budget required in soil mapping processes. As a result, the digital soil mapping (DSM) was conceived. The DSM use proxies, such as terrain attributes (derived from digital elevation models) and reflectance data from remote sensing (RS), to predict the soil spatial variability. Employing satellite images in DSM is still limited by the high vegetation cover of landscapes. In other words, predicting soil attributes from a single satellite image is restricted to the few areas of bare soils from such image. The use of multi-temporal RS databases is essential for deriving reliable soil properties/type maps. Satellite composite images of bare soil are capable of enhancing the DSM procedure, providing better representations of soil spatial variation, including maps of soil type and attributes. Therefore, we aim to: (a) Generate a bare soil composite image based on the GEOS3 methodology and evaluate the potential of such method to describe the soil spatial variability; (b) Employ the composite image in the digital mapping of soil classes from a region of southeastern Brazil; (c) Evaluate the performance of DSM when considering the composite image. The study was conducted at a 500 km2 site located in the southeastern Brazil, at the Sao Paulo state. Three hundred sampling points were defined and soil samples were collected at 3 depths (0-20, 40-60 and 80-100 cm). The samples' physicochemical attributes were quantified based on conventional lab analyses. Besides that, reflectance spectra were measured with a Vis-NIR spectroradiometer. A multi-temporal database containing 27 years of Landsat 5 images was created. This database was used in GEOS3 method, which detects bare soil pixels in each image and later combine these pixels in a single composite image. We also derived 10 terrain attributes. A decision tree model (C5.0) was calibrated using the composite image and terrain attributes. Later, this model was employed to map the soil classes at the study site. The digital map was compared to conventional soil maps at 1:100,000 and 1: 20,000 scales, based on the Kappa coefficient and global accuracy indexes. The composite image generated by GEOS3 presented good relationship with the soil spectra measured in laboratory. The correlation between samples spectra measured in laboratory with the ones acquired from remote sensing, varied between 0.7 - 0.8 according to the Landsat band evaluated. The digital soil map presented similarities with the conventional maps from both scales evaluated. Furthermore, considering the good spatial resolution of satellite images and terrain attributes, the DSM was capable of providing a detailed map. The comparison between DSM and 1:100,000 soil maps resulted in a kappa coefficient and global accuracy of 21.65% and 42.05%. When considering the 1:20,000 soil map, kappa and global accuracy corresponded to 21.65% and 42.05%. These results are considered satisfactory and prove the potential of DSM when combined to a multi-temporal composite image.

Comparing Multiple Radiometric Sensing Platforms for Predicting Soil Texture and Other Properties

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Radiometric, drone, remote sensing, proximal sensing, airborne, texture, modelling

Abstract: Remotely sensed products are essential for modern digital soil mapping, as they deliver total coverage covariates for a mapping area. Elevation maps are often used to infer moisture and mass movement in a landscape, and can also describe surficial formations. Satellite remote sensing products can be used to infer other soil properties based on tone or species distribution; this is not particularly effective in cultivated landscapes. Texture is difficult to sense remotely because textural changes may not be related to elevation, and land use may remove any vegetative indicators.

Radiometric surveys may offer strong remotely sensed predictors of soil texture. Gamma rays released by decaying potassium, thorium and uranium will pass through vegetation and can be sensed using ground, drone and air-based crystals. Areas of higher clay are predicted to have higher radiological signals because naturally-occurring radionucleides may weather and sorb preferentially to clay particles. Where this relationship might weaken is in areas of contrasting lithologies and mineralogies. The purpose of this study was to compare radiometric signals obtained using a ground based, a novel custom made drone-based, and publically available fixed-wing-based surveys. Since each method operates at different spatial scales, we wished to compare these three survey products to an intensively sampled grid, obtained at the time of drone and ground-based data acquisition. We show the relationships and discuss the advantages and disadvantages of these platforms for different mapping applications.

Comparing Soil Carbon Stock Estimation Using Analytical and Digital Mapping Approach of a Drained Salt Marsh in St. Lawrence River Area, Canada

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: carbon storage, spatial pattern, soil organic carbon modeling

Abstract: Globally, salt marshes play an active role at sequestering atmospheric carbon and are important for soil carbon storage due to their anaerobic conditions, which delays the decomposition of soil organic matter. But these anaerobic soil conditions are changing in these marshes, as they are drained and converted to agricultural areas to ensure global food security. Thus these drained salt marshes are losing soil organic carbon (SOC) rapidly, and a study estimated that a maximum rate of SOC loss immediately after draining the salt marshes are of around 4,200 gcm-2yr-1, with a decrease over 130 years to a rate of 1,000 gcm-2yr-1. Change in SOC impacts soil fertility, and there is heightened interest in increasing SOC stocks to improve the agricultural performance of the soil. However, there is a general lack of studies on estimating (or predicting) carbon storage in salt marshes and it is not well established just how much C is stored in these systems. Thus, this research focuses on using a Digital Soil Mapping (DSM) approach to quantify and estimate the SOC storage of a drained salt marsh area along the St. Lawrence River in Canada. The overall objective of this research is to model SOC concentration, SOC stock and their spatial distribution using predictive digital soil mapping techniques coupled with field measurements of SOC and bulk density at 5cm increments. Two approaches to modeling SOC stock are proposed; i) by converting all the SOC concentration data to SOC stock using bulk density data, followed by predictive modeling and ii) by developing predictive models for SOC concentration and bulk density separately, then multiplying the resulting maps. The results are then compared in terms of model calibration efficiency and model validation accuracy for acceptability of the DSM approach. The output would be significant for the scientific community as an approach to determine the carbon stock in salt marsh systems and to find values for marshes with similar environmental conditions using the DSM approach. The findings would inform policymakers and farmers and assist them in taking steps to increase SOC stock and improve soil health.

Comparison of Pedotransfer Functions to Determine Soil Bulk Density with Limited Data at a Regional Scale in the Thompson-Okanagan Region, BC

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Session 3: Developments in pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Digital Soil Mapping; PTFs; Bulk density

Abstract: Information on soil bulk density is crucial to evaluate soil quality and estimate soil carbon stocks. It is especially critical in regions that have considerable variation in topography, and spatial data are limited. Collection of bulk density data is both time-consuming and labour intensive, and thus bulk density is not often measured. In previous studies, pedotransfer functions (PTFs) have been used to fill in the gap, and PTFs have shown promising results. Developments in digital soil mapping have provided an additional resource to estimate bulk density from other soil properties. Assessment of the performance of the traditional PTFs and statistical models is needed. For this purpose, this study used three PTFs and two digital soil mapping models calibrated with previously collected soil data from BC, and then PTFs and machine learning models were applied to data from the Thompson-Okanagan region. In order to make a fair comparison, the same combination of parameters was used for both PTFs and machine learning models.

Internal and external validations were compiled for all the PTFs and machine learning models. R-squared value, root-mean-square error, and mean error were used to determine the model fit with the training data and accuracy of the predictions. In general, machine learning models outperformed all three PTFs even with the same set of parameters. Random Forest (RF) model had the highest model accuracy and highest model-fit with R2 of 0.85 and 0.55, respectively. The results also suggest that systematic and dense sampling will provide robust modelling of bulk density.

Comparison of X-Ray Fluorescence and Inductively Coupled Plasma Optical Emission Spectrometry for Determination of Fe, Mn and Sr in Soils from the Brazilian Cerrado

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Session 2: Developments in Pedometrics 2: Instrumentation and Techniques

Presentation Type: Poster

Keywords: Soil Mapping, Analytical procedures, Elemental content, Metals in tropical soils, Piau State-Brazil

Abstract: We compared two conventional analytical techniques for measuring Fe, Mn and Sr concentrations in environmental soil samples. This research was carried out on 25 samples of soil horizons from 6 discrete profiles from natural Cerrado soils of the Piau? State, in northeastern Brazil. Concentrations of Fe, Mn, and Sr were initially measured using a non-destructive energy dispersive X-Ray Fluorescence (XRF) analyzer and then digested with nitric acid before analysis by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Both methods show that Fe is the element with the largest concentration, with values ranging from 1253 to 37400 mg kg-1, using the XRF (mean of 9193 mg kg-1) and from 700 to 19910 mg kg-1 using the ICP-OES (mean of 6900 mg kg-1). This is expected given the high concentration of iron oxides in Cerrado soils. Mn concentrations were higher than expected, based on the sedimentary origin of these soils, with values ranging from 13.0 to 822.0 mg kg-1, using the XRF (mean of 72.0 mg kg-1) and from 3.7 to 223.1 mg kg-1 using the ICP-OES (mean of 30.0 mg kg-1). We suggest that this Mn content is partially from exogenic processes. Conversely, the sedimentary nature of the parent material was a determinant factor in the low Sr concentrations of these samples. Sr values ranged from 4.4 to 69.0 mg kg-1, using the XRF (mean of 17.0 mg kg-1) and from 0.07 to 21.90 mg kg-1 using the ICP-OES (mean of 6.00 mg kg-1). XRF provided higher values than the ICP-OES for all three elements studied. As reported elsewhere, there is strong empirical evidence that nitric acid digestion does not thoroughly extracts metals from silicate minerals. These results suggest that XRF is more appropriate for mapping Fe and Mn concentrations in soils from the Brazilian Cerrado, while the ICP-OES method would be more appropriate for micronutrients and other elements occurring in low concentration.

Comparing Traditional and Digital Soil Mapping at a District Scale Using Residual Maximum Likelihood Analysis

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: electromagnetic induction; gamma-ray spectrometry; fuzzy k-means clustering; linear mixed model;

Abstract: Conventional soil mapping uses field morphological observations to classify soil profiles into predefined classification systems and extrapolates the classified soils to make a map based on aerial photographs and the experience of the surveyor. A criticism to this approach is that the subjectivity of the surveyor leads to non-reproducible maps. Advances in computing and statistical analysis, and an increased availability of ancillary data have cumulatively led to an alternative, referred to as digital soil mapping (DSM). In this research,two agriculturally productive areas (i.e. Warren and Trangie) located in central New South Wales, Australia, were considered to evaluate if pedoderms and soil profile classes defined according to the traditional approach can also be recognised and mapped using a DSM approach. First, we performed a fuzzy k-means analysis to look for clusters in the ancillary data, which include data from remote-sensed gamma-ray (?-ray) spectrometry and proximal-sensed electromagnetic (EM) induction. We used residual maximum likelihood method to evaluate the maps for a various number of classes (k = 2-10) to minimise the mean square prediction error (MSPE -sigma2p,C) of soil physical (i.e. clay content, field capacity [?FC], permanent wilting point [?PWP] and available water content [?AWC] and chemical (pH, EC of 1:5 soil water extract [?EC1:5], cation exchange capacity ? CEC) properties of topsoil (0-0.3 m) and subsoil (0.6-0.9 m). In terms of prediction, the calculated sigma2p,C was locally minimised for k = 8 when accounting for topsoil clay, FC, PWP, pH and CEC, and subsoil FC , EC1:5, CEC. A comparison of sigma2p,C of the traditional (7 pedoderm components) and DSM approach (k = 8) indicated that only topsoil EC1:5 and subsoil pH was better accounted for by the traditional approach, whereas topsoil clay content, and CEC and subsoil clay, EC1:5 and CEC were better resolved using the DSM approach. The produced DSM maps (e.g. k = 3, 6 and 8) also reflected the pedoderm components identified using the traditional approach. We concluded that the DSM maps with k = 8 classes reflected the soil profile classes identified within the pedoderms and that soil maps of similar accuracy could be developed from the EM data independently.

Deep Learning for Simultaneous Prediction of Several Soil Properties Using Visible/Near-Infrared Spectra, Mid-Infrared, and their Combined Spectra

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Presentation Type: Oral

Keywords: convolutional neural network; multi-task learning; visible near-infrared spectroscopy

Abstract: Because soil is a complex matter, no single instrument can characterize all soil properties. With the advancement of technologies, laboratories nowadays are equipped with various spectroscopy instruments. By combining output from different instruments, better outcome prediction is expected. In this study, model performance from a single instrument (visible-near-infrared spectroscopy (vis-NIR) or mid-infrared spectroscopy (MIR) is compared to the combined instruments (vis-NIR + MIR). Additionally, the use of a new deep learning model, convolutional neural network (CNN) to process a large soil spectra library was explored.

The dataset was split into 75% training set (n = 10,946) and the remaining (25%) was used as a test set (n=3,648). Results show that the CNN model achieved better accuracy ranging in predicting all six soil properties simultaneously between 33 - 42% for vis-NIR, 30 - 43% with MIR in comparison to the conventional partial least squares regression (PLSR). The relative accuracy improvement of CNN when compared to the Cubist regression tree model ranged between 22 - 36% with vis-NIR, 16 - 27% with MIR. We further investigated optimal ways to feed spectral data to the CNN, either as one-dimension (1D) spectrum or a two-dimension (2D) spectrogram. Upon fusing the spectra data and comparing the performance of spectra concatenation (for PLSR and Cubist model), two - channels input method, and outer product analysis (OPA) method (for CNN model), we found that the two channel 1D model works best (R2 = 0.95 - 0.98) followed closely by the OPA (R2 = 0.93 - 0.98), Cubist model (R2 = 0.91 - 0.97), two channels 2D model (R2 = 0.90 - 0.95) and PLSR (R2 = 0.87 - 0.95). Chemometric analysis of spectroscopy data often relies on spectra pre-processing method: such as spectral trimming, baseline correction, smoothing and normalization prior to being fed into the model. CNN can achieve higher performance even without utilizing the pre-processed spectra data. The relevant spectra variables used by the CNN model to predict various soil properties can be readily identified. Furthermore, the CNN model has multi-task learning ability to predict various properties simultaneously while maintaining its correlations.

Developing Digital Soil Mapping Methodologies for Remote Areas of the Northern Territory, Australia

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: remote DSM agricultural suitability

Abstract: Investment over the last 20 years has seen significant growth in the number and scale of intensive irrigated agricultural industries in the Northern Territory. Integral to this growth has been the continued provision of government sponsored, high quality soil and water assessments that underpin and guide investment. Land and water information is critically important to the natural resource based economy of the NT. In recent years, the NT Government injected eight years of funding (2014-2022) to establish a regional soil and land suitability assessment program to facilitate and inform continued agricultural investment.

As part of this program, a trial digital soil mapping (DSM) project was undertaken in the Roper River catchment to assess the applicability and usefulness of DSM in identifying and cost effectively assessing potential agricultural lands within the remote, often complex landscapes of the NT. The Flying Fox study area was selected because of the range of geologic substrates, and variety of landform and elevation changes it offered. It is centrally located within the Roper River valley, and is representative of a wider regional landscape that draws continued interest as a potential irrigated agricultural development precinct. Existing soil information for the area is very limited, extremely broadscale and unsuitable for planning intensive development.

The sampling strategy for the project included preliminary catenary based field sampling providing a network of useful representative sites to help assess and interpret modelled outputs. Randomly stratified sites (fuzzy K-means clustering) populated the remainder of the study area. Cross-validation modelling (using the Cubist package) was used to ensure fieldwork was completed before access was restricted due to the northern monsoon season. Detailed field data was collected at 233 field sites, including lithology and landform characterisation, full soil morphology and vegetation structure and floristics. Twenty representative sites were selected for full laboratory analysis, while all remaining sites were sampled for MIR analysis at standard depths.

Initial catenary investigations highlighted the inadequacies of existing geology mapping. In response, surficial lithology was carefully ground-truthed and mapped, using expert landscape knowledge and signals from Sentinel-2 imagery and the SRTM Shuttle digital elevation model (DEM). The mapping was incorporated as a covariate. An independent vegetation map was also produced using ECognition software and used as a covariate.

Project outputs include a digital package of modelled surfaces (including but not limited to soil depth, drainage, permeability and surface gravel), crop-specific land suitability mapping surfaces and a technical report detailing methodology and outcomes. Land evaluation is crop specific and was assessed in accordance with a regional agricultural land suitability assessment framework compiled in collaboration with local agronomists and industry partners.

The use of DSM methodologies in combination with traditional techniques allowed the department to deliver timely integrated land resource information across a rugged and largely inaccessible study area. Inter-agency collaboration and training played a significant role in the development of the modelling skills required to undertake the project, and demonstrates how digital soil mapping capabilities can be built even in relatively small agencies.

Digital Pedology: Studying Soil Profiles

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: pedology, soil profile, soil horizons, variation

Abstract: Major changes have occurred in the soil science discipline and pedometrics techniques have contributed to the quantification of soil science processes and properties. Pedometric techniques have been applied to legacy soil data as well as information collected by a range of new sensors. It has led to improved quantification and faster assessment of soil resources. For the past 5 years, we have been working on the development of digital soil morphometrics for enhanced understanding of the soil profile. We have studied the soil profile in-situ, and in the lab, and sampled by horizon and using one or more transects. We have rasterized the soil profile and also analysed soil profile images. We have compared different sampling methods and have gained understanding on the variation within and between soil horizons. This talk will summarise the main findings

Evaluating Soil Carbon Stocks in the Forests of British Columbia Canada at Multiple Resolution

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: organic carbon scale soil

Abstract: Surface soils to a depth of 30cm store a significant pool of carbon in the forested ecosystems of British Columbia Canada, accounting for approximately half of the total carbon in many parts of the province. Recent interest in obtaining better estimates of soil carbon stocks and their potential role in climate change mitigation has encouraged soil scientists in BC to undertake field programs and mapping efforts to obtain new estimates of soil carbon stocks. This presentation describes and evaluates several recent estimates of soil carbon, prepared independently using different techniques and at different scale. Input data from legacy soil survey and other datasets, along with field sampling were used to obtain input data. Digital soil mapping techniques including machine learning, polygon disaggregation, and multiple regression analysis were used to obtain carbon stock estimates at 250m, 25m and 3m pixel resolution. Some of these maps were used to inform Canada's contribution to the recently released FAO global soil organic carbon map. Various metrics of model performance for the different mapping approaches will be presented, along with a discussion of how a multi-resolution approach to the analysis of DSM products can improve interpretations for soil carbon inventories.

Exploring Practical Ways of Using NIR, MIR and XRF Soil Spectra: Sampling Design and Calibration

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Spectroscopy, sampling design, uncertainty, loss function

Abstract: Advances in sensor technology and agricultural equipment should enable farmers to improve the precision management of nutrients, water and adjust crop density appropriately, but the decision of when to use what sensor is still ad hoc. A systematic approach to sensor use to determine soil conditions could potentially lead to a more effective, efficient and environmentally and ecologically friendly agriculture as less inputs are used.

The aim of our project is to develop an analytical framework to determine the most cost-effective configuration of sensors to estimate soil properties that are important for agronomic production. This framework consists of three parts; a) to determine which combinations of soil sensor types could be used most effectively, b) to determine how and where to deploy them and c) to quantify the uncertainty as a consequence of these sampling schemes in predictions of soil properties. We will use these findings to quantify the loss functions of profits or impacts to the environment that can occur because our management decisions that are based on uncertain information (Lark and Knights, 2015).

To investigate this, we considered two case study fields in the Cambridgeshire fens (UK) that were planted with lettuce. These fields contain complex soils which are a combination of peaty soils with roddon features that consists of underlying alluvial and marine silts that became elevated features in the landscape due to peat oxidation and shrinkage. We took a total 467 soil samples across the fields and made spectral measurements (VNIR, MIR, XRF). We considered 3 different sample conditions; namely (i) field-based conditions where unprocessed samples were measured, (ii) lab-based conditions where samples were air-dried but not ground and (iii) lab-based conditions where samples were oven-dried and ground. A subset of the soil samples underwent wet chemistry analysis for available P, K, Mg, S, Ca, Na, pH, total C, total N, organic matter content (LOI) and soil particle size fraction.

First, we assessed how well each of the spectral techniques could discriminate between roddons (alluvial and marine silts) and the peat within the field. We then assessed how well the spectral measures could discriminate each lettuce class, by comparing to remote sensed data of lettuce size. Furthermore, we determined which waveband regions were most important in determining this classification. Subsequently, we built calibration models to predict the soil properties of interest and quantify the error in these predictions. We did this using the data from the wet chemistry analysis. We compared our models with those based on spectral databases including global (ICRAF), national (National Soil Inventory), regional and field specific libraries (this PhD research) to assess whether the same waveband regions were deemed important and how prediction accuracy was affected.

Future work in this project will determine the effect of sampling designs and sensor configuration at various spatial scales under sampling regimes informed by ancillary LiDAR data.

Fussy Learning: Reducing the Fuzziness in Legacy Soil Map Disaggregation

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: soil map disaggregation, legacy soil mapping

Abstract: Disaggregation of legacy polygon-based soil maps is important for increasing the useability of embodied expert soil surveyors' knowledge. Probabilistic pseudo-sampling and fuzzy-inference algorithms, such as the Disaggregation and Harmonisation of Soil Map Units Through Resampled Classification Trees (DSMART), provide valuable guidance for such work. However, it may be detrimental to presume that useful model-training data can be extracted from every soil map unit, particularly those containing a mix of heterogeneous soils. For example, many sub-dominant (low area proportion) soil classes or properties can be recorded per map unit where the scale of legacy mapping is coarse compared to the actual spatial variation of soils. Here we report on work to develop downscaled raster mapping of wind and water erosion potential in southern South Australia, required to support newly developing remote sensing-based monitoring assessments of erosion risk. Semi-quantitative ordinal (e.g. low, moderate, high, etc) ratings were available for both wind and water erosion susceptibility of soil landscapes, recorded as unmapped proportions within often coarse map units. However, downstream users wanted fine-resolution continuous numeric raster mapping to directly assess whether wind or water erosion was more important on each piece of land. Separate point-based erosion potential data with limited coverage across the study area were also available for model training and validation. In this study we investigate more discriminating (fussier) approaches to disaggregation modelling. Specifically, we look for an optimal model/map outcome from a matrix of data quality thresholds for map unit purity and area-to-perimeter ratios (accounting for possible edge effects) used to restrict where spatially-randomised pseudo-sampling sites are drawn for disaggregation model training. We combine old and new covariate data, ground sites and map unit-derived pseudo sites, with machine learning modelling, to assess whether more stringent focus on the representativeness of particular soil conditions within legacy soil maps can ultimately produce more reliable disaggregation products.

Generalized Pedotransfer Functions versus Direct Geostatistical (RFK) Inference as Alternative for Quantifying the Uncertainty of Soil Hydraulic Maps

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: generalized pedotransfer function; soil hydraulic properties; machine learning; random forest plus kriging; uncertainty.

Abstract: Information on soil hydraulic properties is important for modelling hydrological, ecological, meteorological processes or planning land use and management. The current measurement methods of the most widely used soil hydraulic parameters, such as water retention capacity and hydraulic conductivity are time consuming, labour intensive and costly. In this way spatial information on those are usually indirectly derived with pedotransfer functions (PTFs) from easily available soil properties. Based on available soil maps these hydraulic parameters can be spatially predicted with the PTFs. This indirect mapping method can be an alternative approach when density of measured soil hydraulic properties does not satisfy the needs of geostatistical analysis.

Most often only the calculated soil hydraulic parameters are available from the derived maps. For better understanding the processes occurring during extreme events, e.g.: floods, drought, extreme rainfall, etc. it is important to provide information on the uncertainty of the calculated soil hydraulic properties. Therefore our aim was to study the differences in performance between soil hydraulic maps and particularly their quantified uncertainty derived with indirect (based on PTFs) and direct (geostatistical) spatial inference methods. For this study we analyzed the soil hydrological characteristics of the catchment of Lake Balaton, which is an important area in Hungary from the point of modelling hydrological, ecological, meteorological processes or planning land use and management. We derived map of the following soil hydraulic properties and their uncertainty: saturated water content (SWC), field capacity (FC) and wilting point (WP). The mapping was performed with indirect (based on PTFs) and direct (geostatistical) spatial inference methods for three soil depths at 100 m resolution. In the case of the indirect mapping method the uncertainty of the mapped values was provided based on the calculation of quantiles within the random forest algorithm, whereas for direct mapping method the uncertainty of spatial prediction was quantified by bootstrapping.

Our poster will present the resulting soil hydraulic maps and their quantified uncertainties by the two approaches, as well as the resulting prediction interval coverage probability plots and G statistics. The results can be useful contribution to understand how the uncertainty propagates in complex spatial soil modelling.

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Generating Interpreted Digital Soils Data Products for Agriculture and Planning - Experiences from Queensland, Australia

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Production mapping; land suitability; data delivery; environmental management

Abstract: To meet demand for more spatially detailed, reliable, and verifiable information about its land resources, Queensland has increasingly been using digital soil assessment (DSA) approaches. A primary driver for this is the need to reduce soil erosion and improve land management in the catchments of the Great Barrier Reef. Better management will reduce the loads of sediment, nutrients and pesticides entering the waters of the Reef. The DSA information products support research, improved land use planning and on-farm decision making.

Cubist and Random-Forest based attribute mapping was conducted across the Burdekin and Fitzroy River catchments, which are grazing-dominated and have a combined area of nearly 300 000 sq km. Both projects used a combination of legacy soil data and new data collected in under-sampled areas. Predicted soil attributes were used to build ordinally-ranked classifications of surface and subsoil erodibility. These products were distributed both as raster geospatial products and an online PDF report service (FORAGE). The PDF report was specifically developed to include both maps and text that assists interpretation. The report meets the needs of land managers in remote areas with very poor internet by delivering information in a compact, portable, offline- and hardcopy-friendly format.

In the more intensively managed coastal areas of Queensland, DSMART disaggregation was applied to 19 medium-scale legacy soil maps covering approximately 35 000 sq km. Neighbouring maps were reconciled within five project subareas, producing a set of five consistent soil type prediction raster stacks. Each soil type was assessed against a range of constraints to the primary land use, sugarcane production (e.g. poor drainage), to provide information to agronomists and land managers on likely drivers of reduced yield. A four-level severity ranking was used to build the constraints dataset, taking into account the severity and in-profile occurrence of production-limiting soil attributes. To meet user technical capabilities, the most probable soil surface was polygonised and used to spatially index the constraints.

These projects have shown the need for developing not only clear workflows for producing soil attribute data, but also for developing interpreted products. These workflows must be transparent, reproducible, and rigorous enough to support land managers and government making decisions on sustainable use of the soil resource. This work continues efforts to apply the FAIR (findable, accessible, interoperable and reusable) data principles to soil and land resource assessment information and extends these efforts to making this complex data digestible.

Experience gained from these projects highlights the need for early consultation with end users regarding potential information products. If clients can easily incorporate new data into existing workflows, confidence in using the products increases. Where changes to client workflows or tool-chains are necessary to support improved management, suitable resources must be made available to support those changes. Land managers and policymakers prefer interpreted data over raw attributes, provided a traceable connection between the two is maintained. Interpreted products should be seen as enhancing rather than replacing a primary soil attribute dataset and be distributed in concert.

Geospatial Data Modelling by Integrating Sensor-Fused Data in Agricultural Field Management

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Data fusion; Geospatial data; Geostatistical methods; Forest model; Soil variability

Abstract: In many regions, it is essential for agricultural scientists to be able to predict soil properties by analyzing proximal soil sensing (PSS) data. Along with sensor datasets, a subset of soil sampling data can be drawn upon to predict soil nutrients in an agricultural field. Data assessment through the use of prediction error is performed during the prediction process. Data mining algorithms and contemporary models serve a vital role in high-density data processing and analysis for agricultural research. The overall objective of this research is to develop a prediction framework for sensor fused data analysis. This involves assessing the effectiveness of geospatial data modeling in assigning calibration zones to soil properties taking into account various management issues. The specific objective is to explore the potential of integrating proximal soil sensing data with remote sensing imagery to delineate field heterogeneity and produce thematic maps suitable for potentially differentiated management decisions. Optimization of a geostatistical and decision tree-based model were applied to determine soil variability for site-specific crop management. Three agricultural fields situated near Guelph, Ontario, Canada were selected and mapped using both Remote Sensing and PSS sensors. The RTK elevation, topographic indexes, and apparent soil electrical conductivity (ECa) variables were processed and the data structure evaluated based on summary statistics. The Kriging method was used to develop topographic and ECa variability maps. Moreover, georeferenced soil samples were collected and used to calibrate and validate the model in an effort to understand soil variability across the fields. Dove nanosatellite data, visible/near-infrared multispectral bands at a spatial resolution of 3 m were analyzed to generate vegetation indexes used in predictive models. Data indices and environmental variables were considered as inputs and as a training dataset for the model. General statistical analysis and a correlation matrix of the selected variables served in determining targeted variables. Analysis and correlation of variables and indices, along with soil sample data enhanced understanding spatial heterogeneity. Random forest model design and algorithms were developed in Python. Development of a model to determine the optimum number of variables was achieved. The coefficient of determination (R2) was used to assess the model fit. Tree models were constructed to build a forest from the collected datasets. This research evaluates the model parameter and training datasets to generate thematic soil properties and scenario maps. An assessment will be performed to understand overfitting to improve predictive accuracy. Preliminary results indicate that soil variability determined using sensor-fused data and related techniques could assist in constructing precise prediction models for soil properties and in developing reliable zone delineation for site-specific crop management. This research may lead to develop better thematic soil maps; therefore, to improved site-specific farm management techniques in the future.

How to Make Sense of the Plurality of Soil Carbon Sequestration Assessed within the Data Envelopment Analysis Indication System.

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Pedo-econometrics, Data Envelopment Analysis, returns-to-scale, quantification, soil functions

Abstract: Indicators and indices are poised to synthesize different soil, environmental, and economic factors to assess soil health and soil security (or other conceptual framework). To compute soil functions (e.g., the capacity to sequester soil carbon) for a given purpose (e.g., soil ecosystem services or crop yield) through an indication system allow to directly link site-specific soil-environmental conditions and desired output(s). Such an indication system offers the advantage to assess more complex soil metrics beyond simple measurement of estimation of soil properties. The purpose of this study was to quantify the capability/efficiency of soil carbon sequestration (SCseq) function under simulated site-specific soil-environmental conditions using an econometric-pedometric indication system. We used a non-parametric linear programming method, Data Envelopment Analysis (DEA), which is one of the econometric techniques. The DEA assumption settings available in the R package "benchmarking" include: free disposability hull and no convexity assumption (FDH); variable returns-to-scale (RTS); Decreasing/Increasing/Constant RTS; Increasing RTS with additivity; FDH with Additivity; FDH with restricted constant RTS; as well as Variable RTS with restrictions on the individual lambdas via parameters (VRS+). FDH allows the surplus input(s) to be freely disposed for achieving the same quantify of output. RTS describes the relationship between the quantitative changes in output(s) and changes in input(s). Variable RTS does not assume the specific scale relationship. These settings can affect calculation of the reference line, a set of reference values, called a frontier line. DEA algorithm discerns capability of each sample's function based on the data-driven frontier line. The SCseq function was chosen as a target output function to be optimized. Soil/environmental inputs that contribute to the function, including the Normalized Difference Vegetation Index, pH, and fertilizer applications (nitrogen, phosphorus, and potassium), were incorporated into the models. Randomly generated values (n=1000) were simulated from the normal distribution for each variable based on values with specific ranges and means found in the literature. We simulated the values for two different land use types: improved pastures and upland forests. The DEA index scores range between zero and one. Scores close to one represent high capability of the function. All methods successfully calculated the scores for each simulated sample and land use type. The DEA assumptions settings led to significantly different conclusions in the scores using non-repeated measures of the analysis of variance (Tukey comparison tests) among the different land use. The distribution shapes of the calculated scores as well as the variances were differentiated among the assumptions. Some assumptions made a clear distinction in the scores by the different land use types. The assumptions affected the frontier line, which resulted in the different conclusions. Thus, these results suggest that future research using the DEA algorithm requires precautions on the selection of the assumptions. This research revealed that the way to identify the appropriate choice for the assumptions in the DEA indication system is critically important to assess SCseq. More research is needed to explore other soil functions within the DEA indication framework.

Identifying Soil Provenance

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: origin, vis-NIR, pXRF, database

Abstract: There is a growing interest in the use of soil composition as a form of evidence in food provenance, forensic, biosecurity and archaeology. Given a soil sample of unknown origin, we'd like to know the likely geographical source of that material. A recent example is the XRD data on Martian minerals from Nasa's Curiosity rover, were compared against the data from the Scottish soil dataset. The matching found that Martian soil to be 'strikingly similar' to basaltic soils of the isles of Skye and Mull. This determination is done by one-by-one comparison with reference soil samples from known sites. In this study, we asked if data provided from rapid and non-destructive proximal sensors can be used to identify the provenance of a soil sample. Vis-NIR and pXRF analyses were conducted to get the minerals, compounds and elemental abundance for the 1450 soil samples (0 ~ 10 cm) from the Hunter Valley, NSW, Australia. Combining the spectral data with the recorded soil properties (e.g. texture, colour), tree model (Random Forest) and neural network model (Deep Learning) were used to determine the origin of soil samples. Comparisons were made to show the different effects of identification: 1) The importance of soil properties data and spectral data in different models; 2) The statistical accuracy of model based on different factors; 3) The importance of determination variables for each predictive model; 4) The accuracy of determination based on different sizes of datasets. An appropriate reference dataset for comparison to question soil samples will be built based on all findings. The soil provenancing approach is potentially useful in narrowing areas of interest in a given examination.

Influence of Spatial and Spectral Resolution of Image Spectral Data on the Prediction Ability in Mapping Soil Properties on Plot Scale

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: soil properties; imaging spectroscopy; hyperspectral image; multispectral; UAV

Abstract: Image spectral data has been proven to offer efficient input data to map spatial variability of important soil properties or level of soil degradation by erosion. Particularly aerial hyperspectral data has proven its ability to map soil organic carbon content and soil texture. The acquisition of this type of data is costly and requires high technical expertise in processing. In contrast, multispectral satellite or UAV data is a well-available source of spectral data that does not require such technical skills for preprocessing. But what is the effect of different spectral and spatial resolution on prediction ability?

Our study aimed to assess the influence of spectral and spatial resolution on the prediction accuracy of models assessing soil organic carbon and texture classes. The study was conducted on a local level (100 ha) in the chernozems region of South Moravia (Czechia) with dissected relief strongly affected by all soil erosion forms (water, tillage, wind). The adopted methods included extensive field sampling, laboratory analysis and predictive modelling of selected soil surface properties using aerial hyperspectral data (CASi and SASI), satellite superspectral data (MSI on-board Sentinel-2) and multispectral UAV data. Multispectral data were obtained using a Parrot SEQUOIA camera mounted on a fixed wing drone Parrot Disco-Pro AG. Random forest regression technique was applied in the predictive modelling of soil properties.

The results showed that predictive accuracy was best for hyperspectral data; R2=0.8 for soil organic carbon (RMSE 0.16) and 0.89 for Clay (RMSE 2.88). When using ultraspectral satellite data, the predictive ability decreased to 0.74 for SOC and 0.71 for clay. When using UAV multispectral data, a further reduction in prediction was recorded. Nevertheless, the mapping could be done in more details. The results showed that even with less accurate data with respect to spectral and spatial resolution, sufficient results can be achieved, especially in SOC mapping. Based on the results it is possible to model in detail selected soil properties (SOC, clay content) or the influence of individual erosion factors and use these results for precision agriculture purposes and propose anti-erosion measures and conservation management.

Mapping Available Soil Water Capacity with Sparse Data- An Inverse Bayesian Approach

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Available water capacity, Bayesian inverse, uncertainty

Abstract: The amount and spatial variability of available soil water capacity (AWC) influence decision making in agriculture, drought monitoring, yield forecasting, hydrology and meteorology. Measuring AWC across a larger spatial extent is a tedious, highly time consuming and expensive exercise. Spatial modelling is an alternative way to predict the AWC across large area. However, these modelling techniques still need a reasonable sample size to build a spatially representative model. When the data is sparsely populated, inverse modelling is an alternative to the common forward mapping method.

Inverse modelling can be defined as the process of inferring the parameters of a model from a set of observations. These parameters are the best approximations of causal factors which in combination produce the observed values. Statistical inversion is a systematic way to use known prior information to solve the inverse problem using a Bayesian framework. In a Bayesian framework, all quantities of prior information are modelled as random variables with joint probability distributions. Bayesian frameworks also allow us to incorporate measurement uncertainties to provide a better estimate of overall uncertainty of the modelling procedure. Although Bayesian inverse methods have been used widely to inversely estimate model parameters, it is still not commonplace in digital soil mapping.

In this work, we present a geostatistical inverse modelling approach for predicting AWC using sparsely populated data. Data sparsity is the major limitation in modelling soil water capacities across larger spatial extents like Australia. Being a major global food supplier and the driest inhabited continent in the world, Australia has a major challenge to sustainably manage the available water recourses. Although there are digital soil maps available, accuracy of such products is questionable particularly when used at farm scale. Therefore, Bayesian inverse modelling is tested as an alternative to common forward mapping. The study is carried out using soil moisture measurements collected in NSW, Australia.

AWC was modelled using two separate models to estimate the upper and lower drainage (DUL & DLL) using field measurements across NSW, Australia. The models were built using mostly related covariates selected from a covariates pool. We used Markov Chain Monte Carlo Metropolis - Hastings Dynamics to estimate the model parameters. The mean and 95% of confidence intervals of the parameters were calculated using MCMC simulated values. The models were validated using a held out 30% validation set. Calibrated models were then used to predict the AWC on 90m grid. Lower and upper CIs of the maps were also created using estimated parameters. AWC is the difference between DUL and DLL raster layers. The maps of AWC are presented with 95% confidence limits. Validation statistics show higher concordance correlations for both models. The DUL model results showed 85% concordance while DLL model predictions have 64% concordance correlation. Moreover, the uncertainty of parameters and the uncertainty of output maps also are presented with the results. These uncertainty estimates are fundamental to correct use of information. Therefore, we conclude that the Bayesian inverse modelling provides more accurate and reliable estimates.

Mapping Clay Minerals of Victorian Soils

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Mineralogy; DSM; MIR; XRD;

Abstract: Clay minerals are known for their important role in soil functions, pedogenesis and contribution to ecosystem services including carbon storage, water storage and filtration. Quantitative assessment of clay mineral abundance, assemblage, diversity and variability in space and depth has been challenging and remains absent in many digital soil assessments. Conventionally, XRD has been the mainstay of clay mineralogy assessment, although in the last two decades, use of spectroscopic techniques including VIS-NIR, MIR or XRF to quantify clay minerals has increased significantly. These techniques are considerably faster and cheaper, achieving good agreement with reference samples and models.

Mapping of clay minerals has been identified as a gap in available soil information. Recent examples of digital soil mineral maps include national (Australia: Viscarra Rossel, 2011) and regional scales (Mulder et al., 2013) using VIS-NIR spectroscopic models. Our study aims to deliver clay mineralogy maps for Victoria, Australia, using MIR spectroscopy, semi-quantitative XRD for calibration purposes and data mining methods for mapping according to GlobalSoilMap specifications.

The approach we have implemented has applied an existing MIR calibration model for kaolinite, illite and smectite (Robinson and Kitching, 2016), further expanded the reference set of available MIR spectra (from 11,532 to 24,623 samples) and analysed selected samples using semi-quantitative XRD that were representative of clusters, or endmembers (generally with high prediction error or additive totals >100 %). The preliminary results of revised MIR models for kaolinite, illite and smectite include an R2 of 0.92, 0.925 and 0.962, RMSE of 6.98, 4.21 and 4.75 wt % and RMSECV of 12.48, 12.00 and 10.82 wt %. New maps for Victoria have been derived using Cubist model trees from 30 bootstrap samples for each clay mineral and depth interval (0-5, 5-15, 15-30, 30-60, 60-100 and 100-200 cm). Map predictions were best for kaolinite and smectite with illite improving significantly with depth interval. These maps can now be used to formulate better understandings on soils and their potential to sustain current and future functions.

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Mapping of Soil Available Water-Holding Capacity in New Zealand Using Visible Near-Infrared Reflectance Spectra and Environmental Covariates

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Soil spectroscopy, digital soil mapping, field capacity, permanent wilting point, machine learning

Abstract: The sustainable management of agricultural land requires reliable information about soil physical properties. Among these properties, available water-holding capacity (AWC) is a key attribute, as it quantifies the amount of water available for plants that the soil can hold. Since direct measurements are costly, pedotransfer functions (PTF) are often used to estimate AWC, leveraging statistical relationships with properties that are easier to measure, such as texture, bulk density, and organic carbon content. This study evaluates visible near-infrared spectroscopy (Vis-NIR) as an alternative to PTF to predict volumetric water content at field capacity (FC) and permanent wilting point (PWP) AWC being the difference between PWP and FC. It also examines whether AWC estimates can be used as input data for national scale digital soil mapping projects.

A suite of 970 Vis-NIR soil spectra, recorded from air-dried, 2-mm, sieved soil samples, were associated with FC and PWP analytical data obtained from New Zealand's National Soils Database. Partial least squares (PLS) regression and support vector machines on PLS latent variables (PLS-SVM) were used for spectroscopic modelling. Final estimates showed promising results with regards to FC with a root mean squared error (RMSE) below 6%, while slightly more accurate predictions were found for PWP with an RMSE below 4%.

The successful direct spectral prediction model for AWC was subsequently used to generate an interpolation set for producing a new generation of high-resolution maps of AWC for entire New Zealand. Preliminary results indicate that a random forest model built from a comprehensive set of environmental covariates derived from satellite imagery and terrain analysis provides a more accurate estimate of the spatial distribution of AWC at pre-defined depth intervals than the official products currently available for New Zealand.

Mapping Soil Color Using Nix Pro-Color Sensor in the Brazilian Cerrado

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: color sensor, kriging, soil management, color determination

Abstract: Soil color is highly heterogeneous in the landscape, mainly due the mineralogical constitution, drainage, management and soil organic matter content. A precise method of soil color analysis can contribute to soil management, to describe soils and to manage precision agriculture practices. The standard method of soil color determination (Munsell Color Chart) is relatively subjective, especially due to human error and environmental conditions (e.g. moisture content, lighting conditions). Hence, there is a need of studies using alternative methods of soil color determination, in order to improve the precision and accuracy. The objective of this study was to map soil color using a NIX PRO-color sensor in an agricultural area in the Brazilian Cerrado. In August 2018, an agricultural area was selected at EMBRAPA Milho e Sorgo, Sete Lagoas, Minas Gerais, Brazil. This area is a government property and has been under agricultural use for almost one century. Nowadays it is used as part of the experimental fields of the Brazilian Agricultural Research Corporation. To characterize the spatial variability of soil color, a non-regular nested 51-point grid was installed, with samples within 20 meters in clusters of three samples within 160 m apart. Spatial location of the points were recorded by using a navigation GPS. The mapped area comprises 14.6 ha. Disturbed soil samples were taken at 0-20 cm depth using Dutch augers. Soil samples were air dried, grounded and sieved through a 2-mm sieve to remove larger pieces of root material and the stony fraction. All the soil samples were analyzed in the soil laboratory of the Federal University of São João del Rei, at Sete Lagoas, Minas Gerais, Brazil. Soil samples were tested for color using a NixTM Pro Color Sensor. It has its own light-emitting diode (LED) light source. The sensor produces scan results in various color system codes, such as RGB. In this work, the resulting RGB color values were converted to the Munsell system: hue, value and chroma (HVC). HVC color values were interpolated by ordinary kriging to generate soil color maps, using the Vesper software (Whelan et al. 2001). Linear regression was performed among HVC color values and altitude. The results show that the studied area has a gradient of HVC color values, losing red intensity from upper to lower parts, especially in the middle of the area. This result is also evidenced by the significant ($p<0.001$) negative linear regression between hue and altitude, despite the low R2 (0.24). The upper part of the studied area is characterized by higher concentration of oxidized iron minerals (hematite and goethite) that gradually decreases towards the lower parts, under hydromorphic conditions. The thematic map also revealed the erosional process in the area (lighter colors), associated with lower soil organic carbon contents. The NIX PRO-color sensor was able to rapidly and accurately measure soil color values, being more sensitive to soil color variation and allowing better identification of soil transitions in the field. Thus, the method provides an opportunity to increase the accuracy of the mapping processes with the use of detailed field color data, contributing to the soil mapping and to the interpretation of the associated soil attributes.

Modelling the Dynamics of Soil Sheet Erosion Using the Universal Soil Loss Equation and Cellular Automata

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: soil erosion, USLE, cellular automata, complex systems, modelling

Abstract: One of the most destructive worldwide phenomenon is soil sheet erosion caused by water. The objective of this project was to couple the Universal Soil Loss Equation (USLE) and Cellular Automata (CA) to study soil sheet erosion as a spatio-temporal phenomenon. The USLE is composed of six factors to predict the long-term average annual soil loss (A). The equation includes the rainfall erosivity factor (R), the soil erodibility factor (K), the topographic factors (L and S) and the cropping management factors (C and P). To understand soil erosion dynamics as a complex system and to explain the future progress of this phenomenon, cellular automata were used to model it. Cellular automata is a type of bottom-up modelling approach that is often used for complex systems. A current soil loss map of a 12 ha dairy farm in Central Massachusetts was produced using the USLE. Then maps were generated with four times iteration of the CA spatial model, displaying the increase of soil loss in four consecutive years. This project demonstrated that CA can effectively be used to model spatio-temporal complex systems such as soil erosion.

Prediction Soil Organic Carbon Stock in the Abyek Region, Iran

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Organic carbon, Bulk density, gravel, arid, semi-arid

Abstract: Different studies reported the significant indirect relationship between spatial distribution of soil organic carbon (SOC) with local ecosystems, the vegetation characteristics, and human activities. Soil organic carbon distribution is of high paramount for controlling global climate change, reducing the adverse effects of climate change, and the sustainability of natural resources. One of the creation options for the organic carbon spatial map is to setup a predictive model by linking SOC values with environmental variables such as vegetation, land cover, and soil characteristics. In the current study, predicted soil organic carbon stocks (SOCS) was carried out by the Random Forest model consist of 189 profiles, Landsat 8 satellite images, and DEM. In the first method, organic carbon, bulk density, and gravel contents up to 100 cm depth were predicted by using Random Forest Model and environmental variables. Achieved results were integrated and SOCS map was depicted. In the second method, the amount of SOC was calculated for each sampling point; then SOCS was performed by Random forest model. The results indicated that the obtained map of the first method with a coefficient of determination (R2) of 0.75 and root-mean-square error (RMSE) of 38 Mg C ha-1 was more precise than the obtained map from the second method with an R2 of 0.41 and RMSE of 69 Mg C ha-1.

Predicting Soil Properties in 3D: Should Depth be a Covariate?

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: DSM, soil depth, depth functions, equal-area spline

Abstract: The equal-area spline depth function was introduced to facilitate mapping soil properties with depth for the GlobalSoilMap project. The procedure involves standardising unequally thick and spaced soil observations to a common thicknesses and depths. Modelling was done to predict soil properties at each of the standard depth ranges using scorpan covariates. A continuous soil-depth function can be reconstructed once soil properties at each of the standard depth ranges has been predicted.

More recently, there have been various studies that propose a soil property at any depth can be mapped using a model incorporating depth along with spatial covariates as a predictor. While this seems to be an attractive proposition, some predictive approaches s such as Random Forest do not automatically generate a smooth depth function.

This paper will evaluate the proposition that soil properties can be evaluated at any depth.

Proximal Sensing to Support Predictive Mapping of Soil Properties for Precision Agriculture

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: precision agriculture, proximal sensing, DualEM, predictive soil mapping, vis-NIR spectroscopy

Abstract: There is an increasing demand for the collection and interpretation of proximal sensing information, coupled with soil sampling, to support predictive soil mapping and improve prediction of important soil parameters for precision agriculture. Sites with highly contrasting soil types are of interest to test predictive models over a wide range of soil properties and assess performance in properly capturing soil variability. In the Niagara region of Ontario, nestled along the Niagara Escarpment, there is a striving specialty crop industry which produces vast quantities of tender fruits such as peaches, plums, apricots, cherries, grapes, apples and pears. The region is also known as a major wine-producing area in Canada and is home to a number of wineries established at the base and on the benches of the escarpment. These areas are protected from the harsh winter conditions, experienced across much on Canada by the Niagara Escarpment, which traps warm air rising from Lake Ontario, giving enough warmth for the grapes to overwinter. Soils at the base of the escarpment vary from sandy beach deposits from ancient lake shores to heavy clay deposits of glaciolacustrine origin. Clay-textured tills are also common as the glaciolacustrine clays were incorporated into the till sheets as they re-advanced and retreated. This combination of material is present on the Hipple Farm, located near Vineland, Ontario, which will be the subject of the conference field tour. A DualEM survey was completed with transects on 12- to 18-meter centers through the vineyard and orchard on the farm of 44 hectares. The DualEM data was interpolated to 5-m resolution raster, and used along with an RTK digital elevation model (DEM), as covariate data for site selection using conditioned Latin hypercube sampling design. A total of 22 sites were selected for sampling using a drill truck to extract intact cores to a depth of 1-m or to contact with bedrock. Soil cores were segmented into pedological horizons for analysis. Soil physical and chemical properties determined were: soil organic carbon, bulk density, pH, moisture content, electrical conductivity, % sand, % silt and % clay. In addition, vis-NIR spectral data were captured for all soil horizons in the laboratory using both moist and dry samples. Predictive models of soil properties using vis-NIR spectral data were built, which will allow prediction of soil properties from spectral data with the option to supplement field work without collecting new soil samples. In addition, predictive models for soil properties were developed using the DualEM data, digital elevation model and derivatives of the DEM. In addition to the poster, these results will be discussed on site and soil pits will highlight the variability of the soil during the tour.

A Cell-Phone App to Quantify Soil Organic Matter from Images

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: digital images, computer vision, nondestructive characterization, modelling

Abstract: Recently, with the advancement of image acquisition systems, image-based SOM prediction has gained a lot of attention in soil science. The use of a smartphone camera as a soil color sensor has been well established (Gomez-Robledo et al., 2013) demonstrating its capability to detect soil color and hence justifying its utilization to estimate soil properties, for instance, soil organic matter, which has previously shown to exhibit reasonable correlations with the measurements of soil color (Chen et al., 2006; Gelder et al., 2011; Liles et al., 2013). The objective of this study is to predict SOM content from images taken using a smartphone camera in a laboratory. To accomplish this, a set of fifty samples of soil were collected from 9 different. Images of these samples were then acquired using the camera of a Samsung Galaxy J7 in the laboratory. The organic matter content of soil was also determined using conventional laboratory techniques. Multiple linear regression was used to establish relationship between color features (Mean R, Mean G, Mean B, Mean H, Mean S, Mean V, Mean Gray) derived from images and SOM for predictions of SOM content. Though not as precise as laboratory measurements, this app provides an approximation of SOM content which can help land managers and farmers make informed decisions. Our future work aims to target color scale transform and illumination normalization techniques to dispatch the usage of the app under non-uniform lighting conditions such as in a field.

Schemes for Feature Selection and Predictive Modelling of Soil pH

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: rotated principal components; fuzzy logic; random forest; generalized linear models

Abstract: The comprehension of physical, chemical and biological properties of soils is fundamental to establish adequate management practices involving not only the soil system, but also water, microorganisms and crops. The prediction of soil properties through statistical models becomes useful when precise management is required, but the lack of resources does not allow intensive soil sampling campaigns. This study aimed to evaluate the performance of 3 different schemes for feature selection and predictive modelling of soil pH. Soil pH data consisted of a legacy survey with 663 soil surface samples, collected in the study site in El Salvador. Three schemes were established to select the most accurate feature selection procedure and predictive model to infer soil pH. The first scheme consisted of feature selection based on rotated principal component analysis (PCA), coupled with a fuzzy logic-based inference. The second scheme consisted on recursive feature elimination (RFE), coupled with a random forest regression. The third scheme applied an elastic net regularization to select significant features within a generalized linear model (GLM). In all schemes, an initial set of 23 predictors were considered. The initial 23 predictors meant to capture the influence of topography, climate and vegetation on soil properties, specifically pH. The statistical performance of the 3 schemes was evaluated in terms of mean absolute error (MAE), root mean squared error (RMSE) and agreement coefficient (AC). Results show that the RFE/random forest regression scheme outperformed both the rotated PCA/fuzzy logic-based inference and the elastic net/GLM schemes. Overall, the adequate selection of predictive features via statistical methods allowed parsimonious models which provided a robust inference of soil pH.

Surface and Undersurface Soil Drainage Inference by Sensors Located 800 Km from the Target

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: soil morphology, drainage, soil mapping, soil management, color

Abstract: Soil drainage is an important property that must be well known for proper soil management and agricultural sustainability. Soil drainage has to be analyzed in a profile vision, such as in A and B horizon, assessing the predominant color, texture and presence of mottles. For large areas, determining soil drainage through the traditional methods is impracticable due to the high demand of time and financial resources. For this reason, remote and proximal sensing can be very useful tools for inferring soil drainage classes. In this work, we aimed to study and predict soil properties as color and texture and use them to delineate soil drainage classes in Piracicaba, Brazil, through remote and proximal sensing information. We used a large data set comprising 1250 and 950 soil samples collected in A and B horizon, respectively, in an area of 481462 ha. For these soil samples, reflectance in the visible (350-780nm) spectrum was determined using a FieldSpec sensor. The obtained reflectance values were used to determine soil color in the Munsell notation for both horizons. Soil texture was determined following the pipette method. A bare soil dataset from Landsat images following the GEOS3 methodology1 was used (bands 1, 2 and 3) for soil color (hue, value and chroma maps), and texture prediction and spatialization for the entire study area through Cubist method. Undersurface soil color and texture was inferred and pedotransfered to similar surface data in unknown locations. Soil color maps were reclassified and related to soil drainage classes as follows: red soil, very well drained (1); brown soil, well-drained (2); yellow soil, imperfectly drained (3); gray soil, poor drained (4), and black soil, very poor drained (5). Soil texture maps were also reclassified as: sandy (1), loam sandy (2), loam clay (3), clay (4) and very-clay (5). Then, soil drainage was determined by a combination of color and texture attributes. Results showed that well drained (58%) and imperfectly drained (27%) groups were predominant in A horizon. In B horizon, the same pattern was observed (60 and 30%, respectively). Regarding soil texture, loam sandy and clay texture were predominant for A and B horizon, respectively. Combining A and B horizon, there was the prevalence of three combinations of soil drainage, representing nearly 40% of the area: imperfectly drained medium sandy soil in both A and B; well drained medium clay soil in A and well drained clay soil in B; and well drained loam sandy soil in A and well drained clay soil in B. A first qualitative evaluation between a traditional soil map and the drainage obtained in the present work indicated that: a) areas with well-drained clay soil are in accordance with the soil drainage predicted in our work and b) areas marked with sandy soil in the traditional soil map present considerably different drainage results than the obtained in this work.

Surprisingly High Variation of Soil Map Diversity in Country-Wide Study of Flood-Affected Areas Using the High Density Legacy Data

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Floodplains, pedodiversity, soil geography, soil and land use

Abstract: The pedosphere has the distinguishing variability in horizontal and vertical dimensions and soil diversity as a measure of the variation of soil properties or soil classes within an area have become an emerging topic of expert discussion (McBratney and Minasny; 2007). Ibanez et al. (1995) showed how the biodiversity indices and models may also be employed to measure the pedodiversity. Since Aitchison (1986) has suggested the decent statistical treatment of data summing to unity, the soil science has reflected these findings when analysing the compositional soil data (e.g. soil particle size classes, soil class proportions, nutrient contents). In order to avoid methodological bias of using raw proportions, we interpreted the pedodiversity results within the compositional perspective based on the orthonormal coordinate representation coherent with the geometrical structure of sample space for compositional data which has been an area of the active research (Egozcue and Pawlowsky 2005).

Conventional soil maps are usually the representation of the soil-landscape relationships that were extensively used in the soil-survey to make statements about soil classes and their spatial distribution (Hudson 1992). Traditionally, such maps were made by aggregating soil surveyors' knowledge about the soil and its relations with geology, geomorphology, vegetation and land use from typical sites. This approach became the operative paradigm for extensive soil surveys worldwide and the Czech Bonitation Soil Information System was also the case. We used these legacy Czech soil data to estimate and interpret the regional trends of pedodiversity and soil taxa composition in agricultural landscapes of the inundation areas using the pedodiversity concept and compositional analysis. On the basis of the statistical analyses (ANOVA, Mantel's test using the Aitchison's distances) we proved the existence of significant differences on pedodiversity among the catchments, among three spatial scale of inundation according to the flood periodicity and between the group of cultivated soils and grassed soils. The compositional approach combined with expert knowledge may help to define a sequential binary partition to get a meaningful set of balances and an interpretable CoDA-dendrogram for the compositional vectors such as soil taxa composition. This approach improved the interpretability of soil information within the Czech legacy soil maps and hence the general patterns of pedodiversity in floodplains might be effectively described in an informative and quantitative manner.

More generally, the methodological approach adopted here should be applicable to any pedodiversity studies when interpreting the compositional factors and may be worthwhile in many survey directions (i.e. examination of soil distribution by various ecological boundaries, monitoring changes in soil diversity in response to changing land-use, upscaling or downscaling the method to local or global scales).

Tea Bag Index (TBI): As a Promising Quantitative Approach for Analysing SOM Dynamic and Increasing Soil Connectivity via Citizen Science

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: soil organic matter, tea bag index, decomposition, citizen science

Abstract: The need for rapid and inexpensive techniques for collecting high-resolution of quantitative soil data has brought innovative methods (e.g. visible near-infrared spectroscopy) for measuring soil attributes representing specific characteristics including particle size, colour, clay, organic matter content etc. Yet, there are not many cost-effective and simple approaches for tracking the dynamic patterns of soil processes such as the decomposition of organic materials - e.g the kinetics of the microbial processes. In 2015, the Tea Bag Index (TBI) was released as a simple, cost-effective and, principally, a standard tool for providing values in both the rate (k) and the stabilisation (S) of the organic components during the decay of two different types of teas (green and rooibos). The method aims to standardise these values on which to rely a cross-comparison among different soil environments in their ability to perform decomposition and the storing of organic carbon over time. The study here embodies an analysis on how each of the TBI parameters (k and S) relates with other soil properties and how such relationships can be reflected in the dynamic of soil organic matter (SOM). Are the k and S parameters following the well-known relations between SOM and other soil properties, e.g. the positive association with the stability of soil aggregates? A better understanding of this dynamic will be useful for the improvement of SOM stabilisation and quality. In addition, the simplicity of the TBI method has had a positive reception by the non-scientific community (e.g. farmers and students). This study also aims to assess how promising has been the use of TBI for collecting soil data and the increasing of soil connectivity via citizen science. The results and evidence to be analysed here are based on two study cases: (1) A TBI experiment carried out with students (~ 2,000) over seventy schools of New South Wales (Australia) and; (2) A TBI experiment over a smallholders Cocoa Board farming system in the East New Britain Province in Papua New Guinea. In both experiments, the TBI parameters were measured in two-paired land uses including managed and unmanaged areas. The data is still in process and final results will be discussed at the conference.

The Use of National Soil Vis-NIR Spectral Library for Field-Scale Soil Organic Matter Estimations

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: vis-NIR spectroscopy; large-scale library; multivariate modelling; data mining; Bayesian model averaging

Abstract: There is global interest in the development of large-scale spectroscopic databases, and several are currently being developed or has been developed at regional, continental and global scales. However, few reports have been published on successful estimation of soil properties on local sites. Here we proposed a framework with the aim of making better use of large spectral library for local prediction of soil properties. The Swedish soil visible and near-infrared spectroscopic library (SSL), which contains a total of about 12,000 samples collected in the agricultural fields (upper 0.2 m depth) all over Sweden (one sample per ha), were used to derive calibrations and make predictions in four local fields with various soil type and soil organic matter (SOM) content. Genetic algorithm (GA) were performed on the whole library samples to select feature variables (wavelengths) for SOM. Various existing approaches, including partial least square regressions (PLSR), locally weighted regression (LWR), spectrum based learner (SBL), cubist and random forest (RF), were then used to derive multivariate models with full wavelengths and GA selected wavelengths, respectively. Principle component (PC) analysis was used to aid interpretation of the predictions. The performances of LWR and PLSR were improved with GA selected wavelengths compared to with full wavelengths, but it was not the case for cubist and RF. The SOM content from field 1, 2 and 4 was best predicted using SBL with R2=0.60 and RMSE=0.30 %, LWR with R2=0.84 and RMSE=0.52 %, and RF with R2=0.72 and RMSE=0.53 %, respectively. In field 3, SOM was poorly predicted no matter which methods were used. This can be interpreted by the out scoped positions of local soil samples when projected to the PC space of the whole library with GA selected wavelengths. However, it was not shown with full wavelengths. A subset of samples from field 3 should be included or spiked to the Swedish SSL for future estimation. LWR with GA selected wavelengths offered relatively stable estimations when compared to other algorithms. Since there is not one algorithm perform well for all the fields, Bayesian model averaging was used to fuse the predictions from all the regression models. The result shows a better prediction than any of the regression models without a need to select a proper regression method. In summary, we suggest to firstly perform GA algorithm on the SSL for predicted soil properties; and project the soil spectra from local sites onto the PC space of SSL; if local samples are within the scope of SSL, the model fusion method performed in this study were suggested.

The Use of Soil Colour in Predicting Some Soil Chemical Properties in Sokoto, North-Western, Nigeria.

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Soil colour, prediction, Chemical properties of soils

Abstract: Soil colour reflects an integration of chemical, biological and physical transformations and translocations that have occurred within a soil. It could therefore, be used as a basis of predicting certain chemical properties of the soil. The main aim of the study was to investigate the relationship between soil colour and some selected chemical properties of the soils. The specific objectives are:-

- To determine the colour of the different soils in the study area

- To relate the colour obtained from the different soils with some chemical properties of the soils.

- To predict the management requirements of the different soils based on their colour.

The research was conducted at the Dryland and Lowland Teaching and Research Farm of the Usmanu Danfodiyo University, Sokoto. The Dryland Teaching and Research Farm is located within the University, after the University Primary and Secondary Schools and the lowland teaching and research farm is located after River Sokoto, along UDUS-Sokoto road. Sokoto State lies between latitude 130 01◦N and longitude 50 15 ◦E. Soil samples were collected at different locations from the study area at the depth of 0 - 15cm and 15 – 30cm. A total of 12 composite samples were collected based on changes in the soil colour and/or topography of the site. The samples from the upland soils were designated A1, A2, B1, B2, C1 and C2 respectively. The samples collected from the lowland soils were designated D1, D2, E1, E2, F1 and F2 respectively .The sample were air-dried and sieved through a 2mm sieve. The soil colour (moist) was determined by the use of the munsell colour chart in which a soil is held next to the chips to find a visual match and assigned the corresponding munsell notation. The physical and chemical properties of the soils were determined according to standard laboratory methods.

The study reveals that soils with a hue of 5YR had organic carbon values that ranged from 0.23 to 0.40%, those with a hue of 7.5YR had values of 0.14 to 0.63% and those with a hue of 10YR recorded organic carbon values of between 0.73 to 0.92%. The colour of soils from the upland farm varied from yellowish red (5YR4/6) to dark reddish brown (5YR 3/4), while those of the Lowland areas varied in colour from Dark grayish brown (10YR 4/2) to pale brown (10YR 6/3). In addition, the lowland soils exhibited some level of mottling as evidence of water saturation at some period of the year. Soils with a hue of 5YR had organic carbon values that ranged from 0.23 to 0.40%, those with a hue of 7.5YR had values of 0.14 to 0.63% and those with a hue of 10YR recorded organic carbon values of between 0.73 to 0.92%. Further studies are needed using a wide range of soil colours in order to conclude on the possible relationship between soils of this area and those elsewhere and other chemical parameters of the soil.

Three-Dimensional Mapping of Clay and Cation Exchange Capacity of Sandy and Infertile Soil in Northeast Thailand

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Cation exchange capacity; Three-dimensional mapping; quasi-3d inversion; clay content prediction

Abstract: Most cultivated upland areas of northeast Thailand are being used for cash crops. However, these areas are characterized by sandy and infertile soils, which are difficult to improve agriculturally. Information about the clay (%) and cation exchange capacity (CEC – cmol(+)/kg) are required, respectively. Because it is expensive to sample, prepare and analyse these soil properties, proximal sensed data acquired from electromagnetic (EM) induction instruments are increasingly being used. This is because the measured apparent soil electrical conductivity (ECa – mS/m), can often be correlated directly with measured topsoil (0-0.3 m), subsurface (0.3-0.6 m) and subsoil (0.6-0.9 m) clay and CEC. In this study, we explore the potential to use this approach and considering a linear regression (LR) between EM38 acquired ECa in the horizontal (ECah) and vertical (ECav) modes of operation and the soil properties at each of these depths. We compare this approach with a universal LR relationship we develop between the calculated true electrical conductivity (– mS/m) and laboratory measured clay and CEC at various depths. We estimate by inverting the ECah and ECav data, using a quasi-3d inversion algorithm (EM4Soil). The best LR between ECa and the soil properties was between ECah and subsoil clay (R2 = 0.43) and subsoil CEC (0.56). We concluded these LR were unsatisfactory to predict clay or CEC at any of the three depths. In comparison, we found that a universal LR could be established between obtained from using the S1 inversion algorithm, full-solution (FS) and using a damping factor (λ) = 0.07 and 0.9 with clay (R2 = 0.65) and CEC (0.68), respectively. The LR model validation was tested using a leave-one-out-cross-validation. The results indicated that the universal LR between and clay at any depth was precise (RMSE = 2.17), unbiased (ME = 0.27) and very good concordance (Lin's = 0.78). Similarly, very satisfactory results were obtained by the LR between and CEC (RMSE = 0.53; ME = 0.07 and Lin's = 0.80). The implications of these results are that in a field, which has limited spatial variation, in terms of clay or CEC and therefore cannot be directly correlated with ECa across a field, can still be mapped by developing a LR model between estimates of with soil properties (i.e. topsoil, subsurface and subsoil) which vary with depth.

Three-Dimensional Modelling and Mapping of Soil Constraints, Combining Machine Learning and Geostatistical Methods

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Session 1: Developments in Pedometrics 1: Mathematical and methodological

Presentation Type: Oral

Keywords: 3-D kriging, vertical sample support, machine learning, soil constraints

Abstract: Soil constraints have a negative impact on crop yields, and are one cause of yield gaps. An important part of effectively managing the land in the presence of these constraints is an understanding and knowledge of their variation, both horizontally across the landscape and vertically through the soil profile. We apply an approach that combines machine learning algorithms and geostatistical methods for modelling and mapping the three-dimensional variation of soil constraints. The approach uses a Cubist model to represent the horizontal and vertical trends associated with covariates (including depth), while horizontally and vertically correlated residuals are modelled using an increment-averaged kriging method, which explicitly accounts for the vertical support of soil data collected over different sampling intervals. Furthermore, the Cubist and geostatistical methods are combined in such a way as to allow the regression parameters within the rules of the Cubist model to be fitted while accounting for the correlation and vertical support of the soil data. Previous work with the increment-averaged kriging approach has dealt with small datasets only (<200 profiles); here we apply an approximation to the likelihood to allow modelling and prediction based on larger datasets (~3000 profiles). The methods are applied to model and map soil constraints across the cropping regions of Queensland and New South Wales, Australia, using legacy soil data held in state databases.

Three Dimensional Prediction of Soil Constraints for Assessment of Amelioration Strategies and Losses in Yield Potential

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: 3D mapping, Soil constraints

Abstract: Soil constraints such as acidity, sodicity and salinity are present in many soils across the globe and can result in losses in production and yield. Whether they are naturally occurring or human induced constraints, in many cases there are options for amelioration such as gypsum or liming. In cases where the constraints are too extreme or deep in the profile growers need to adjust their yield targets when considering management inputs such as fertiliser. Before such decisions are made growers need to know where the constrained zones are in their paddocks and within their profiles. This requires a three dimensional map of soil constraints where we have fine interval depth predictions of soil properties at each prediction location. This is the starting point from which amelioration options can be considered and losses in yield potential can be estimated.

We use this serious management issue to illustrate (i) the importance of predicting in three dimensions in Pedometrics (ii) how a suite of existing approaches, old and new, in Pedometrics can be used together to solve this real-world problem.

Our solution consists of five stages:

-soil spectroscopy to gain cost efficient observational data related to soil constraints, e.g. exchangeable sodium percentage (ESP);

-three dimensional modelling of soil properties using the area-to-point kriging approach of Orton et al. (2016) to predict every 1 cm within each profile at each prediction location to identify the three dimensional distribution of constrained zones;

-use pedo-transfer functions (PTFs) to estimate water holding properties at each site to estimate the yield potential;

-combine our three dimensional predictions of constrained zones and water holding properties to estimate the yield potential conditional on soil constraints. For example, roots cannot access water from parts of the profile with high ESP so the bucket size is reduced;

-explore amelioration strategies given the location in the profile, i.e. how deep, of the constrained zone.

We illustrate the approach on a dryland cropping farm in Eastern Australia with a focus on pH and ESP induced soil constraints as they relate to wheat yield.

Understanding and Quantifying the Categories of a National Legacy Map on Water Management by Data Mining Methods and Newly Elaborated, Digital Hydro-Physical Soil Property Maps

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: data mining; disaggregation; legacy soil map; quantification; water management classification

Abstract: Soil physical properties and soil water regime have been in the focus of soil surveys and mapping in Hungary due to their importance in various environmental processes and hazards, like waterlogging and drought, which endanger extended areas.

In the late 1970s a category system was elaborated for the planning of water management, which was used as the legend of a nationwide map prepared in the scale of 1:500.000. Soils were characterized qualitatively (e.g.: soil with unfavorable water management was defined with low infiltration rate, very low permeability and hydraulic conductivity, and high water retention), without quantification of these features. The category system was also used for creating large-scale (1:10.000) water management maps, which are contained legally by expert's reports prepared on the subject of drainage, irrigation, liquid manure, sewage or sewage-sludge disposal. These maps were prepared eventually, essentially for individual plots and are not managed centrally and are not available for further applications.

Recently a 3D Soil Hydraulic Database was elaborated for Europe at 250 m resolution based on specific pedotransfer functions and soil property maps of SoilGrids. The database includes spatial information on the soil water content at the most frequently used matric potential values, saturated hydraulic conductivity, Mualem-van Genuchten parameters of the moisture retention and hydraulic conductivity curves. Based on similar, idea the work has been continued to produce more accurate and spatially more detailed hydrophysical maps in Hungary by generalizing the applied pedotransfer functions and using national soil reference data and high resolution, novel, digital soil property maps.

We initiated a study in order to formalize the built-in soil-landscape model(s) of the national legacy map on water management, together with the quantification of its categories and its potential disaggregation. The relation of the legacy map with the newly elaborated 3D estimations were evaluated at two scales: nationwide with 250 m resolution and at catchment scale with 100 m resolution. Conditionally located random points were sequentially generated for virtual sampling of the legacy map to produce reference information. Hydro-physical maps were used as predictor variables. Various supervised and unsupervised classification methods and machine learning approaches were used to analyze the information content of the legacy category system and map. The deliverables of the study are disaggregated maps with the legend of the traditional water management classes at both national and catchment level; interval estimation of the applied hydro-physical properties for the individual water management categories, together with some primary estimations on the accuracy of the results.

Using Field Data and Airborne Lidar-Acquired Digital Elevation Data to Model Depth to Bedrock at a High Resolution

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Field Data/LiDAR/DSM/Models/Validation

Abstract: Digital soil mapping is a sub-discipline of soil science that can be used to produce high resolution maps of soil properties. One goal of digital soil mapping is to populate soil information systems using field data coupled with environmental covariates including derivatives of digital elevation models. It is believed that high resolution digital elevation models (DEM) generated from LiDAR technology can help make better maps. The objectives of this project were:1) to model soil depth to bedrock using three machine learning models; 2) to determine an effective method of selecting covariates;3) to test and compare validation results for the three models; and 4) to test the effect of different grid resolutions on model validation. Soil depth to bedrock was recorded in the field at 213 points within the Eagle Hill Forest study area (150 km^2), northwest of Kamloops, BC. Three machine learning models (Multiple Linear Regression, Random Forest, and Cubist) were used to model soil depth. Results showed that the best covariates for making models are those covariates that are more highly correlated with the property being modeled. The results also showed that a random hold back validation cannot produce a single reliable value, and the validation results depend on different randomly selected training data. Therefore, a range of validation results were considered in analysis rather than accepting a single value. According to these results, a set of grids were produced and averaged using randomly selected datasets, and the final averaged map was validated using an external dataset. The other results of this study showed that one-meter resolution LiDAR DEM produced the best soil depth model.

Validation of Digital Maps Derived from Spatial Disaggregation of Legacy Soil Maps

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Poster

Keywords: Digital soil mapping, Soil sampling, Expert knowledge, Validation,

Abstract: Spatial disaggregation of soil map units involves the downscaling of existing information to produce new information at a finer scale than the original source. Currently, it is becoming a powerful tool to address the spatial distribution of soil information over large areas, where legacy soil polygon maps are the only source of soil information. Because of the high expense of additional resampling, only few studies have sought to validate disaggregated soil maps using independent sampling. This study aims to implement this approach to measure the quality of soil properties predictions derived from disaggregated soil maps, using a stratified random sampling approach over a study area of 6,848 km?. The existing legacy soil polygon map at 1:250,000 scale of Brittany (France) was spatially disaggregated at 50m resolution using an algorithm called DSMART, which uses soil-landscape expert rules of soil distribution in space. By fitting equal-area spline functions, soil properties were then estimated at six depth intervals according to GlobalSoilMap.net specifications. For soil maps, depicting qualitative soil properties (soil parent material, drainage soil class, soil type and soil depth class), the overall strict purity was estimated at 34%, while the overall average purity achieved 70% and the overall soil type partial purity achieved 60%. Quantitative soil maps, depicting soil properties (clay content, fine silt content, coarse silt content, total silt content, fine sand content, coarse sand content, coarse fragments, CEC, and pH) were validated at two soil depth intervals 5-15 cm and 30-60 cm. In general, soil properties predictions were unbiased expect for coarse fragment and CEC values regarding the topsoil layer. Statistical validation parameters were better for the deeper soil layer expect for soil particle size distribution. Thus, differences of prediction accuracies between strata denote areas where more soil data or better soil prediction models are needed to improve the disaggregation process.

Volumetric Mapping of Soil Organic Carbon and Soil Water Content with Electrical Conductivity Data

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Session 3: Developments in Pedometrics 3: Connecting Existing to the New technologies, Data, and Methods

Presentation Type: Oral

Keywords: Three-dimensional digital soil mapping; Soil organic carbon; Soil water content; Machine learning; Proximal soil sensing

Abstract: Soil organic carbon (SOC) and hydro-geophysical properties as soil water (SW) content are closely associated to food production and fresh water provision. To preserve these essential soil functions, information of the variability and quantity of SOC and SW in the spatial domain is crucial. Within the scope of digital soil mapping (DSM), this knowledge can be generated using machine learning approaches. However, most studies focus on the horizontal domain, although distribution and variability within the soil continuum should be addressed in the vertical domain as well. Multiple predictions in the horizontal domain and different depths can be interpreted three dimensionally but effectively lack volumetric information. In addition, the interpretation of this setup as volume has a subjective error. In comparison, spatially predicted depth functions comprise volumetric information with high vertical resolution. The major hypothesis of this study is that volumetric models based on measurements of geophysical sensors with depth dependent sensitivities provide stable predictions of SOC and SW content for the whole soil continuum. We calculated the spatial sample distribution of 25 profiles with weighted conditioned Latin Hypercube Sampling (wecLHS) based on six electrical conductivity data sets measured with different inter-coil spacing and a gamma-ray spectrometer. The study area is an agricultural field located in the Elbe floodplain near Lutherstadt Wittenberg, Saxony-Anhalt (Germany). Soil samples were taken from 0 to 60 cm depth in four even intervals of 15 cm. The tested profile depth functions are 2nd degree polynomials, logarithmic and exponential functions. The coefficients of these depth functions were modelled and predicted spatially with the electrical conductivity and gamma-ray spectrometry data as environmental covariates with Cubist, deep learning (DL), random forests (RF) and support vector machine (SVM). The final 3D maps were calculated by solving the depth functions at any grid point with 5 cm vertical resolution. For evaluation, we used repeated cross-validation and compared the 3D predictions with predictions of each depth interval in the horizontal domain directly. The results showed that DL had higher accuracies in the modelling and spatial prediction of soil profile depth function coefficients than RF, SVM and Cubist. DL models provided the best 3D predictions, being stable over multiple depths for SOC and SW. Overall, volumetric predictions with geophysical measurements provide accurate models throughout the soil continuum at field scale. The correspondence between volumetric and multi-layered spatial predictions of SOC was high. Therefore, we recommend the spatial prediction of soil profile depth functions for 3D soil property mapping on field scale.

Session 4

A Bayesian Belief Network to Operationalize the Concepts of Soil Quality and Health

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Soil Quality and Health, Stakeholder Engagement, Bayesian Inference, Mapping

Abstract: Soil Quality and Health (SQH) can be visualised as a three-legged stool, integrating three components; sustained biological productivity, environmental quality, plant and animal health. Implicit in the idea of assessing and interpreting soil quality is a multi-disciplinary approach. Simply measuring and reporting the response of an individual soil parameter to a given perturbation or management practice has proven not be sufficient.

SQH is hard to quantify in a consistent, objective fashion, due to the complexity and multiplicity of the functions that we expect soil to fulfil. There is an understanding that the properties of soil that make it able to deliver a particular function (e.g. yield) are the same as those that enable it to deliver other functions. The issue is then that properties of soil such as organic matter content, bulk density, range of minerals, pH etc affect the functions to different degrees. SQH then becomes a catch-all for different aspirations from different stakeholders who may interpret results in a different way. Given this background of expectation, it is interesting to see how far it is possible to operationalise the concept of SQH such that each stakeholder gains a metric that is consistent with purpose and sufficiently self-consistent with other purposes so as to be close to universal.

Because SQH is a subjective, multifaceted concept, it can only be operationalised by incorporating physical data within an expert-driven, knowledge-based probabilistic framework. Bayesian Belief Networks are graph-based, directional networks that can incorporate probability distributions of these various kinds of data. Essentially the directedness leads from multiple pieces of data to a conclusion - in our case a rating of SQH. The network is self-learning in that any additional soils and data for which quality assessments are available will reinforce the pathways that decide the quality rating.

To accommodate the various functions and scales needed to operationalise SQH, this will require a set of Bayesian Belief Networks that considers the interactions of soil properties with SQH but also the impact of land use and management on soil quality. Here we report on systematic approach to obtain expert knowledge from a wide variety of experts, using BBN as the structured approach to expert knowledge elicitation. We do this for the four main landuse categories in Great Britain, arable, grassland, livestock and semi natural. The variables considered, and topology of the BBN's were determined by our panel of experts. We also ensured that these models could be directly linked to observable data about soil, and for which national level GB datasets existed. We then considered various forms of uncertainty in the models. The ultimate aim of the BBN is to obtain a distribution for SQH: (=)=, which can be interpreted as aleatoric uncertainty. However, we also attempted to capture epistemic uncertainty through a description of the experts' confidence and through using multiple experts. We then considered the impact of certain knowledge (available soils data) about given nodes, and the impact this has on the importance of nodes in determining SQH. We found that the use of any single variable resulted in poor predictions of SQH, thus confirming our hypothesis that connected data expresses SQH more reliably. Using the associated national soils datasets, and the SQH BBN's, we were then able to predict SQH for soils across GB

A Government-Funded Program of Applied Pedometrics to Stimulate Agricultural Growth in Tasmania, Australia

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Government Program, Soil, Climate, Suitability Mapping

Abstract: Since 2010, Pedometric approaches have been applied to Government core-business agricultural land resource assessment in the state of Tasmania, Australia, where a series of new irrigation schemes, along with Government policies, has been stimulating agricultural growth. The Department of Primary Industries Parks Water & Environment has developed a program of ?Enterprise Suitability Mapping?, using Pedometrics, Climate Modelling and Enterprise Suitability Rulesets to produce high resolution (30m) interactive digital maps of the suitability status of a range of agricultural enterprises. Up until 2010, Tasmanian spatial soil interpretations had relied on conventionally developed soils mapping that was up to 80 years old in some areas. There was an emerging need identified for more up-to-date and finer resolution spatial soils information, with mapping of soil properties rather than types needed to allow better-targeted interpretations.

A pilot project was undertaken with the University of Sydney, Faculty of Agriculture and Environment, to trial and refine the pedometric processes and develop functional soil grids of key soil properties for a range of important and emerging agricultural enterprises, derived from new and existing soil sites. These were integrated with climate grids developed from a suite of temperature sensors and terrain-based models, then applied to rulesets developed by the Tasmanian Institute of Agriculture and refined by industry to develop the suitability maps. The pilot project was eventually rolled-out state-wide in 2014 at 80m resolution, before being refined to 30m resolution in 2018 newly collected soil cores, strategically sampled where modelling uncertainties were highest, in important agricultural areas.

Well-tested and proven Pedometric approaches were used to develop the soil grids, generating standard-depths by fitting mass-preserving depth-splines to the calibration data, Regression-Trees and Random-Forest modelling approaches for continuous soil-properties, and Decision-Trees for categorical properties. K-fold cross validation was used to reduce model sensitivity to calibration data, and a leave-one-out cross-validation within each tree partition used to determine uncertainty ranges. The resulting Enterprise Suitability Maps were evaluated and refined in consultation with key agricultural industry representatives. Additional Soil Vulnerability maps were developed using the soil grids for erosion by wind and water, sodicity, salinity and waterlogging, and integrated with the suitability maps to identify where additional soil-conservation management would be required to achieve soil security. The maps were uploaded to a publicly accessible internet mapping portal (www.thelist.tas.gov.au), and gives users the capacity to interactively identify the suitability rating, soil and climate parameters and required management at any location in the State. The mapping has achieved a high level of interest in Tasmania, totaling > 143,000 internet mapping visits in the 6 months between April and September 2018.

As this mapping gains increasing exposure, industry and Government-based coordinators are placing new and increasing demands on these products. The modelling used has consequently been automated to allow new soil properties and mapping to be generated as new data becomes available, and as industry requests of new or refined enterprises arise.

Accumulation Rates and Chronologies from Depth Profiles of 210Pb in Sediments of Northern Beibu Gulf, South China Sea

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Poster

Keywords: geochronology; radiotracers; Beibu Gulf; South China Sea; sedimentation rates

Abstract: Being a complex environment subject to coastal and marine processes, little is understood concerning the evolution of northern Beibu Gulf and the human impacts on its ecosystem. Since various environmental information can be stored in the deposited sediments, it is considered to be useful tracers for natural and anthropogenic processes. The aim of this study is to determine a detailed reconstruction of the sedimentation rates in the past decades by applying the 210Pb dating method. To achieve this, 3 sediment cores located in different regions along the coast of northern Beibu Gulf were collected. 226Ra and 210Pb were measured using gamma spectrometry and age determination was analyzed by the CRS model. Physical parameters (water content, grain size and bulk density) and TOC were determined for each core. The results showed that the average sediment mass accumulation rates (dry mass) calculated from 210Pb profiles was 0.043-0.008 g cm-2 yr-1in core of Sanniang Bay and 0.028?0.003 g cm-2 yr-1 in core of Lianzhou Bay. Sediment mass accumulation rates decreased with increasing water depth. The sedimentation rate was 0.54 cm/y in Sanniang Bay and 0.38 cm/y in Lianzhou Bay. Water content and grain size did not change much with age variation, while TOC showed a general decline during past decades, probably due to the terrigenous input. This study provides a chronological framework for comparing the depositional histories and inventories of various pollutants that have been measured in the same sediment cores. This information will be useful for resolving scientific environmental quality and coastal management in northern Beibu Gulf.

Comparison between Conventional and Digital Soil Mapping Approaches for Mapping Soil Hydrological Classes in Scotland

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Soil hydrological classification, Spatial disaggregation, Random Forests, Base Flow Index

Abstract: This study compared conventional (polygon-based) and digital soil mapping (DSM) approaches for mapping soil hydrological classes used for predicting catchment hydrological response. Soil morphological attributes recorded during soil surveys known to describe key features of soil hydrology have been used in the UK to map soil regulatory functions. This Hydrology of Soil Types (HOST) classification scheme was developed using expert knowledge to link soil hydrological indicators with conceptual models of surface and subsurface flow pathways through the soil profile. In addition, HOST has been optimised by regressing HOST class proportions against the Base Flow Index (BFI) to estimate catchment hydrological response.

In Scotland, spatial representation of HOST classes is based on the digitised polygons of a) the Soil Map of Scotland (national cover) at a 1:250,000 scale (HOST-250k) and b) the Soil Map of Scotland (partial cover) at a 1:25,000 scale (HOST-25k) that provide detailed mapping of soil types in the country?s cultivated areas. HOST-250k map consists of both single class and multiple (complex) class map units while HOST-25k consists predominantly of single class map units of the 21 HOST classes that are present in Scotland. Disaggregated HOST class maps have also been produced to provide continuous representation of HOST class variation within both single and complex map units of the HOST-250k map in two grid cell resolutions: a) 100m for national coverage (HOST-100m) and b) 50m for the partial coverage (HOST-50m). The disaggregated maps were produced using a scorpan model approach and represent the most-probable HOST class at each grid cell based on 100 realisations from respective training datasets and Random Forests (RF) model runs.

The four HOST class maps were validated using 1063 soil profiles from the National Soil Inventory of Scotland (NSIS) sampled on a regular 5km grid, to which HOST class values were assigned using available soil property information. In addition, the performance of the conventional and disaggregated maps for predicting catchment hydrological response was assessed by comparing BFI values in 23 catchments that lie within the study area (partial cover), calculated using HOST class proportions from the four HOST maps, with catchment BFIs calculated using flow data from gauges.

Match accuracy for the NSIS profiles was greatest for the HOST-25k map (39%) compared to around 34% for the other three HOST maps. However, the disaggregated maps provided better predictions of catchment hydrological response based on BFI: agreement with flow-calculated BFI based on Lin’s concordance was greatest for the HOST-100m (0.68) and least for the detailed HOST-25k polygon map (0.59). Improvements in the predictions of hydrological catchment response made by the disaggregated maps were mainly attributed to their under prediction and over prediction (compared to the conventional maps) of alluvial and more freely-draining soils, respectively, within the study catchments.

The results indicate that at a landscape or catchment level, finer scale soil mapping may not always be the most appropriate for mapping soil water pathways; mapping resolution needs to be consistent with and reflect the scale on which soil processes operate. Overall, the study suggests that DSM techniques can produce predictions of catchment hydrological response that are comparable, if not better, than maps based on detailed and intensive soil surveys.

Comparison of Soil Organic Carbon Maps of France Using Global and National Soil Databases

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Digital Soil Mapping; Soil organic carbon; National modelling; Global modelling; Sampling density

Abstract: Climate change and food security for a growing population are two of the greatest challenges facing humanity in this century. Soil organic carbon (SOC) is key in addressing these two challenges. Therefore, a better understanding of the spatial distribution of SOC is vital for decision making in land management. However, the spatial distribution of SOC concentrations and stocks both have large uncertainties. There are currently various initiatives to map SOC at national, continental and global scales, and using a variety of soil legacy data and spatial predictive models. These SOC maps generated from national (bottom-up) and global (top-down) scales come with differences in accuracy in France. The main cause of the difference may result from soil sampling density and representativeness of the soil samples (soil data used in the top-down model is not representative for France). One solution to improve top-down model (e.g., SoilGrids) is to add national representative national soil data. France is a good pilot study area for two reasons: 1) soil data (WoSIS) used in SoilGrids is biased; 2) France has an unbiased national soil database (RMQS) designed by 16 km by 16 km grid sampling. In this study, we compared SOC maps for France generated by global (WoSIS) and national (RMQS) soil databases using covariates commonly used at the global scale (e.g., SoilGrids). Four soil data combinations were generated: 1) WoSIS; 2) WoSIS data located in France; 3) WoSIS and RMQS, 4) WoSIS data located in France and RMQS. The same machine learning technique from SoilGrids were used for SOC modelling. A 10-fold cross-validation was applied to evaluate model performance for each of the four soil data combinations. Among others, the comparison reveals whether nationally calibrated models outperform globally calibrated models and how data density influences map accuracy. This case study provides a reference on how representative national data influences the SOC maps generated by top-down and bottom-up models and thus evaluate the its added value for top-down models.

Delineating dambo soil-landscape elements: an extension of the solution using 3 arc-secs SRTM DEM-derived covariates

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Soil-landscape modeling, digital terrain modeling, African dambos

Abstract: Much of Africa suffers from limited soil information, which impacts land use planning for agricultural purposes. However, for an African dambo landscape, it is possible to map catenary units, and assign them data of soil properties to generate useful information urgently required to plan for the use of the continent?s soil resource. Attempts have been made to delineate dambo catenary units using optical sensor or aerial gamma-ray data, combined with DEM-derived covariates. However, the cost of high resolution sensor data makes it inaccessible to many scientists working on the continent, and aerial gamma-ray surveys are limited to a few countries in Africa. In this study, we used primary (i.e. altitude, curvature, plan and profile curvature, relative slope position, elevation relative rank at 12 levels of processing window ranging from 11 to 231 pixels, and topographic position index at 10 levels of processing window ranging from 200 to 2000m) and secondary (i.e. topographic wetness index) terrain attributes as the only predictors of expertly derived catenary units (i.e. uplands, margins, floors and bottoms) of a dambo in central Uganda. We found the means of the covariates to be significantly different between uplands and the dambo, but not necessarily so between dambo catenary units, which also could not be readily separated using topographic position index based on smaller processing windows. Moreover, there is an inversion with this particular index, which suggests that bottoms occupy a higher ground than the floors. Nonetheless, the map of catenary units predicted using random forest and terrain data was fairly accurate (i.e. overall accuracy and Kappa is 72.8% and 0.63, respectively), and is comparable with the outputs of similar studies conducted in the area. This proves the efficacy of terrain data to map soil-landscape elements, hence an alternative where high quality optical data is not readily available. However, caution has to be exercised when comparing terrain attribute values across a dambo. This is because the mean surface backscatter of the mapped area is affected by vegetation, so that heavily vegetated members of the landscape occupying the lowest position might appear to be higher than the neighbors.

Developing a Crop Suitability Assessment Framework for Underutilised Crops

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: soil suitability, underutilised crops, land capability assessment, crop selection, R

Abstract: Lack of knowledge and proper analytical methods are the major barriers to wider adoption of many resilient underutilised crops at the global level. For instance, methods that rely on modelling the crop performance, require detail local calibration data on soil, climate and genotypes to estimate variety- specific biomass and yield. As more information on genotypic and agronomic characteristics of crops and environmental factors such as soil become available, new methods for suitability assessment of high potential underutilised crops can be developed and tested. In this work, we developed a crop suitability index based on an augmented species niche classification framework that takes into account local biophysical data for a range of crops. To be able to broaden the list of plant species, a minimum set of environmental variables were used to develop 28 suitability classification algorithms that were compared for accuracy. More than 80,000 accession data for 40 crops of different types; cereals, legumes, fruits, tubers, and vegetables were extracted from the Global Biodiversity Information Facility (GBIF), species occurrence database to test the accuracy of suitability indices. A range of crop requirement data including optimal and marginal temperature and rainfall were extracted from the FAO EcoCrop database. Other information such as soil fertility requirement and optimal root depth were also obtained and validated through literature analysis. Edaphic information including pH, depth to bedrock and texture were acquired and harmonized according to the root depth of each crop from the latest version of ISRIC global soil grids database. This database provides continuous maps that are the result of interpolations of soil profiles across the globe. Climate information was extracted from the WorldClim dataset which provides gridded maps of historical averages at the global scale. A script for data extraction and suitability calculation was developed using R statistical language. The result showed that a combined index that takes into account the thermal requirements of crops averaged by the soil pH, depth and fertility requirements has the potential to accurately predict the presence of all crops. The successful suitability index was built into a crop selection tool that is available online. We will demonstrate the benefits of this tool in comparison with the traditional method of land capability assessment for the diversification of local farming systems. We will also discuss the implications of using uncertain globally available datasets with various degrees of uncertainty for the purpose of multi-scale crop suitability assessments.

Efforts towards a national scale, fine resolution grid of soil pH for New Zealand

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: digital soil mapping; soil grids; soil pH

Abstract: Soil pH has always been an attribute of interest for soil scientists --- but this is also the case outside soil science. pH is a major input variable for crop suitability rules, for soil ecosystem services modelling exercises, and it has been widely used as an explanatory variable for species distribution models in ecology.

Despite the importance of this attribute across scientific disciplines, soil pH information (as a map) is not easy to source in New Zealand, particularly at the national scale. The main nation-wide map of soil pH for New Zealand is one of the New Zealand Fundamental Soil (FSL) layers, generated by pedologists more than 30 years ago, and based on their best guess of the most likely pH value for the whole profile, for every polygon of the New Zealand Land Resource Inventory (NZLRI) polygon. It is widely regarded by NZ soil scientists as a qualitative, outdated resource.

The digital soil mapping (DSM) framework offers an opportunity to update and improve this map. DSM is building quantitative, statistical relationships between points observations of soil attributes, and a suite of environmental covariates (often derived from remote sensing). As a result, continuous grids of soil attributes can be generated. A nice addition is that uncertainty of the estimates can also be mapped.

This paper reports on the efforts towards the creation of a soil pH grid at the national scale and at a fine spatial resolution (100 m). Several thousands of soil pH observations were collated, along with a suite of climatic, topographic, geologic environmental layers. As a result, several spatial layers were created for different depth intervals (0-5 cm, 5-10 cm, 10-30 cm, 30-60 cm, 60-100 cm), according to the GlobalSoilMap specifications. The accuracy of the resulting maps was assessed against both the reference soil profile measurements, the FSL map, and ISRIC's SoilGrids.

Evaluating the Accuracy of Machine Learning Based Digital Soil Mapping Models for Multiple Categories of Environmental Variables in an Agricultural Landscape

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Digital Elevation Model, Generalized boosted model, Landsat, Random Forest, Soil organic carbon

Abstract: Landscape-scale digital soil mapping (DSM) in agricultural lands is challenging due to the large heterogeneity of soil properties and the seasonal variation of crops and other vegetation. Incorporation of soil and vegetation indices developed from multi-date satellite images, e.g. Landsat Operational Land Imager (OLI), may help to capitalize on this variation. In addition, topographic indices derived from digital elevation models (DEM) and soil and land use information extracted from historic surveys may aid in improving the accurate mapping of soil properties. However, it is unclear whether including such a broad range of environmental covariates improves the accuracy of analysis sufficiently to offset the increased effort required. To evaluate these potential trade-offs, we investigated the impacts of three categories of environmental covariates (i.e. Landsat based, topographic, and soil survey variables) on the accuracy of DSM models developed for mapping soil organic carbon (SOC) and clay (CL). We utilized two machine learning models, namely random forest (RF) and generalized boosted model (GBM), for the analysis of a 100 km2 agricultural area in Delta, British Columbia, Canada. Our covariates (n=80) comprised: (1) a suite of indices derived from four Landsat OLI images from May to August of 2016, (2) a suite of topographic indices generated using the Provincial 25-meter DEM, and (3) additional variables derived from existing land use and soil survey maps. We sampled soils from 55 fields across the study area representing various land use types, with 4-6 random points for each field. We used the data from these points (n=310) to train (70%) and test (30%) the models of SOC and CL. After training the models, we selected the most important covariates (n=37 for SOC, n=39 for CL) based on a threshold of variable importance (VI) scores. The prediction accuracy, in terms of coefficient of determination (R2), concordance correlation coefficient (CCC), normalized root mean square error (nRMSE), was determined from the recalibrated models with these top covariates. We found that topographic covariates and land use and soil survey covariates were similarly important for predicting both SOC and CL, with accuracy metrics improving by 18-32% for SOC and 12-26% for CL using RF. Alternatively, Landsat variables were comparatively less important but still contributed substantially with accuracy improvement of 10-15% for both SOC and CL predictions using RF. Similar results were achieved for GBM models with Landsat variables where the accuracy was improved by 5-10%. For all cases, RF outperformed GBM, achieving R2, CCC, and nRMSE values of 0.55, 0.62, and 0.12, respectively for SOC, and 0.62, 0.72, and 0.15, respectively for CL when including all three categories of covariates. Running the models with only the two most important covariates from each category, however, achieved almost the same accuracy. Based on these results, we conclude that identifying a few key environmental covariates based on the VI scores for a specific geographical area can produce highly accurate DSMs, and the additional improvement in accuracy achieved when using multi-date Landsat imagery may not justify the effort when DEM and historic soil survey data is available.

Exploring Relationships between Remotely Sensed Thermal Imagery, EM Data, Crop Yield, and Soil Texture

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Crop yield, thermal imagery, texture, heat stress

Abstract: Field scale soil mapping for commercial farms has tremendous value for developing management zones and streamlining precision agriculture operations. Different approaches to delineating management zones are developed by agronomists and farmers and these often reflect changes in soil types, textures and landscape forms. Satellite images, proximal sensors and yield data are critical inputs for the development of these management zones.

In this study, we use remotely sensed thermal imagery and proximally sensed EM data, combined with crop yield and ground-truthed field samples to assess the relationship between these products for determining soil texture and for predicting crop performance in a variety of fields. The outcomes for using these products for delineating management zones is discussed.

Identifying Microplastic in Soil Using NIR Spectrometer and Deep Learning

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Poster

Keywords: microplastic

Abstract: Microplastics, pieces of plastic less than 5 mm in size, in the environment have gained much attention the last few years. Microplastics in soil may be a far greater problem. Sewage sludge and plastic mulch are the two biggest known contributors of microplastics to agricultural soil.

Quantifying the amount of microplastic in soil is more difficult than in water. Current procedure involves density separation and examining the type and amount of plastic. As plastic has a distinct infrared reflectance characteristic, it is expected that NIR diffuse reflectance on soil maybe able to quantify the amount of microplastic. We mixed a known amount of plastics (polyacrilic and polyethylene) to different soil type and measure their reflectance. Plastic contamination in soil produced distinct spectral reflectance on several of the O-H bands. A convolutional neural network model is used to identify the amount of plastic contamination in soil. As microplastic is a point source pollutant, it is difficult to quantify the concentration in soil. We predict the amount of contamination into 4 classes: none, low (<1%), medium (1-5%), and high (>5%). The model was tested on real soil, and results showed that the deep learning model is able to distinguish non-contaminated soil accurately. However, at low and medium level of contamination, there is a small amount of classification. This model can potentially be used to screen microplastic contamination in soil.

Integrated Data Mining for National Scale Probabilistic Digital Mapping of Soil Thickness (Australian Case Study)

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: digital soil mapping; soil thickness; national soil infrastructure; censored data; data mining.

Abstract: Soil thickness as we have defined in Australia for nationwide digital soil mapping efforts, is the length of distance from the soil surface to para-lithic or lithic contact. The spatial prediction of soil thickness is fraught with numerous technical difficulties. The most significant of these is the issue of appropriately handling right-censored data. As has been previously discussed in soil science literature, contextually right censored data relates to the situation where the observed soil thickness at an observation site is does not correspond to the actual soil thickness. With current technologies and available equipment it is difficult and expensive to measure soil thickness in an efficient manner. From a soil surveying perspective we find in Australia most soil site observation do not go beyond 1.5m. Therefore, a significant part of our legacy soil information inadvertently mis-represents actual soil thickness across landscapes

Because of its importance for quantifying various soil functions including capacity to store carbon and water, the spatial prediction of soil thickness has received considerable attention in the past. Physical based approaches have included those described Minasny and McBratney (1999), McKenzie et al. (2003) and Pelletier and Rasmussen (2009). Empiro-statistical approaches include those from Odeh et al. (1991) and Moore et al. (1993), among others. Studies focused on dealing with the right-censored data issue are relatively scarce with useful and methodologically divergent contributions from Kempen et al. (2015) and Lacoste et al. (2016). There is also some anecdotal evidence to suggest that survival-based methods that are common in the medical research fields for dealing with censored data are potentially applicable in soil thickness mapping.

On balance of what potential approaches to pursue for national scale mapping of soil thickness, an empiro-statistical approach was determined to be the best option in Australia. Australia has a relatively large soil sites observation data base (Searle 2015) in addition to a National Groundwater Information System (NGIS) database or bore-hole observations that notionally provides useful information about depth to the lithic contact. With successive data mining processing routines of the observation data, we were able to collate over 150 000 sites to provisionally inform about soil depth across the country. Approximately half of these observations were considered to be right-censored. To develop a spatial model to accommodate right-censored data we adopted a re-sampling and data mining approach to generate plausible realities of soil thickness, based of empirical relationships between observed data and a large suite of environmental data. On average, independent validations of the plausible realities resulted in concordance estimates of 75%. Through aggregation of these plausible realities we are able to derive very useful statistical moments of the likely soil thickness, for example, empirical quantiles, and importantly, probability of soil thickness exceedance at prescribed thicknesses. Such an approach accommodates the quite significant amount of uncertainty we have in mapping this important soil attribute.

Our approach to mapping soil thickness across Australia represents a pragmatic attempt to leverage multiple data sources and mine them in an appropriate manner for the development of useful national extent soil information products for end-users.

Mapping Functional Soil Properties of the Mcmurdo Dry Valleys, Antarctica

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Antarctica; species distribution modelling; digital soil mapping

Abstract: Antarctica is the most arid continent in the world. A range of extreme environmental conditions combine to create a harsh, cold desert environment: extremely low and fluctuating temperatures, very little water in an accessible form, and high salinity. While most of the continent is covered in snow and ice year round, a small proportion of Antarctica (representing about 50,000 km2) is permanently ice-free.

Despite the extreme environmental conditions encountered in these ice-free areas, soils have developed there, and do harbour life. A range of organisms (viruses, bacteria, but also larger animals like nematodes or collembollas) are distributed throughout soils of the region. Long thought sterile, the application of new molecular techniques showed that these soils present a surprisingly high and unique biodiversity. The trophic simplicity of these ecosystems also provides scientists with an excellent opportunity to track climate change, as microorganisms living in these environments present a consistent and rapid response to increasing temperatures.

The McMurdo Dry Valleys system is the largest ice-free region in Antarctica, covering about 6900 km2. It is a designated Antarctic Specially Managed Area (ASMA), and home to the Onyx River, the largest and longest river in Antarctica. Soils in the McMurdo Dry Valleys are predominantly developed in glacial drift, colluvium, alluvium, or re-worked aeolian deposits.

While microbiologists face a wide range of questions concerning the biodiversity of the terrestrial systems in these valleys, a major hurdle is the sparse coverage of soil information. The spatial distribution of these microbiological communities has been shown to be strongly influenced by soil attributes such as water content, salinity, organic carbon, and pH. But while pedological maps have been published for various ice-free regions across the continent, the spatial distribution of those soil attributes themselves is largely unknown.

Antarctic research is very costly: considering the operational costs, it is important not only to make the most of the existing legacy data, but also to maximise the amount of data collected in the Dry Valleys each season. The use of digital soil mapping (DSM) has been tested to address this lack of soil attributes information: local soil observations can be combined with a range of spatial layers reflecting different factors of soil formation using a machine learning model, in order to predict the spatial distribution of soil attributes measured at those locations.

In this project, we are collating and harmonising data from different soil surveys in order to investigate the spatial distribution of pH, one of the soil properties that are critical for understanding the distribution of life in Antarctic soils. Since other parameters of interest are also measured, this opens an opportunity to extend this soil information system to other important soil properties for the region, such as electrical conductivity, or organic carbon content.

The application of those digital soil mapping techniques can (i) be a tool to understand and predict where microbial habitats occur, and (ii) has the potential to generate base layers for researchers outside the soil science community (in particular the fields of microbiology and climate change).

Mapping Soil Organic Carbon Content Using Crop Phenology Parameters Extracted from NDVI Time Series Data

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: soil organic carbon content, digital soil mapping, crop phenological parameters, NDVI time series, crop rotation

Abstract: Mapping the spatial distribution of soil organic carbon (SOC) content or stock is significantly important for climate change studies and land management decisions. When using environmental covariates to map SOC content or stock, variables indicating human activities have drawn more and more attentions except for using the natural environmental variables such as climate and topographic factors. Crop species/crop rotations and management practices significantly affect the amount and spatial variation of soil organic carbon in croplands. Crop phenology, a good indicator of crop growth characteristics, is shown possessing good relations with soil organic carbon dynamics. For areas which farming managements are uniform for one crop species/crop rotation, crop rotation with phenological parameters can be effective for indicating the impact of agricultural activities on soil organic carbon. In this study, we used direct crop rotation information and phenological parameters generated based on NDVI time series data in predicting topsoil organic carbon content in a largely agricultural area in Anhui province, China. There were four crop rotations all with two crops for one year in this study area. Twenty two HJ-1 A/B images for 2010 year with a 30 m resolution were obtained. Several crop phenological parameters were obtained with a dynamic threshold method on the NDVI time series data. Various combinations of predictive environmental variables were developed based on variable importance results and experimented for mapping topsoil organic carbon with random forest. The results were validated using a cross validation approach. Results showed that the combination of natural environment variables with both crop rotation type and two phenological parameters yielded the highest accuracy. Compared with using only natural environmental variables, the increase of mapping accuracies were 50% in terms of R2 and 13% in terms of RMSE. Base levels, given as the average of the left and right minimum values of a time series profile for one crop, for both crops in one crop rotation were the most important phenological parameters for predicint topsoil organic carbon content in this study area. This study demonstrates the effectiveness of including crop phenology and crop rotation information in digital soil mapping in agricultural landscapes with differences in crop rotation.

Minimum Detectable Difference: Using Composites or Using NIR Spectroscopy?

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: NIR spectroscopy, soil organic carbon, minimum detectable difference, composites, spiking

Abstract: The identification of those agricultural practices that have a positive effect on SOC contents is an important task. Often, the variation in SOC contents induced by management is small in comparison with the background variability, requiring a large sample size that may become unaffordable. In some cases, an adequate soil sampling design (e.g., monitoring using paired approach), and also an adequate sample support (e.g., composites) can substantially reduce the overall costs. If the change is cumulative, and such assessment is not urgent, we can wait until the induced differences are large enough to be detected with an affordable (small) sample size. Nevertheless, there are several cases where the assessment still implies large costs, because differences are small even after decades, or the assessment is needed in independent fields. In these cases, the use of cheap methods (such as NIR spectroscopy) seems to be the unique way to analyze the required large sample size at a reasonable cost. However, the quality of the data provided with cheap methods might be low, compromising the supposed benefit of deal with a large sample size at a reasonable cost. Some approaches, such as spiking, can improve the quality of the spectroscopic predictions, although it requires the analysis of a few samples (i.e., the spiking subset) using the reference method (Walkley-Black, WB). But it remains unclear if such investment is worth and allows to obtain any net advantage respect to statistical inferences made directly on a small affordable set analyzed with the reference method.

In this study, 144 soil samples were collected in two adjacent fields which differ in management (no-tillage vs conventional). In each field, 72 individual soil samples were collected at nodes of a randomly placed regular grid (75 m), and SOC content was analysed with WB. Then, samples were scanned in a FT-NIR spectrophotometer. After that, the individual samples (72 per field) were bulked into 6 composites, mimicking a composite sampling (n=6) across 12 strata defined by compact geographical stratification. Next, we computed the minimum detectable difference (MDD) when this parameter was computed with SOC data from: i) 72 individual samples, analyzed with WB; ii) 6 composite samples, analyzed with WB; iii) 72 individual samples, predicted with NIR (national model spiked with the composites); iv) 72 samples, predicted with NIR (national model spiked with samples selected by Kennard-Stone). In each case, the MDD was corrected by the error of the corresponding method used to measure SOC.

When errors were not considered (unrealistic), the MDD is not affected by bulking, because the decrease in variance was proportionally counterbalanced by the decrease in the sample size (from 72 to 6). This is interesting in terms of cost-efficiency. However, when errors from methods were considered, their negative effect (increasing the MDD) was higher when the sample size was small. As consequence, the MDD obtained with WB on 6 composites was even higher than the MDD obtained with NIR using 72 individual samples. Therefore, the WB analysis of the spiking subset represents an advantage in terms of cost-efficiency respect to the analysis of the same number of composites. Moreover, NIR offers an additional benefit over composites, since it maintains the possibility to create maps with the predictions.

New Field Research Paradigms in the Digital Agriculture Era

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: digital agriculture, field experimentation, experimental design

Abstract: Digital agriculture allows for high levels of individuation of farm resource management and targeting of unique production environments. Rapid scaling of technologies requires new scientific paradigms for on-farm experimentation and data analytics, as well as testing new technologies through field-scale experiments over broad geographies. Digital Agriculture Science can bring together diverse groups (agronomists, scientists and data experts) who use digital experiments and smart on-farm trials to develop and test new knowledge, technologies and methods that proactively build scientific validity of tools rather than reactively justifying or defending them. It promotes rapid scaling and employs the latest experimentation methodologies, data analytics, sensing and modeling capabilities.

Pedometric Techniques for Detailed Soil Class Mapping Using Topsoil Reflectance Data

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Poster

Keywords: Soil spectroscopy; Landsat; Soil patterns; Digital soil mapping; MESMA

Abstract: The traditional soil survey and mapping methods are expensive and time-consuming. The use of pedomorphogeological relationships allows to identify representative areas with similar pedometric attributes for soil sampling, used for digital soil mapping. McBratney et al. (2003) proposed scorpan model used for digital mapping of soil classes or continuous soil attributes. The s refers to soil information either from remote or proximal sensing or expert knowledge, and the n represents the geographic position of the soil. We use pedomorphogeological (pedometric attributes) relationships and spectral techniques for detailed soil class mapping using topsoil reflectance data from satellite and laboratory. The study area is located in the Rio Jardim watershed, Central Brazil, with a total area of 53,614 ha, where we defined six toposequences according to pedomorphogeological assessments. We collected 34 sites for laboratory analysis (texture and chemical) and VIS-NIR-SWIR (350-2500 nm) spectroscopy reflectance analysis of Ferralsols, Plinthosols, Regosols, and Cambisols. We used topsoil spectra (TS) to group similar soil samples for obtaining patterns by clustering method. We convolved topsoil patterns (mean spectral curve for each cluster) to Landsat 5 TM bands to obtain endmembers. Then, we used a time series of Landsat 5 TM (30 m spatial resolution) to produce a bare soil composite denominated Synthetic Soil Image (SYSI). We modeled endmembers and SYSI by the Multiple Endmember Spectral Mixture Analysis (MESMA) method to map the soil classes. Soil sampling in toposequences based on pedometric relationships provided reliable information for mapping the different soil classes. This method increases efficiencies by increasing the capture of soil variability. TS clustered soil samples that were similar in texture, mineralogy and color, and identified 13 endmembers. SYSI achieved 74% of bare soil area coverage and presented very similar spectra to endmembers. The RGB 543 composite highlighted the differences between soils which was related to the main mineral constituents (i.e. sesquioxides, kaolinite and quartz), texture and color. MESMA modeled almost 100% of SYSI from endmembers, with low global RMSE of 0.86% and high global fraction of 62%. We mapped soil classes using TS patterns and satellite images by MESMA method. We validate the digital soil map by using independent field-visited sites, which reached a Kappa coefficient of 0.73. We mapped soil classes using topsoil reflectance patterns and satellite images by MESMA method. The topsoil patterns were representative regarding the soil classes variability due to the pedomorphogeological relationships initially verified in the study area. The SYSI was representative to the soil surface patterns, providing an almost spatially-continuous surface of the soil landscape. The non-detection of the subsurface reflectance by remote sensing was not impeditive in the pedological classification. The soil surface patterns are related to the subsurface variations and dynamic process which occurs within the soil profile.

Progress on Application of Soil Infrared Spectroscopy in Agricultural and Environmental Management in Developing Countries and Remaining Challenges

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: soil properties, machine learning, cloud-based software, societal benefits

Abstract: It is now 12 years since I published a vision for infrared spectroscopy (IR) as enabling an evidence-based diagnostic surveillance approach to agricultural and environmental management in developing countries (JNIRS 15, 1?19, 2007). How far has this vision been realized and what are the main remaining challenges?

I considered that Africa could benefit most from IR technology. Under the Africa Soil Information Service (AfSIS) we established 30 soil spectroscopy laboratories across 16 countries and helped four countries establish national soil information systems based on spectral technology. National information systems are helping to target soil fertility restoration and fertilizer recommendations in croplands. Private soil testing initiatives are now operating mobile laboratories and handheld near infrared devices in rural areas to bring soil testing services to farmers. Spectral technology is also now being taken up for quality assessment of fertilisers, organic manures and feeds. AfSIS established a statistically valid baseline sample for Sub-Saharan Africa and statistical sampling frames for soil surveys and coupled agronomic trials are in use.

Machine learning methods and work flows for spectral calibration of soil properties have steadily advanced, providing sample level uncertainty estimates in predictions, either using Bayesian or bootstrap methods. A Kaggle competition on AfSIS data showed the power of ensemble modelling. A first digital map of soil properties of Africa was produced, which is widely used to guide interventions. Data fusion of infrared spectroscopy with x-ray fluorescence technology has been demonstrated. There are examples of soil surveys and agronomic trials using statistical sampling schemes.

A new not-for-profit company, Innovative Solutions for Decision Agriculture (iSDA), has been created to help scale soil MIR spectroscopy in Africa. New types of business models are being explored with commercial soil testing companies, fertilizer companies, food companies, and agro-dealer networks to support efficiency in the deployment of IR technology and propagate benefits across the agricultural value chain.

Several challenges remain to get transformative scaling of spectral technology for development impacts. Easy to use cloud-based software for spectral quality control, management, calibration and prediction will ease uptake. Smart prediction models are needed to transfer spectral calibrations across instruments based on minimal standards. Global spectral libraries would generate large efficiencies, but the standardization and quality control of reference methods remains a key challenge. Advisory services for smallholders will be enabled by the commercialization of very low-cost spectrometers ($100). More needs to be done to relate responses in soil functions or crop performance directly to spectral measurements, maintain links to the original data, and present the uncertainty in recommendations.

Quantitative Soil Quality Indices for Benchmark Soils in Taiwan

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Poster

Keywords: soil quality index, benchmark soil, standard scoring function

Abstract: Soil security and planet health are the emerging issues of global concern. Sustainable management of soil resource is inevitable approach for food safety, human health, environmental quality, and ecological conservation. To elevate the efficiency and empower the resource management ability, it is necessary to develop the assessment system as a pedometric tool by clarifying and defining the soil quality. Taiwan is of highly population density as well as complexity of the land use with agricultural and industrial area activities. Hence, the agricultural lands had been contaminated from industrial sources. Taiwan Environmental Protection Administration (EPA) has conducted a big-scale investigation to collect soil database by grouping benchmark soil series as various soil management groups. Soil morphological characteristics of these soil series were recorded and the corresponding soil horizon samples were performed with selected physical, chemical, and biological properties.

This study focused on the soil function upon contaminant retention and aimed to develop the assessment system and soil quality index for each benchmark soil series in Taiwan. Expert opinions method is utilized to define the soil function and followed by discriminated the soil properties. According to the specific soil function, this study collected the crucial soil attributes and assembly into minimum data set. Standard scoring function is exploited to transform the measurement of soil characteristics between 0-1 with interpolation approach. Standard scoring functions (SSF) utilized in this study including three types, and they were: 1. SSF3, the more the better, 2. SSF5, the optimum the better, and 3. SSF 9, the lower the better. In order to generate a universal assessment system for all benchmark soils, which also took into account of the vertical factor of soil depth, by considering the depth of each soil horizon as well as whole pedon. Combining the soil depth into the transformation of soil attributes, the assessment system offered a manner to make the soil quality index comparable.

The study developed soil quality index for some target issues, definition of soil function such as the mobility of cationic heavy metal in affected soil?, and ?the mobility of anionic heavy metal in affected soil?. Data of 85 benchmark soil series were exploited and evaluated to establish the assessment system and the standard scoring function. Soil quality index for each benchmark soils series were calculated, the outcome value could discriminate the vulnerability or retardation of different soil series. For example, the Tachuwei (Tw) series obtained higher soil quality index for the mobility of cationic heavy metal in affected soil. The result inferred that Tw series showing the benefit for protecting rice from contaminant polluted on the soil. Based on the location of the investigated benchmark soil series, along with the results of soil quality index, the study generated the preliminary achievement of the soil quality and soil function in some of the provinces in Taiwan. This study provided the insight for soil resource management and the roadmap of pollution prevention for Taiwan EPA.

Soil Information Integration for Agroecological Intensification Policy Development in Indonesia

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Poster

Keywords: soil carbon; Bayesian structural time-series analysis; food security

Abstract: Global climate change, land use change, and population growth impose challenges to maintain food security in the future. Still it is rare that quantitative soil carbon assessments are explicitly incorporated into agricultural policy development considering soil and food security projected into the future. We developed a prototype of agroecological intensification policy model utilizing Bayesian Structural Time-Series analysis to project the annual level of paddy-rice cropping frequency in Indonesia in 2050. This model also integrated historical, predicted, and current soil organic carbon data (1961 - 2016) to represent land degradation, together with the time-series atmospheric carbon concentration (climate uncertainty) and paddy-rice production and consumption data. These model parameters were used to develop agroecological intensification policy scenarios to achieve the goal of maintaining the current level of Indonesia paddy-rice self-sufficiency for the next three decades. The results of the analysis showed that the current level of paddy-rice self-sufficiency in Indonesia could only be maintained for the next three decades by the implementation of agricultural soil carbon improvement programs in conjunction with the implementation of the Intergovernmental Panel on Climate Change B1 emission scenario policy option. The output of this model simulation option also showed that the implementation of these policy scenarios will be able to limit the paddy-rice annual cropping frequency to the level of maximum 2 times per year to fulfill the increasing demand of rice following the growing population in Indonesia for the next three decades. This level of paddy-rice annual cropping frequency allows the application of agroecological cropping practices to maintain high-level of agricultural-soil productivity, under the pressures of increasing population, land use change, soil degradation, and climate uncertainty in Indonesia. Therefore, this research suggests the prioritization and incorporation of soil quality improvement programs in the land-resources management policy to maintain national food security in Indonesia and other regions.

Supporting Enhanced Forest Resource Inventories Using Machine Learning for High-Resolution Digital Soil Mapping

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Session 4: Applications of Pedometrics 1: Emerging needs and demands

Presentation Type: Oral

Keywords: Digital soil mapping, Machine learning, Remote sensing, LiDAR, Forestry

Abstract: Soil is essential to forested ecosystems as it provides a medium for plant growth and is a critical component for the cycling of water, nutrients, and carbon. To effectively manage the productivity of forests and support future land-use decisions at the site level, high-resolution and accurate spatial soil data is required. Acquiring soil data through field observation is costly when scaled up to the landscape scale, so it is necessary to rely on other methods to predict soil attributes across large spatial extents. Machine learning is becoming a popular tool to understand and predict the complex, non-linear relationships between environmental variables and soil attributes and how these attributes vary across large spatial extents. Using the Hearst forest in Northern Ontario as a study system, we show how machine learning models can use LiDAR remote sensed data (10 metre resolution) and field observations to predict plot level soil attributes. We use a k-fold cross validation procedure to test the accuracy of random forest, support vector machine, and k-nearest neighbor machine learning models. From these models, we develop predictive maps of soil moisture regime, soil textural classes, and soil mottling. We demonstrate the influence of variable selection and reduction, spatial resolution, and machine learning algorithms for predicting the soil attributes of interest. Although our results are still preliminary, they are very promising. Future work will assess the transferability of these high-resolution digital soil mapping techniques on other management forests in Ontario.

Session 5

Characterizing Soil Hydromorphism in Riparian Zones by Magnetic Susceptibility

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Poster

Keywords: Iron oxides, magnetic susceptibility, bartington system, hydromorphism

Abstract: Soil hydromorphism reflects redox conditions, which is important for determine the drainage condition, land suitability for agriculture and greenhouse gas emission. In Ontario, soil drainage classes are based on hydromorphic features, specific to the presence and nature of gleying and mottling. The objectives of this research are to characterize the nature and dynamics of soil magnetic susceptibility in relation to soil hydromorphism. The study is being conducted within the Washington Creek long term Research area, located in Oxford Country, Southern Ontario. Four different management systems are included: i) a rehabilitated forest buffer zone, ii) a natural forest buffer zone, iii) a grassland buffer zone iv) as well as a reference agricultural field. The initial phase of the study is to determine the relationship of soil magnetic susceptibility to the nature of pedogenic iron oxides in the profile. Magnetic susceptibility is determined by Bartington MS2B meter equipped with the MS2B dual frequency sensor also considered frequency dependence. Pedogenic iron oxides are characterized by citrate- dithionite and acid ammonium oxalate extraction method. Results reveal that natural forest buffer zone had highest amount of total pedogenic (303.3 mgkg-1) and poorly crystalline iron oxides (275.82mgkg-1). Higher degree of crystallinity was observed at the natural forest buffer zone (0.92). Rehabilitated forest buffer zone had highest value of mass specific magnetic susceptibility (32.7 x 10-8m3kg-1), grass land buffer zone had highest frequency dependence (2.05%). Study concludes, results will serve as reference for subsequent characterization of dynamics of soil magnetic susceptibility.

Coupling Proximal Soil Sensing (VNIR) and a Process-Based Model to Understand SOC Dynamics

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: process-based model, visible and near-infrared spectroscopy, soil organic carbon, RothC, Andes

Abstract: The Rothamsted Carbon (RothC) model with its multiple soil carbon pools has been widely used to estimate soil organic carbon (SOC) changes in response to environmental conditions and land use change. However, to predict temporal variations in SOC, process-based models need local/ region-specific observation data to be incorporated into the model. This poses a limitation if the region of interest is under-sampled or long-time experiments are not carried out in the area.

Visible and near-infrared spectroscopy (VNIR) has been broadly used for rapid prediction of different soil properties and found to be cost-effective and less time consuming when compared to traditional laboratory-based soil analysis. In spite of its potential advantages, the coupling of VNIR spectra to a process-based model has not been fully explored. The objective of this study was to link VNIR spectra to soil carbon pools in the RothC model. The dynamic of these pools is largely driven by the soil moisture content in soils and RothC uses a soil moisture factor (b) to calculate it. We investigated the use of VNIR spectra to model b and calculate the carbon pools using this predicted value.

We used VNIR spectra and soil properties (clay content and SOC) of 400 topsoil samples collected across the Peruvian Central Andes. These samples were identified using a conditioned Latin Hypercube design and comprised a wide range of ecosystems with marked soil, topographic and climatic differences, and diverse land use. The simulations were implemented using temporal climate data for the period 1970-2013 and plant-residue carbon input data estimated from remote-sensing derived land use information. This data was used to initialize the model by spinning up the carbon pools and reach steady-state. After equilibrium was obtained, the model was run in predictive mode from 2013 to 2050 and the resultant conceptual pools were analyzed. We assessed the simulation performance by comparing the resultant soil carbon pools in the RothC using the default soil moisture factor (CPdef) and the pools obtained by using the VNIR spectra as a moisture factor proxy/predictor (CPVNIR).

The prediction fit (R2) of the CPVNIR varied in the range 0.85-0.93 with higher values associated to the predictions of RPM (resistant plant material) and HUM (humified organic matter) pools and moderate values for DPM (decomposable plant material), BIO (microbial biomass) and IOM (inorganic matter) pools. We present the results from our study and discuss the implications of using VNIR for modeling soil carbon conceptual pools and SOC change in process-based models.

Digital Soil Mapping Using Remote Sensing Derived Products and Machine Learning Algorithm: The Case of the Upper Awash Sub Basin, Ethiopia

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Digital Soil Mapping (DSM), Landsat Image, Random Forest Model, Upper Awash Sub Basin, Ethiopia

Abstract: The use of Remote Sensing data as source of covariates in digital soil mapping (DSM) has been found to be cost effective and less time consuming. But the potentials of high resolution Remote Sensing data in improving knowledge of spatial soil information in Upper Awash sub basin, Ethiopia, have not been studied. This study investigated the use of relatively high spatial resolution satellite data (Landsat 8), Shuttle Radar Topography Mission (SRTM) - Digital Elevation Model (DEM) derived terrain data, field and laboratory analyzed soil samples for DSM.A statistical prediction model i.e. random forest regression (RFR) was tested. Surface soil layers were generated at 30 meter spatial resolution at 0-15cm depth for soil pH, % of clay, % of sand, and % of silt over a 1,069.10 km2area of the upper Awash sub-basin of Ethiopia. Depth to bedrock was also predicted over the sub-basin. Internal 5 fold-cross validation was conducted to validate the predictions accuracy in the modeling area. Prediction accuracies of the RFR model ranged from 85% for soil depth to 91% for soil pH. These prediction accuracies are reasonable, considering the high soil variability in the sub-basin and the target high spatial soil grid (30 meter) resolution. DEM derived indices of relief including Multi Resolution Index of Valley Bottom Flatness (MRVBF) and Multi Resolution Ridge-Flatness (MRRF); Landsat 8 (long-term mean image of February) spectral channels(NIR, SWIR 1, and SWIR 2);and mean annual rainfall representing climate were found to be the most important predictors of the soil properties considered in this study. While Landsat 8 based indices: saturation index (SI) indicating spectral slope and coloration index (CI) representing the soil color were the prominent variables in predicting soil properties. Comparison of prediction accuracy of the global 250 meter resolution soil grids with the present local 30meter soilgrids revealed the gained relative improvement of 6.7% to 47.2% and 42% to 68% in terms of amount of variation explained by the model and RMSE, respectively. Considering the increased availability of freely available Remote Sensing data (Landsat 8 and SRTM), the findings of the study confirmed that soil information at local scales in data scares areas can be improved with relatively little cost. Furthermore, the produced maps of soil properties describing lateral variability are important for further modeling and management of soil ecosystem services.

Digital Tropical Peatland Mapping

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Tropical Peatland, digital mapping, remote sensing, GIS

Abstract: Digital peatland mapping approach is developed to overcome problems, not only that comes from analyzing immense spatial soil data but also conversely that raises from limited data, especially when conducting mapping in vast tropical pristine peatland area. However, peatland has specific characteristic that required integrated multi-temporal physiography and bio-physical data when mapping them, added to its development factors such as its underlain soil, climate, topography, age and space. The objectives of this study is to develop digital peatland mapping conceptual and technical frameworks by involving all peat development variables/factors, specifically the analysis that are supported by remote sensing and GIS, and to preliminary determine the appropriate mapping model and its accuracy assessment method to map peat and non-peatland based on legacy soil data in various level of detail, scales, geographic location and type of remote sensing data.

This study utilizes multi-temporal remote sensing data processing to achieve the indexes of wetness, vegetation and topographic elements from peat and non-peat mapping unit from optical and non-optical satellite sensors imageries. These indexes and elements together with the considerably complete legacy data of peatland on parts of Sumatera and Kalimantan were spatially analyzed and validated using several machine learning models. Similar process applied on limited peatland data of Papua, but in the same time the best model from earlier complete data analysis is used as guidance and comparison. The combination of criteria from satellite spectral data transformation and legacy data resulted from the constructed predictive model indicate that the pristine peatland model must be treated differently to disturbed peatlands based on the causes of its changes in Sumatera and Kalimantan. This model is now applied in Papua and is in continuing process. The result of this study will provide accurate digital tropical peatland mapping, for the decision makers, stakeholder and farmers to be able to determine the area/peatland to suit their legal (and appropriate) function to achieve natural balance in providing sustainable planning for environmental protection, food security, agriculture product and social and economic needs.

Field-Scale Application of Sequential Gaussian Simulation to Delineate Copper Micronutrient Critical Thresholds in Dry Rangeland Soils

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Botswana; semi-arid soil; probability mapping; nutrient management; GIS

Abstract: Geostatistics presents to soil science useful tools for the representation of spatial patterns of soil variables. One of such applications is the mapping of spatial pattern in micronutrient concentration for both nutrient and environmental management purposes. In this study, we present an application of Sequential Gaussian Simulation (SGS) to map the distribution of Cu concentration in Maibele Airstrip North (628200 and 631100 Easting; 759120 and 759680 Northing), which is located in the central part of Botswana. The SGS approach shows superiority over kriging in that kriging generally overestimated where lower values are probable and underestimated where higher values are probable. Two extremes have been captured by the choice of an exponential variogram: Cu values lower than 60 mg kg/1 indicating potential Cu deficiency and Cu values in excess of 125 mg kg?1 indicating potential toxicity within the plant rhizosphere. Generally, cupper toxicity should be a concern but this results should be reconciled with studied on plant available Cu. The result obtained in this study provides a decision support module for both nutrient and environmental management.

Impact of Climate Change on Zonal Soils

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Poster

Keywords: soil distribution, climate, global

Abstract: Climate is one of the major soil forming factors affecting soil presence on a global scale, yet described quantitative relationships between soil and climate are scarce. This limits our ability to predict how soil distribution could change under future climate scenarios. The goal of this work was to statistically analyze the link between the global distribution of individual soils reported in the ISRIC (International Soil Reference and Information Centre) WISE soil property database and global climate (WorldClim). We implemented a 2 step approach to model presence/absence and occurrence of soil type using a combination of extreme gradient boosting and rule and instance based regression modelling (cubist). We demonstrated that about 30 soils are strongly linked with climate (soils with permafrost, various acrisols, ferralsols, podzols, etc.). For theses soils we also determined potential future changes in distribution under two contrasting climate scenarios using the WorldClim future climate projection data for 2070. By analyzing changes in the surface area of each climate-linked (zonal) soil, the importance of climate variables in the statistical models, and potential alternative soils for an area, we were able to draw broad conclusions regarding what soil properties could be most affected by climate change.

Is Anyone Using the Results of Pedometrics Applications? In Australia the Answer is Yes.

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: pedometrics applications information use

Abstract: At the 2017 Pedometrics Conference in Wageningen, Alex McBratney (2018) posed the question, "Are results of pedometrics applications really used by land users?" He questioned if pedometrics is still supply driven and are we as pedometricians doing enough to make soils information available in forms suitable for land managers? In Australia the pedometrics community is increasingly active and is making relevant soils information readily available. Here we present a range of examples of how pedometrics outputs are being used for real world land management decisions.

McBratney postulated that the general and global decline in funding support for soil mapping and capability assessments over the last few decades is due to the inward facing nature of soil science. It is arguable that, in Australia, this was once the situation. With soil mapping and capability assessment work, there was traditionally a strong focus on producing a hardcopy map and a voluminous technical report. This information was often difficult for the general public to find, interpret and use for decision making, and its use depended on an active and interested extension service.

In Australia, the way we produce and deliver spatial soils information has evolved significantly. Digital Soil Mapping (DSM) is now routinely used in broad scale soil and land capability assessments. Studies using pedometrics methods, such as the Northern Australia Water Resource Assessment, are delivering critical soils information to land use planners and private investors, in timescales and across spatial extents not previously possible.

The development of the Soil and Landscape Grid of Australia (SLGA) in 2014 (Grundy et. al., 2015) has also significantly changed the way people access and use soils information. The consistent nature of these pedometrics products has enabled easy access to detailed soils information via a range of web service architectures. Government and commercial providers are developing tailor made products and Apps that access these soil data web services to provide relevant information and answer questions specific to particular end user groups. Some examples of these include;

"SoilWaterApp" A grains industry sponsored App which tracks seasonal soil water use in cropping paddocks (Freebairn, et. al., 2018).

"rCambium" A private industry developed commercial forestry production model (Drew, et. al., 2010).

"Yield Prophet" A grain production decision support system providing detailed seasonal analysis and yield forecasts to farmers (Hunt, et. al., 2008).

These Apps and others like them are focused on delivering answers to particular questions, not soils information. In some cases the end user may not even realise the crucial role that soils information plays. We contend that this does not diminish the demand for soils data, but instead enhances it by increasing reliance on this information for real world decision making.

Modeling of Soil Temperature Based on Soil and Environmental Characteristics in Cold Season

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Poster

Keywords: Modeling, Soil and environmental characteristics, Soil temperature, stepwise regression.

Abstract: Soil temperature is very important in various applications such as transport of matter and energy, evapotranspiration, decomposition of soil organic matter, soil conditioning, seed germination, plant growth, soil microorganism activity, nutrient transport, exchange of carbon dioxide and nitrogen, frost depth and agriculture. The purpose of this study modeling of soil temperature based on soil and environmental characteristics in cold season. For this purpose, temperatures data recorded with thermal data loggers at depths of 5 and 10 cm, soil characteristics including the texture, moisture content, bulk density, and color and organic matter and environmental parameters such as air temperature, sunshine or shadow conditions, days per year and hours per day were used. In this study, for modeling of the soil temperature based on various soil and environmental parameters a stepwise regression was used. Finally, for accuracy assessment of the results the correlation coefficient (R2) and relative error (MAPE) were used. The results indicated the air temperature, day, time, relative humidity, depth, bulk density, and sun's state had the greatest impact on the soil temperature. The difference between the soil temperatures with various colors was not statistically significant. The increasing soil moisture causing the soil temperature decreased. With increasing depth and bulk density, soil temperature was increased. The R2 and MAPE between observed and modeled soil temperature by stepwise regression was 0.79 and 29, respectively. The results of this study indicated the stepwise regression is suitable model to modeling of soil temperature based on soil and environmental characteristics.

Monitoring Soil Moisture Using Observations from Multiple Spatial Supports

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Remote sensing, Soil moisture, Machine learning, Dryland cropping, SENTINEL

Abstract: Soil moisture monitoring provides necessary and important information for many end users from farmers to hydrologists and policy makers. Whilst there are a variety of available technologies currently existing for the monitoring of soil moisture, many observe soil moisture at a variety of spatial supports. Two extreme examples are soil moisture probes which measure a small volume of soil, and satellite remotely sensed data, which provides information of significantly larger horizontal resolution, upwards of 20km in some instances. Neither is useful by itself for many management purposes, and may misrepresent the impact of the properties of the soil on the soil moisture status. By integrating these technologies with water balance models based upon the information available in digital soil maps, these technologies could hold more value for end users.

Therefore, we present a method for combining soil moisture observations collected at different spatial supports into a predictive model that can predict at spatial supports useful for many end users, at different layers in the entire soil profile.

We use a case study in the Muttama Creek catchment, a 1025 km2 subcatchment of the Murrumbidgee River in south eastern Australia, for the purposes of constructing a model based on the Random Forest machine learning framework. The soil moisture data includes a network of capacitance probes distributed throughout the catchment, remotely sensed estimates of soil moisture from the SMAP and SENTINEL1 platforms and water balance model predictions. We validate the results at the farm extent with three independent surveys, using stratified random sampling, of soil moisture at three time points during the winter growing season (pre-, mid- and post-season).

Parameter Optimisation of a Multi-Level Unsaturated Water Balance Model

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation: Oral

Keywords: soil moisture, water balance model, parameters, machine learning, mapping

Abstract: Change in aspects of the Hydrological cycle can cause many environmental problems. The hydrological cycle can be described quantitatively from the water balance, and a better understanding of it gives a valuable insight into these problems leading to better management and solutions. The scientific and technological developments in geospatial data have given us an opportunity to parameterise the components of the soil water balance equation in space and time;

The water cycle can be described quantitatively with the following water balance equation

soil moisture = precipitation * evapotranspiration * deep drainage * runoff.

These water balance components with the combination of soil layers can provide an informative overview of its components, their relationships and processes. Multi-layer models account for vertical variation in soil water holding capacity, and therefore, better represent soil moisture variation within a profile. In this work, we improved the performance of an unsaturated multi-layer water balance model by parameter optimisation and using machine learning techniques. The five layers are in the model are 0-5, 5-15, 15-30, 30-60 and 60-100 cm, which coincide with the layers of the Soil Landscape Grid of Australia which is available at ~90 m spatial resolution. Pedotransfer functions are used to predict water retention properties for each soil layer. Precipitation and evapotranspiration are estimated by gridded BOM precipitation data (5 km, one day) and the MODIS 16 ET product (500 m, eight days), respectively.

The optimised parameters were precipitation infiltration into the soil, percolation through layers and the proportion of evapotranspiration for each layer. A Random Forest model was fitted to a suite of covariates that vary in space, e.g., slope, aspect, soil order with the process-based model to improve it further. For the evaluation of the model predictions, the calibrated soil moisture network of Kyeamba from the OzNet Hydrological monitoring network was considered. Leave-one-out-site cross-validation (LOOSCV) was performed to assess the quality of the predictive model at three depth interval, i.e. topsoil (0-30 cm), subsoil (30-100 cm) and root-zone (0-1 m). Across all sites the prediction quality was reasonable: topsoil (Concordance = 0.69, Accuracy = 0.05 cm3 cm-3); subsoil (Concordance = 0.72, Accuracy = 0.04 cm3 cm-3); and root-zone (Concordance = 0.75, Accuracy = 0.05 cm3 cm-3). These results highlight the potential of this approach, and since it is based on readily available data, it is scalable to large spatial domains. Soil moisture estimates can be used effectively for soil moisture mapping at spatial scales suitable for productive farming. The 90 m resolution soil moisture maps were created at three depth intervals to demonstrate the potential of the modelling approach.

Predictive Modelling and Digital Soil Mapping of Microbial Community Diversity and Soil Organic Matter Properties in Atlantic Canada.

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Poster

Keywords: soil health, predictive modelling, microbial diversity, soil organic matter properties

Abstract: Pedometrics, a branch of soil science that aims to develop digital soil maps (DSMs) and provide knowledge of soil variability over space using statistical techniques, has been an emerging field of research globally. Pedometrics leverages advances in computing technology, remote-sensing technology, geographical information systems (GIS), machine-learning techniques, and geospatial datasets, which are increasing in availability. The authors propose to evaluate the diversity and the abundance of soil microbial communities and their relationships with soil health, land-use and management practices on a biogeographical scale in the Atlantic region of Canada by producing predictive models and digital maps through the use of pedometrics in conjunction with data collected through a network of sampling points across the four Atlantic provinces. The network consists of approximately 500 sampling points conducted in primarily agricultural areas in the four Atlantic Provinces. The sampling points are selected by the conditioned Latin hypercube method (LSH) which is a stratified random procedure that provides an efficient way of sampling variables from their multivariate distributions. The LSH randomly selects the sampling points while ensuring representativeness of landscape positions, pedo-climatic zones and land use (e.g., annual crops, perennial agricultural, wetlands, forested areas) in each province. Each sampling point is geo-positioned with a precision of <0.5m and consists of a 2 m2 square. Environment, climatic factors, vegetation and land use are recorded on site to corroborate satellite data, aerial pictures and legacy maps. Soil samples from the sampling locations are used to analyze soil microbial diversity and function, mycorrhizal fungi diversity and soil physical and chemical properties. To establish the relationships between the soil and the environment, soil observations with known properties are spatially intersected with a suite of environmental variables representing relief, vegetation, and climate derived from a combination of digital elevation data, LiDAR and satellite imagery, and climate model data. The training data is then submitted to a predictive model where machine-learning techniques (e.g., Random Forest, support vector machines, artificial neural networks), geostatistical techniques (kriging), and hybrid modelling techniques (regression-kriging) are compared and used to predict soil attributes for unsampled locations. The resulting DSMs are then be validated using a cross-validation procedure and uncertainty rasters are produced for each soil attribute. DSMs are produced at a wide range of spatial resolutions (25 - 250 m) in order to assess the effects of scale and soil attributes within the context of predictive modelling. Target soil attributes include soil bacterial and fungal diversity as well as SOM properties. The resulting predictive models will be used to generate spatially-explicit maps which will be instrumental for landscape- to regional-scale management of agricultural soil resources where effective soil management practices may be informed on a pixel-by-pixel basis.

Process-Based Predictive Soil Mapping in the Virgin Forest-Steppe of Russia

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Presentation Type: Oral

Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Keywords: digital mapping, Chernozem, Phaeozem, SIMWE

Abstract: Predictive soil mapping is focusing on finding quantity relations in the soil cover of the territory, both between individual properties of soil and between the soil and other components of the landscape. Soil-landscape mapping can be based both on the establishment of quantitative patterns in factor models, for example, SCORPAN, and in models linking the soil-forming factors: soil forming processes and soils (soil properties).

The key areas are studding by a regular grid, for each element of which the values of potential soil forming factors, are known. In the regional specific is the predominance of water runoff in soil properties formation. The intensity of runoff is calculating for each grid element in accordance with the existing imitational models for the surface runoff calculation. Then defining the boundary values of the parameters of the functioning (runoff) at which there is a qualitative change of soil taxon and biogeochemical parameters. The process-based mapping is focusing on finding runoff - soils relations.

The local soil-landscape relationships modelling was completed on the sub-horizontal part of the interfluve in the southwestern part of the Central Russian upland of the East European Plain within the virgin steppe of Central Chernozem Reserve. Key plot area is about 35 ha. Its topography was studied in detail by GNSS surveys. The Digital Elevation Model (DEM) with resolution 2.5m was created. It was used for creation terrain attribute space for factor-based soil-landscape modelling.

The surface runoff values were modelled by SIMWE in the GRASS GIS. The model input parameters are the slope steepness, horizontal and vertical curvature, the amount of excess precipitation, infiltration rate, water diffusion coefficient, surface roughness coefficient.

The soil survey points are arranged for description of all the diversity of soils. Totally, 157 boreholes with a depth of 1 to 6 meters were completed. The pedodiversity in key plot is presented by 5 different soils.

The statistical comparison of modelled runoff value and the observed soil taxon: Calcic and Haplic Chernozems (zonal rate of atmospheric moistening of automorphic microrelief positions) - Chernic Phaeozem (depressions with additional atmospheric-leaky humidification of 8-50 mm) - Greyzemic Chernic Phaeozem (bottoms of troughs with a catchment of less than 1 ha with additional atmospheric-leaky humidification of more than 50-120 mm and long with seasonal overmoistening up to 1 month) - Stagnic Chernic Phaeozem (closed drainage basins and bottoms of troughs with a catchment of more than 1 hectare with additional atmospheric leaky humidification more than 120 mm and duration of over-moistening more than 1 month). The accuracy of this approach is 79%.

The discriminant analysis of soil-topography relation had shown, that spatial distribution of soils can be modelled only by 2 morphometry values: topographic wetness index and topographic position index with accuracy 81%. The modelled soil cover is similar with the one that was described before.

Thus, two approaches to the analysis and mapping of the soil cover spatial structure were tested: soil forming factor - soil and a soil forming factor - soil process - soil. In the virgin steppe conditions, both approaches showed a high quality of the description of the observed variation.

Revealing Air, Water and Soil Volumes in 2D Transects with Soil Cores and Penetrometer Readings

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: soil bulk density, cone penetration resistance, compositional data analysis, universal kriging, anisotropy

Abstract: Deep soil compaction hampers crop productivity in many regions of Québec province, Canada. Subsoiling and tillage practices used to alleviate deep soil compaction need to be properly assessed in different types of soils before recommending these practices at large. Soil bulk density and water content measured at depth intervals within undisrupted soil cores can reveal air, water and soil matrix volumes in a soil profile. But to evaluate subsoiling effects on soil, these measurements can be labour intensive and costly over long transects at small spacing intervals. Soil resistance to cone penetration measured at a higher resolution could be used as a proxy since correlation with bulk density is usually a function of soil water content. A method using compositional data analyses and universal kriging is presented to produce high resolution 2D transects of air, water and soil volumes produced under different tillage practices. A Giddings hydraulic soil sampler mounted on a tractor was used to sample soil cores from soils with texture classes ranging from silt loam to heavy clay. Air, water and soil volumes were measured within soil cores sampled at 60 to 80 cm depth and sectioned at 7.5 or 10 cm depth increments. These soil cores were sampled at 1 to 2 m increments on 10 to 15 m horizontal transects. Soil resistance was measured on the same transects with a Veris Profiler 3100 cone penetrometer on 1-m deep profiles, at 2 cm depth increments and 20 or 25 cm horizontal distance, giving sampling intensities 3 to 10 times greater than for soil cores. Compositional data analysis was used to create two isometric log ratios (ilr) representing the three matrix volumes of soil, water and air. Variography on the three soil volumes, ilrs, and penetrometer readings revealed strong spatial structures and more importantly a high anisotropic component. Coefficients of determination (R2) between ilrs (simplexes of air, water and soil volumes) and penetrometer readings varied from 0,2 to 0,5. Different geostatiscal methods using Ordinary kriging with anisotropy or Universal kriging were used to interpolate and calculate the different volumes of air, water and soil in soil transects under different subsoiling treatments and compare the results under control plots.

Simulating the Effects of Management Patterns and Future Climate Change on Ecological Footprints in Crop Production Using the DAYCENT Ecosystem Model

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: DAYCENT; Ecological footprint; Cropland; Climate change; Sustainable agriculture

Abstract: Ensuring food security and combating severe climate change are both big challenges faced by agriculture over the world, especially for the developing countries. Both climate change and agricultural activities may significantly affect the eco-environment through soil carbon, nitrogen and water cycles. Given these, how to achieve sustainable crop production through minimizing the risk of eco-environment while producing food is an important challenge in agriculture of China under future climate change. Carbon, nitrogen and water footprints are important indicators for quantifying the impact of human activities on the eco-environment in recent years. This study developed the carbon, nitrogen, and water footprint methodologies based on the combined statistics and model simulation to evaluate crop production sustainability, and further developed an integrated footprint quantification approach based on environmental risk assessment methods. Based on model evaluation and the developed methodologies, we quantified the carbon, nitrogen and water footprints of current crop production systems using the data from 10 field test sites representing the nine agricultural regions of China, and the relative contributions in the footprints was also quantified. The results indicated that there was a large spatial variation in the carbon, nitrogen and water footprints in China, and there was also a trade-off between the three footprints. In general, the integrated footprint of rice-based systems is slightly higher than that of dry farming systems, and the risks of the two systems to the eco-environment are mainly due to the consumption of water resources. The management patterns could affect the footprints, and the integrated footprint could be an indicator to assess the sustainability of management patterns. When the future daily weather data by GCMs was entered into DAYCENT, the impacts of different climate change scenarios on agro-ecosystem processes were simulated. We found that the variation attributed to differences between the GCMs were higher than the variation attributed to either emission scenarios or site specific conditions, which indicated that there was a big uncertainty in future climate change simulation. Future climate change had the big impacts on greenhouse gas, reactive nitrogen loss and water consumption, though there was still a remarkable regional variation in these effects.

Soil, Climate and Native Tree Species in Great Britain

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Digital Soil Assessment, soil/plants interactions, climate change

Abstract: Robust information on the distribution of tree species is essential for many applications in ecology and conservation. While climate-related variables are important drivers, often well investigated, soil properties have received less attention. In this study we addressed how soil properties influence the distribution of native tree species in Great Britain (GB), in the present and in future climate scenarios. We used detailed presence records in GB to model and map the tree species distributions with climate information for the present and for two representative concentration pathways for 2050 and 2070, assessed with four regional climate models. We also used data from soil survey programmes in Scotland and in England and Wales to map soil properties following the GlobalSoilMap specifications. We then modelled observed and future distributions of native tree species based on climate and soil at 100m resolution. The results highlighted the need to consider soil properties when mapping tree distributions at the national level.

Soil Contamination Predictive Mapping Model on Oil and Gas Pre-exploration Assessment to Assist Soil Remediation Economic Valuation

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Remediation, Contaminated soil, Proximal sensing, Remote sensing

Abstract: The Indonesian economy dependency on hydrocarbon exploration and extraction has led to severe pressures on the environmental components from its discharge and products into the environment especially on soil. It has been affecting local community whose economic income is dependent of rivers and alluvial fertile soil. These existing explorations has just reached about 30% of potential basins that are in land. It means that the potential of soil contamination for the rest 70% are prominent, thus mitigation, prevention and remediation plan are extremely needed in Indonesia. The purpose of this study is to develop a soil contamination predictive mapping model from reflectance information to assist the oil and gas pre-exploration assessment and soil remediation planning.

Legacy spatial soil properties data from undisturbed and contaminated land in several potential and post-exploration areas were selected and analyzed. Proximal sensing and multi-resolution remote sensing techniques were also applied in conjunction to these legacy data sites. Selected soil contaminants in various domain were examined using machine learning methods to recognize the potential toxic element and the constructed model are used to predict the potential contaminated areas. The outcome of this study will provide the potential of soil contaminant areas that assist the pre-exploration assessment process in calculating the environment, social and economic cost and benefit on the future exploitation areas.

Soil Erosion Risk and SOC-Balance Based on Remote Sensing Data for Bioenergy Purposes

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Crop Residues Potential, Soil Conservation, Renewable Energy, Soil Reflectance, Agro-ecological Modelling

Abstract: Modeling agro-ecological dynamics has the purpose to guide in conservation planning due to the several combinations of cropping systems. Sugarcane crop residues have the potential of bioenergy. Although, is known that minimum coverage is required to maintain the soil ecosystem health. This work aims to assimilate the minimum coverage of sugarcane residues required to preserve the soil by assessing soil erosion by water and Soil Organic Carbon (SOC) balance. Here, we used the Revised Universal Soil Loss Equation (RUSLE) to model the 50,000 ha cultivated with conventional sugarcane culture in the west of S?o Paulo State, Southeastern Brazil. The rainfall erosivity (R factor) and soil erodibility (K factor) were assessed by satellite-based estimation methodologies while the LS, C, and P-factor were derived from methods reported in the literature. We calculated the R factor using a 10-years (2008-2018) data of the Tropical Rainfall Measuring Mission (TRMM). To calculate K factor we estimate clay, sand, silt and organic carbon using a surface reflectance time-series of Landsat data (VIS-NIR-SWIR) from 1984 to 2018. We obtain bare soil images by masking targets such as vegetation, crop residues, cloud, and water. The median reflectance of the bare soil images produced a bare soil composite (BSC) that covered the entire site. We extracted the spectral reflectance of the BSC and was performed the partial least square regression (PLSR) model to quantify such soil attributes. We used an SRTM 3-arc second spatial resolution (90 m) Digital Elevation Model (DEM) to compute slope length, L factor and slope steepness, S factor. To calculate C factor the combination of the variables was required such as local, planting and tillage date, tillage system, crop rotation, residues management, sugarcane life cycle, and management levels. The P factor measured the supporting practices for conservation such as contouring. RUSLE provides a specific guideline for bringing about erosion control within the specified limits. Cropping management alternatives that the predicted erosion rate is less than the rate for soil loss tolerance could be projected to deliver suitable control of erosion, and such alternatives may then be selected for residues removal. However, the residue removal only is possible if the annual amount of exported residues preserves a sustain positive C stocks. The model quantifies the OC input from crop cultivation and organic fertilizers application and the humus depletion from a hypothetical removal of crop-residues. The erosion risk and the SOC balance are combined into one map with the spatial distribution of crop-residues. The management practices from 2013 to 2017 resulted in 98 scenarios, where the management practices related to residue management consider 100% of straw left in the post-harvest phase (an optimistic scenario). The K factor obtained by the BSC was consistent with an R2 = 0.7. Soil loss first approach demonstrated that 73% of the entire site present soil loss tolerance acceptable. In such areas when it comes to SOC balance to keep the stocks of C, 74% of the residues should remain on the soil for preservation at post-harvest, which means approximately 100,000 ton year-1 of residues for bioenergy. This study provides information to guide on the decision-making of straw removal for bioenergy production. Financial support: CAPES, FAPESP (processes 2014-22262-0, 2014/14965-0, 2015 - 01587-0, and 2017/03207-6)

Spatial Distribution of Potentially Toxic Elements in Forest Soils in Regional and National Scales: Effect of Natural vs. Anthropogenic Factors

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Forest soils; soil pollution; digital soil mapping; potentially toxic elements

Abstract: Spatial distribution of potentially toxic elements (PTEs) in forest soils is controlled by many factors, both natural and anthropogenic. The former include for example geology of the bedrock, topography, climatic conditions, and vegetation effect. The latter can be represented by land use changes, soil management, and the proximity of and direction to potential sources of pollution. The aim of this study was to compare and quantify the effect of factors influencing PTE spatial distribution in two regions with different level of soil pollution. In addition, the effect of factors was compared between this regional scale and national scale of the Czech Republic.

Available forest soil databases including data on PTE contents (particularly forest soil monitoring, projects ICP Forest, Biosol, INTERREG) from the district of Frydek-Mistek impacted by steel metallurgy in vicinity in North-eastern part of the Czech Republic, and from a rather clean district of Domazlice in South-west of the Czech Republic were collected and analyzed. Models for spatial prediction of PTE distribution were developed based on environmental covariates (terrain parameters, geology, and forest type) and on information about relative position of the main potential sources of pollution. Artificial neural networks, multiple additive regression splines, regression trees, and random forests were used to describe the relationship between soil PTE contents and the covariates and to provide suitable models. The relative importance of predictors in these models was evaluated. The same approach was applied on the data of the whole Czech Republic and the importance of factors was also evaluated.

It was shown that the relative effect of natural and anthropogenic influencing factors (model predictors) of spatial distribution of PTE in forest soils differ between the polluted and clean regions, as well as between the scales. Contribution of particular factors is element specific and different relative effect was quantified even using different model types. Nevertheless, the results of this study can be used for model development in digital soil mapping of PTEs distribution.

The Importance of Soil for Global Ecosystem Modelling

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Oral

Keywords: Land Productivity, Soil-Landscape modelling, Global ecoregions, Mapping hotspots, Climate Change Mitigation

Abstract: Knowledge about soil geography and soil-landscape functioning is essential for global studies, particularly to model the impact of climate change on natural resources, including biomass production, land degradation and soil carbon sequestration.

Few studies addressed soil geography and abiotic soil-landscape properties as a driver of changing natural resources due to climate change. In this work, we provide insights on the importance of soil properties for global ecosystem modelling. This was achieved by modelling the mean annual cycle (MAC) of the Normalized Difference Vegetation Index (NDVI) as a function of climatic conditions and soil and landscape variables. For each of the 847 terrestrial ecoregion a spatial model was calibrated using kriging with external drift, which considered local variability in soil-landscape properties and captured both fixed effects and autocorrelation within the residuals. We built models relying solely on climatic conditions (CL), as is typically done in global ecosystem modelling, and compared them with models relying on both climatic conditions and soil-landscape characteristics (CLS). The calibrated models were assessed by the Akaike information criterion (AIC) whereas prediction uncertainty was evaluated by the ecoregion average error variance. The soil and landscape variables included in the model entail elevation, slope, topographic wetness index, soil texture, cation exchange capacity, pH and soil carbon. The climatic conditions included in the model were the long-term average monthly precipitation, temperature and solar surface radiation.

Results show that the AIC was larger for CLS than CL models, for all ecoregions during the growing season. Model performance therefore increased when using soil properties as additional explanatory variables. In addition, the spatially averaged prediction error variance of the predicted NDVI was smaller for most months (e.g. global mean variance in July of 0.0031 for the CL model and 0.0019 for the CLS model). Aside from modelling the land productivity by the proxy NDVI, the calibrated models also enabled the identification of ecoregions as global hotspots or sensitive areas for mitigation measures. This was achieved by evaluating the standardized regression coefficients of the models. It was found that soil carbon, clay content and elevation were the most important soil characteristics driving vegetation activity and thus land productivity.

The ability of global models to provide insights on general trends and the strength of local models to differentiate specific regions in the world provide valuable information for natural resource assessments. Therefore, we advocate the use of global-scale assessments which should rely on multi-scale analysis, including local-scale models with soil and landscape variability as drivers. This is key for advancing soil and food security and develop more effective large-scale climate change mitigation strategies.

Use of Terrestrial Laser Scanner to Estimate Waste Volume of Iron Ore in Fluvial Terraces

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Session 5: Applications of Pedometrics 2: Process-based Ecosystem Modelling and others

Presentation Type: Poster

Keywords: Technosol, Airbone Laser Scanner, Terrestrial Laser Scanner

Abstract: With the magnitude of the dam disruption of the Fundao dam, a significant amount of tailings was deposited in the fluvial plains and terraces of the Gualaxo/Carmo/Rio Doce Rivers, whose most accurate estimate encounters methodological and operational difficulties due to the extension of the area. In this work, a method was used to estimate the volume and thickness of the tailings layer, using the Airbone Laser Scanner (ALS) and Terrestrial Laser Scanner (TLS) technology, comparing high resolution micro topography using a previous point cloud database (ALS) and later (TLS) to the disaster of part of the Rio Gualaxo do Norte. After scanning with TLS, points cloud was performed in the Riscan Pro program and digital elevation model (DEM) were generated in ArcGis 10.1 using the Inverse distance weighted (IDW) interpolator. The ALS cloud, already available and adjusted, was submitted to interpolation only. When comparing the two clouds, a large variation of the waste volume was observed in relation to the total area, whose average value was 0.82 m3/m2. Areas where there was post-disaster intervention to remove the tailings were also analyzed, revealing large variations, with a mean of 0.79 m3/m2 of waste removed. The river channel was also analyzed and a change was observed in the canal course, areas where there was erosion and large deposition of tailings. Before the disaster the river bad was of approximately 44,797 m2, being that after the disaster happened to have 47,358 m2, meaning greater overlap of its meanders what caused that the channel of the river gained 2,561m2, although this area was also filled with tailings in levels forming new heights within the channel itself. The volume of tailings deposited in the fluvial plains, estimated by means of Laser Scanner technology, presented values very spatially variable, keeping coherence with field evaluations. Laser Scanner technology has shown promise for a broader study, presenting accuracy and scale for such a study.

Session 6

Determining an Optimal Mathematical Model, Sample Size and Ancillary Data to Map Exchangeable Calcium and Magnesium at the Field Level

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: digital soil mapping, mathematical models, sample size, ancillary data

Abstract: Understanding the spatial distribution of exchangeable calcium (Exch. Ca) and magnesium (Exch. Mg) at field level is a fundamental component in managing fertilizer application for sugarcane farming. This information can potentially be created by digital soil mapping (DSM) protocols; using mathematical models to couple soil properties and ancillary data (i.e., gamma-ray (γ-ray) and apparent soil electrical conductivity (ECa)). In this research, we aim to show which mathematical model (i.e. linear mixed model (LMM), regression kriging (RK), random forests (RF) and supportive vector machine (SVM)) was best, how many samples were required to generate an accurate DSM and which ancillary data is most useful. To do this, we collected 182 soil samples across an irrigated sugarcane field (Burdekin valley) with 42 samples removed for validation. The remaining 140 calibration samples were used along with a Conditioned Latin Hypercube Sampling (cLHS) method to generate nine groups of calibration data (i.e. n=10 ? 140) based on ancillary data. The comparisons between different models and sample sizes were based on calculating Lin's concordance correlation coefficient (LCCC) and mean square prediction error (MSPE). Result indicate that to predict Exch. Ca and Mg the best model in terms of strongest LCCC and smallest MSPE was LMM followed by RK, RF, and SVM. In terms of the number of samples, n = 60 samples were enough to permit the development of accurate predictions of Exch. Ca given all models reached large LCCC (> 0.8) and small MSPE (< 0.01). In the case of Exch. Mg, a minimum of 80 samples were required. However, from a farm management perspective, 30 samples with LMM was satisfactory for prediction of Exch. Ca (LCCC = 0.83) and in the case of Exch. Mg, 40 samples with were sufficient (0.84). With respect to the ancillary data sources, ECa data (with LMM and n = 60) was more accurate (RMSE = 0.06), less biased (ME = 0.003) and had a strong concordance (0.85) as compared to the use of γ-ray data alone. However, using both ancillary data in combination was most accurate (0.05) and had the strongest concordance (0.87). Similar findings were observed for Exch. Mg.

Disaggregation of Legacy Soil Survey Maps in the Agricultural Region of Saskatchewan Using DSMART

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: disaggregation, DSMART, digital soil mapping, prairies, soil survey

Abstract: There is a need for enhanced resolution of soil data in Saskatchewan to facilitate precision agricultural applications. The existing soil survey maps for Saskatchewan are typically at a scale of either 1:100,000 or 1:250,000, which are too coarse in resolution to provide spatial soil information to inform field-scale agricultural management decisions. One of the goals of the Saskatchewan Soil Information System (SKSIS) is to provide land managers with improved spatial soil information through digital soil mapping. One approach to achieve this is to disaggregate the legacy soil survey polygon maps, which are defined by multi-component soil map units that describe a range of soils expected to be found within the polygons. Disaggregation and Harmonisation of Soil Map Units Through Resampled Classification Trees (DSMART) (Odgers et al., 2014. Geoderma, 214:91-100) is a disaggregation method that has been used throughout the world to improve soil map resolution. This study tests the potential of this method to generate improved soil information for the agricultural region of Saskatchewan. The environmental variables used as predictor variables in the DSMART models include the Canadian Digital Surface Model (DEM), multiple topographic attributes derived from the DEM, Moderate Resolution Imaging Spectro-radiometer Enhanced Vegetation Index, Soil Moisture Index, and Natural Resources Canada's Potassium, Equivalent Thorium, and Equivalent Uranium surface concentrations derived from airborne gamma-ray spectrometry. A concern is whether the 20-m Canadian DEM is detailed enough to reflect the small-scale topographic variability of the Saskatchewan prairies. Topographic features of the prairies are subtle and can often occupy spaces of only a few meters, but these features can have substantial influence on soil formation. The 20-m DEM may not be detailed enough to capture these topographic features. The methodology is being tested using the 20-m DEM as well as using 1-m DEMs, which exist for certain smaller regions within the Saskatchewan prairies, to determine if the 20-m DEM is of adequate resolution.

Estimation of Soil Chemical and Nutrient Properties Using New Data Fusion Approach with Diffuse Reflectance Spectroscopy

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: DRS, PLSR, PLSRFS, PLSRLW, DTPA-Fe, DTPA-Zn, CaCl2-Al

Abstract: The diffuse reflectance spectroscopy (DRS) approach has been used for the estimation of soil physical, chemical, nutrients, and engineering properties. However, the prediction accuracy of this technology varies greatly. The improvement in the prediction accuracy of DRS technology can be achieved through i) More intelligent algorithms and ii) applying new data fusion approaches. In this study we applied soil structure based new data fusion approach for estimation of soil chemical i.e. pH, EC and SOC and soil nutrients such as DTPA-Fe, DTPA-Zn and CaCl2 extractable Al. The aggregate fractions size spectra that is one at a time was combined with the whole soil spectra for model calibration. Further, the same approach was tested with PLSR, PLSRFS and PLSRLW chemometric models. The results showed the new data fusion approach aid to improve prediction accuracy of soil properties and PLSRLW was superior modeling approach.

Evaluation of Global Soil Moisture Predictions based on Remote Sensing and Digital Terrain Analysis

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Session 6: Scaling in sampling and mapping

Presentation Type: Poster

Keywords:

Abstract: Soil moisture has a direct influence in soil and atmosphere interactions and the ESA-CCI (European Space Agency Climate Change Initiative) provides historical (>30 years) satellite soil moisture estimates at the global scale (across 27km grids). We increased the spatial resolution of the ESA-CCI soil moisture estimates by determining the predictive capacity of machine learning (ML) and digital terrain analysis at the global scale (using 15km grids). We modeled and predicted the ESA-CCI soil moisture values across 26 years of available data (1991-2016) using a ML based kernel method and multiple terrain parameters (e.g., slope, wetness index). We used ground information from the International Soil Moisture Network (ISMN, n=13376) for evaluating soil moisture predictions. The soil moisture predictions based on digital terrain analysis and ML showed 1) high accuracy (0.69-0.87% and 0.04 m3m-3 of cross-validated explained variance and root mean squared error), 2) improved spatial resolution (from 27 to 15km grids) and, 3) similar agreement with ground information compared with the original ESA-CCI soil moisture product. These results highlight the large potential of digital terrain parameters for improving the accuracy and spatial detail of satellite soil moisture grids at the global scale. Thus, we conclude that topography could be used to operationally improve the spatial detail of globally available remotely sensed soil moisture datasets. Supporting our conclusion, we provided a fully reproducible example containing code, terrain parameters (15km grids), annual soil moisture estimates from the ESA-CCI product (1991-2016, 27km grids), annual soil moisture predictions based on digital terrain analysis (1991-2016, 15km grids) and annual ground soil moisture estimates from the ISMN for further modeling (i.e., upscaling) and evaluation purposes.

Exploring How Proximal Soil Sensors Account for Spatial Variability and the Effect of Scale to Optimise Soil Property Estimates in UK Precision Agriculture

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: variability, proximal sensing, sample optimisation

Abstract: In many countries proximal sensors which measure geophysical properties are increasingly used by farmers to map the key soil properties. These maps can be used to estimate field scale nutrient status and to infer the required fertiliser additions or to implement other management practices e.g. irrigation. The widespread application of proximal sensing is less common in the UK. We conduct case studies in two fields of the Centre for Sustainable Cropping, Balruddery farm, James Hutton Institute near Dundee, Scotland, UK. In each field two proximal sensing methods were used: (1) electromagnetic induction (DUALEM-21) and (2) gamma radiometric. Both geophysical sensors were surveyed across the field the day before soil samples were collected at two depths: 0-30 cm (the local depth of ploughing) and 30-60 cm. The soil and sensor data were analysed and used to establish the cost effectiveness and to determine optimal strategies for proximal soil surveys in UK conditions. We estimate a series of linear models of co-regionalization which relate the variation of the sensor measurements to the values of the selected soil properties. We use this model to optimize the configuration of the proximal survey and the location and number of soil cores that are required to map the soil nutrient status and produce prescriptions for the within-field variation of fertiliser additions according to UK guidelines. The survey optimization procedure can equally be applied to airborne geophysical surveys.

Identifying the Spatial Drivers and Scale-Specific Variations of Soil Carbon Fractions in a Montane Natural Forest Ecosystem in Sri Lanka

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: soil carbon fractions, tropical ecosystems, linear mixed model,

Abstract: Different forms of soil carbon fractions have different ecosystem functions and inherent with its own rate of decomposition. Identifying the forms of soil carbon in natural ecosystems enables to get an idea about soil health and its vulnerability to climate change. In this study, we considered three forms of carbon fractions namely microbial biomass carbon (MBC), water-soluble carbon (WSC) and labile carbon (LC). This study was carried out in Knuckles forest reserve across ~ 21,000 ha of tropical montane forested catchment in Sri Lanka. Stratified random sampling was adopted to collect soil samples considering vegetation types (6 major types) as a stratum. A total of 190 locations were sampled and soil samples were collated from 0-0.1 m fixed depth interval. Soil carbon fractions were modelled and mapped with digital soil mapping techniques across the study area using environmental covariates as drivers of soil carbon fractions. Further, several (4) spatial transects of 100 m interval were extracted from the digital maps representing the study area and noise-assisted ensemble empirical mode decomposition analysis was carried out to examine the scale-specific variability of soil carbon fractions. Spectral analysis was performed to identify the exact scales and the correlation analysis was performed with different environmental covariates to identify the dominant controlling factors at different depths. Here we are presenting the initial results of this study. It is anticipated that results of this study will provide valuable information for ecosystem models to initialize across landscapes to assess the impact of climate change and human-induced changes in tropical ecosystems.

In-Situ Characterization of Soil Properties and Horizon Separations to Depth Using Vis-NIR Spectroscopy

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Session 6: Scaling in sampling and mapping

Presentation Type: Poster

Keywords: digital soil mapping (DSM), Non-destructive, proximal sensing

Abstract: Visible- Near infrared (Vis-NIR) spectroscopy has shown potential when used in lab to determine soil properties. The speed and accuracy of Vis-NIR spectroscopy offers potential use for determining information needed for digital soil mapping (DSM) such as organic matter (OM), pH, Electrical conductivity (EC), texture and horizon separations. Intensive soil sampling is needed to produce accurate large-scale digital soil maps, which can be costly and time consuming. Vis-NIR spectroscopy offers the potential to decrease the time and cost associated with intensive sampling; however, physical sampling and sampling prep are still a limiting factor. In-situ sampling with Vis-NIR spectroscopy would greatly decrease the time required to obtain the information needed to produce digital soil maps. The aim of this project is to demonstrate the use of vis-NIR spectroscopy in a non-destructive manner directly in the field.

Vis-NIR readings were collected from 160 points located across 13 different farms within Wellington County. A modified Veris P4000 soil probe was used to collect 3 replications of Vis-NIR spectral data up to 1 meter in depth at each of the 160 sample points. Partial Least Square Regression (PLSR), cubist, random forest, and Extreme learning machine (ELM) models were used to compare in-situ spectral readings to laboratory measured data for OM, pH, EC, texture and horizon differences. The study aims to not only determine the accuracy of vis-NIR spectroscopy in predicting soil properties but also aims to demonstrate the ability to predict soil properties at specific depths.

Mapping of Soil Thickness in Mountainous, Upland and Hilly Area of Japan Using Small-Catchment-Scale and Regional-Scale Sampling Data

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Session 6: Scaling in sampling and mapping

Presentation Type: Poster

Keywords: DSM, random forest, boosted regression tree, soil thickness, Japan

Abstract: In Japan spatial information of soil thickness (soil depth) is not well developed in mountainous, upland and hilly area occupying more than 80% of the country. This is one of the largest uncertainty factor in the soil organic carbon stock at national scale or various model studies (e.g. biogeochemical, ecological and hydrological models). In recent years, mapping of soil thickness had been developed based on DSM or geomorphological approach using high resolution DEM at global scale. However, the accuracy of the soil thickness in those map is very poor particularly in mountainous, upland and hilly area of Japan. This might be because of the effect of large heterogenic distribution of the volcanic oriented soil deposited on the complex topography. Our objective of the study is to develop the appropriate method for the spatial estimation of soil thickness in Japan based on machine learning approach.

The training dataset of soil thickness were obtained from intensive sampling data using handy dynamic cone penetrometer in 2 small catchments (2.3 ha and 1.2 ha, N = 664) in addition to regional (national) -scale data obtained from soil profiles in legacy soil dataset of Forestry and Forest Products Research Institute (N = ca 1500). Soil thickness was defined as the thickness of A + B horizon (above C) in this study. As for explanatory variables, we mainly used various terrain attributes (e.g. elevation, slope, aspect, curvature, slope height, TWI, HAND) from high resolution DEM (10m) in addition to climate, vegetation, surface geology and some information about the volcanic soils and tephra. We used random forest and boosted regression tree as the machine learning model. As for random forest model, relative importance and partial dependency was computed. All calculation, mapping and parameter tuning were conducted using R package (e.g. caret, ranger, xgboost. GSIF), SAGA and GDAL. The accuracy of the map was evaluated by RMSE and correlation coefficient using 10-fold cross-validation approach.

As a result, the mapping accuracy of the soil thickness was 0.87 m by random forest model (ranged from 0.2 to 7 m). In this model, the relative importance was high in topographic factors related to slope position and curvature. Estimated map showed that soil thickness in north part of Kanto region was deeper in upper part of the slope than in lower slope and near stream. This tendency was consistent with field observation in the area covered with volcanic soil. Actually, the relative importance of the model was also high in volcanic soil-type (Andosols) following topographic factors. We assumed that the information about the tephra and volcanic soil distribution was crucial for regional-scale soil thickness which was independent of local topographic effect, in Pacific Rim countries.

Modelling Particle Size and Soil Organic Carbon in Tepequem Settlement Project, Roraima State, Brazilian Amazon

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Session 6: Scaling in sampling and mapping

Presentation Type: Poster

Keywords: Machine learning, Spatial prediction, Random Forest, Ranger, Brazilian Amazon.

Abstract: The lack of detailed pedological data in the Brazilian Amazon limits accurate environmental analyzes. The application of digital soil mapping techniques can help enhance information concerning this natural resource and it can generate data related to soil classes and attributes at reduced cost and time. In this sense, this work aimed to evaluate the use of environmental covariates in predicting soil attributes (particle size and soil organic carbon). In a rural settlement in the northwest region of the state of Roraima (44.000 ha), Brazilian Amazon, a total of 320 soil samples, distributed to cover all the lithological and geomorphological variation of the area, were collected in two layers (0-10 and 10-30 cm) for particle size (clay, silt and sand) and soil organic carbon analysis. The covariates database was composed of 52 variables including aerogeophysical and climatic data, geological and pedological maps, vegetation indexes, and morphometric maps derived from a digital elevation model, with a 12.5?m spatial resolution. To obtain the best prediction performance, we tested three machine learning algorithms: Random Forest, Ranger and Cubist. The number of environmental covariates used to predict particle size and soil organic carbon was simplified with the correlation analysis and recursive feature elimination, reaching 5 variables in most models. The selection of covariates allowed prediction of the data in the study area, evidencing the use of terrain attributes and aerogeophysical data for prediction particle size, with addition of drainage index, in the case of prediction organic carbon. Random Forest and Ranger showed the best performance in predicting sand at 0-10 cm and silt at 10-30 cm, with $R2 > 0.44$ and Root Mean Square Error (RMSE) < 0.14. Random Forest and Ranger had an R2 of 0.31 to 0.39 and $RMSE < 0.11$ in predicting clay at 0-10 and 10-30 cm. Random Forest and Ranger showed the best performance in predicting organic carbon, but only at 0-10 cm, with R2 0.23 and 0.25, respectively. Cubist presented the worst performance for particle size and organic carbon prediction at all depths.

Monitoring Agricultural Land Use Change Trend Using Remote Sensing and GIS-Based Approach

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Session 6: Scaling in sampling and mapping

Presentation Type: Poster

Keywords: land use and land cover change, remote sensing, agriculture, land management, GIS

Abstract: Over the last decades, land use change issues have aroused increasing attention of scientists around the world. More significantly, population growth along with increasing demand for and extraction of natural resources is one of the challenges facing humanity today. This puts extra pressures on the Earth's ecosystem including climate change, declining stratospheric ozone and environmental quality, changing water and nutrition cycles, loss of biodiversity and land use/ cover changes. These changes, which are mostly related to changing land use patterns, have great importance in environmental studies and, therefore, are the main aspect of land use management decision- making. It is important to understand the relationship between the pattern of land use/cover change and its drivers in a region to initiate specific planning for land management decisions. Moreover, it is well known the important role of RS and GIS in monitoring the dynamic changes of land use/cover due to time and cost-effective approach, with greater accuracy in quantification in land use/cover studies, repetitive coverage and real-time data acquisition in capturing and analyzing multi-spectral and multi-temporal data in both urban and rural areas. This study identifies geophysical (e.g., topography, accessibility, and soil) and socio-economic (e.g., population density, the tourist industry, and land price) driving forces of land use change interconnecting with farmer characteristics to assess the actual impact of drivers on trends of land use change. We used multi-temporal satellite images and geographic information systems (GIS) to evaluate the spatiotemporal dynamics of land use/cover changes over a 20-year period (1996-2016). Supervised classification was performed based on the maximum likelihood algorithm in ENVI (5.3) to obtain the land use class with the overall accuracy of 87%, 92%, and 93.50 %, and kappa coefficients of 82.87%, 88.66% and 89.98% for the years 1996, 2006 and 2016 respectively. Change detection analysis also revealed that agricultural land reduced by 11.09% and built up area increased by 15.89 % from 1996 to 2016. Moreover, the evaluation of geophysical and socio-economic driving forces and their actual impact on the change trends of the study area as well as the local farmers characteristics showed that economic drivers and tourist industry as the socio-economic drivers, and topography as the geophysical drivers were the main driving forces that caused agricultural lands to change to built-up area. In addition, according the results of farmers? interviews, a lack of comprehensive support from the government and the agricultural ministry for preparing pesticide, fertilizer and other preparations was an interconnected cause of these conversions, which makes it indispensable to investigate the complexity of socio-ecological relationships and interaction between land use change drivers of the region for policymakers.

Multi-Scale and Multi-Resolution Analysis of Spatial Position, Spatial Context and Relevant Process Scales for Digital Soil Mapping

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: Euclidean Distance Fields (EDFs), Contextual Spatial Modelling (CSM), Gaussian Pyramids, Multi-scale, multi-resolution analysis for DSM, Digital Soil Mapping, Machine Learning.

Abstract: We present an overview of results from a series of investigations into multi-scale modelling of spatial position and spatial context for digital soil mapping (DSM). These efforts are leading towards a methodology and a general framework, for multi-scale, hierarchical contextual mapping and analysis for DSM. We proposed and evaluated several practical methods to account for complex interactions of spatial location and environmental covariates across multiple physical and process scales and their respective influences on soil formation. We computed and evaluated Euclidean Distance Fields (EDFs) as measures of spatial position or spatial location in multiple contexts. We derived terrain derivatives and other environmental covariates at multiple resolutions based on up-sampled octaves of the Gaussian pyramid and analysed the ability of these multiple resolution inputs to improve predictions in digital soil mapping. We investigated and compared three different approaches for computing a hierarchy of covariates across a broad range of scales. We applied and evaluated these various different covariate data sets for several test areas using a variety of different prediction models. Tested algorithms have included linear models, bagged multivariate adaptive regression splines (MARS), radial basis function support vector machines (SVM), Cubist, random forest (RF), a neural network (NN) ensemble and Deep Learning. Results from these algorithms were compared with those achieved using ordinary kriging (OK), RK, GWR as well as by the multiscale methods ConMap, ConStat and contextual spatial modelling (CSM). In all cases, incorporation of these additional measures of spatial position and multi-scale spatial context has improved prediction accuracy relative to models that did not use these measures. Inclusion of multi-scale measures of spatial context and spatial position in machine learning (ML) models appears to mimic the effect of the separate kriging step applied in Regression-Kriging (RK). The spatial position measures appear to somehow help account for spatial non-stationarity, spatial autocorrelation and environmental correlation. They appear to produce results similar to those achieved by RK, where predicted values are adjusted according to the distance of a prediction location from locations of known values, as conventionally computed from the variogram. It would appear that multi-scale covariates can act as measures of spatial position as well as spatial context. In this way, they are seen as being similar to the previously described hyperscale covariates of ConMap and ConStat. Because the approach is based on analyzing a relatively small set of scales and range of terrain attributes it is efficient and feasible to apply for operational DSM. Depending on the regression algorithm and the covariates used in the modelling, the results can often be interpreted in terms of soil formation. It is possible to identify which covariates, at which resolutions contribute most strongly to achieving improved prediction accuracy. We can relate the type of covariate and its nominal resolution to effective process scales for processes that are known to influence the formation and alteration of soils. Instead of trying to search for a single, best performing, 'right pixel size', we can let the ML algorithms identify which covariates, at which resolutions are most useful.

Quantification of Soil Organic Carbon on Large Scales Based on the Spectrally Clustered LUCAS Soil Database

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: soil organic carbon, reflectance spectroscopy, cluster analysis, soil spectral library, Europe

Abstract: Hyperspectral imagery shows a great potential to quantify soil properties from airborne and in the future from spaceborne platforms, where it can deliver regular updates on larger scales. With larger scales the prediction accuracy decreases due to the inhomogeneity of samples. In this study we focused on the quantification of soil organic carbon (SOC) and investigated the effect of spectral clustering of the LUCAS EU-wide topsoil database on the SOC prediction accuracy without using other covariates than the spectral database. In a first step, this approach is tested with laboratory data. The clustering results were compared to a reference model that was calibrated on the whole database without any clustering. We tested different clustering methodologies: (i) a k-means clustering based either on a principal component analyses or based on spectral feature variables, both combined with partial least squares regression (PLSR) models, and (ii) a clustering based on a local PLSR approach which builds an individual multivariate model for each sample to be predicted. Additionally, atmospheric water wavelengths were removed for the analyses to allow for later application to remote sensing image data. The best results were accomplished by the local PLSR approach: R2 = 0.66, RMSEP = 5.2 g kg -1 and RPIQ = 1.95. The k-means clustering approach did not show substantially better results than the reference model. Overall, our results were similar to other approaches using PLSR with a larger spectral range and other soil parameters as covariates. This study showed (i) that the local PLSR approach is transferable onto a wavelength-reduced soil spectral library allowing SOC estimations at low-cost and with reasonable accuracy based on large scale soil databases and satellite imagery in the future; and (ii) that the local PLSR approach can be applied without using other soil covariates and is therefore a valuable tool for SOC quantification based solely on spectral data. In a further step, the approach will be tested for its application at remote sensing scale.

Revealing the Scale- and Location-Specific Controlling Factors of Soil Organic Carbon in Tibet

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: soil organic carbon, two-dimension EMD, empirical mode decomposition, scale analysis, Tibet

Abstract: Soil organic carbon (SOC) leads to a significant impact on global carbon (C) cycling and soil quality. Variations in SOC are controlled by vegetation, geomorphic and climatic factors that are scale and location dependent. In this study, the two-dimension empirical mode decomposition (2D-EMD) is applied to examine the variations of SOC at different scales and locations, and the correlations between SOC and environmental factors are explained. The spatial distribution of SOC in Tibet was decomposed into three IMFs under different scales, with spatial variation scales of approximately 7 km, 109 km and 338 km, which represented the small, medium and large scale, respectively. The remaining residual represented the variation trend of SOC across Tibet. The correlations between SOC and environmental factors (elevation, radiation, evapotranspiration and temperature) are distinguished by the physiographic zone at small and medium scale. Normalized difference vegetation index (NDVI) and precipitation influenced SOC mainly at small scales, while the effects of precipitation and ET on the distribution of SOC were due to geomorphology and type of permafrost. The combination effect of climate on SOC was larger than other factors at large scale while factors refer to land surface characteristics including evapotranspiration, water erosion and NDVI accounted for more contribution. The results indicated that the environmental factors influence SOC under a combination of scale and location effect. The limiting factors for soil organic carbon accumulation in different regions of Tibet are different. These findings are of great significance for future studies in SOC dynamic modelling under the influence of natural changes and human activities.

Sampling Design Optimization for Soil Mapping with Machine Learning

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: Sampling design optimization / Machine learning / K-means / Random forest / Pedometrics

Abstract: Machine learning (ML) techniques are widely employed to generate digital soil maps. The map accuracy is partly determined by the number and spatial location of the measurements used to calibrate the ML model. However, finding the optimal sampling design for mapping with ML techniques has not yet been considered in digital soil mapping studies. In this paper, we investigate sampling design optimization for soil mapping with ML. A design is optimized using spatial simulated annealing by minimizing the root mean squared error between a predicted and measured soil property on an independent validation dataset. We applied this approach to mapping soil organic carbon for a part of Europe using subsamples of the LUCAS dataset. The optimized subsamples are used as input for the random forest ML technique, using a large set of readily available environmental data as covariate. We also predicted the same soil property using subsamples selected by either simple random sampling, conditioned latin hypercube sampling, spatial coverage sampling and k-means optimized feature space sampling. The process is repeated several times using leave-group-out cross-validation so as to compute the sampling distribution of the population mean squared error (MSE) of maps based on different designs. Differences between MSE values are tested for significance using the non-parametric Mann-Whitney test, for different sample sizes. We analyzed the distribution of the optimized designs in both geographic and feature space to reveal their characteristics. Results show that optimization of the sampling design by minimizing the MSE is worthwhile for small sample sizes. For larger sample sizes, the effect of using an MSE optimized design diminishes. In this case, we recommend to use a sample selected by k-means in the feature (covariate) space. In addition, it is possible to optimize the sampling design in terms of minimum MSE only when subsampling an existing dataset with known values of the soil property at all locations.

Scale Dependency of Environmental Variables on Soil Organic Carbon Prediction across the Conterminous USA

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Session 6: Scaling in sampling and mapping

Presentation Type: Oral

Keywords: soil organic carbon, pedometrics, environmental variables, grid size

Abstract: Achieving an accurate representation of the spatial heterogeneity of existing soil organic carbon (SOC) stocks in Earth system models (ESMs) is a prerequisite for reducing the existing uncertainty in predicting carbon-climate feedbacks. Scaling properties of SOC stocks and its environmental controllers can help in appropriate representation of SOC spatial heterogeneity and its vulnerability in ESMs. We hypothesize that the strength of environmental controllers on SOC stocks changes with scale, and beyond certain scale, there is no significant influence. In this study, we quantified the scaling impacts of environmental controllers of SOC stocks across the conterminous USA using > 6,200 SOC observations and a range of environmental variables as SOC predictors compiled following "SCORPAN" principles. Environmental variables included terrain attributes, climatic variables (precipitation, temperature, incoming solar radiation, and potential evapotranspiration), land use/land cover data, satellite vegetation indices, soil types, soil temperature and moisture regime, parent material, and the geographical coordinates of the pedons. Terrain attributes were derived from digital elevation model (DEM) at 100m, 250m, 500m, 1km, 2.5km, 5km, 10km, 25km, and 50km grid size (scale) through subsequent DEM aggregation. All the remaining variables were resampled to the similar spatial scale. Significant environmental controllers were identified at each scale using best subset regressions and SOC stocks were predicted using geographically weighted regression (GWR) model. The scaling properties of environmental controllers were quantified by plotting the median GWR coefficients of significant environmental controllers with scale, and fitting with appropriate mathematical functions. The predicted variance of SOC stocks at different scales was plotted with scale and fitted with appropriate mathematical function to determine the scaling property of SOC stocks. This study will determine the scaling properties of SOC stocks and its environmental controllers that will improve spatial representations of SOC stocks and its vulnerability in ESMs.

Uncertainty Guided Sampling Optimizes the Application of Legacy Data for Soil Class Mapping

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Session 6: Scaling in sampling and mapping

Presentation Type: Poster

Keywords: mapping soil classes, random forest, free brazilian repository, open soil data, uncertainty

Abstract: In order to provide soil spatial information with greater agility and adequate spatial resolution pedometricians applied Digital Soil Mapping (DSM). The possibility of making use of previously generated soil maps and reports, called legacy data, may allow the implementation of MDS at a reduced cost, and even, to optimize the application of these previously executed surveys. We hypothesized that new samples can optimize the application of legacy soil data. Thus, the objective of this work was to evaluate to what extent the collection of a new set of data, in areas of greater uncertainty, improves the prediction of soil classes.

The study area, of approximately 13,000 km2 in south of Brazil, presenting a relief that varies from plan to mountainous with altitudes between 21 and 605 m. The legacy data were obtained from The Free Brazilian Repository for Open Soil Data febr, www.ufsm.br/febr. In the study area, the febr provided 1922 irregularly distributed points (226 profiles), with 13 different soil classes if considered the 2nd categorical level of Brazilian Classification System (SiBCS).

Soil maps were generated by the Random Forest (RF) algorithm, in R environment, using a set of 22 environmental covariates related to the soil formation factors parental material, organisms and relief. Model training used cross-validation and soil class prediction models had their performance evaluated by general accuracy. In addition, maps of soil class maps were evaluated by an external validation set with the application of 113 soil profiles. Besides, a confusion index measure was derived to express model uncertainty. An additional data collection of 200 sample points was randomly allocated guided by pixels of maximum uncertainty in the first map.

The soils classified up to the second categorical level revealed a predominance of Argissolo Vermelho and Argissolo Bruno-Acinzentado (Umbric - Alisols - Arenic) classes in elevated regions and Planossolo Haplico (Planosols) in flat areas of the terrain. Soil mapping with legacy data alone, using RF, showed a general accuracy of 0.58 in cross-validation and 0.48 in external validation, with general uncertainty of 0.84. These quality values are a consequence of the large study area, geologic complexity and the use of only soil legacy data. In addition, there is a great variation of soil classes, many of them differentiated only in the second categorical level.

The incorporation of a new set of 200 sampled points, based on the uncertainty, brought improvements in the accuracy values when compared to the model generated only with legacy data. The model with additional data presented a general accuracy of 0.55 in the cross-validation and 0.51 in the external validation, the latter being more rigorous in the evaluation of the model and more indicated for comparisons. In addition, the overall uncertainty of the model reduced to 0.81. This model improvement can be considered significant considering the small amount of additional data versus the large extent of the study area and the large class variation at the second categorical level.

So, the use of soil legacy data is indicated as data source to MDS. In addition, uncertainty-guided resampling presents potential for bringing improvements to the predictive model of soil classes. The strategy demonstrated here has great potential for application in the new Brazilian program of soil surveys “Pronassolos” which is about to begin.