International Soil Carbon Network: Advancing Soil Carbon Monitoring, Reporting, and Data Synthesis

Luke Nave, University of Michigan

2017 Joint NACP and AmeriFlux Principal Investigators Meeting
Acknowledgments

• **Funders:** USDA (FS-IP, NRS; NIFA), NSF (EF; BIO), University of Michigan

• **Key Collaborators:** Deb Agarwal, Norm Beekwilder, Maria Covarrubias, Ricardo Covarrubias, Grant Domke, Rafael Flores, Chris Gough, Mario Guevara, Jen Harden, Jeff Hatten, Kate Heckman, Gustaf Hugelius, Marty Humphrey, Kris Johnson, Corey Lawrence, Jim Le Moine, Avni Malhorta, Knute Nadelhoffer, Jim Ozenberger, Eunice Padley, Hobie Perry, Mike San Clements, Steve Shetron, Brian Strahm, Chris Swanston, Carl Trettin, Catharine van Ingen, Rodrigo Vargas, Chris Vogel, Brian Walters, Chris Woodall, Alexandra Zamecnik

• **Photo credits** include Kailey Marcinowski, Nick Van Van Dyke
Motivation for ISCN

• Soil organic matter contains at least two thirds of terrestrial organic carbon
• Soil carbon feedbacks to climate change are still uncertain, but likely are large
• Soil carbon is fundamental to ecosystem services from hydrologic regulation to food, fiber, and forest products supply

➢ Major and mounting pressure to understand soil carbon distribution, turnover, vulnerability, and feedbacks to ecosystem services
Goals of ISCN

• **Coordinate** soil carbon **observation**, **archiving**, **experimentation**, and **modeling**
• **Characterize** the **distribution** and **stability** of soil carbon
• **Understand** relationships between soil carbon and ecosystem services
• **Forecast** soil carbon **vulnerability** to loss under changing climate, land use, and other disturbance
• **Organize and distribute** this information to land managers, modelers, and policy makers

➤ These goals are beyond the scope of any one group. Large-scale collaboration is required!
Inventory and Monitoring

• Baseline SOC estimates and monitoring programs are needed for robust national greenhouse gas inventories

• Nations vary in institutional and technical capacity

• ISCN partners with US Forest Service International Programs to run annual workshops that foster training and collaboration throughout the western hemisphere
Inventory and Monitoring

Workshops cover all components:

- designs for inventory, monitoring, and experimentation
- field tools and sampling techniques
- sample preparation and basic analysis
- data interpretation and management
- scaling, mapping, and reporting
Inventory and Monitoring

• Technical instructors from US government agencies and academic institutions provide training on specific topics
• Participants share their own expertise and examples
• Participants take their experiences back to their home institutions for programmatic application
Inventory and Monitoring

• In 4 years, the workshop has trained 56 scientists, practitioners, and students from 9 countries

• Independent evaluation reveals that >50% of participants frequently apply what they learned

• Recruitment through in-country contacts has been augmented by word-of-mouth endorsement
Inventory and Monitoring

2013

2014

2015

2016
Inventory and Monitoring

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Alexandra Zamecnik (alexandrazamecnik@fs.fed.us)

USFS-International Programs Overview:
https://www.fs.fed.us/about-agency/international-programs

Workshop Materials:
www.soilcarb.net
• Workshop flier, agenda
• Course pack, case studies, PPT presentations
• Programmed spreadsheets
International Reporting

• Many signatory nations to the United Nations Framework Convention on Climate Change rely on default values, modeling, and prediction in SOC reporting.

• Observations can add to and improve such estimates.

• In the U.S., the National Forest Inventory program and ISCN database are ready sources of point data that can be used for independent estimates.

• Harmonize NFI data (to 20cm) with ISCN data (to 100cm)
• Compute 100cm SOC depth distributions by soil order
• Predict 20-30 and 30-100 cm SOC stocks for NFI plots, add to 0-20 NFI SOC stocks
**International Reporting**

- Derive relationships between plot variables, 0-30 and 0-100 cm SOC predictions for NFI plots (random forests regression)
- Predict 0-30 and 0-100cm SOC for NFI plots that lack soil samples
Soil orders have different SOC depth distributions; total stocks and distributions are congruent with pedogenic expectations. Mean SOC stocks in NFI plots vary from 40-595 Mg C ha\(^{-1}\); 38% of variation is predictable from LAT, LONG, elevation, P/PET, MAP, and mean annual maximum temperature. Bottom line: nationally, a 75% increase in mean SOC density.
International Reporting

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Hobie Perry (charleshperry@fs.fed.us)
Luke Nave (lukenave@umich.edu)

USDA-FS NRS Forest Inventory and Analysis overview:
https://www.nrs.fs.fed.us/fia/

USDA-FS NRS Research Highlights, featuring this project:
https://www.fs.fed.us/nrs/highlights/

* one of five Director’s Choice highlights for 2016
Data Synthesis

- The ISCN Database is in its 3rd generation and holds >71,000 soil profiles (>430,000 layers)
- Soils are associated with dozens of chemical, physical, ecologic, and geographic predictor variables
- Additional data contributions are ongoing, and include more detailed information (e.g., soil fractions, spectra, radiocarbon)

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<tr>
<td>Δ14C (‰)</td>
<td>58</td>
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Data Synthesis

• Extramurally supported project teams are leveraging ISCN templates, database, and collaboration opportunities

• Examples:
  
  – Soil Organic Matter – Mechanisms of Stabilization (SOM-MOS; Lead PI M. San Clements; NSF-EF Macrosystems)
  
  – What Lies Below? (Improving quantification and prediction of soil C storage, stability, and susceptibility to disturbance; Lead PI C. Lawrence, USGS Powell Center)
  
  – Enhancing long-term research through improved soil archiving (Lead PI L. Nave; NSF-BIO FSML)
Data Synthesis: SOM-MOS

- NEON sites span 11 of 12 USDA soil orders
  - 1-2 m core extraction for soil sensor deployment
  - No plans to utilize cores
- NEON-RC-ISCN partnership:
  - Get cores from 40 sites
  - Analyze for physical and chemical parameters
  - >500 $^{14}\text{C}$ analyses on soils & fractions

PIs: M. San Clements, J. Hatten, K. Heckman, D. McKnight, L. Nave, B. Strahm, C. Swanston
SOM-MOS Approach

Three major components:

– **Observational** characterization of cores to quantify SOM stability and controls (e.g., climate, physicochemical parameters)

– **Experimental** framework to quantify vulnerability (incubations, landuse comparisons)

– **Data integration and analysis**, including sharing of finished datasets via ISCN
Data Synthesis: USGS Powell Ctr.

• Association of SOM with metals and minerals is an important regulator of SOM cycling, but this mechanism of SOM stabilization is poorly parameterized

• Many approaches are used to separate SOM into pools (e.g. density, particle size, solubility) but their comparability is ill-defined

PIs: C. Lawrence, K. Heckman, M. Keiluweit, S. Crow
Powell Center Approach

• Adapt ISCN templates and approaches for synthesizing soil fraction and isotope data
• Create a database of SOM fractions with accompanying mineralogical (XRD) and metal (selective dissolution) data
• Evaluate fractionation methodologies and whether they predict radiocarbon signatures and C concentrations
Data Synthesis: Soil Archiving

- Archived soils are work performed: opportunities for re-sampling, new techniques, analysis of change over time
- Many valuable, long-term soil archives are at risk due to retirement, space loss
- There is need for distributed, data-linked archives to preserve samples and make them usable

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<table>
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<tr>
<td>2000-5000</td>
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Pls: L. Nave, P. Drevnick
Soil Archiving Approach

• Move beyond individual, *ad hoc* approaches to archiving
• Provide well-characterized soil samples with designated archive space for the long term
• Link samples to data online
• Link participating archives via a distributed system
• Contact: lukenave@umich.edu
Conclusion

- ISCN is a community of scientists working at national to international levels, at various levels of integration
- Major efforts include monitoring, synthesizing, and reporting data on soil carbon stocks, turnover, vulnerability, and management impacts
- Recent and incipient changes in Network leadership and coordination are creating new opportunities for scientists to guide efforts and define future priorities
  - SSG Co-Chairs Jen Harden (iscnchair@gmail.com) and Gustaf Hugelius (gustaf.hugelius@natgeo.su.se)
  - Avni Malhotra (malhotraa@ornl.gov), incoming ISCN Coordinator
  - Action Groups, 2016 pre-AGU All Hands Meeting, 2017 Winter Workshop, database discussions with ISRIC