Biogeochemical Research Priorities for Sustainable Bioenergy Feedstock Development in Pan-America

H. Gollany[1], B. Titus[2], D.A. Scott[3], H. Asbjornsen[4], S. Resh[5], R. Chimner[5], A., D. Kaczmarek[6], L. Leite[7], A. Ferreira[7], K. Rod[8], J. Hilbert[9], M. Galdos[7] and M. Cisz[5]

[1] USDA Agricultural Research Service, OR, USA
[2] Natural Resources Canada, Canadian Forest Service
[3] USDA Forest Service, AL, USA
[4] Natural Resources & Environment, University of New Hampshire, NH, USA
[5] Forest Resources & Environmental Sciences, Michigan Technological University, MI, USA
[6] USDA Forest Service (ret'd), Aiken, SC, USA
[7] EMBRAPA, Brazil
[8] Washington State University, USA
[9] INTA, CIA, Buenos Aires, Argentina

RCN Conference on Pan American Biofuels & Bioenergy Sustainability
Recife, Brazil, 22-25 July 2014

Natural Resources Canada / Ressources naturelles Canada

Canada

Soil and nutrient cycling principles are universal but operate at local (site) level within the landscape

- Local soils, sites/ecosystems, climate
- Local feedstock type (demand on soil reserves; quality of OM input)
- Local management practices (including intensity)

Pedro Martin Ureta's farm, nr General Levalle , Cordoba, Argentina; whudat.de

Importance of OM

Physical properties

- Reduced OM → reduced soil aggregate size

bulk density ↑ → rooting ↓ → nutrient uptake ↓

water repellency ↑ → sorption ↓ → nutrient uptake ↓

water repellency ↑ → erosion ↑

  - Few studies on aggregates in forestry *(exception:* Lupi et al. 2007.
    - Lupi AM, Conti M, Fernández R, Cosentino D, López G. 2007. Efecto de las prácticas de repoblación forestal sobre el carbono orgánico del suelo y la estabilidad de los agregados en el noreste de Argentina*. [Effect of reforestation practices on soil organic carbon and aggregate stability in northeastern Argentina. In Spanish with English abstract.]* Investigación Agraria: Sistemas y Recursos Forestales 16:230–240)

Importance of OM

Physical properties

- Reduced OM → reduced soil aggregate size
- Roadbed for equipment (mostly forestry)
  - Reduces rutting (erosion) and compaction

Importance of OM

Physical properties

- Reduced OM → reduced soil aggregate size
- Roadbed for equipment (mostly forestry)
  - Reduces rutting (erosion) and compaction
  - But compaction in forestry can sometimes increase productivity (soil water-related?)
    - *Long-Term Soil Productivity (LTSP) network in Canada & US: benefit of collaborative networks with common research designs (see Eric Vance, on Steering Committee)*
    - *(See also CIFOR network in tropics and sub-tropics)*

Importance of OM

Physical properties

Biological properties

- Reduced OM
  - →reduced earthworms, fungal growth, microbial community structure and function, below-and above-ground saproxylic organisms (and larger above-ground organisms)
  - →affects decomposition and biogeochemical cycling processes in soil

Importance of OM

Physical properties

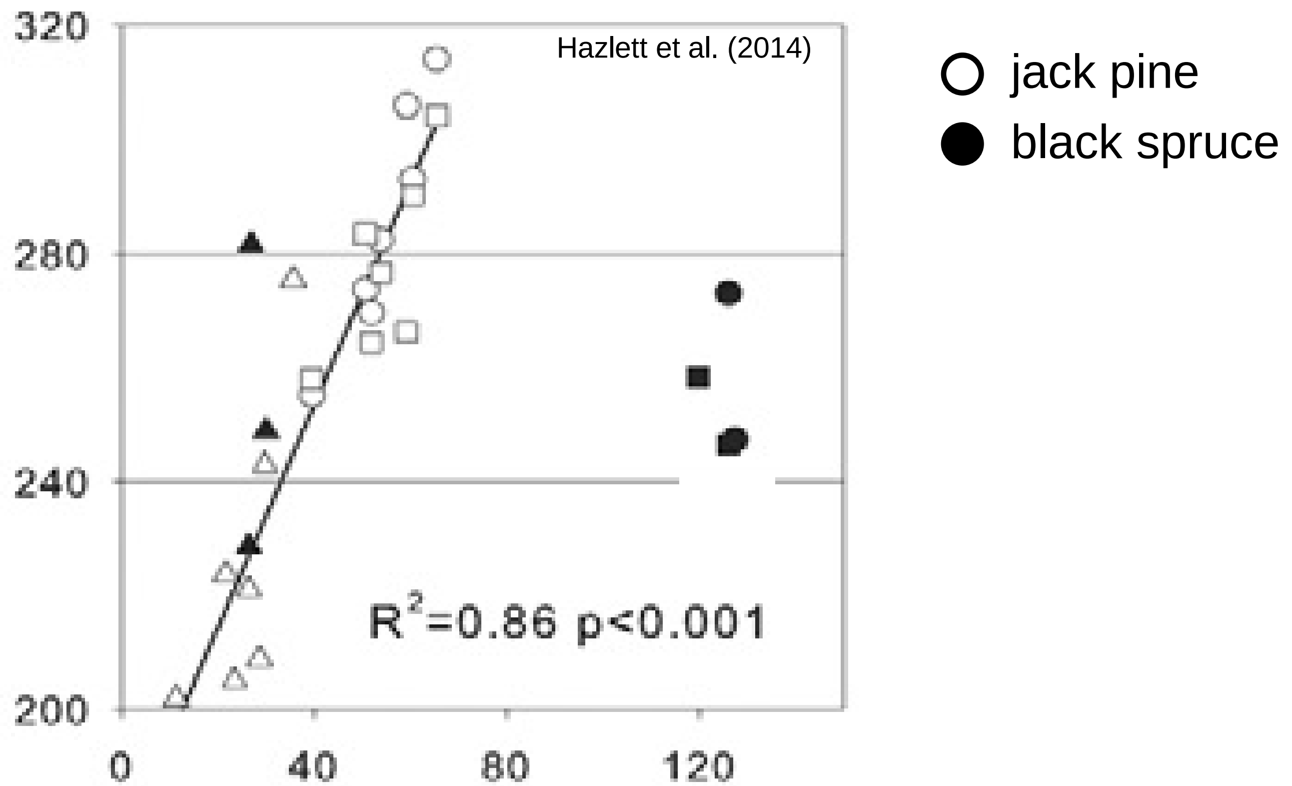
Biological properties

Chemical properties

- OM removal → reduced nutrient availability
  - Loss of nutrient capital in removed OM
  - Changed dynamics (pH, CEC, electrical conductivity)

Importance of OM

5-year tree ht. growth (cm) (10-15 y)



Immediate post-harvest site C content

(Harvest residues + forest floor + 0-20 cm mineral soil; kg ha^{-1})

In forestry, OM can be “friend or foe” (Prescott et al. 2000)

Importance of OM

Hazlett, P.; Morris, D.; Fleming, R.L. 2014. Effects of biomass removals on site carbon and nutrient retention and jack pine tree growth across a site productivity gradient in upland boreal forests of Ontario. 2014. Soil Science Society of America Journal.

Prescott CE, Maynard DG, Laiho R (2000) Humus in northern forests: friend or foe? For. Ecol. Manage. 133:23–36

Importance of OM

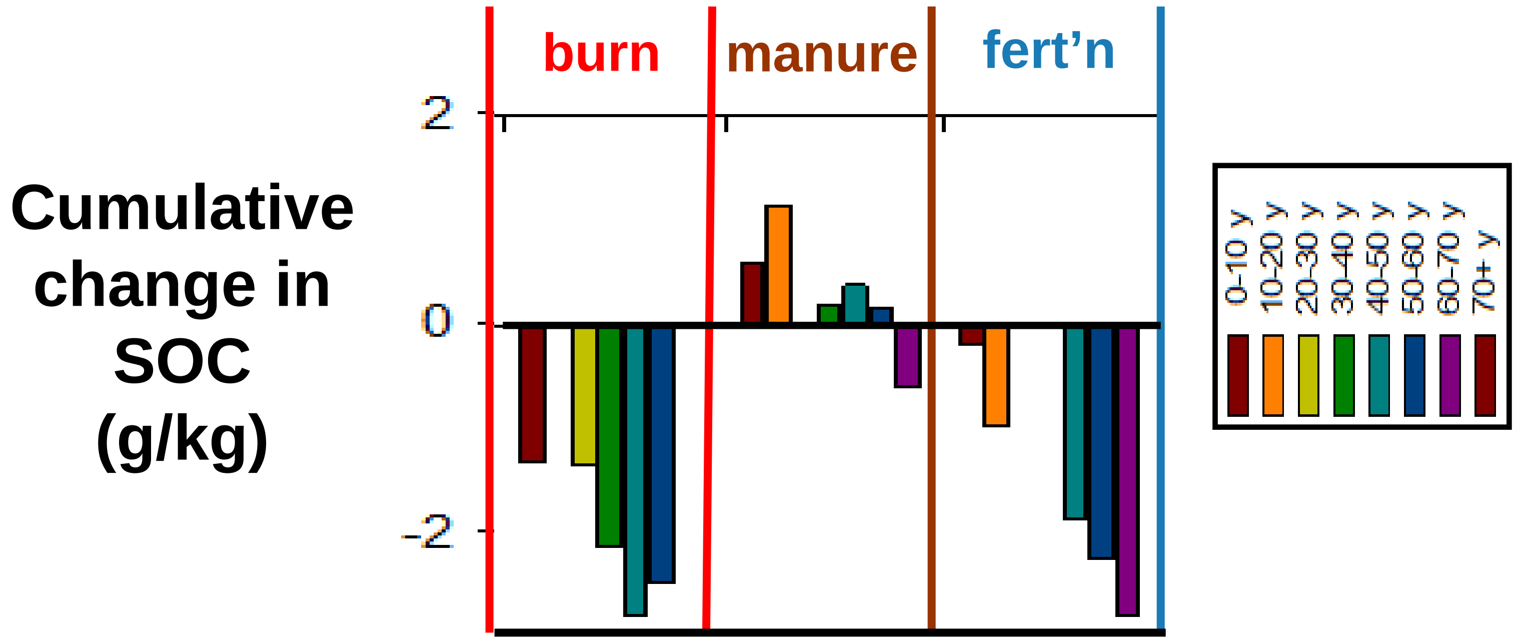
- *What are the biomass retention thresholds that sustain soil properties and functions for different combinations of crops, management systems, sites and soils? (this threshold interacts with biodiversity threshold)*

Nutrient management

- Chemical fertilization
  - Fertilization ≠ OM retention
  - Fertilization + OM retention → improve both yield & soil quality

Pendleton Plots, OR

60- to 70-year data for winter wheat, with fallow



Nutrient management

- Chemical fertilization
  - Fertilization ≠ OM retention
  - Fertilization + OM retention → improve both yield & soil quality
  - Forest Stewardship Council (FSC): discourages forest fertilization in some countries/regions
- Conserve P ("peak phosphorus")
- Ash from bioenergy production
  - If addresses limitations; lacks N and P; can be toxic
- Biochar
  - Outcomes variable; not all biochars are created equal
  - Need strategic research approach to elucidate mechanisms (Jeffery et al. 2011)

Nutrient management

- *What nutrient management/amelioration practices are economically and environmentally sustainable?*
  - How do we better define “precision” agriculture/ agroforestry/forestry to minimize fertilizer use?
  - How do we optimize nutrient availability and plant uptake while conserving OM (and P)?
  - On which sites does addition of ash or biochar increase soil productivity/long-term soil C sequestration?

Process-based models

In the absence of long-term data, reliable models would help us predict the future (within limits)

- Long-term results can be very different from short-term results
- Field trials for generating long-term data can be expensive to maintain
- Current models have varying degrees of predictive capability

How can we improve models for predicting long-term soil impacts of biomass removals?

Off-site impacts

- GHGs: CO_2, N_20 (nitrous oxide) and NO_x
  - Decomposition → CO_2 (soil respiration)
  - Increase biomass growth (including fertilization) → increase CO_2 sequestration
  - Fertilization → 69% of U.S. N_20 emissions
    - N_20 is 200-300x more potent (per-molecule) than CO_2
    - (Much less of a problem in forestry)

Off-site impacts

- GHGs: CO_2, N_20 (nitrous oxide) and NO_x
- Eutrophication
  - >400 eutrophication-associated hypoxic "dead zones" in oceans (245,000 km^2)
    - (But 1 million km^2 natural hypoxic zones; Helly & Levin 2004)
  - Optimal fertilization ("precision" management)
  - Reduce leaching/run-off with SRWC, perennial grasses in boundary areas

Off-site impacts

- GHGs: CO_2, N_20 (nitrous oxide) and NO_x
- Eutrophication
- Sedimentation
  - Erosion (OM, topography, soil disturbance)

Off-site impacts

- GHGs: CO_2, N_20 (nitrous oxide) and NO_x
- Eutrophication
- Sedimentation
- Waste disposal
  - Ash
  - Biochar

Off-site impacts

- GHGs: CO_2, N_20 (nitrous oxide) and NO_x
- Eutrophication
- Sedimentation
- Waste disposal

- *How can we reduce off-site impacts?*
- *How can we use “waste” products to increase growth (if this does not cause other problems)?*

Soil sustainability indicators

Qualitative (±) and quantitative indicators of soil "quality" and function

- Land management
  - Site-level prescriptions
  - Landscape-level planning
- LCA
  - If metric can be scaled spatially and temporally
- Governance
  - Guidelines, BMPs, regulations, policies
- Markets
  - Certification
  - Trade (import regulations)

Soil sustainability indicators

Suggested indicators include (McBride et al. 2011):

- Total organic C and N
- Extractable P
- Bulk density
- Stream concentrations of NO_3, P, suspended sediments
- GHG emissions
- productivity

Soil sustainability indicators

- *Which soil indicators are*
  - Scientifically valid, operationally feasible, and affordable?
  - Universal vs. crop- or site-specific?

- *How can we aggregate multiple indicators?*
  - e.g., C *vs.* C + N *vs.* C + N + base cations

- *How can we scale up spatially?*
  - feedstock supply chains → investor confidence, policy
  - LCA → soil impacts in context of entire supply chain

Suggested biogeochemistry research strategies

- Long-term field trial remeasurements
  - Comparative studies of old field trials
  - Money cannot buy time
- Collaboration increases value: “multi-” principle
  - Multi-feedstocks, -disciplinary, -agency, -national
- Build networks of new trials addressing emerging issues with coordinated common designs and measurements
  - Shared insight, more efficient, better comparisons, statistically stronger meta-analyses
  - E.g., CIFOR, LTSP, etc.
- Strategic syntheses, reviews, meta-analyses, “thought” articles

Suggested biogeochemistry research strategies

- Link research networks to bioenergy operations
  - Operators install plots as they go
- Scale up from site to landscape level
  - (Weyerhaeuser; Eric Sucre)
- Comparative case studies integrating biogeochemical research with other disciplines and industry
  - (e.g., PIRE)
- Balance research funding opportunities within bioenergy sector
  - Technological research with (not at cost of) sustainability research

Obrigado!
Gracias!
Merci!
Thank you!