Multistate Research Activity
Accomplishment report

Project Number: NC1178

Project Title: Land use and management practice impacts on soil carbon and associated agroecosystems services

Period Covered: 2020-06-01 to 2021-05-31

Date of This Report: 2021-09-15

Annual Meeting Date: 2021-07-15

Participants: Arriaga, Francisco (farriaga@wisc.edu) – University of Wisconsin Madison; Cihacek, Larry (larry.cihacek@ndsu.edu) – North Dakota State University; Dou, Fugen (f-dou@aesrg.tamu.edu) – Texas A&M AgriLife Research; Golabi, Mohammad (mgolabi@triton.uog.edu) – University of Guam; Lal, Rattan (lal.1@osu.edu) – Ohio State University; Noormets, Asko (noormets@tamu.edu) – Texas A&M AgriLife Research; Pierzynski, Gary (pierzynski.3@osu.edu) – USDA-NIFA (project administrator); Ye, Rongzhong (rongzho@clemson.edu) – Clemson University.

Brief summary of minutes of annual meeting

Golabi (project chair) – opening remarks, agenda
Pierzynski (project administrator, NIFA) – welcoming remarks

- The annual report will be used for mid-term review for the project (2nd year coming to a close). Emphasize:
    - how we address the project objectives,
    - what cross-institutional activities result from these activities,
- Next year we should start planning the next 5-yr renewal
- Update of NIFA move to Kansas City
- Update on anticipated funding opportunities
    - NIFA budget expected to increase 10-20%, priorities: AFRI and capacity grants
    - Agricultural Research Infrastructure Advocacy (ARIA) – program to improve land grant university facilities in all states and territories. $11.6B of needs declared to date. May be appended to various bills.

Lal – proposed developing a synthesis review of crop residue management. Potential venue: Journal of Soil and Water Conservation.

- Noormets seconded, suggested broadening the theme to “soil carbon balance”

- Arriaga seconded, expanding the topic to "management of crop residue management for C sequestration and soil health"
- Ye alerted the group of other potential ongoing efforts on this topic. Further discussion concluded that none of these efforts are currently active.

Election of officers: Rongzheng Ye was unanimously elected for vice chair for the coming year, and will serve as chair in 2022-2023.

Next year's annual meeting:

- Time: 2nd week of June annual meeting June 6-10, backup June 13-17
- Location: College Station, TX

Accomplishments

The reported results show that the increase of soil carbon stocks under conservation tillage and carbon amendments through cover crop residuals and biochar application (objectives 1 and 2 of the project) occurs at varying in different soils. The effect of soil type and fertility act as important modifiers. We have also found that traditional soil health metrics do not capture or correlate with the changes in soil carbon, pointing to the need for new metrics (Jagadamma, TN). The incorporation and mineralization rates also differ significantly by amendment type (Cihacek, ND). The interactions and feedbacks (soil acidification) arising from nitrogen fertilization and irrigation of point to the need to match amendment types, amounts and timing to a particular ecological context. We have expanded the project to encompass forest crops, and the effect of forest management techniques on soil carbon stocks. The investigated southern pine forests all exhibit soil carbon deficit (losses exceeding inputs), but the effect of prescribed burning as a management treatment is no clear. New hyperspectral monitoring system for soil C on landscape scale has been proposed to scale plot and field level observations. Collectively, these efforts promise field deployable economic solutions to quantify soil C stocks and dynamics in managed landscapes to protect soil resources for sustained crop production, climate mitigation, more efficient resource use resilience to disturbance events.

Key findings by individual groups:

State/ Territory	PI	Key findings
Guam	Golabi	• Conservation tillage and biochar application resulted in greater soil C content and lower CO_2 emissions.
MA	Keiser	• New isotopic pulse labeling study of cover crops to trace carbon inputs.
ND	Cihacek	• N is mineralized only from soybean leaves in no-till systems, whereas it is immobilized in other tissues. • N immobilization in no-till fields is thought to contribute to acidification.

OH	Lal	• Crop residue retention is an effective way of increasing soil C concentration and stocks, although there are differences among soil types. • Each ton of biomass retained increased SOC stock in 0-20 cm layer by 66 kg/ha in a silt loam soil and 130 kg/ha in clayey soil. • Crop yield exhibited complex response to residue retention. • The magnitude of SOC stock was affected more by clay content than by the amount of residue retention. • Humification efficiency was 16.5% at South Charleston for silt loam soil compared to 32.5% at Hoytville for clayey soil.
SC	Ye	• Conservation tillage increases soil C concentration and soil aggregates in the top 5 cm but not deeper soil layers. • The effect of cover cropping varies with crop type and soil.
SD	Osterloh	• Hyperspectral monitoring of soil C.
SD	Xu	• Established a new soils lab and two new projects, hired 2 graduate students. Topic: Impact livestock integration, cover crops, C_4 grass integration, grazing management, and long-term no-till management on soil carbon distribution and dynamics.
TN	Jagadamma	• In comparison to no-till system, chisel tillage redistributes soil carbon from the surface layer to deeper horizons. • Wheat cover crop increases soil C in both tillage types. • Traditional soil health metrics are ineffective in differentiating conventional and integrated conservation management practices.
TX	Dou	• N release from clover residues for rice is greater and faster than from other cover crop residues.
TX	Noormets	• Three southern pine forests in AR, GA and TX lose more soil carbon through heterotrophic respiration than they regain through above- and belowground detritus inputs. • The frequency of prescribed burning affects carbon fluxes, but not the magnitude of soil C deficit. • Prescribed fire reduces root respiration but not heterotrophic microbial respiration.
WI	Arriaga	• Soil carbon stabilization increases with aggregate size, aggregate stability, specific particle surface area, silt, clay and albite content. • Aggregates larger than 2-mm can recover annually after tillage, however aggregates smaller than 2-mm don't reform within the same time frame. • Soil carbon in 0.5-2mm aggregate sizes is used more by microbes than C in other aggregate sizes, thus being more vulnerable to physical disturbance from tillage.
WY	Zhu	• Irrigation of high-elevation (2000m) meadows resulted in formation of thick organic layers above the soil, but increased microbial immobilization of nitrogen (N) and decreased plant-

		available N, consequently limiting the N fertilization efficiency and productivity of the meadows. • Fertilization did not affect TOC and TON but increased DOC concentration compared to the unfertilized soils, suggesting that DOC is a more sensitive indicator than TOC for soil management. • Microbial biomass N suggested that both fertilization and irrigation enhanced microbial biomass and had synergistic effects. However, potentially mineralized N showed the opposite trend.

Impacts

Results to date identify soil conditions at which crop residue and other carbon amendment techniques translate to improvements in soil carbon content and to soil aggregate formation. These changes are not captured well by traditional soil health metrics. Effective management and subsequent monitoring will help select best conservation management techniques for restoration of agricultural soils.

Significance: The carbon sequestration potential in soils through natural processes offers great promise but has been compromised by intensive management practices disturbing soil structure, and stimulating microbial activity and carbon mineralization. The current project explores the magnitude and mechanisms of carbon inputs, stabilization and losses from the soil system, and the extent to which conservation management techniques can reverse the trends of soil C and nutrient loss. Soil carbon is a proxy of many soil health metrics, including nutrient and water holding capacity, and productivity, yet is not well captured by traditional soil health metrics.

Progress to date: Substantial body of knowledge has been accrued by this working group on the effects of crop residue management and carbon supplementation on soil C stocks and dynamics, its interactions with nutrient and water cycles, and potential side effects.

The project PI-s graduated three PhD-s, and continue the training of four more, as well as undergraduate research assistants. The members made 34 science and outreach presentations and published three technical reports. Xu presented guest lectures in three university courses. The members collectively received cash or in-kind funding from 21 external funding sources equivalent to over $ 3.1M (3 contributions lack an estimate of monetary value).

Dissertations

1. Alghamdi R (2020) Nitrogen Mineralization Dynamics and Post-harvest Crop Residue in No-till Systems – Ph. D., Environmental & Conservation Sciences.
2. Ozlu E (2020) Dynamics of Soil Aggregate Formation in Different Ecosystems. PhD in Soil Science with minor in Statistics. University of Wisconsin-Madison.
3. Singh S (2020) Soil health assessment for the agroecosystems of west Tennessee.

Science and outreach presentations

1. Abramoff R, Georgiou K, Guenet B, Torn M, Huang Y, Zhang H, Feng W, Jagadamma S, Kaiser K, Kothawala D, Mayes M, Ciais P (2020) How much more carbon can be sorbed to soil. EGU General Assembly (Oral), May 4-8. Virtual.
2. Bera T, Yang Y, Wilson LT, Dou F, Rooney W (2020) Dynamics of biomass yield under biomass sorghum in Southeast Texas. Virtual Annual Meeting of ASA-CSSA-SSSA. November 2020.
3. Desamito C, Golabi MH (2019). The Impact of Land Application of Biochar on Carbon Sequestration and Agricultural Sustainability- Follow up Research. Conference of Island Sustainability, which was held in Hyatt Regency-Guam, during April 8-12, 2019.
4. Cihacek L (2020) Effects of crops, soil OM and soil composition on soil acidity. Dickinson Research Extension Center 2020 Soil Health Workshop. September 15, 2020. (Invited presenter, oral).
5. Cihacek LJ, Alghamdi R (2020) N mineralization dynamics in no-till crop residues in the Northern Plains. Great Plains Soil Fertility Conference. March 10-11, 2020. Denver, CO. (Presenter, oral)
6. Cihacek L, Landblom D, Senturklu S (2020) Changes in soil plant nutrient status in a long-term integrated crop-grazing system. Poster no. 19. Abstracts of the 75th SWCS International Annual Conference, July 27-29, 2020. Des Moines, IA. p. 165. (Presenter, oral)
7. Dou F, Zhou C, Huang Y, Jia B, Wang S, Omar S, Samonte P, Chen K, Wang Y (2020) Optimization of nitrogen rate and planting density for improving the grain yield of different rice genotypes in Northeast China. 38th Rice Technical Working Group Meeting. Orange Beach, AL. February 2020.
8. Dou F, Samford J, Liu G, Li X (2020) Responses of rice production to nitrogen applied to main crop. Texas Rice. 35.
9. Dou F, Samford J, Liu G, Liu X (2020) Effects of rice variety on main, ratoon, and total crop yields. Texas Rice. 32-34.
10. Dou F, Li X, Samford J, Lamichhane S (2020) Varietal evaluation and N application for rice main and ratoon crop yield potential. Virtual Texas Rice Field Day. June.
11. Dou F, Wang X, Ma X (2020) Evaluating the effect of nanoagrichemicals on the fate and uptake of arsenic in rice. 38th Rice Technical Working Group Meeting. Orange Beach, AL. February 2020.
12. Integrating the application of 'biochar' into Agricultural Conservation Practices for Sequestering Soil Carbon in the cultivated lands of southern Guam. Abstract Submitted to the: Soil Science Society of America's annual meetings that was held in San Diego, California, during January 6-9, 2019.
13. Jagadamma S (2020) Soil health tests – challenges and opportunities. Milan No-Till Field Day at the Research and Education Center, Milan, TN (Oral), July 23. Virtual.
14. Jagadamma S, Kramer A (2020) Cover crops: nutrient release and soil health. UT Fertilizer Update Meeting (Oral-Invited), December 8. Virtual.

15. Jagadamma S, Singh S (2020) Applicability of soil health assessment methods in the agroecosystems of southeastern United States. ASA-CSSA-SSSA Annual Meeting (Oral), November 9-13. Virtual.
16. Jagadamma S, Duncan L, Raper T (2021) Conservation management practices on soil health and yield in Tennessee cotton systems. Beltwide Cotton Conference – Sustainability Conference (Oral-Invited), January 5-7. Virtual.
17. Jagadamma S, Xu S, Oakes R, Cui S (2020) Forage production and soil health in organic forage cropping systems. UT Beef and Forage Center Meeting (Oral-Invited), December 15. Virtual.
18. Lal R (2020) Achieving Zero Net Land Degradation by 2030 in Developing Countries. Achieving Land Degradation Neutrality. 22nd July 2020. Indian Association of Soil and Water Conservationists (IASWC), Indian Institute of Soil and Water Conservation (ICAR), Indian Council of Forestry Research and Education, Dehradun, India. Online.
19. Lal R (2020) Conservation to Sequester Carbon. Expanding Horizons: Where Conservation Meets Innovation. SWCS 75 International Annual Conference. 28 July 2020. Soil and Water Conservation Society, Ankeny, Iowa, USA. Online.
20. Lal R (2020) Soil and Sustainable Development. TEDx pause ... COUNTDOWN 2020. Session #2 Food. 15 July 2020. TEDx Vail, Colorado, USA. Online.
21. Lal R (2020) Soil: The Essence of Life on Our Planet. 30th Annual Online Organics Recycling Conference. 30 September, 2020. IICA Canada and Compost Council of Canada. Online.
22. Lal R (2020) Strengthening agricultural curricula in India. Inaugural Address for 111th Foundation Course (FOCARS). 5 October 2020. National Academy of Agricultural Research Management (NAARM) and Indian Council of Agricultural Research (ICAR), Hyderabad, India. Online.
23. Lal R (2020) Where Does Our Food Come From? It's the Soil Stupid (ITSS). Case Study #5: Middle East Studies Center. Where Does Our Food Come From? Global Agricultural and Economic Sustainability. 5 June 2020. 2020 Global Teacher Seminar. The Ohio State University, Columbus, Ohio, USA.
24. Lal R (2020) Food Production Systems to Sequester Soil Carbon and Offset Emissions. Monday Nutrition and Global Health Seminar Series. 31 August 2020. T.H. Chan School of Public Health, Harvard University, Cambridge, Massachusetts, USA. Online.
25. Lamichhane S, Li X, Jiang J, Dou F (2020) Effects of soil moisture on nitrogen loss associated with ammonia volatilization in drill-seeded, delay-flooded rice production. Virtual Annual Meeting of ASA-CSSA-SSSA. November 2020.
26. Li X, Tan A, Dou F (2020) Effect of cover crop mineralization on soil N supply. 38th Rice Technical Working Group Meeting. Orange Beach, AL. February 2020.
27. Parajuli B, Ye R, Ducey T (2020) 40-year conservation and conventional tillage induced distinctive C and N response in soil at different depths. ASA-CSSA-SSSA International Virtual Annual Meeting.
28. Parajuli B, Ye R, Park D, Smith M, Ducey T (2020) 40-year conservation tillage promoted C accumulations in soil aggregates. ASACSSA-SSSA International Virtual Annual Meeting.

29. Patra R, Saha D, Jagadamma S (2021) Long-term conservation management practices on depth distribution of soil organic carbon in croplands. Ecological Society of America Annual Meeting (Poster), August 2-6. Virtual.
30. Singh S, Jagadamma S, Walker F, Yin F, Yoder F (2020) A weighted soil health approach for refined assessment of soil health in cropping systems. ASA-CSSA-SSSA Annual Meeting (Poster), November 9-13. Virtual.
31. Xu S (2021) Guest lectures on soil carbon, soil health, and management in following courses:
    i. Environmental Soil Physics
    ii. Field Crop Diseases and Management
    iii. Organic Food and Plant Production
32. Xu S, Jagadamma S, Oakes RN, Cui S (2020) Soil health influenced by forage composition in organic systems. ASA-CSSA-SSSA Annual Meeting (Poster), November 9-13. Virtual.
33. Zhou X, McClung A, Dou F, Huang B, Bagavathiannan M, Way M, Watkins B, Shade J, Abugho S, Ward B, Ntamatungiro S, Jun S, Zhou Y (2020) Strategies effective for integrated pest management in organic rice in the Southern United States. 38th Rice Technical Working Group Meeting. Orange Beach, AL. February 2020.
34. Zhou X, McClung A, Dou F (2020) Use of genetic resistance and biocontrol agents for management of sheath blight in organic rice. 38th Rice Technical Working Group Meeting. Orange Beach, AL. February 2020.

Technical publications

1. Xu S (2021) Soil Health Management for Sustainable Agriculture in South Dakota. Dakota Lakes Research Farm Annual Meeting, Pierre, SD.
2. Xu S (2021) Soil Health Management for Sustainable Agriculture in South Dakota. South Dakota Soil Health Coalition Board of Director meeting, Pierre, SD.
3. Desamito C, Golabi MH, Marutani M (2020) Evaluating the impact of land application of biochar and compost on soil carbon sequestration and soil fertility. Western Pacific Tropical Research Center (WPTRC), University of Guam. TECHNICAL REPORT No. 3

External funding

1. Arriaga: PhD student with funding from home country (4 years of funding, estimated at $200,000)
2. Cihacek: Funding for this research has been obtained from the North Dakota State Board of Agricultural Research and Extension (SBARE) corn, soybean and wheat commodity committees as well as the ND Corn Council, ND Soybean Council, and ND Wheat Commission and USDA-NRCS.
3. Dou: Rice varietal evaluation, ratoon and nutrient management improvement for Texas production practices. Texas Rice Research Foundation. 2020-2022. $56,280.

4. Golabi: 2021 – 2023. Application of biochar-based amendments in boosting soil fertility and crop disease resistance in the porous soils of northern Guam. PI: Mohammad H. Golabi, NIFA ($110,000).
5. Jagadamma: Demonstrating the impacts of cover crops for soil health and farm profitability in Tennessee. PI: Jagadamma, S; Co-PIs: Walker, F., Singh, S., Duncan, L., McClure, M., Upendram, S. Tennessee Department of Agriculture, 10-2019 to 09-2023 ($341,493). On-going
6. Jagadamma: Optimizing plant-soil-microbial interactions through crop diversification to enhance sustainability in southeastern croplands. PI: Jagadamma, S; Co-PIs: Lee, J., Duncan, L.A., McClure, A., Raper, T.B., Kivlin, S. USDA-NIFA Foundational Program, 09-2020 to 08-2024 ($500,000). On-going
7. Jagadamma: Row crop production under climate change – assessment of sustainable management practices and soil additives in sand deposited fields. PI: Lee, J; Co-PI: Jagadamma, S. USDA-Agricultural Research Service, 09-2020 to 08-2021 ($103,704).
8. Lal: Funding support have been obtained from international organizations in support of this work through visiting scholars, Fulbright scholars, and the Borlaug award.
9. Noormets: "Grazing management effects on soil health, the delivery of ecosystem services and economic profitability on cattle ranches in the Southern Plains" 09.2020-08.2023 (Kreuter, Noormets, Smith), USDA NIFA, $500,000.
10. Noormets: Borlaug International Fellowship to incoming PhD student Benju Baniya. $24,400. Renewable for 2 more years.
11. Noormets: Johnson-Aviles Fellowship to incoming PhD student Chali Simpson. $69,000.
12. Noormets: Lehner Scholar Grant Chali Simpson. $1500.
13. Noormets: Personal Development Grant to Chali Simpson. $1000.
14. Osterloh: $514,000 for a project examining the extent of erosion in the last century caused by agricultural use, as well as an educational outreach exhibit on soil conservation.
15. Osterloh: $167,000 for purchase of a PXRF and a project to examine the use of PXRF in rapidly assessing saline soils.
16. Xu: Xu, S., Zilverberg, C., Bauder, S. Midwest Forage Association: Impacts of C3/C4 Cover Crop Mixtures on Productivity, Forage Quality, and Soil Health in Livestock-Cropping Systems. $5,000.
17. Zhu: Nitrogen Limitation in High-Elevation Hay Meadows: Understanding Processes for Improved Agroecosystem Health, Function, and Management, PD: Jay Norton; Co-PDs: Mengqiang Zhu, Linda Van Diepen, and Ursula Norton. ARFI 2021-67020-33422 (Renewable Energy, Natural Resources, and Environment: Agroecosystem Management), $499,985, 2021 – 2024.

Multistate synthesis and integration: It was resolved at the annual meeting that the members will produce a review on crop residue management and soil C dynamics. A tentative outlet for the paper is *Journal of Soil and Water Conservation*.

Publications

1. Abramoff RZ, Georgiou K, Guenet B, Torn MS, Huang Y, Zhang H, Feng W, Jagadamma S, Kaiser K, Kothawala D, Mayes MA, Ciais P (2021) How much carbon can be added to soil by sorption? *Biogeochemistry* 152: 127-142.
2. Ademola AA, Rahman S, Cihacek L, Nahar N (2020) Comparison of the reactor performance of alkaline-pretreated corn stover co-digested with dairy manure under solid state. *Waste and Biomass Valorization* https://doi.org/10.1007/s12549-020-01116-z
3. Aguilos M, Sun G, Noormets A, Domec JC, McNulty SG, Gavazzi MJ, Prajapati P, Minick K, Mitra B, King JS. 2021. Water use efficiency of managed loblolly pine is stable over the length of the rotation despite varying environmental conditions. *Forests* 12: 1123. http://doi.org/10.3390/f12081123
4. Al-Kaisi MM, Lal R (2020) Aligning Science and Policy of Regenerative Agriculture. *Soil Science Society of America Journal.* https://doi.org/10.1002/saj2.20162
5. Amorim HCS, Ashworth AJ, Moore PA, Weinhold BJ, Savin MC, Owens PR, Jagadamma S, Carhalho TS, Xu S (2020) Soil quality indices following long-term conservation pasture management practices. *Agriculture, Ecosytems & Environment* 301: 107060.
6. Chang K-Y, Riley WJ, Knox SH, Jackson RB, McNicol G, Poulter B, Aurela M, Baldocchi D, Bansal S, Bohrer G, Campbell DI, Cescatti A, Chu H, Delwiche KB, Desai A, Euskirchen E, Friborg T, Goeckede M, Helbig M, Hemes KS, Kang M, Keenan T, King JS, Krauss KW, Lohila A, Mammarella I, Mitra B, Miyata A, Nilsson MB, Noormets A, Oechel W, Papale D, Peichl M, Reba ML, Rinne J, Runkle BRK, Ryu Y, Sachs T, Schäfer KVR, Schmid HP, Shurpali N, Sonnentag O, Tang ACI, Torn MS, Trotta C, Tuittila E-S, Ueyama M, Vargas R, Vesala T, Windham-Myers L, Zhang Z, Zona D (2020) Substantial hysteresis in temperature sensitivity of global wetland methane emissions. *Nature Communications*: (In press, 2021-3-15)
7. Chatterjee A, Filipe de Jesus A, Goyal D, Sigdel S, Cihacek LJ, Farmaha B, Jagadamma S, Sharma L, Long DS (2020) Temperature sensitivity of denitrification, volatalization, and nitrogen mineralization of agricultural soils across the United States. *Open J. Soil Sci*. 10: 298-305. https://doi.org/10.4236/ojss.2020.107016
8. Chu H, Luo X, Ouyang Z, Chan WS, Dengel S, Biraud SC, Torn MS, Metzger S, Kumar J, Arain MA, Arkebauer TJ, Baldocchi D, Bernacchi C, Billesbach D, Black TA, Blanken PD, Bohrer G, Bracho R, Brown S, Brunsell NA, Chen J, Chen X, Clark K, Desai AR, Duman T, Durden D, Fares S, Forbrich I, Gamon JA, Gough CM, Griffis T, Helbig M, Hollinger D, Humphreys E, Ikawa H, Iwata H, Ju Y, Knowles JF, Knox SH, Kobayashi H, Kolb T, Law B, Lee X, Litvak M, Liu H, Munger JW, Noormets A, Novick K, Oberbauer SF, Oechel W, Oikawa P, Papuga SA, Pendall E, Prajapati P, Prueger J, Quinton WL, Richardson AD, Russell ES, Scott RL, Starr G, Staebler R, Stoy PC, Stuart-Haëntjens E, Sonnentag O, Sullivan RC, Suyker A, Ueyama M, Vargas R, Wood JD, Zona D (2020) Footprint Representativeness of Eddy-Covariance Flux Measurements Across AmeriFlux Sites. *Agricultural and Forest Meteorology*: https://doi.org/10.1016/j.agrformet.2021.108350
9. Das A, Layek J, Idapuganti RG, Basavaraj S, Lal R, Rangappa K, Yadav GS, Babu S, Ngachan S (2020) Conservation Tillage and Residue Management Improves Soil Properties under

an Upland Rice–Rapeseed System in the Subtropical Eastern Himalayas. *Land Degradation & Development* 31, no. 14 (August 30): 1775–1791. https://doi.org/10.1002/ldr.3568

10. Davis RL, Greene JK, Dou F, Jo YK, Chappell TM (2020) A practical application of unsupervised machine learning for analyzing plant image data collected using unmanned aircraft systems. *Agronomy-BASEL* https://doi.org/10.3390/agronomy10050633
11. de Oliveira Ferreira A, de Moraes SJC, Lal R, Amado TJC, Inagaki TM, Briedis C, Tivet F (2020) Can no-till restore soil organic carbon to levels under natural vegetation in a subtropical and tropical typic quartzipisamment? *Land Degrad. Dev*. 2020; 1– 9. https://doi.org/10.1002/ldr.3822
12. De M, Riopel JA, Cihacek LJ, Lawrenko M, Baldwin-Kordick R, Hall SJ, McDaniel MD (2020) Soil health recovery after grassland restoration. Evidence from a 40-year chronotoposequence. *Soil Sci. Soc. Am. J.* 84:568-586. https://doi.org/10.1002/saj2.200037
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14. Golabi MH, Galsim FP, Iyekar C (2020) Agronomic value of land application of composted organic waste to porous soil of northern Guam. *Malaysian Journal of Soil Sciences* https://doi.org/10.2489/jswc.75.2. 27a
15. Irvin J, Zhou S, McNicol G, Lu F, Liu V, Fluet-Chouinard E, Ouyang Z, Knox SH, Lucas-Moffat A, Trotta C, Papale D, Vitale D, Mammarella I, Avati A, Kondrich A, Ng A, Rey-Sanchez AC, Valach AC, Richardson AD, Kalhori A, Lohila A, Malhotra A, Noormets A, Desai AR, Mitra B, Runkle BR, Helfter C, Sturtevant C, Baldocchi D, Campbell DI, Lai DY, Zona D, Euskirchen E, Ward EJ, Stuart-Haëntjens E, Bohrer G, Jurasinski G, Vourlitis GL, Wong GX, Chu H, Iwata H, Dalmagro HJ, Chen J, Delwiche KB, Hemes KS, Schäfer KV, Merbold L, Aurela M, Nilsson MB, Goeckede M, Helbig M, Heimann M, Peichl M, Ueyama M, Sonnentag O, Alekseychik P, Vargas R, Bansal S, Feron S, Hirano T, Jacotot A, Sakabe A, Varlagin A, Wille C, Szutu DJ, Billesbach DP, Schuur EA, Nemitz E, Tuittila E-S, Parmentier FJ, Koebsch F, Celis G, Dolman H, Verfaillie JG, Goodrich JP, Fuchs K, Kasak K, Ono K, Hörtnagl L, Alberto MCR, Gondwe MJ, Gottschalk P, Oikawa PY, Sullivan RC, Maier R, Shortt R, Gogo S, Friborg T, Morin TH, Sachs T, Oechel WC, Windham-Myers L, Poulter B, Jackson RB (2021) Gap-filling eddy covariance methane fluxes: Comparison of machine learning model predictions and uncertainties at FLUXNET-CH_4 wetlands. *Agr Forest Meteorol* 308-309: 108528. https://doi.org/10.1016/j.agrformet.2021.108528
16. Jahromi NB, Lee J, Fulcher A, Walker F, Jagadamma S, Arelli P (2020) Effect of biochar application on quality of flooded sandy soils and corn growth under greenhouse conditions. *Agroecosystems, Geosciences & Environment* 3(1): e20028.
17. Lal R (2020) Managing Organic Matter Content for Restoring Health and Ecosystem Services of Soils of India. *Journal of the Indian Society of Soil Science* 68 (1): 1-15. http://doi.org/10.5958/0974-0228.2020.00001.8

18. Lal R (2020) Soil Organic Matter and Water Retention. *Agronomy Journal* 112: 3265–3277. https://doiorg.proxy.lib.ohio-state.edu/10.1002/agj2.20282
19. Lal R (2020) Soil organic matter content and crop yield. *J. Soil Water Conserv*. 75: 27A-32A.
20. Li X, Dou F, Guo J, Velarca MV, Chen K, Gentry T, McNear D (2020) Soil microbial community responses to nitrogen application in organic and conventional rice (*Oryza sativa* L.) production. *Soil Science Society of America Journal*, 84, 1885-1997
21. Li X, Dou F, Watkins K, Wang S, Chen X, Zhou X, McClung A, Storlien J, Hons FM (2020) Seeding rate effects on organic rice growth, yield, and economic return. *Agronomy Journal*: 5, 1-16. https://doi.org/10.1002/agj2.20304
22. Lin W, Noormets A, King JS, Marshall J, Akers M, Cucinella J, Fox T, Laviner M, Martin T, McNulty S, Meek C, Samuelson L, Sun G, Vogel J, Will R, Domec J-C. 2021. Spatial variability in tree-ring carbon isotope discrimination in response to local drought across the entire loblolly pine natural range. *Tree physiology*: (In press 2021-07-21).
23. Littrell J, Xu S, Omondi E, Saha D, Lee J, Jagadamma S (2021) Long-term organic management combined with conservation tillage enhanced soil organic carbon accumulation and aggregation. *Soil Science Society of America Journal.* https://doi.org/10.1002/saj2.20259. (in press)
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