Croplands Research Group Meeting

Online

19 January 2022

Meeting Report

OVERVIEW

The thirteenth meeting of the Croplands Research Group (CRG) of the Global Research Alliance on Agricultural Greenhouse Gases (GRA) was held 19 January 2022. The GRA meeting was chaired by USA (Dr Mark Liebig, USDA-ARS), Spain (Prof. Rosa Mosquera-Losada, University of Santiago de Compostela) and Brazil (Dr Ladislau Martin, Embrapa) as Co-Chairs of the Group.

This report is a summary of the key discussions and outcomes of the online meeting. Presentations pre-recorded for this meeting may be viewed in the resource library on the GRA website (https://globalresearchalliance.org/library/croplands-research-group-annual-meeting-presentations-2022/) and links to individual videos are provided throughout this document. The full meeting recording can be viewed here.

PARTICIPANTS

The meeting was attended by 36 participants, representing 15 GRA member countries, and invited experts.

- **GRA Members attending:** Argentina, Brazil, Canada, China, Denmark, Indonesia, Ireland, Japan, New Zealand, Poland, Republic of Korea, Senegal, Spain, UK, USA

MEETING OUTCOMES

The meeting achieved the following outcomes:

- Increased awareness among meeting attendees regarding 2021 accomplishments associated with CRG networks, research activities, capacity building, outreach and education, and select participating countries.
- Documentation of mitigation co-benefits associated with GHG mitigation practices for five CRG research networks (i.e., agroforestry, conservation agriculture, integrated crop-livestock systems, nutrient management, peatland management).

SUMMARY OF DISCUSSIONS

WELCOME

1. Mark Liebig opened the meeting and welcomed the participants on behalf of the CRG Co-Chairs. Mark highlighted that the registrations for the meeting covered 19 countries across the globe. The agenda was reviewed and noted that the timings were flexible.

SECRETARIAT UPDATE

2. The GRA Secretariat provided an update to the Group on the main activities of the GRA since the 2020 CRG meeting, including new Members and Partners. The GRA has 65 Member Countries, with Cuba joining most recently in mid-2021. The GRA now works with 24 Partner organisations. The GRA continues to work via 4 research groups and 17 science networks. The number of staff supporting the Secretariat has increased in the past year, both in NZ (where the Secretariat is based) and in Europe and Africa.

3. Achievements from across the GRA this year include:

- Adoption of new 2021-2025 Strategic Plan at 2021 GRA Council Meeting (March 2021) and annual Operational Plan.
- Involvement in ERA-NET Circularity and EJP Soil research calls to provide funding to support participation from GRA member countries (outside of Europe). A second EJP Soil call is expected in 2022. The GRA is currently involved in the discussions about topics.
- GRA working with FONTAGRO (https://www.fontagro.org/en/) in Latin America to support their work and ensure alignment with GRA priorities.
- Building global recognition by supporting / partnering with the Global Action Agenda for Innovation in Agriculture (https://www.climateshot.earth/action-agenda) and Agricultural Innovation Mission for Climate (AIM4C; https://www.aimforclimate.org/). Both of these initiatives are looking to increase funding and investment in agriculture related to climate.

4. The next GRA Council Meeting will be held 21-23 February 2022 in a virtual event, hosted by Chile as the incoming Council Chair. Chile’s priority areas are (i) integration between research and innovation and (ii) challenges posed by small holder production. Proposed GRA Flagship Projects will be presented at the Council Meeting. Contact the Secretariat for more information about Flagship Project criteria and the approval process.

NETWORK, ACTIVITY & SPECIAL PUBLICATION UPDATES

CRG NETWORKS

5. Three of the six Networks provided an update of activities to the Group ahead of the meeting and responded to questions during the live session.

Conservation Agriculture Network - Craig Drury, Agriculture and Agri-Food Canada

6. The Conservation Agriculture (CA) Network has 19 members from 7 countries. The main accomplishment since the last meeting was editing and publishing a special section in the Soil Science Society of America Journal (SSSAJ) titled “The Role of Conservation Agricultural Practices on Reducing Greenhouse Gas Emissions and Enhancing C Sequestration”. The section comprised 10 peer-reviewed papers. The CA practices included: conservation tillage, crop rotations, cover crops and residue management.

7. On-going work is dealing with a meta-analysis of CA practices to mitigate N_2O emissions. This is being conducted by Diego Abalos (Aarhus University) and a PhD student.

8. Exploring the possibility of a meta-analysis of CA practices related to nutrient management strategies. Investigating how this topic might fit into a new N flagship project that is under development.

Landscape Management of Agricultural Systems - Xunhua Zheng, CAS

9. The LAMs Network has members from 5 countries (CN, GE, ES, FR, US).

10. Main focus of the network is the CNMM-DNDC model. This is a hydro-biogeochemical model, which is a DNDC family member with special features such as space distribution (3D) and customised resolutions. It has been developed for all land types and inland waters.

11. Since the last meeting, the model has been revised (v2 -> v3) to better facilitate catchment landscape simulation and this is being validated. The model has also been adapted to Linux to enable regional high-res 3D simulation. The model as been applied to high-res 3D simulations to evaluate (i) net land GHG balances of provinces and (ii) water quality management of a lake in a mega city in China.

12. Recently, a new 5-year (2022-26) NSFC-UNEP cooperative research project, with the CNMM-DNDC as the core model, has been granted (~USD$0.5M). The project is titled “Reduction Strategies and Decision-Supporting Tool for N_2O emissions from Cultivated Uplands in China and Kenya”.

13. Publications related to tool development:
   - Zhang et al., 2021, Agr. Ecosys. & Environ.
   - Zhang et al., 2021, Biogeosciences

14. Research priorities:
   - To test / validate CNMM-DNDC applicability
     - GRA members are all welcome to join in doing this
   - To further improve CNMM-DNDC functions

15. Capability priorities
   - To apply for cooperative research projects
   - To identify opportunities of cooperation with other groups
   - To apply for international students
   - To apply for international postdoc positions in universities of the institutes of CAS

16. Examples of the model application / validation in a range of catchment regions were shared.

Peatland Management Network – Fahmuddin Agus, ICALRD

17. Despite being a vulnerable ecosystem, peatland has been used for various agricultural crops. The government of Indonesia has banned the issue of new licenses for agro-industry on peatland. It's crucial to intensify management systems on existing agricultural land on peatland to increase yield and minimize environmental degradation.

18. Main activity since the last meeting has been initiating field activities of a 2020-2023 collaborative (ICRAF and Indonesian Soil Research Institute) project on "Improving the Management of Peatlands and the Capacities of Stakeholders in Indonesia (Peat-IMPACTS Indonesia)". (The start of this project was delayed due to the pandemic.) Objectives of the project include:

- Evaluating peat subsidence from forest, shrubland, plantation, and fire prone shrubland.
- Measuring the effects of water table fluctuation on CO_2 flux from oil palm plantation. Raising water table for prolonging the lifespan of peatland and reducing CO_2 emissions from decomposition (and peat fire).
- Results from research findings will be used for improving national and sub-national GHG Inventories from peatland.

19. Research opportunities:

- Project titled "Oil palm land use and management systems on peatlands for improving environmental and economic indicators". Funded by Palm Oil Plantation Fund, so not much room to expand project into other areas. Plus closes soon.
- Project titled "Improving crop nutrient management on peatland: Crop yield increase and GHG emissions reduction". Opportunities for collaborators to get involved.

CRG ACTIVITIES UPDATES

20. A summary of the updates of CRG activities that were provided ahead of the meeting and discussion from the meeting sessions is provided below in the Q&A section.

Global Research Alliance Modelling Platform (GRAMP) - Jagadeesh Yeluripati, James Hutton Institute

21. The aim of the GRAMP is to create an open web-platform for models to improve the predictions of soil C & N cycling in agro-ecosystems in the context of climate change. It offers the ability to track model genealogy and to provide tools to evaluate how models are changed over time and what modifications led to improved predictions.

22. GRAMP currently covers three model families. 1 - DNDC models, with its evolution and around 23 variants documented. 2 - ECOSSE and 3 - BASGRA model families. GRAMP has been under maintenance for the last few months and major upgrade is planned for this year. The site is expected to be fully active again by April 2022.

23. The networks established under GRAMP have led to the development of several projects. Last year the RETINA project was presented. Funding for a new project (SENSE) has recently been confirmed. The project will start in March 2022.

- Title: Synergies in integrated systems: Improving resource use efficiency while mitigating GHG emissions through well-informed decisions about circularity (SENSE), 2022 – 2025, funded by ERA-NET and co-funded with GRA (total budget: €1.4 million)
- Project involves 10 partner organisations, 7 in Europe and 3 in South America.

- Overarching objective: Develop integrated agriculture management approaches through increased circularity to support EU net zero emission targets.

Croplands Literature Database – Livia Olsen, Kansas State University

24. The Croplands Literature Database has existed for over 10 years, but a few years ago a collaboration with JournalMap (a website that maps journal articles onto the geographic locations where the research took place) was established. Funding provided by an Institute of Museum and Library Services (IMLS) grant facilitated the development of a prototype for a new JournalMap that can interact with external databases. Work was completed in August 2021.

25. New citations were added to Zotero in 2021, which will eventually be added to the Croplands Literature Database.

26. Moving forward, an application for another IMLS grant has been submitted which includes the University of Arizona as a collaborator. Outcome of round 1 of application will be known in early 2022.

MAGGnet – Mark Liebig, USDA-ARS

27. The Managing Agricultural Greenhouse Gases Network (MAGGnet) was established in 2012 and has a membership of 23 countries. The network seeks to compile metadata from experimental sites throughout the work where GHG fluxes and soil C dynamics are monitored (with published data). The data is used to help identify experimental sites with specific attributes for meta-analyses.

28. Data is compiled by way of a data entry template, with a focus on collecting metadata. The intention is that the data can be added in 15 minutes per site. This is facilitated by clear instructions, colour coded worksheets and lots of drop-down menus.

29. The compilation includes: 14 unique climate subdivisions, 11 surface soil textures, 23 countries, 381 experiments. Information about the early part of the project can be found here.

30. 2021 was a quiet year. No new submissions in the past year and official funding has ended. Less PI time is available to support this activity.

31. Going forward, there is an opportunity to make project meta-data accessible on a publicly available website such as figshare. Plus, it is probably time to hand over the reins to a new custodian who has the time to improve and expand MAGGnet. Mark is happy to be contacted by with anyone that may be interested in this role.

Q&A Discussion Session

32. CA Network: Highlights of the Conservation Agriculture Network's special section discussed and editors commended.

33. LMAS network: Are other models being considered for evaluation alongside the CNMM-DNDC model? A number of landscape models have been compared (work involved one of the modellers in the network) and this has been published. The model being used is nearly ready for wide scale validation, and GRA members are welcome to help to apply it in different situations around the work. Contact the network if interested in collaboration. The UK are starting a new project in this area and may be interested. Note: GRAMP covers evolution of the DNDC models (and others).

34. New SENSE project ("Synergies in integrated systems: Improving resource use efficiency while mitigating GHG emissions through well-informed decisions about circularity"), which involves a number of GRA member countries was highlighted. This came out of the ERA-NET Circularity call. The GRA acted

as a funder in this case (allocating NZ government funds). If other countries would like to provide funding to facilitate wider cooperation, please contact the GRA Special Representative.

CAPACITY BUILDING, OUTREACH AND EDUCATION UPDATES

Education and Outreach Activities - Ayaka Kishimoto-Mo & Nuria Ferreiro Dominguez

35. Three webinars were held in 2021:

- March 2021 - "Global soil organic carbon sequestration potential map. The Argentinian case." Dr Marcelo Javier Beltran, Argentina.
- May 2021 – "Full inversion tillage in mixed crop/pasture systems to sequester soil C and reduce the risk of N_2O emissions." Dr Mike Beare, New Zealand.
- December 2021 – "Mediterranean agroforestry and climate change". Dr Anastasia Pantera, Greece.

36. CRG newsletter is published every three months. Circulated to around 2,500 subscribers. Sign up to receive the newsletter here. In 2021, news and events were publicised from 10 different countries. All suggestions and news articles are welcome. Please contact the editors if interested in submitting an article.

37. There is an increasing number of followers on the CRG Facebook page. Webinars get the most attention. It would be great if attendees could like the FB page, post "getting to know you" posts, post/share new publications and new findings from your country (bilingual if possible), and react to posts/shares.

38. Twitter followers are also growing. Page started in Nov 2019. Planning to increase Twitter activity. Attendees are requested to follow the group and retweet CRG tweets, tag the CRG into any interesting news/publication, and share tweets that the CRG account could retweet.

Q&A Discussion Session

39. Summary of recent activities. Webinars have been very well received and thanks to those in Spain for leading these. Good platform to be able to talk about emerging and interesting research to an international audience. If group members are interesting in presenting their work, please contact Rosa Mosquera-Losada.

40. Related to capacity building, Round 5 of the CLIFF-GRADS programme will be opening in 2022. Will be looking for hosts for the students. If members have projects running over the two years which could host a visiting PhD student for 6 months, please consider putting in an expression of interest.

41. The GRA also has a relationship with RUFORUM, which is a platform of over 100 African Universities. RUFORUM has a masters level scholarship scheme, and there are about 20 masters students across Africa focussing on livestock related GHG research currently. There could be an opportunity to set up a call for masters projects for croplands research, pending available funding. About US$80k is needed for 2 masters and 4 undergraduates to be supervised for 2 years. Contact the GRA Special Representative if this is of interest.

42. University of Santiago de Compostela has an international PhD programme which brings in students from a wide number of countries. This is also relatively low cost and a good way to involve other regions in research and to increase collaboration.

COUNTRY UPDATES

43. Countries provided an update on national research activities prior to the meeting, either as a pre-recorded presentation or slides. These updates can be viewed on the meeting webpage, and summaries are provided below.

Argentina – Marcelo Javier Beltrán, INTA

44. Activities/Accomplishments since last meeting:

- Webinar about the global SOC sequestration potential map and the Argentinian case in March 2021.
- Presentation of national project information about climate change mitigation in the GRA newsletter.
- One Argentinian student is currently in Spain with a GRA CLIFF-GRADS scholarship. Next year Argentina will host two CLIFF-GRADS students from Zimbabwe and Brazil.
- Analysis of the IPCC Tier 2 steady state soil carbon method under different cropland scenarios. Nitrous oxide emissions estimation from managed soils in Argentina: differences between IPCC 2006 guidelines and the 2019 refinement.
- Next year Argentina will be involved in the part-GRA funded SENSE circularity project.

45. Research opportunities in measurement and modelling of (i) SOC sequestration and (ii) GHG emissions from different agricultural practices.

46. Capability opportunities related to (i) the SENSE project and (ii) a national project about the measurement of nitrous oxide emissions from different N fertilisers.

Brazil - Ladislau Martin-Neto, Embrapa

47. Activities/Accomplishments since last meeting:

- Closing of first period of Brazilian Agricultural Low Carbon Plan 2010-2020 (ABC Plan), devoted to stimulating farmers' adoption of 6 eligible agricultural practices such as: no-tillage, integrated crop-livestock-forest systems and agroforestry, biological nitrogen fixation, pasture recovery, planted forest and animal residues management. Financial stimulus is mainly lower loan interest rate (not subsidy).
    - Mitigation of 170 Mi ton CO_{2eq} (higher than goal proposed initially).
- New period of plan (ABC+) was launched in 2021 increasing the eligible activities to 8. This period has a mitigation goal (2030) of 1.1 Bi ton CO_{2eq} (72 Mi ha involved).
- Embrapa's Climate Change portfolio has 33 on-going projects related to mitigation, adaptation and forecasting impacts in agriculture. Embrapa Beef Cattle was the main organiser of the II World Congress on Integrated Crop-Livestock-Forest Systems in May 2021 (>500 participants).
- FAPESP's Climate Change Program – Strategic Plan 2020-2030 was launched in 2021 with opportunities for international cooperation in themes of mutual interest.

- Brazil is involved in the SENSE project with seven research centres from Embrapa contributing to the project (funded by the GRA).
- Growing interest of private corporations (companies, agricultural associations) regarding neutral carbon products and agricultural production systems. Croplands, integrated systems (crop-livestock-forest), and livestock are the current main interests. Some partners who are involved in project cooperation with Embrapa include: Bayer (emphasis in crop production system), Brazilian Cotton Farmers Association, Nestle (milk), Marfrig (Brazilian meat industry), and others. New partners are interested in GHG mitigation and carbon markets with support to soil carbon stocks, new analytical tools, life cycle assessment (LCA) and other topics.

48. Research opportunities:

- Adaptation and resilience of agricultural production systems with higher economic impact and importance to food security using climate change scenarios.
- To establish a digital and integrated platform for large scale monitoring of C and N stocks and GHG emissions of relevant production agricultural systems

49. Capability opportunities:

- Digital Agriculture Opportunities Applied to Climate Change Context
- Challenges to Expand and Consolidate a Soil Carbon Credits Market

Germany – Heinz Flessa, Thünen Institute of Climate-Smart Agriculture

50. General political developments in Germany since last meeting:

- Revision of the federal climate change act 5/2021. More ambitious emission reduction targets. Agriculture emissions have to be reduced from 70 mio t CO_{2eq} in 2020 to 56 mio t CO_{2eq} in 2030.
- New government in Germany: Ministers from the green party in the Federal Ministry of Food and Agriculture and in the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection. → joint transformation of agriculture production and human nutrition towards more sustainability

51. Research and Capability priorities:

- New N_2O emission factors for nitrogen fertilizer inputs (synthetic and organic) to agricultural soils: Mathivanan GP, Eysholdt M, Zinnbauer M, Rösemann C, Fuß R (2021) New N_2O emission factors for crop residues and fertiliser inputs to agricultural soils in Germany. Agric Ecosyst Environ 322:107640
- New project: German peatland monitoring program for climate protection (Thünen Institute, running until 2025, large project with a team of 15 people).
- The Thünen Institute will be involved in projects related to (1) carbon farming (EJP-Soil: "Road4Schemes") and (2) Biochar as negative emission technology (contact: Leonardo Amthauer Gallardo).
- Recent research call supported by the German Federal Ministry of Food and Agriculture (7/2021): "Climate friendly nitrogen management in crop production". The call is now closed and the proposals and all applicants are waiting for the decision.
    - Key topics: i) reduction of NH_3 and N_2O emission in crop production, ii) effect of nitrification inhibitors on annual N_2O emission and ecotoxicological effects of

long-term application of inhibitors, iii) Reducing nitrogen losses by denitrification.

- German researchers have shown their interest to participate in the proposed GRA flagship project "Optimising the use of nitrogen fertiliser, more production and less environmental impact (N4R)".
- Dr. Andreas Meyer-Aurich (Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Germany) is the guest editor of the Special Issue on "Greenhouse Gas Mitigation in Agriculture" in the journal "Agriculture" → GRA researchers are invited to submit their papers to the journal with a 15% discount of the regular publication fee:
    - Submission deadline: 20 May 2022
    - If you are interested, please contact the journal office (Ms. Miguel Zhou, miguel.zhou@mdpi.com) to ensure that you will get the mentioned discount
    - More information on the Special Issue.

South Korea – Sun-Il Lee, National Institute of Agricultural Sciences, RDA

52. Activities/Accomplishments since last meeting:

- South Korea declared it's Carbon Neutral Strategy in Dec 2020. It has a mitigation plan for the agricultural sector to 2050 that includes: Smart farms, Low carbon agricultural technology. Eco-friendly energy and Consumer participation for policy (e.g. reduction of food waste).
- 2021 P4G Seoul Summit in May 2021 included the "Agricultural Technology Innovation for Carbon Neutrality by 2050" international symposium. Presentation by GRA representative at meeting.
- New carbon neutrality law in South Korea (Sept 2021) and country joined the Global Methane Pledge (Oct 2021).
- Stronger 2030 NDC target to 40% (Oct 2021).
    - National GHG emissions: 727.6 MT (2018) -> 436.6 MT (2030)
    - Agricultural sector GHG emissions: 24/7 MT (2018) -> 18.0 MT (2030)
        1. Water management technology in paddy
        2. Reduction of N fertiliser use in cropland
        3. Biochar use for carbon sequestration in cropland
    - 7 research projects looking at voluntary technology use

53. Research and capability opportunities:

- Agricultural climate change response project, 2020-2027, $170 M. Collaboration possibilities in the areas of: biochar, GHG modelling, water management (paddy), etc.
- 8th International Symposium on Soil Organic Matter coming up in June 2022.
- RDA welcomes graduate students for international internships.
- RDA has Official Development Assistance (ODA) R&D initiatives working on continent-specific issues. 3 FACIs and KOPIA.
    - Asia (AFACI), Korea – Africa (KAFACI), Korea – Latin America (KOLFACI) and a bilateral cooperation program (KOPIA)

New Zealand – Mike Beare, Plant & Food Research

54. Research Projects relevant to the CRG:

- NZ GRA funding has been provided for developing countries and/or to support NZ-based researchers in the EJP Soil – Soil Carbon Research Call 2021 (6 projects) and the Crop-Livestock Circularity Call 2021 (4 projects). (High level project details on slides).

55. Other research projects and capability building activities relevant to the CRG:

- SLMACC projects – 2022 funding round may include projects of relevance to CRG
- Sustainable Food & Fibre Futures Projects – New soil N test methods to improve N fertiliser forecasting
- FONTAGRO project in Latin America on soil C research
- Greenhouse Gas Inventory Research projects – project to develop nitrous oxide emission factors from fertiliser
- On-going capability building activities
    - CLIFF-GRADS programme – 6 month research visits for PhD students. Round 5 will open in 2022.
    - NZ GRADS – PhD scholarships for developing country students in NZ

USA – Mark Liebig, USDA-ARS

56. Both direct contributions to the CRG (RG Co-Chair, scientist participation in networks and the Literature Database maintained by Kansas State University) and aligned contributions (providing research and engaging with stakeholders, especially via the USDA agencies) have been made by the USA.

57. USDA agencies aligned work in the past year includes:

- New NIFA funded projects for 2021 at Auburn University (plant nutrient responses to rising CO_2 in the atmosphere) and UC Davis (accelerating wheat improvement to mitigate the impacts of climate change). Total value ~$3.6 M.
- ARS held a series of workshops in 2021 on "Achieving GHG-Neutral Agroecosystems" over 4 weeks. Aim is to develop a new research strategy which will be ready to share in 2022.
- Aligned efforts within NAL and NRCS include data resources, e.g. AgCROS, which is a network of networks hosting agricultural research databases, and Climate Hubs, which provide region-specific information to stakeholders to enable climate-informed decision-making.

58. Research Opportunities:

- Evaluate the efficacy of soil health strategies to enhance GHG mitigation and adaptive capacity. Strategies that seem to resonate with producers include maintaining soil cover, continuous living roots, livestock integration, increased plant diversity, and minimizing soil disturbance.

59. Capability Opportunities:

- NIFA – Agriculture and Food Research Initiative has various programs (LINK) and a Centre for International Programs (LINK)
- ARS – has hosted CLIFF-GRADS and has a postdoc program.

- FAS – Borlaug Fellowship Program provides opportunities for mid-career scientists (LINK)
- National Academies of Science has US-AID partnerships (PEER) (LINK)

Q&A Discussion Session

60. If any other members would like to provide a meeting report following the meeting, these will be most welcome and can be added to the meeting webpage to be shared with the group.

61. From the country updates presented, there is growing government and private company interest in, and commitment to, carbon neutrality globally. Engagement with the farming sector seems to be increasing and there is motivation to work with researchers. Agriculture is facing a wide range of environmental issues, floods, etc. There needs to be planning to address these challenges. There is an appetite to work collaboratively and there are some big projects starting up. The GRA is well placed to get involved in these and to support the implementation of better agricultural practices to mitigate GHGs and reduce environmental impacts.

62. Discussion about what a good "carbon-neutral" system looks like in a developing country. In countries such as Indonesia, which is still intensifying agriculture, chemical use etc is also increasing. In Brazil, there is a low carbon plan with 8 recommended actions including alternatives to chemicals. Also, life cycle analysis is being evaluated for Brazilian agroecosystems.

63. Verbal country update from Spain: In the past year they have published 16 papers, attended 17 conferences, and are currently preparing a paper related to climate-neutrality. In Europe there is a new CAP (common agricultural policy). The aim of the EU is to have climate neutrality by 2050. Some interim targets including 25% ha of farmland in EU must be under organic farming by 2030. A group including representatives from 28 countries have been working together on agroecology.

64. Reducing agricultural GHGs is challenging given the prevalence of non-CO_2 gases from cropland coupled with the need to increase food production. Therefore, we need to focus on optimising farming processes and consider carbon offsetting and sequestration options. Whether a sustainable intensification or extensive regenerative agriculture path is taken, we must remember there are trade-offs involved in both approaches. In the UK, for example, there is limited ability for agricultural soils to sequester carbon. In this case, land use change, afforestation etc, can be considered from an environmental perspective, but these options limit food production capacity. There is a complex set of challenges related to achieving net zero. Over next few years the UK is working to understand what their best pathways to net zero agriculture look like. It's unfortunately not an option to "have it all". Most countries will need to approach net zero on a pathway somewhere in between the fully intensive / extensive extremes.

65. Large farming companies are also interested in working with researchers to look at their carbon footprints and seeing how they can reduce it.

66. Work has been done in India looking at zero budget natural farming (ZNBF) system. In general, input costs have been increasing and profits decreasing. Farmers were keen to use more locally available organic material to apply to their crops so that there are no external inputs to their system. Therefore, profits increase even though output might decrease slightly. Project running over next 3 years and will reach out to 3 M farmers. Paper in Nature Sustainability about this work. Good for decreasing GHGs, but also multiple other benefits including increasing biodiversity as no longer using pesticides etc. Yield decrease of about 10%. However, there is about 30% of food wastage in general in the food system in India. Need to look at the system in a more holistic way. More of the grain produced in the ZNBF system

makes it to the food chain as it is more resilient during processing. A range of factors at both the plot and system level need to be considered when considering changing agricultural production methods.

67. A group in the USA is currently developing a report on carbon-negative farming. Aiming to publish this in mid-2022.

MITIGATION CO-BENEFITS

PRESENTATION

68. "Co-benefits of Agricultural Mitigation of Greenhouse Gases" presentation by Prof. Chuck Rice.

- Keys to climate resilient agricultural systems include considering: soil health, less tillage: no tillage, intensifying systems (efficient use of water, nutrients and energy, and continuous cover), diversifying systems (crop rotations, cover crops, landscape management).
- Conservation Agriculture – restores soil carbon, conserves moisture, planting on the best date, improved soil fertility, saves fuel and labour, lowers machinery costs, reduces erosion, controls weeds, improves wildlife habit.
- Summary of the meta-analysis contained in the special edition (Nicoloso and Rice, 2021) presented.
- Further co-benefits of no-tillage agriculture, crop rotations and cover crops etc demonstrated. Slides accompany this report as Appendix 2.

69. Noted that many of the co-benefits can be region and context dependent (e.g., not possible to double-crop in the UK). In the US and some South American countries the best crop rotation can be a 5-7 year long.

70. Discussion about whether the economics of different cover crops have been studied. In this case, most of the work has been looking at the scientific benefits and 'feeding' the soil. However, if livestock are introduced into a system, the cover crops can be used for grazing / forage.

71. In Canada, cover crops provide benefits for soil health and reducing erosion etc, but there are some publications suggesting N_2O emissions might increase with cover crop use? Also, some studies show decreased emissions. It is challenging to know whether to recommend cover crops from an emissions perspective. Agriculture is a complex system, dependent on a range of factors. Need to think about rainfall and whether the system can be 'tweaked'. Policy makers would like prescribed practices which can be applied everywhere and that doesn't necessarily work. Need to have flexibility to match practices to the region and the soil.

72. Resilience is an emerging topic that researchers are interested in, but long-term studies are needed for investigations. Studies of greater than 30 years in the US can show different impacts compared to outcomes after 5 years. Long-term funding is required for this type of work.

73. How can we make payments to farmers to incentivise certain practices? This is a new challenge for the EU, where policy makers have pledged to reduce emissions from agriculture. In the US / South America, farmers who are implementing some of these practices are seeing benefits without getting associated government payments. There are US programmes related to planting cover crops and emerging private markets in this space. Need to quantify the economic benefits of the co-benefits we've been discussing. What do water-savings and more biodiversity mean in terms of dollars? There are a few

studies in this area, but it's not a key focus for scientists currently. Need to consider social barriers to implementing certain practices too.

74. One option for reducing N_2O emissions from cover crops would be to harvest them and use them for biogas or a livestock feed.

GROUP EXERCISE

75. Exercise introduced by Mark Liebig.

- What are mitigation co-benefits? "Outcomes that arise subsequently from GHG mitigation practices." Co-benefits can serve as additional motives in the design and implementation of GHG mitigation policies.
- GRA Operational Plan 2021-25 – Thematic Focus No. 3 - "Identification of co-benefits from reducing emissions, as a way to prioritise agricultural practices that also contribute to adaptation and other areas (e.g., air quality, water saving, productivity, etc.)"
- Goal of exercise is to stimulate discussion on mitigation co-benefits with the aim of identifying potential research opportunities. Using the current CRG network framework, identify GHG mitigation practices and then identify associated co-benefits and assign a confidence rating for these.

76. The exercise overview slides and completed group templates accompany this report as Appendix 3. The verbal report-outs from the five groups can be viewed starting here.

77. Hayden Montgomery provided an overview of a possible GRA Flagship Project related to N fertiliser. The aim is to improve emissions factors to align policy with practice. A large meeting was held at the end of 2021. A project is being developed by FONTAGRO and there in an open invitation for those that are interested to join subsequent discussions. Contact Hayden for further information.

78. The meeting was closed by the Co-Chairs and attendees were thanked for their time and participation.

MEETING ACTIONS

Action	By whom
Forum paper on carbon neutrality and the associated challenges proposed	TBC

APPENDIX 1: Participants list

Country	Attendees
GRA Member Countries	
Argentina	Mr Andres Said, Ministry of Agriculture Dr Marcelo Beltran, INTA (National Institute of Agropecuarian Technology) Dr Vanina Cosentino, INTA (National Institute of Agropecuarian Technology)
Brazil	Dr Beata Madari, Embrapa Dr Giampaolo Pellegrino, Embrapa Dr Ladislau Martin-Neto, Embrapa Dr Pedro Machado, Embrapa
Canada	Dr Craig Drury, Agriculture & Agri-Food Canada
China	Prof Xunhua Zheng, Institute of Atmospheric Physics, Chinese Academy of Sciences
Denmark	Dr Diego Abalos, Aarhus University Prof Lars Munkholm, Aarhus University
Indonesia	Dr Fahmuddin Agus, ICALRD Prof Oslan Jumadi, Universitas Negeri Makassar
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Japan	Dr Ayaka Kishimoto, NARO
New Zealand	Dr Mike Beare, NZ Institute for Plant and Food Research Dr Nilusha Ubeynarayana, Ministry for Primary Industries Ms Trish Ranstead, NZ Ministry for Primary Industries
Poland	Dr Magdalena Borzęcka, IUNG
Republic of Korea	Dr Sun-Il Lee, National Institute of Agricultural Sciences, RDA
Senegal	Dr Alioune Fall, Forum for Agricultural research for Africa (FARA) Dr Bassirou Sine, CERAAS/ISRA
Spain	Dr Francisco Javier Rodríguez-Rigueiro, University of Santiago de Compostela Dr Marisa Tello, INIA-CSIC Prof Maria Rosa Mosquera-Losada, University of Santiago de Compostela
UK	Dr Jagadeesh Yeluripati, The James Hutton Institute Dr Luke Spadavecchia, Defra
USA	Dr Charles Rice, Kansas State University Dr Jane Johnson, USDA-ARS Dr Mark Liebig, USDA-ARS
Secretariat: Mr Hayden Montgomery, GRA Special Representative Ms Ekaterina Bessonova, Ryan Institute NUI Galway | GRA Secretariat Ms Nina Grassnick, Thünen Institute | GRA Secretariat Ms Deborah Knox, GRA Secretariat Dr Heather Went, GRA Secretariat	

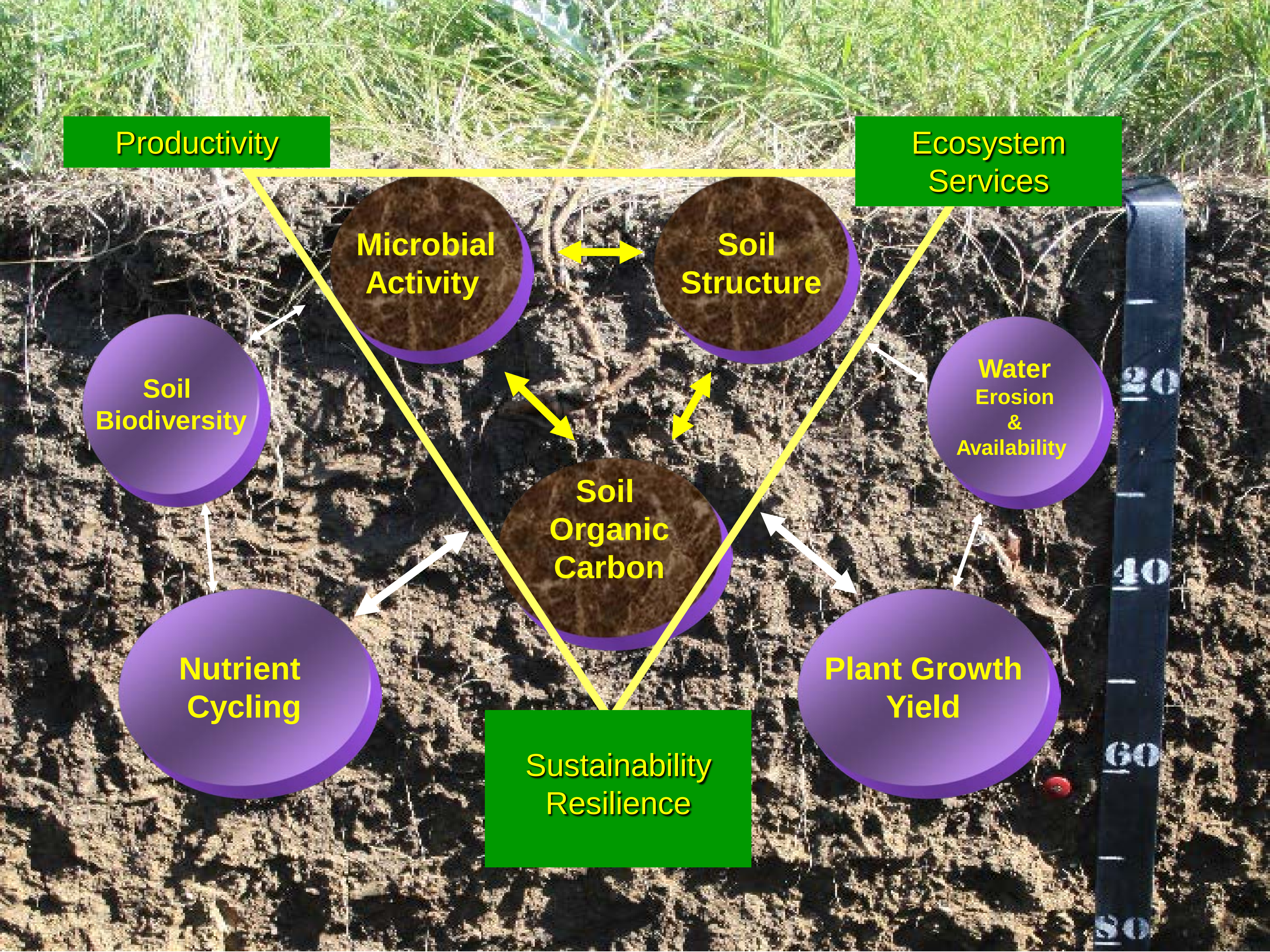
Co-benefits of Agricultural Mitigation of Greenhouse Gases

CHARLES W. RICE

University Distinguished Professor
Mary L. Vanier Professor
Soil Microbiology, Department of Agronomy

Chair, National Academies Board on Agriculture and Natural Resources

KANSAS STATE UNIVERSITY


Productivity
Ecosystem Services
Microbial Activity
Soil Structure
Soil Biodiversity
Water Erosion & Availability
Soil Organic Carbon
Nutrient Cycling
Plant Growth Yield
Sustainability Resilience
20
40
60
80

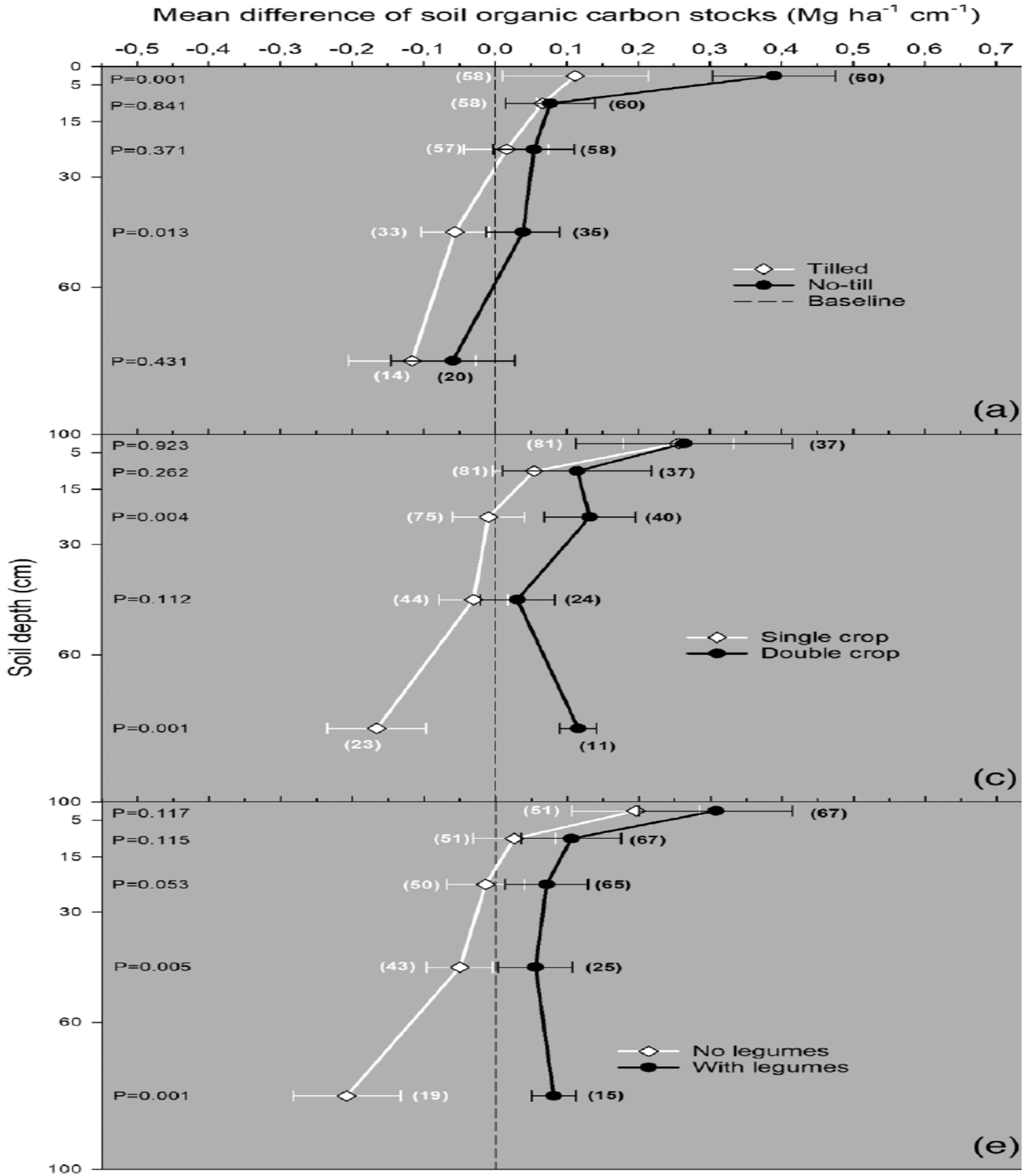
Keys to Climate Resilient Agricultural Systems

- Soil Health
- Less tillage: No-tillage
- Intensify Systems
  - Efficient use of water, nutrients, and energy
  - Continuous Cover
    - Double cropping
    - Cover crops

- Diversify Systems:
  - Crop rotations
  - Cover crops
  - Landscape management

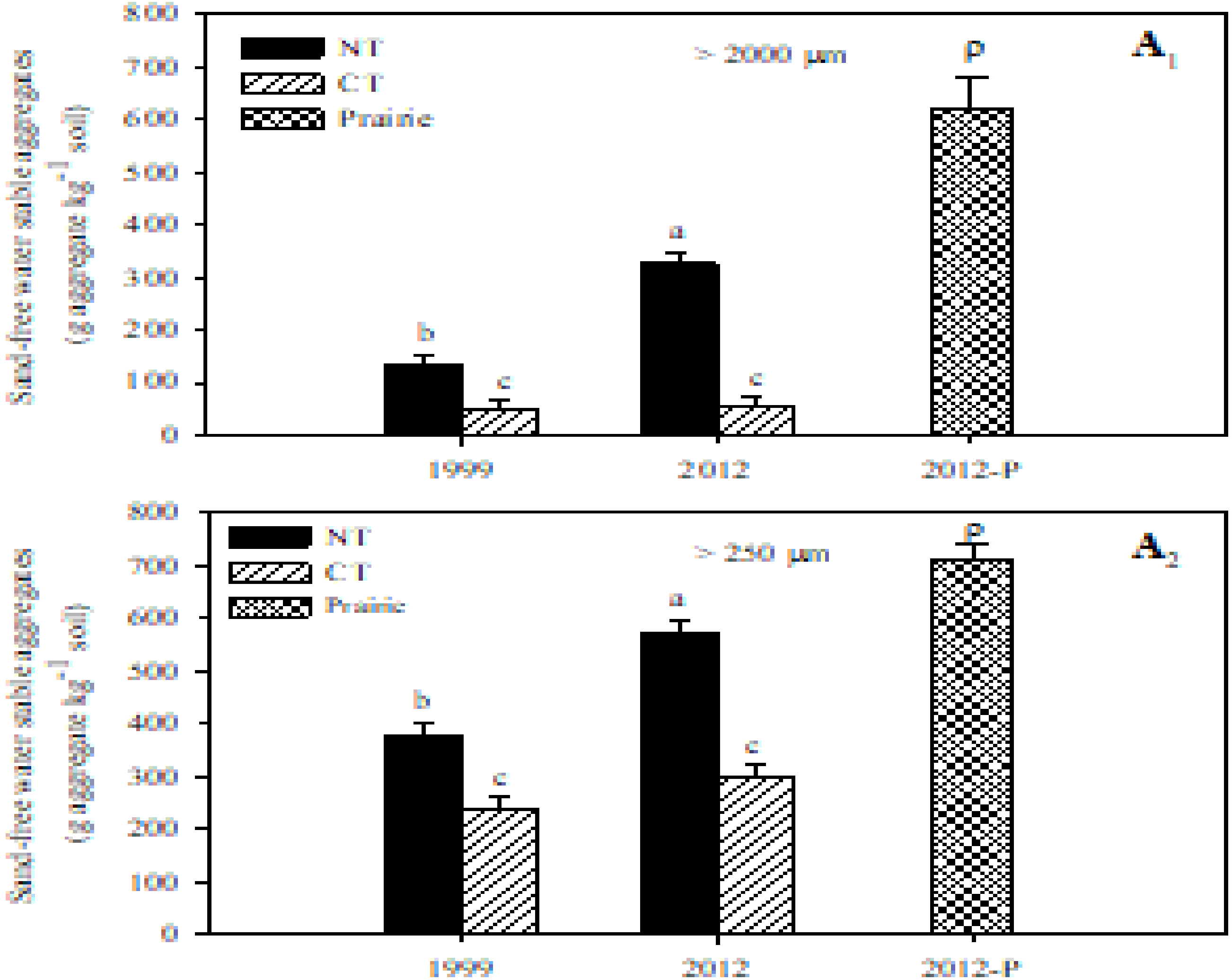
Conservation Agriculture

- **<u>Restores soil carbon</u>**
- **<u>Conserves moisture</u>**
- **<u>Planting on the best date</u>**
- **<u>Improved soil fertility</u>**
- Saves fuel
- Saves labor
- Lowers machinery costs
- Reduces erosion
- Controls weed
- Improves wildlife habitat



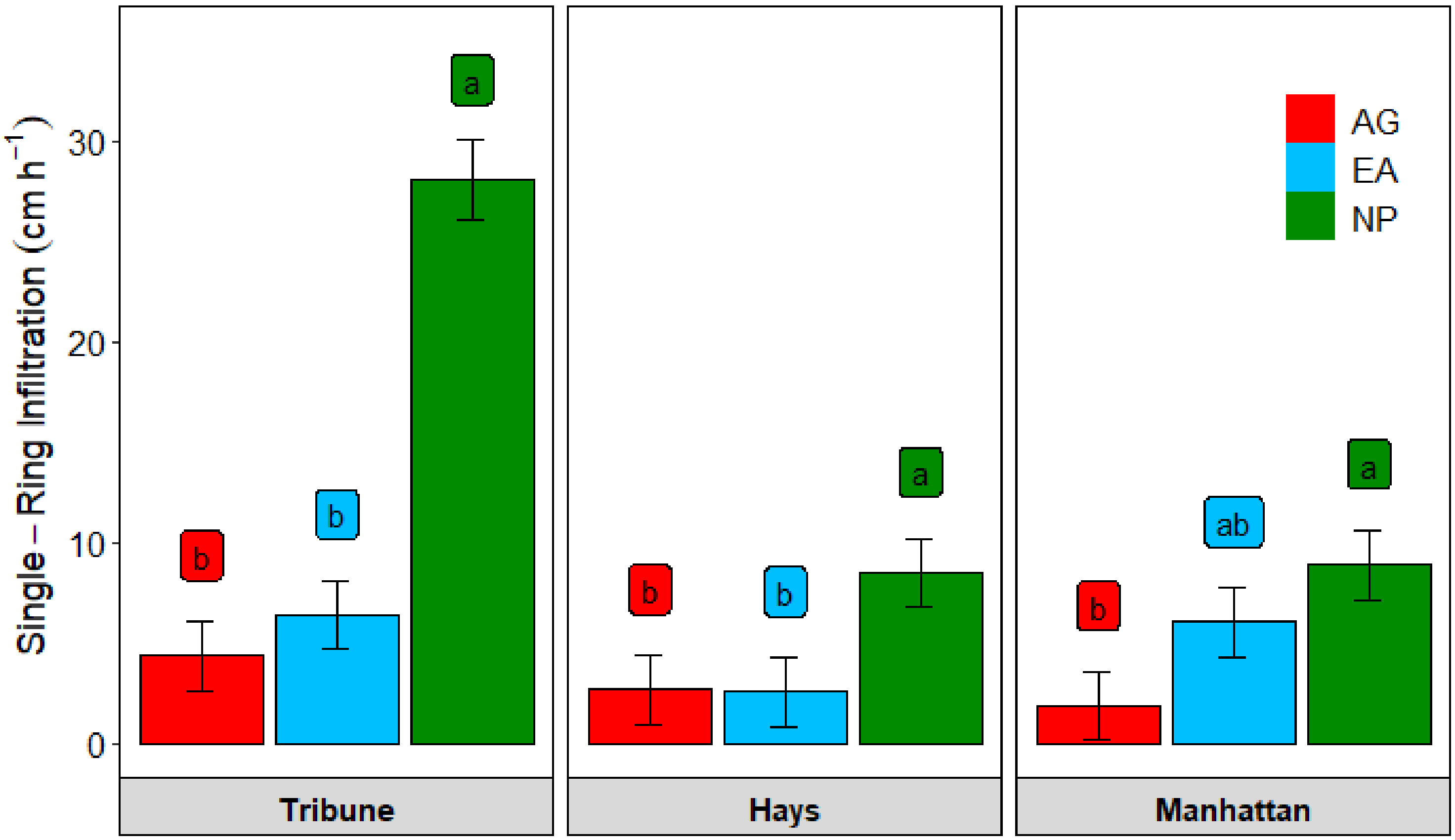
Nicoloso and Rice 2021 SSSAJ

Water stable aggregates between 10 and 22 yrs of management

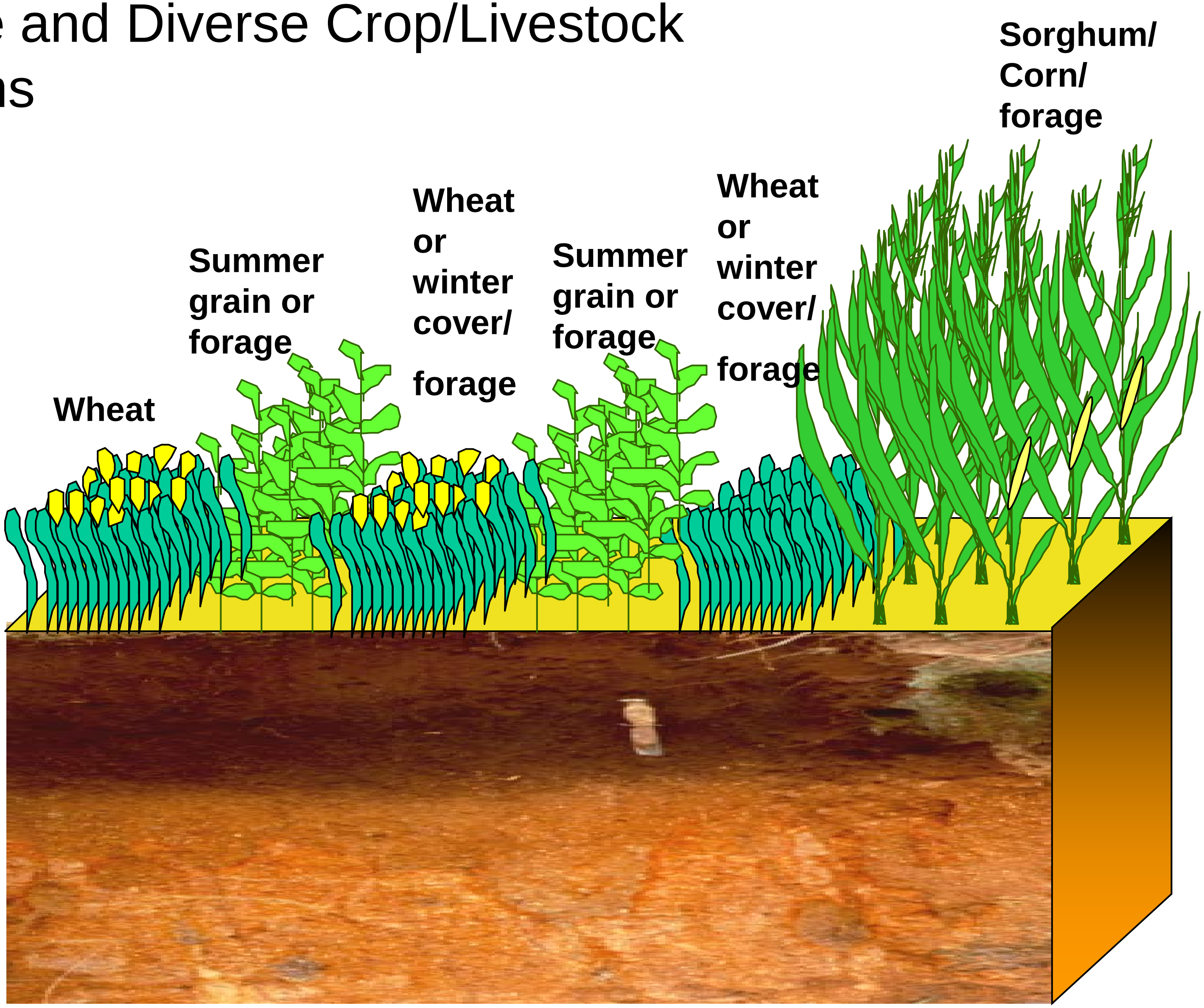


Mika et al.

Infiltration



Intense and Diverse Crop/Livestock Systems



Oxisol

Table 2.4. Average annual aboveground carbon input to the soil between 1985 and 2007 as affected by no-tillage (NT), conventional tillage (CT), and crop rotations (R0 and R2).

Source	CT R0	CT R1	CT R2	NT R0	NT R1	NT R2
	---------- Mg ha^{-1} y^{-1} ----------					
Soybean	2.36	2.87	2.53	2.57	2.57	2.80
Wheat	1.23	1.73	1.43	1.34	2.00	1.58
Oat	-	2.21	2.12	-	2.63	2.46
Corn	-	-	3.84	-	-	4.68
Oat+Vetch	-	-	2.61	-	-	2.94
Radish	-	-	1.51	-	-	1.51
Total	3.59	4.84	5.31	3.91	4.88	6.05

[1] Means with different letters between nitrogen sources within corn or total C inputs are significantly different (Tukey test, P<0.05). R0: soybean/wheat; R1: soybean/wheat/soybean/oat; R2: soybean/oat/soybean/oat+vetch/corn/radish/wheat.

Intensification and Diversification

Water efficiency

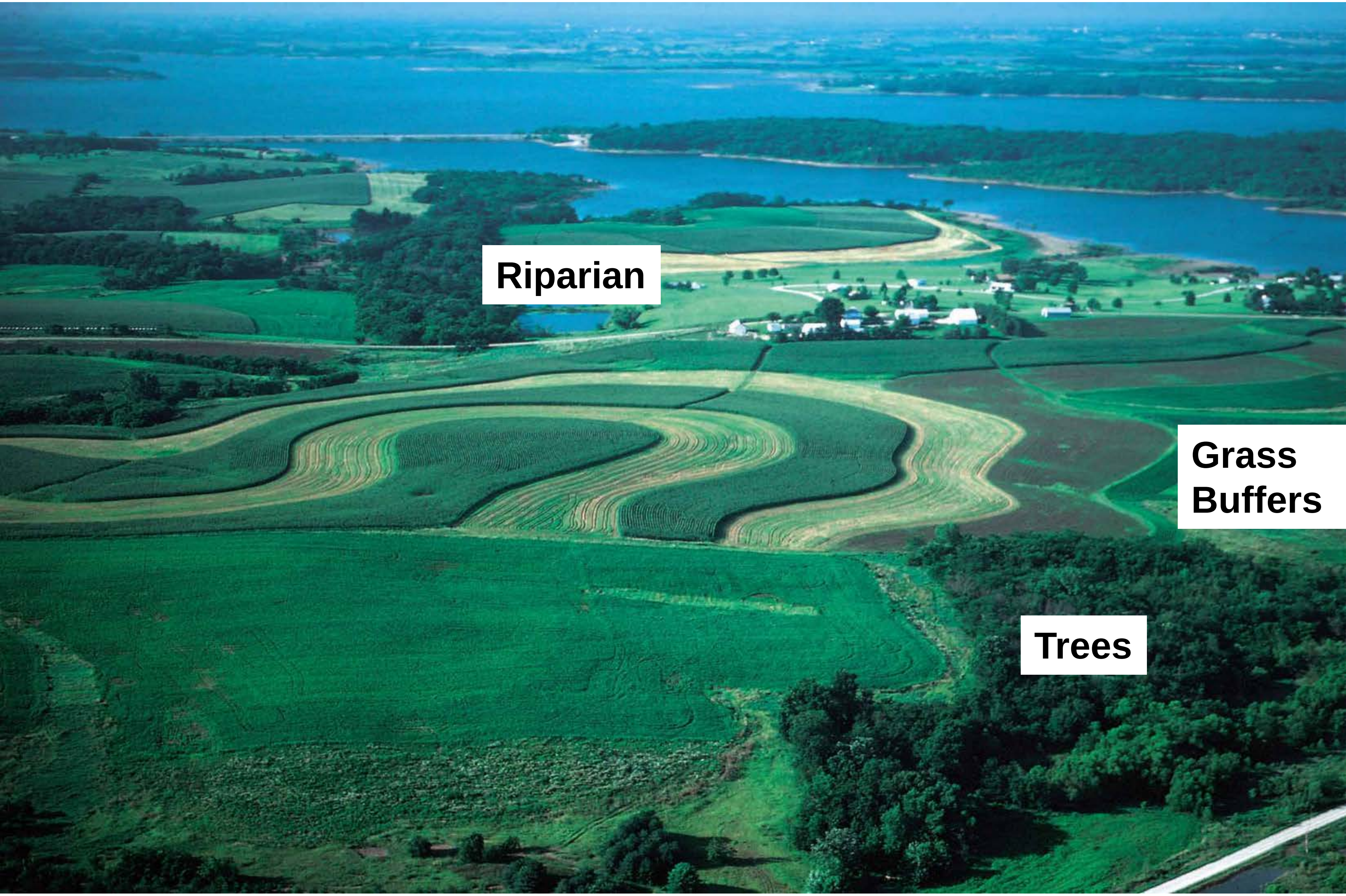
N efficiency

C sequestration

Soil Health

- Cover crops = Diversity/Roots/Efficiency
- Crop rotations = Diversity/Roots/Efficiency
- Nutrient management to increase efficiency and reduce GHG
- Weed management= Water
- Integration with livestock and forestry
- Potentially less chemical inputs

Managing the Landscape



Summary

- Water efficiency (infiltration)
  - Resilience to drought
  - Less runoff
    - Reduced nutrient and soil loss
    - Reduced flooding
  - Allow for intensification
- Nutrient efficiency
  - SOM= N+P+K+micronutrients
  - Similar or reduced N2O
- Integrated crop-livestock-forestry
- Lower yield variability – Reduced economic risk
- Pollinator habitat
- Biodiversity

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United States Department of Agriculture
National Institute of Food and Agriculture

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GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

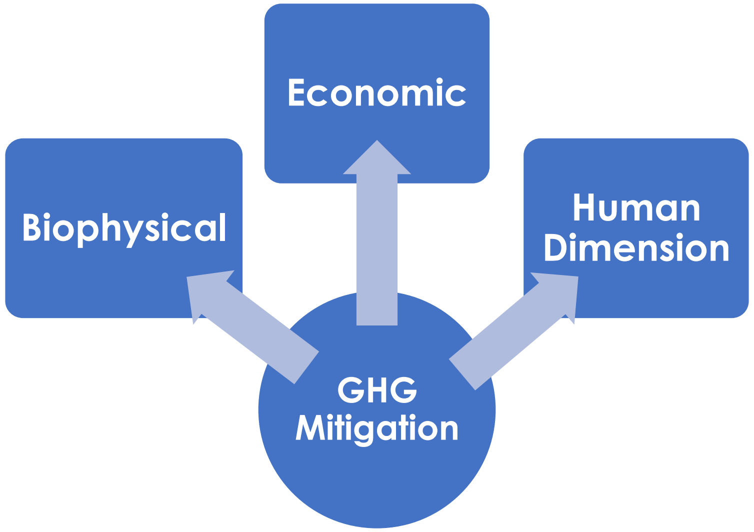
MITIGATION CO-BENEFITS EXERCISE – EXERCISE OVERVIEW

GRA Croplands Research Group Meeting

19 January 2022

What are mitigation co-benefits?

- *"Outcomes that arise subsequently from GHG mitigation practices."* Deng et al. (2018)



- **Co-benefits can serve as additional motives in the design and implementation of GHG mitigation policies**

Why are co-benefits important?

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

- Accelerating climate action is paramount!
- Farmers are those who must ultimately adopt mitigation strategies
- Agriculture is characterized by millions of farmers, most of whom are small-holders
- Measurement, reporting, and verification (MRV) of GHGs in agriculture is improving, but challenges remain
- Can carbon price drive action at the farm level?
- Identifying co-benefits and associated GHG outcomes can help facilitate adoption of low-emission practices

Why are we spending time on co-benefits?

GRA Operational Plan, 2021-2025

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

FURTHER RESEARCH COLLABORATION

Thematic Focus No. 3 (assigned to Research Groups) -

- *Identification of co-benefits from reducing emissions, as a way to prioritize agricultural practices that also contribute to adaptation and other areas (e.g., air quality, water saving, productivity, etc.)*

Kristen Veum, ARS

Mitigation Co-Benefits; CRG Exercise

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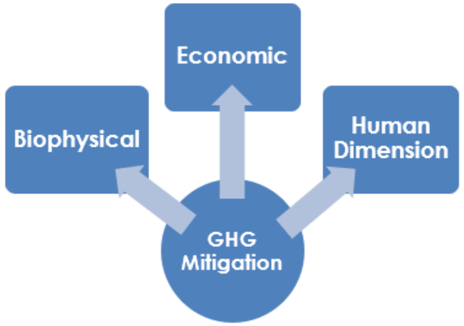
GOAL: Stimulate discussion on mitigation co-benefits with the aim of identifying potential research opportunities

- **Step 1: Using the CRG network framework, identify GHG mitigation practice**

- **Step 2: Identify co-benefits associated with GHG mitigation practice**



- **Step 3: Assign confidence rating to co-benefits, with suggestions for research**

HIGH

MEDIUM

LOW

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MITIGATION CO-BENEFITS EXERCISE – GROUP SLIDES

GRA Croplands Research Group Meeting

19 January 2022

Mitigation Co-benefits: Agroforestry

Description of mitigation practice 1: Silvopasture (Europe, Latin America, Indonesia)

Co-benefit	Agreement	Evidence	Comments
Biodiversity	HIGH	HIGH	Disturbance caused by animals (feed selection, trampling, dung) and tree shade in Europe
Nutrient cycling - N	HIGH	MEDIUM	Reduction on nitrate leaching – uptake of nitrate released from the rhizosphere from the deeper to the superficial soil layers
Nutrient cycling – P	HIGH	LOW	Reduction of phosphorous run-off and improves the P uptake from the deeper to the superficial soil layers
Economic	MEDIUM	LOW	In Europe, at least a 25% more efficient from an economic perspective, which some challenges (CAP eligibility) In Argentina, increases also economic return
Results-based payment schemes for farmers	HIGH	MEDIUM	Carbon footprint reduction

Mitigation Co-benefits: Agroforestry

Description of mitigation practice 2: Silvoarable/alley cropping

Co-benefit	Agreement	Evidence	Comments
Biodiversity	MEDIUM	LOW	Due to the shade of the tree
Nutrient cycling	MEDIUM	LOW	Reduction on nitrate leaching – uptake of nitrate released from the rhizosphere from the deeper to the superficial soil layers
Nutrient cycling – P	HIGH	LOW	Reduction of phosphorous run-off **and improves the P uptake** from the deeper to the superficial soil layers
Economic	POTENIAL	LOW	France avoids cereal losses for extreme heats
Results-based payment schemes for farmers	HIGH	LOW	Carbon footprint reduction

Mitigation Co-benefits: Agroforestry

Description of mitigation practice 3: Riparian systems

Co-benefit	Agreement	Evidence	Comments
Biodiversity	HIGH	HIGH	Due to the shade of the tree
Nutrient cycling	HIGH	MEDIUM	Reduction on nitrate leaching – uptake of nitrate released from the rhizosphere from the deeper to the superficial soil layers
Nutrient cycling – P	HIGH	LOW	Reduction of phosphorous run-off and improves the P uptake from the deeper to the superficial soil layers
Results-based payment schemes for farmers	HIGH	MEDIUM	Carbon footprint reduction

Mitigation Co-benefits: Agroforestry

Description of mitigation practice 4: Forest farming

Co-benefit	Agreement	Evidence	Comments
Biodiversity	HIGH	LOW	Improves the use of biodiversity

Mitigation Co-benefits: Agroforestry

Description of mitigation practice 5: Home gardens – did not get to this

Co-benefit	Agreement	Evidence	Comments

Mitigation Co-benefits: Conservation Ag

Description of mitigation practice #1: Diverse Crop Rotations

Co-benefit	Agreement	Evidence	Comments
Increase soil C	HIGH	HIGH	3 or more years/crops e.g. Grass/legume rotation mix
Improve soil structure	HIGH	HIGH	Clay/clay loam textured soils in particular e.g. Oxisols, Gleysols
Reduce N_2O emissions	MEDIUM	MEDIUM	Depends upon crops in the rotation, soil type & climate GHG balance should be considered (CO_2, CH_4 & N_2O)
Economic benefits & yield increases	MEDIUM/ HIGH	MEDIUM	Marketing flexibility
Weed/pest control	HIGH	HIGH	Weed suppression
Biodiversity	HIGH	HIGH	Microbial, fungal below ground Above ground

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Conservation Ag

Description of mitigation practice #2: **Ground-Cover Rice Production System with Deep Urea Application**

Techniques: using biodegradable plastic film to mulch soil surface of raised beds but leaving furrows uncovered; irrigating furrows to allow for growing traditional lowland rice cultivars at near-saturated soil conditions with no standing water; applying granular urea at transplanting to the 15-cm soil depth beneath rice seedlings.

Co-benefit	Agreement	Evidence	Comments
Soil Eh enhancement			+73% during rice season [1]
Increase soil temperature			Increase soil temperature from 22°C to 25°C during the early two-month stage of rice season [1]
Saving water	HIGH	HIGH	Reduce water demand by 40% to 60% [1]
Enhancing rice yields	HIGH	HIGH	Increase yields by 10% to 18% [1, 2]
Methane mitigation	HIGH	HIGH	Reduce CH_4 emission by 83% [1]
N_2O + NO mitigation	MEDIUM	MEDIUM	Reduce N_2O + NO emission by 60% [2, 3]
Increase carbon sequestration	MEDIUM	MEDIUM	Significantly increase SOC stock in cultivated soil layer
Reduce herbicide use	HIGH	HIGH	
Reduce NH3 emissions	HIGH	HIGH	
Reduce nitrate leaching	HIGH	HIGH	

1. Yao et al., 2015, BG. 2. Yao et al., 2017, SR. 3. Yao et al., 2019, STOTEN.

Mitigation Co-benefits: Integrated Crop-Livestock

Description of mitigation practice #1: Nutrient Optimization

Co-benefit	Agreement	Evidence	Comments
Circularity	High	Med-Low	Understanding but lack evidence
Economic (diversification)	High	Low	Barriers due to specialization, need to document benefits, vary based on climatic regions
Non-CO_2 gases reduced	Medium	Low	Depends on systems
Greater biodiversity	High	Low	
Dual purpose forages	Medium	Medium	Benefits to crop cycle

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Integrated Crop-Livestock

Description of mitigation practice #2: Addition of Organic Matter (Manure and biomass production)

Co-benefit	Agreement	Evidence	Comments
Water retention	High	High	Economic evaluation needed
Nutrient retention	High	High	Provides resilience, Less runoff (downstream impacts)
Weed management	Medium	Low	Need more evaluation
Soil structure (erosion, aeration)	Medium	Medium	Depends on soil texture and water

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Nutrient Management

Description of mitigation practice #1: Use of nutrient budgeting tools

Co-benefit	Agreement	Evidence	Comments
Net returns (e.g. fert cost savings)	MEDIUM	MEDIUM	May not improve returns, but generally won't reduce returns
Reduced risk of N loss	HIGH	HIGH	Key co-benefit
Yield benefits	MEDIUM	MEDIUM	Better match N supply with crop demand
Crop quality (e.g. protein)	HIGH	HIGH	
Farmer soil fertility knowledge	HIGH	LOW - MED	Need better understanding of the scope of this benefit
Demonstrate compliance with environmental policy	MEDIUM	MEDIUM	

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Nutrient Management

Description of mitigation practice #2: Catch crops / cover crops

Co-benefit	Agreement	Evidence	Comments
Reduced risk of N losses	MEDIUM	HIGH	
Improved soil health	MEDIUM	MEDIUM	
Nutrient circularity	MEDIUM	MEDIUM	
Providing supplemental livestock feed or additional cash crop	MEDIUM	MEDIUM	

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Peatland Management

Description of mitigation practice #1: Raising water table on the drained peatland

Co-benefit	Agreement	Evidence	Comments
Lower CO_2 emissions from decomposition	MED-HIGH	MED-HIGH	
Lower CO_2 emissions from peat fire	MEDIUM	LOW	
Longer use of peatland (lower subsidence rate)	MEDIUM	LOW	

Footnotes:
- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Peatland Management

Description of mitigation practice #2: Sustainable intensification on existing agricultural areas

Co-benefit	Agreement	Evidence	Comments
Increased yield	HIGH	HIGH	
Reduced pressure of expansion	LOW	LOW	
Higher farmers' income	MED	LOW	

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Peatland Management

Description of mitigation practice #3: No new concession on peatland

Co-benefit	Agreement	Evidence	Comments
Conservation of peatland			High opportunity costs
Lower CO_2 emissions			
Maintenance of biodiversity			
Maintenance of landscape ecosystem function such as water storage capacity			

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)

Mitigation Co-benefits: Peatland Management

Description of mitigation practice #4: Paludiculture (under undrained conditions)

Co-benefit	Agreement	Evidence	Comments
Long-term and sustainable use of peatland	MED to HIGH	MEDIUM	Not many examples from the tropics, but more evidence from temperate and boreal climate zones. The current drained system is considered more economically attractive, especially when it comes to large scale plantations.

Footnotes:

- Co-benefits inclusive of biophysical, economic, and human dimension domains
- Agreement = Relative degree of agreement/consensus in the literature (LOW, MED, HIGH)
- Evidence = Relative amount of data in support of effect (LOW, MED, HIGH)