THE AGRICULTURAL GREENHOUSE GAS FOOTPRINT

Executive Summary

Anthropogenic climate change is caused by excess atmospheric emissions of greenhouse gases (GHGs), especially carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). Globally, food production accounts for 21%-37% of annual GHG emissions[1]. In the United States, crop production and livestock cultivation account for 9% of GHG emissions annually[2]. Crops like rice, wheat, soybean, and cotton are produced for food, feedstock, biofuel, fiber, and consumer-product goods. Agriculture's GHG footprint can be reduced through mitigation strategies and sustainable improvements in crop and livestock production systems. With thoughtful management, the agricultural system can yield climate benefits without sacrificing economic benefits and can make our food system more resilient to natural events.

Agricultural emissions can be reduced and atmospheric CO_2 can be drawn down into soils through the adoption of climate-smart land management practices that have clear, permanent, and quantifiable mitigation effects. Practices like avoided land conversion, cover cropping, no-till, and use of perennials can reduce carbon losses, increase carbon inputs into soil, and reduce N_2O and CH_4 emissions. By implementing these practices across millions of acres, farmers and ranchers can become leading actors in the collective effort to address climate change. In addition to presenting a climate change mitigation solution, evidence is growing that climate-smart land management practices also function as a climate-change adaptation solution, with practices increasing farm resilience to extreme weather events like drought and flood. These practices also yield social and economic co-benefits and can increase the profitability of agricultural operations, especially via the generation of a new revenue source for farmers: carbon credits.

US Agricultural Production and Greenhouse Gases

Agricultural activities associated with soil manipulation and livestock are a prominent source of GHGs, estimated to contribute 9%-14% of global emissions, with soils contributing nearly 40% of those emissions[3,4]. GHG flux from soils to the atmosphere influences climate change due to direct and indirect emissions of carbon (C) as CO_2 and CH_4, as well as nitrogen (N) as N_2O. These emissions arise from biological processes, management practices, and interactions with the climate and underlying soil.

Carbon dioxide (CO_2) is the leading contributor to climate change and has millennia-long atmospheric persistence time per ton emitted[5]. While fossil fuel burning is the main source of CO_2 emissions, land-use change is a significant contributor. Plants absorb atmospheric CO_2 during photosynthesis and store it as organic carbon in plant tissue. As plants grow and decompose, they deposit carbon-rich root exudates and particulate matter residues in soils, which soil microbes mineralize and release back into the atmosphere as CO_2. Conventional land management practices, such as reduced or no tillage, typically reduce plant residue inputs and stimulate microbial mineralization, lowering soil carbon stocks, and increasing CO_2 emissions.

[1] Mbow, C., et al. 2021. "Food security," in Climate Change Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food 2Security, Greenhouse Gas Fluxes in Terrestrial Ecosystems, eds P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts.
[2] Environmental protection agency Feb 2019, https://www.epa.gov/sites/default/files/2019-02/documents/us-ghg-inventory-2019-main-text.pd
[3] IPCC 2019
[4] US EPA 2020
[5] Archer and Brovkin, 2008

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Nitrous oxide (N_2O) is produced by microbes that can reduce nitrate (NO_3-) to nitrite (NO_2-) and then to N_2O through respiration[6]. Approximately 60% percent of anthropogenic N_2O emissions are tied to human activity in agriculture due to overuse of fertilizers, manure, N leaching, and N runoff from agricultural fields[7,8]. Chemical fertilizer applications (N, phosphorus, and/or potassium) can be beneficial in crop production, but these inputs emit significant CO_2e during their own production and can be overused by growers looking to increase crop yields (or simply due to bad agronomic advice). The overuse of chemical fertilizers is highly unsustainable; compared to CO2, N2O has 298 times the global warming potential and can persist in the atmosphere for 100 years[9].

Methane (CH_4) is produced from the reduction of CO_2 and other organic C compounds by: methanogenic microorganisms under anaerobic conditions, flooded rice cultivated fields, during manure decomposition, and by ruminant digestion[10]. Agriculture produces 35%-40% of global CH4, accounting for 3.3 Gt CO_2e/yr[11,12]. Although methane has a much shorter atmospheric lifespan compared to CO_2 (12 years), it has a 28-fold greater global warming potential when considered over a 100-year period, highlighting the importance of decreasing CH_4 emissions as part of climate-change mitigation strategies[13].

How Farmers and Ranchers Can Mitigate GHG Emissions

Standard management activities such as land-use conversion, tillage, use of internal combustion engines, manure storage and management, and excess fertilizer and manure inputs, contribute to increased emissions of CO_2, N_2O, and CH_4 . Soil carbon-enriching conservation practices (also called regenerative agriculture, discussed below) can help to sequester organic C in soil and positively influence the soil N cycle, thereby partially or entirely fixing the overall GHG balance on the land[14,15]. In addition, rapid deployment of readily available methane mitigation measures can immediately slow global warming[16].

Figure 2.

Crops:
Corn, Oats, Soybeans

Regenerative practices:
Cover crops, No-Till

Angela's soil health, crop yield and profitability have increased since she started implementing regenerative practices

Crops:
Corn, Cotton, Rice, Soybeans

Regenerative practices:
Cover crops, No-Till, Fertilizer/pesticide elimination

When invasive weeds threatened his farm, Adam implemented new sustainable practices to save his land

[6] Ussiri and Lal, 2013
[7] Galloway et al., 2004
[8] Mosier et al. 1998
[9] IPCC AR4 WG1 (2007), Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K.B.; Tignor, M.; and Miller, H.L. (ed.), Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, ISBN 978-0-521-88009-1 (pb: 978-0-521-70596-7).
[10] Dutaur and Verchot, 2007
[11] Global Methane Initiative, 2015, globalmethane.org/documents/gmi-mitigation-factsheet.pdf
[12] U.S. EPA, 2020, www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
[13] Wiesner et al., 2020
[14] Paustian et al., 2016;
[15] National Academy of Sciences 2019
[16] Ocko et al., 2021, https://iopscience.iop.org/article/10.1088/1748-9326/abf9c8/pdf

The quickest path to leveraging agriculture as a climate solution is to make it financially attractive and technically feasible for farmers. When properly implemented, carbon credits are an outcomes-based market mechanism that can accelerate the transition to climate-smart agriculture. Agricultural carbon crediting has already garnered support from the private sector and bipartisan support from the public sector[17]. Companies within and outside of agriculture are turning to these credits as a nature-based tool for advancing their sustainability strategies, in part due to the substantial economic and environmental benefits these investments support. By adopting these practices farmers can access a new revenue stream in the form of carbon credits, see improved soil health[18], greater water retention, increased biodiversity, and can reduce use of chemical and fertilizer inputs (see Figure 2 for Indigo case studies).

The Soil Health Institute has also linked adoption of soil-beneficial land management practices with increased profitability. Net incomes increased for 85%-88% of corn and soybean growers respectively and nearly 70% of growers reported higher yields than conventional systems based on in depth budget analyses of 100 farmers[19]. Data and case studies such as these illustrate the power of a systems approach to climate-smart agriculture (vs. focusing on a single practice), and that assessment should be outcomes-based (vs. practice-based). Outcomes-based success measures ensure that the benefits of climate-smart practices are not negated by the negative impacts of environmentally harmful practices, such as increased herbicide use.

Supporting Agricultural GHG Mitigation Solutions

Despite the benefits of climate-smart agriculture, myriad barriers inhibit its broad scale adoption. Barriers are multifactorial, ranging from social and cultural barriers around entrenched conventional cultivation practices (tillage, land conversion, fallow periods, over application of chemicals, etc.) that increase GHG emissions, to economic and information barriers. Practice transition costs are borne upfront by growers and limited access to low-cost financing compounds this issue. Land tenure (owner-operator vs. tenant farmers) and land type (working cropland vs. conservation lands) can affect incentive structures and deter carbon sequestration and GHG emission mitigation. Cultural norms and heuristics around land management within families and communities can also make it difficult to adopt new practices.

Climate-smart policy can provide essential support for farmers who want to adopt climate-smart practices on working lands and support land conservation strategies to mitigate the effects of climate change. Government can support practice adoption by providing technical assistance and transition payments to farmers and can support investment in climate-smart agriculture by providing pricing and quality benchmarks to enhance market assurance. Payments alone are not the whole solution; despite some growers receiving payments of up to $92/ac. for cover cropping, the practice has not been broadly adopted in the U.S. This can be attributed to lack of trusted information and/or technical assistance in implementing novel, oftentimes unfamiliar practice on an operation for all growers. Growers may also perceive low market interest and pricing for regeneratively-farmed crops. In addition, cover crop seeds are expensive and must be purchased every year, so there is a very real and recurring cost to the farmer that must be outweighed by near-term, tangible benefits.

[17]GCSA 2021
[18]Indigo Ag Soil health brief, in progress
[19]Soil Health Institute 2021 Economic analysis, https://soilhealthinstitute.org/economics/

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To encourage broad adoption, we recommend:

- Continuation and/or expansion of existing conservation programs, such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP)
  Supporting the Growing Climate Solutions Act (GCSA) which can strengthen the existing voluntary carbon market by providing clarity on minimum quality standards and by providing services to support farmer participation

- Increased investment in USDA research and data sharing efforts with Land Grant Universities and other partners across diverse cropping systems in research areas with the most opportunity to drive measurable climate benefits. A USDA-led data collection, analysis, and practice-influencing publication process could offer insights that may help scale climate-smart practice adoption among the farmers who care for > 300 million acres of cropland across the country when complemented by existing high-quality carbon credit programs.

- Continued conservation land protection to prevent land conversion and degradation which are linked to increased GHG emissions. Because conservation lands can also promote carbon sequestration they have strong potential to complement the environmental resilience co-benefits of climate-smart agricultural practices on working lands.

Conclusion – Climate and Broader Benefits

Climate-smart agriculture is a major opportunity to address climate change and to secure environmental, economic, and social co-benefits. These practices can bolster land resilience to environmental threats (i.e., drought, flooding, pest pressure), support food security, preserve water quality, and increase economic development and American prosperity. Climate-smart agriculture could also help the US achieve nationally determined contribution (NDC) goals under the Paris Agreement. While aspirational, this goal can be achieved by leveraging and improving the approach to soil assessment and GHG mitigation standards in the public and private sectors. For example, rigorous and consistent agricultural GHG emission and mitigation accounting in third-party registry protocols (e.g., Climate Action Reserve and Verra), improved data collection and interoperability, and comprehensive soil and GHG emission monitoring, reporting, and verification in high-quality carbon offset programs. The vast majority of farmers are observing the development of carbon credit programs from the sidelines – only 7% are actually engaged in discussions – and remain cognizant of how the Administration will translate its signals of support into regulatory action. It is an opportune time for policies to shift to support investments in our transition to climate-smart and resilient agricultural systems.

Acknowledgements

The authors would like to thank all our contributors and reviewers for their time and effort spent contributing to this piece. Your comments and suggestions `helped us to refine and improve this work.

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[20] Lal R (2004) Soil carbon sequestration impacts on global climate change and food security. Science 304:1623–1627
[21] ___