EDITORIAL

The agroecosystem role in climate change mitigation and adaptation

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> “While the question of yields has been argued to be paramount for understanding GHG emissions from agroecosystems, emerging issues in global agroecology point to climate change mitigation from agroecosystems of equal or greater magnitude.”

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Modern agriculture has been hugely successful in meeting global demand for food, fiber and feed, and has recently made impressive strides in the production of liquid transportation fuels. Agriculture productivity was achieved through a vast transformation of the Earth’s surface on 15 million km^2 of cropland and 28 million km^2 of pasture [1]. This change in land-use has resulted in impacts on a global-scale to ecosystem structure and function, including reductions in critical ecosystem services that moderate climate, air pollution, water contamination and soil degradation. New constraints may amplify these impacts as the agriculture system confronts rising production costs, accelerating climate change and increasing scarcity of natural resources.

An emerging response to the diverse impacts from the agriculture system has been to turn to ecologically sound agriculture practices that may enhance environmental quality, while also improving social and economic sustainability [2]. Conservation tillage, cover cropping, intercropping and integrated pest management are among the many strategies employed. One underlying theme in developing the scientific basis and design of these agroecological practices is the biotic interactions that determine agroecosystem function [3]. Managing biotic interactions in farm systems may reduce or eliminate the need for the very external inputs, which drive pollution, land degradation and the loss of biodiversity. Global adoption of such low-input practices has risen dramatically owing to new market opportunities for organic foods, as well as government incentives and mandates [4].

Agroecological approaches to farming represent a transformative change to many existing agriculture systems. Such a dramatic shift in agriculture practices may incur tradeoffs. One tradeoff highlighted in recent work is the potential for low-input agricultural systems to result in greater GHG emissions than the farming systems that they replace [5]. The climate change dimension of agriculture sustainability is of great concern since on-farm GHG emissions are currently 5.1–6.1 billion tons CO_2-equivalents y^{-1}, which is 10–12% of total anthropogenic GHG emissions [6]. In addition to on-farm emissions, agriculture is responsible for significant emissions in other categories reported in GHG inventories including deforestation, as well as industrial and energy sectors through the production of fertilizers, pesticides, herbicides, machinery and electricity. It is

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certain that low-input systems will reduce the emissions associated with fossil fuel intensive inputs. At the same time, there exists a potential for increased GHG emissions if the low-input systems are assumed to result in a decrease in crop yields, which drives an increase in agriculture areas and deforestation (extensification). Recent work on this tradeoff concludes that low-input agriculture systems result in greater net GHG emissions than high-input systems, since the increase in emissions from extensification is greater than the decrease in emissions from reduced inputs [5]. The central assumption that a global-scale adoption of low-input systems would lead to extensification is equivocal [7–9]. Nevertheless, the results of this study point to a critical knowledge gap where the role of agroecological systems in global GHG emissions as well as other potential synergies and tradeoffs with climate change mitigation and adaptation are uncertain.

The difference in yields between agroecological farming practices and the systems they replace has long been a subject of debate. The yield question is framed within the context of food security and the ability of agroecological farming systems to meet the growing global demand for agricultural goods. Some question whether this is relevant given other barriers to equal food access. Regardless of the relevance of yields to food security, yields appear to be important to the question of net GHG impacts of agriculture. In general, agroecological approaches may reduce yields in developed countries and increase yields in developing countries, but the impact on global production is unclear [7–9]. Furthermore, it is uncertain how yields will compare for future climate regimes. There is evidence that agriculture practices designed with agroecological principals may be more robust to the changing climate system and thus yields may benefit from these practices [10]. In this sense sustainable agriculture is an important climate adaptation measure. Another central uncertainty is the spatial distribution of the yield gaps. The spatial gradients in the yield gap will contribute to the spatial distribution of extensification, which in turn determines the magnitude of the GHG emissions associated with land use change. Given the importance of yield to determining the climate impacts of agriculture, there is a great need for spatially diverse farm experiments as well as geospatial analysis incorporating global land-use models and ecosystem carbon storage.

While the question of yields has been argued to be paramount for understanding GHG emissions from agroecoystems, emerging issues in global agroecology point to climate change mitigation from agroecosystems of equal or greater magnitude. In additional to GHG emissions, agriculture contributes to climate forcing through the exchange of water and energy between the land and atmosphere. This so-called biophysical effect includes changes in the amount of sunlight absorption, water evaporation from plants and the soil, the roughness or unevenness of the vegetation canopy, and the production of convective clouds and rainfall. A recent study of the biophysical effects of perennial agriculture systems finds substantial climate cooling from increased evaporation that is significant at regional and global scales [11]. While this study focuses on low-input biofuels cropping systems, the results suggest that investigations of food systems have also overlooked the beneficial biophysical climate effects of agroecosystems. Furthermore, the biophysical cooling effects of agroecological farming practices would likely have an indirect impact on yields. Increasing temperatures may lead to a nonlinear degradation in crop yields [12]. Thus, the biophysical cooling associated with agroecological farming practices would tend to reduce temperatures and ultimately moderate degradation in yields. The biophysical effects of agroecosystems on climate and regional yields are largely unknown. The scientific basis for these effects could be developed through a combination of integrating eddy flux measurements into trials and integrating agroecological management into regional climate models.

Even if the net effect of GHG and biophysical forcing from agroecological farming practices yields a warmer climate, the climate impact needs to be carefully evaluated within an integrated assessment of agroecosystems. A warming climate is not an impact in and of itself. The problems that stem from climate change are in many cases the very ecological, social and economic problems that agroecological practices address. For example, climate change will likely lead to more concentrated precipitation events, which will degrade water quality while agroecological design can reduce nonpoint source pollution from runoff, sediment loss and leaching of nutrients and pesticides [13]. Thus, simply knowing that an agriculture approach contributes to climate change is not sufficient to provide an assessment of sustainability.

There is a need for a more careful examination of GHG emissions from agroecosystems, for new investigations of biophysical climate impacts and for the inclusion of these studies into an integrated assessment of agriculture sustainability. The integrated assessment in particular is a formidable scientific challenge, which would bring together multiple disciplines as well as farmer/researcher collaborations to address key dimensions of agroecosystem sustainability. It is perhaps fitting that such a transformative approach to agriculture would require an equally transformative approach to science.

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