The mitigation pillar of Climate-Smart Agriculture (CSA): targets and options

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Abstract

The need to prioritise food security in the face of a changing climate raises the question of how much agriculture should contribute to global mitigation targets. A global target for reducing methane and nitrous oxide emissions from agriculture of ~1 gigatonne of carbon dioxide equivalent per year ($GtCO_2e$/yr) by 2030 would limit warming in 2100 to 2°C above pre-industrial levels. Yet low emissions development (LED) in agriculture, based on available technologies and policies, will deliver only a portion of the needed mitigation. More transformative options will be needed, including carbon sequestration, reduced food loss and waste, and shifts in consumption.

Introduction

The potential for agriculture to contribute to climate change mitigation globally is well-documented (Smith *et al*, 2007). However, the threat of food insecurity in the face of a changing climate raises the question of how much agriculture should contribute to global mitigation targets, if at all. Most developing countries, especially those most vulnerable to climate change, are focused on adapting to climate change, rather than reducing it.

Growing evidence suggests reducing emission in the industrial, energy or transport sectors will not be enough to limit warming in 2100 to 2°C above pre-industrial levels, the target set by the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement. As emissions in other sectors decrease, agriculture-related emissions will become the largest source of surplus emissions by 2030, so the pressure and need to mitigate emissions in agriculture will increase (Bajzelj *et al*, 2014; Gernaat *et al*, 2015). In addition, the Paris Agreement states the aim of achieving *"a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century…"*. Agriculture's potential to store carbon in the soil, and in above- and below-ground biomass, means that it could be a major contributor to negative emissions. For many countries, mitigation of agricultural emissions is an opportunity to meet national mitigation targets. For the Paris Agreement, 119 countries pledged to reduce their agricultural greenhouse gas (GHG) emissions (Richards *et al,* 2015b). Agricultural emissions contribute an average of 35 percent of emissions in developing countries and 12 percent in developed countries (Richards *et al*, 2015a).

Given the need to meet the global 2°C warming limit, how can agriculture best contribute to mitigation in ways that also meet food security goals? Also, since three-quarters of agriculture's emissions of 5.0 to 5.8 gigatonnes of CO_2e per year originate in developing countries (Smith *et al*, 2007), what are the implications of a mitigation target for places that are the most vulnerable to food insecurity and need to prioritise adaptation?

To address these questions, I present a 2°C-linked target for mitigation in agriculture and discuss the potential and limitations of low emissions agriculture as an option to meeting climate change and food security goals.

A mitigation goal of 1 gigatonne CO_2e per year

Estimates suggest that in 2030, global anthropogenic emissions of 68 gigatonnes CO_2e (all sectors) will need to be reduced by 26 gigatonnes CO_2e to meet the 2°C limit (New Climate Economy, 2014). Can this global goal be allocated across sectors to estimate a sectoral goal for agriculture? Having such a goal would help to guide ambition and assess the relevance of mitigation contributions.

To develop such a goal, experts from twenty universities, research institutes and other organisations, collaborated to consider the emissions reductions necessary in agriculture in a 2°C world (Wollenberg *et al,* 2016). The scope of agricultural emissions considered included methane (CH_4) and nitrous oxide (N_2O) emissions. Carbon sequestration resulting from the production of crops, livestock and agroforestry on farms was not included due to the models available. Other agriculture-related emissions not included in the study due to the available models were emissions in the supply chain (transport, processing, fertiliser production, post-harvest loss), and those related to land use change or consumption (diet and food waste).

The team examined the 2°C target using the Representative Concentration Pathway (RCP) 2.6 scenario prepared for the Intergovernmental Panel on Climate Change (IPCC). We identified the mitigation needed by comparing this reduced budget with the scenario's baseline, business-as-usual emissions. The RCP 2.6 scenario represents conditions expected to limit emissions to 450 ppm of CO_2e in 2100, which results in a 66 percent or 'likely' chance of staying below the 2°C warming limit (van Vuuren *et al*, 2011). We examined the same scenario using three different integrated assessment models: Integrated Assessment of Global Environmental Change (IMAGE); Global Change Assessment Model (GCAM); and the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE).

The comparison showed that, on average, agricultural emissions would have to be reduced by 1 gigatonne of CO_2e per year by 2030 to stay within a 2°C emissions budget of 6 to 8 gigatonnes CO_2e for agriculture (Figure 1). This would reduce agricultural emissions by 11-18 percent in 2030, contributing 4 to 5 percent of the mitigation needed across all sectors in 2030 to achieve the 2°C limit.

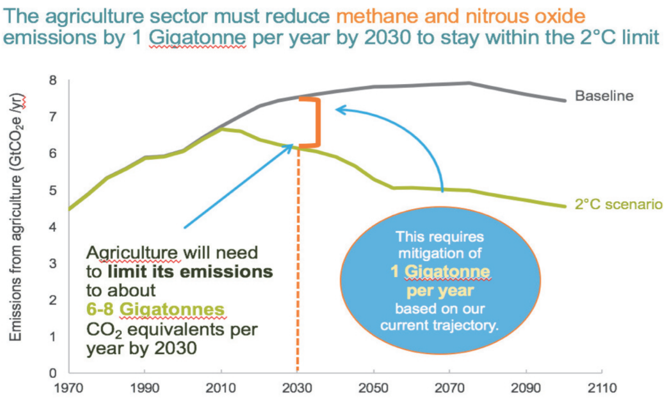

Figure 1. Mitigation needed in agriculture to achieve the 2°C target in 2030.

Mitigation in agriculture would need to increase in 2050 to 2.5 to 2.6 gigatonnes CO_2e per year, reaching a maximum of 2.9 to 4.2 gigatonnes CO_2e in the period between 2070 to 2100. These estimates indicate that significant reductions in agricultural emissions will be necessary in the decades to come.

Since developing countries will need to focus on food security and climate change adaptation, what would be their contribution to this target? Social justice considerations suggest that the burden for mitigation should be carried by the more industrialised countries. However, if the priority is meeting the 2°C goal in conjunction with food security, scenarios show that the mitigation burden needs to be shared among all countries, including developing countries. Kleinwechter *et al* (2015) found that mitigation in agriculture was most efficient for food production when based on a policy regime of full global collaboration rather than exemptions of the least developed countries or developing countries. The implication is that new approaches to agriculture will be needed everywhere, including developing countries. Mitigation measures thus need to be introduced in the context of agricultural development.

Low emissions development (LED) in agriculture

LED is the emerging paradigm for mitigation in agriculture in developing countries. LED in agriculture can be defined as sustainably advancing human well-being and agroecological productivity and sustainability in ways that also reduce agricultural GHG emissions. Reductions in emissions should be compared to what emissions otherwise would have been with conventional agricultural development or based on the projection of current practices. LED puts the need to produce food and other goods for human needs first, and mitigation second (Nash *et al,* 2015).

LED differs from mitigation-driven approaches. Mitigation-driven planning identifies practices that deliver the largest reductions in emissions at the least cost (usually expressed in monetary terms, but can also be in terms of food security losses, see Kleinwechter *et al*, 2015) and then seeks the policy incentives enabling adoption of these practices. An LED approach instead identifies agricultural development goals and then develops mitigation practices compatible with these goals. Farmers are assumed to shift to LED practices because the practices also best meet their own goals.

GHG-efficiency is the guiding principle of LED. Practices should be sought that minimise the GHG emissions per unit of yield or what is called 'emissions intensity'. Many agricultural development practices already seek to increase input efficiencies, such as improved feed digestibility for cattle, reduced water use for paddy rice or efficient use of nitrogen fertiliser (see for example CSA practices https://ccafs.cgiar.org/publications/csa-practices-and-technologies or Gerber *et al*, 2014 on livestock), which often also reduce emissions per unit yield. Improved GHG-efficiency in LED does not however guarantee reductions in emissions compared to the present. It only guarantees the reduction of future emissions relative to a business-as usual baseline based on present practices.

LED agriculture ideally also contributes to enhanced productivity, adaptation and mitigation, the three pillars of climate-smart agriculture. The challenge is in ensuring optimal multiple benefits to the farmer and optimal reductions in emissions, while also meeting other development goals. Meeting multiple public and private objectives in agriculture will become increasingly necessary, but trade-offs are inevitable. For example, sequestering more carbon in the soil can enhance productivity and resilience to drought, but also increases methane emissions during flooding in paddy rice. Traditional livestock breeds are often more resilient to extreme weather conditions and produce lower emissions than more productive breeds that will also produce lower emissions per kg of meat.

Can we meet the goal?

LED in agriculture seems like a reasonable way to pursue mitigation, but is the amount of mitigation that it can provide enough? The 1 gigatonne goal allows us to assess the significance of different options for achieving LED.

Sustainable intensification of food production provides one example of the mitigation possible as a co-benefit of development. According to projections from the FAO, intensified food production from 2005 to 2050 will come mostly from increased yields (73 percent), and somewhat from expanded area for cultivation (21 percent) and increased cropping intensity (6 percent) (see http://www.fao.org/fileadmin/templates/esa/Global_persepctives/world_ag_2030_50_12_rev.pdf). FAO statistics project that intensification will reduce emissions in 2030 by about 0.4 Gt, or 7 percent of expected emissions – a significant amount of mitigation, but short of the goal.

Intensification along the food supply chain can also provide mitigation benefits, although 2°C-linked goals for specific supply chains need to be calculated to assess their significance. Some food supply companies are already exploring goals for their sectors (Smith *et al,* 2017). Gerber *et al* (2013) provided a comprehensive review of the opportunities for mitigation associated with intensification of production and increased efficiency of livestock products. They estimated that the livestock supply chain's emissions could be reduced by 1.8 gigatonnes CO_2e/yr, or about 30 percent (Figure 2), if all producers shifted their practices to those used by the 10 percent of producers with the lowest emission intensity. This number indicates the scale of mitigation possible in the supply chain.

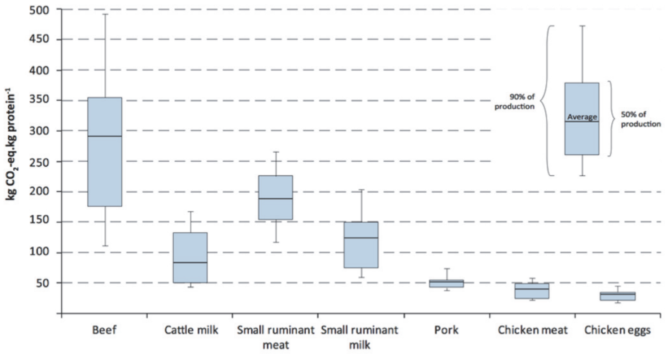

Figure 2. Global emissions intensities of livestock products (Source: Gerber *et al*, 2013).

Using future scenarios, Valin *et al* (2013) showed that reducing the yield gap in agriculture by 50 percent for crops and 25 percent for livestock by 2050 would decrease agriculture and land use change emissions by 8 percent overall, with the outcomes depending on the approach used. For example, emphasising crop yield increases would achieve a larger increase in food production, while livestock productivity gains would achieve the most mitigation of GHG emissions. Valin *et al* (2013) conclude that productivity should be increased in both sectors to best achieve both food security and mitigation.

Other estimates of the impacts of LED agriculture benefits also fall short of the goal. Using the best global evidence available, our team examined what could feasibly be achieved by (i) summing the impacts of all mitigation practices compatible with food production using IPCC data (Smith *et al*, 2008, 2014), and (ii) examining increases in production efficiency based on trade, improved production techniques and shifting the location of production designed to also yield mitigation co-benefits (Havlík *et al*, 2014). Both approaches used relatively low carbon prices of US$ 20 per ton of CO_2e. Assuming realistic rates of change and projecting impacts to 2030, these approaches provided only 21 to 40 percent of the mitigation needed in 2030 (Wollenberg *et al*, 2016).

Our projections of what is needed in the 2°C world, and what is possible, therefore reveal a major gap. Countries want to take action on agriculture, but the options currently available will not make the impact needed to meet the global target agreed to in Paris. We need a much bigger and better menu of technical and policy solutions with major investment to bring them to wider scale.

Two degree Centigrade-linked mitigation goals are not currently available for carbon sequestration associated with agriculture or changes in consumption, but estimates of aspirational goals possible in 2030 suggest that significant mitigation of absolute emissions, rather than emissions intensities, could occur with these interventions (Wollenberg *et al,* 2016):

- Soil carbon sequestration – 1.2 $GtCO_2$e/yr at US$ 20 per tCO_2e (Smith *et al*, 2014);
- Reduced land use change due to clearing for agriculture – 1.71 to 4.31 $GtCO_2$e/yr at US$ 20/tCO_2e (Carter *et al*, 2015);
- Decreased food loss and waste by 15 percent (estimates vary from 30 to 50 percent for total lost or wasted food) – 0.79 to 2.00 $GtCO_2$e/yr (Stehfest *et al*, 2013);
- Shifted dietary patterns, based on the diet recommended by the World Health Organisation (Stehfest *et al*, 2013), or in response to increases in carbon prices (Havlík *et al*, 2014) – 0.31 to 1.37 $GtCO_2$e/yr.

These interventions reinforce the need for reducing agriculture as a driver of deforestation, and addressing the potential for mitigation through changes in food loss and waste, and consumption. Agroforestry practices can be expected to have significant impacts as well. A recent analysis of tree cover on agricultural land indicated increases in biomass carbon stocks between 2000 and 2010 of more than 4.6 percent (2 PgC) (Zomer *et al*, 2016) (see also http://www.worldagroforestry.org/global-tree-cover/data-download.html).

A review of USAID's portfolio of sustainable agriculture investments in 2015-2016 further reinforces the importance of carbon sequestration in achieving mitigation. The USAID portfolio reflects realistic bundles of practices that countries currently want and that donors are promoting. The analysis examined 25 agricultural development projects involving dozens of LED practices across 15 countries in 3 continents. These often involved multiple interventions across a landscape and along value chains. The analysis estimated emissions using the *Ex-ACT* tool over a twenty-year period. Field-level practices included:

- Land use change, including avoided deforestation and afforestation/reforestation (low value agricultural or degraded lands changed to forest);
- Crop transitions to perennial crops or agroforestry or from flooded rice systems to other crops such as wheat;
- Management practice improvements: (i) Rice crops – alternate wetting and drying, urea deep placement, short duration rice; (ii) Crops – soil, manure and water management improvements, including crop residue burning reduction and perennial management; (iii) Fertiliser – increased use and increased efficiency; (iv) Livestock – including herd size management, feed quality and breeding improvements, and increases in grassland.

The major sources of emissions across the portfolio were from increased fertiliser use and livestock intensification, but these were easily offset by carbon sequestration. Overall, carbon sequestration exceeded increases in emissions of the 25 projects by more than two times (Nash *et al*, in press). Further reductions due to reducing post-harvest loss were also possible (Nash *et al*, in press). While this analysis does not provide an estimate of the mitigation possible in 2030 globally, it does suggest that bundles of interventions that include carbon sequestration associated with land use change already occur and have the potential to achieve net reductions in emissions.

Tweaks or transformation?

The evidence suggests that LED can make progress towards achieving the 2°C goal. We need to continue to scale-up available options for LED through intensification and GHG-efficiency gains at field levels and in supply chains. Just tweaking current agricultural intensification will not be enough to achieve policy targets.

More transformational, high-impact technical and policy interventions are needed, including options that meet the needs of farmers in the developing world. If such radical measures are not pursued, we risk increasing the cost of mitigation by having to mitigate more in other sectors or exceeding the 2°C limit. Promising innovations include recently developed methane inhibitors that reduce dairy cow emissions by 30 percent without affecting milk yields; breeds of cattle that produce lower methane levels; and varieties of cereal crops or pasture grasses that inhibit nitrous oxide emissions associated with fertiliser or animal waste. Policies that support more ambitious mitigation include more rigorous carbon pricing, taxes and subsidies; sustainability standards that include reduced emissions in agriculture; and improving the reach of technical assistance for farmers on locally relevant mitigation options through web-based information portals.

Sequestering soil carbon, reducing deforestation due to agriculture, increasing agroforestry, decreasing food loss and waste and shifting dietary patterns will all contribute significantly to mitigation, but we do not yet have a target for assessing their significance. In the meantime, expanding these practices, particularly as part of LED packages, will help offset expected increases in emissions.

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