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RESEARCH BACKGROUNDER

Synergies and Tradeoffs for Small Farmers and Climate Mitigation

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EXECUTIVE SUMMARY

As world attention begins to focus on agricultural greenhouse gas mitigation, the potential conflicts and synergies with the needs of small farmers have become a major topic of interest. This paper explores the technical issues and policies that can encourage the synergies and reduce the conflicts.

While many mitigation measures can help small farmers, these measures do not perfectly overlap with adaptation requirements, and a mitigation focus must divert at least some resources from adaptation. Institutions from the World Bank to the Rockefeller Foundation have begun focusing on mitigation based on the belief that it will lead to additional resources overall. Such outcomes are not automatic, but the long-term self-interest of developed countries in solving climate change provides a rationale for this belief. Yet not all mitigation and adaptation efforts are inherently self-supporting. For example, while conversion of natural habitats may often be a reasonable adaptation strategy for local farmers (e.g., as coffee farmers seek cooler, higher altitude lands as temperatures increase), such conversion also contributes to climate change, and small farmers in developing countries will face some of the harshest consequences. A broader congruence between climate goals and the welfare of small farmers, along with many potential synergies in execution, does not imply a complete absence of trade-offs.

One reason to focus mitigation efforts on small farmers is the likelihood that such efforts will primarily work through incentives. Governments have strong reason to focus mitigation efforts on agricultural emissions, as combined emissions from agricultural production and associated land-use change could reach 15 gigatons per year by 2050, roughly 75 percent of commonly accepted global emissions targets for all sources for that date. Governments are also likely to support such efforts through incentives; ignoring small farmers would limit their access to these incentives. Although not entirely proportionate to their numbers as farmers, small farmers do contribute meaningfully to these emissions, particularly through livestock (globally), agricultural expansion (particularly in Africa), and the use of fertilizer and generation of rice methane in Asia.

To date, agricultural mitigation efforts have focused primarily on supporting carbon sequestration measures, particularly in soils; this focus needs to shift. While most soil carbon sequestration efforts do have some potential to help small farmers, thanks to the linkage between soil carbon and productivity, these mitigation potentials have been overemphasized and should not be the primary mitigation focus in the future. Scientific uncertainties with most soil carbon sequestration measures are higher than previously believed, especially because many carbon sequestration projects do more to move carbon around the

landscape than to increase overall carbon storage. Experience has also revealed higher costs and practical challenges for small farmers implementing these projects, in particular, high labor and local transactions costs and the need for upfront investments. Although concern with potential harms to small farmers may seem overblown, some forest-planting projects may displace small farmers. Agroforestry is a notable exception: Above-ground carbon is easier to monitor, and agroforestry may generate rapid economic returns to farmers through productivity gains.

In addition to some forms of agroforestry, mounting evidence suggests that other changes can both boost agricultural productivity and reduce emissions as measured per unit of food. Measures include improving livestock feeding and health care, removing rice straw and improving water management for rice, reducing overuse of nitrogen fertilizer in some parts of Asia (which improves profitability but not yields), and improving the efficiency of diesel pumps. More broadly, coupling improved yields with natural area protection to spare land provides important mitigation. For this reason, any adaptation measure that maintains production and avoids agricultural expansion can contribute to mitigation goals. These alternative mitigation measures – which have direct synergies with production and the potential to work for small farmers – should be the primary area of technical focus.

Institutionally, carbon offsets have been the primary focus of funding mechanisms for carbon sequestration, due to the hope that offsets will release private investment funds from the Organization for Economic Co-operation and Development (OECD) member countries. But offsets present major challenges for mitigation, and especially carbon sequestration. Concern with high transaction costs and monitoring is probably overblown: the costs estimated by pilot projects are high only in proportion to the low price of carbon offsets. That low price largely reflects the policies of the European Union (EU), which dictates most of the world's present purchases of carbon credits in response to a relatively modest world demand and commitment to climate mitigation. Both of these factors could change. But the reduced benefit of potentially impermanent carbon sequestration, as well as the high scientific uncertainties with soil carbon sequestration and the need to use indirect and uncertain methods of verifying its gains, suggests that soil carbon is likely to remain, and probably should remain, a lower valued and less compensated source of offset credits than other measures.

Other forms of agricultural mitigation do not necessarily present permanence problems but are harder to verify than typical energy offsets. Small farmers face particular obstacles to the use of offsets: these farmers generally need up-front financing of mitigation measures, while offset programs typically pay out funding only as credits emerge. With limited rights to tenure, and therefore offsets, many small farmers cannot practically commit to long-term measures. All offset funding faces inherent challenges and long-term uncertainty because of the challenge of demonstrating "additionality," i.e., that mitigation only occurs because of offset funding. For all these reasons, Oxfam should place little emphasis on offset funding in general, and on carbon sequestration offsets in particular.

An alternative funding mechanism would build up Nationally Appropriate Mitigation Actions (NAMAs) to establish a system that would not require clear proof of Greenhouse Gas (GHG) savings as traditional offsets, but, unlike traditional foreign aid, would be based on quantifiable and reasonably verifiable mitigation. Such a system would focus on supporting investments in measures that have high potential to be self-sustaining, thanks to their benefits for agricultural income, and would be quantified based on practically verifiable criteria. What and who such efforts fund, the timing of funding, and division between grants and loans could vary as with typical aid projects, while meeting quantitative goals for GHG reduction could be tied to additional incentives. Estimates and measurements of emissions reductions could be based on credible, but viable, simplified criteria. For example, in the case of livestock, they might include such relatively simple measurements as milk and meat outputs per number of cattle in some locations. More technical work is necessary to establish credible but simplified criteria on how to estimate emissions reductions, and to demonstrate which practices are the most practically viable.

Two greenhouse gas accounting issues are critical to the potential synergies versus trade-offs for small farmers. First, accounting must focus on emissions per unit of food. Second, accounting must reflect land-use "opportunity costs." Alternative accounting systems could reward decreases in production and would fail to recognize the benefits of productivity gains. Productivity gains are the principal ways in which many small farmers can contribute to greenhouse gas mitigation, particularly those in Africa.

While UNFCCC language favoring agricultural greenhouse gas mitigation, the focus of international negotiations, could encourage the process, it is probably not necessary because agreements regarding NAMAs provide a reasonable basis for moving forward. A more detailed elaboration of agricultural NAMAs in specific farming system contexts is probably the critical first step toward realizing the potential synergies set forth here. Such efforts should not only establish viable proxy methods for quantifying gains but also add detail to the economic and practical challenges and opportunities in specific farming systems and regions.

1. INTRODUCTION

Early public attention on the connection between agriculture and climate change focused almost exclusively on the potential adverse effects of climate on agricultural production and the potential for carbon sequestration in agricultural landscapes to provide a source of revenue for farmers and a source of offsets for energy producers. In the last few years, increasing attention has focused on the importance of mitigating agricultural greenhouse gas emissions because of its own contribution to climate change. That focus has grown, in part, because of the need of some developed countries to control their agricultural emissions to meet their Kyoto obligations, particularly New Zealand and Australia, for which agriculture contributes a large share of their emissions. Potential funding from REDD (Reduce Emissions from Deforestation and Forest Degradation) has also drawn attention to the potential transfer of funds to developing countries, and some parts of the agricultural sector eye those funds as potential support for agricultural development. Some countries and many large food companies are trying to reduce the carbon footprint of food products, including those imported from developing countries. In September 2011, an African ministerial meeting issued a communiqué calling for efforts to support win/win agricultural mitigation and adaptation.[1] The World Bank and Food and Agriculture Organization of the United Nations (FAO) are supporting the same concepts under the name "climate smart agriculture." This paper focuses on trade-offs and synergies between small farmer needs, food security, and agricultural mitigation.

2. POSSIBLE RELATIONSHIPS OF ADAPTATION AND MITIGATION

Could a focus on mitigation distract attention from the challenges of adaptation or even push farmers into adverse measures?

Agricultural climate adaptation is an evolving concept and, in discussion or action, likely takes several different forms:

- Efforts to breed crops or livestock to resist higher temperatures or more frequent droughts or floods, to control more difficult pests, or to help farmers shift to alternative crops as their climates change;
- Measures that would improve farming regardless of warming effects but that take on added urgency because of climate change including better weather prediction, increased access to irrigation, and practices that improve the water-holding capacity of soils;
- Economic or social measures to help farmers address greater variability in rainfall, such as weather index insurance;

1 The Johannesburg Communiqué as agreed at The African Ministerial Conference on Climate-Smart Agriculture "Africa: A Call to Action", (Sept. 14, 2011), http://www.nda.agric.za/index2011ClimateChange.htm.

- Any measure that improves farming for all weather conditions, because better yields on average translate into better yields even under climate change.

If resources do not increase, adding a mitigation focus should, by necessity, detract at least somewhat from the adaptation efforts because adaptation would otherwise be the total focus of funding. The agricultural interest in mitigation rests on the ultimate importance of climate mitigation to farming, as well as the potential for that focus to attract additional resources to agriculture. As many of the world's hungry people are not farmers, and climate change is expected to harm agricultural production overall and particularly its production in hungry continents, there is also an independent hunger reason to focus on mitigation. Key political and policy questions then involve whether mitigation funding will in fact add to, or only compete with, adaptation funding. Key technical questions involve the extent to which mitigation and adaptation efforts can or are likely to support or detract from each other and what policies might encourage the positive synergies and avoid the adverse ones.

The World Bank, International Fund for Agricultural Development (IFAD), FAO, and organizations such as the Rockefeller Foundation have been working under the assumption that mitigation can attract additional resources that support adaptation and agricultural development, particularly by small farmers. Their focus on making carbon offsets work is based on the thinking that doing so can attract billions of dollars from industrial sectors in the developed world into funding agriculture in the developing world, and that increasing soil carbon is a core strategy for increasing the resilience of and generally improving developing world agriculture.

An alternative source of funding would be that which developed countries have committed in principle to supply for Nationally Appropriate Mitigation Activities (NAMAs). Under the framework established in Copenhagen and codified in Cancun, developing countries are supposed to pursue such NAMAs in part on their own and in part with external funding. With the global economic crisis, few funds are actually flowing for any climate purposes, so the potential for new funding for NAMAs is unrealized, as is most of the potential funding for adaptation. Since mitigation activities contribute to the self-interest of developed countries more directly than adaptation, however, one political theory would suggest that developed countries will ultimately provide more total funds for mitigation and adaptation than they would for adaptation alone.

On the technical side, much of this paper focuses on potential synergies between adaptation and mitigation, but there are also potential conflicts. One obvious area involves land-use change. Many carbon-rich habitats provide either inherently resilient or potentially rich farmland for small farmers and rich farmers alike. Wetlands, in general, provide promising alternatives to present cropland in a changing climate, since many typically receive water in ways that supplement direct rainfall either in the form of high groundwater or runoff from a broader watershed. Africa has abundant wetlands. Rwanda's agricultural plan calls for increasing agricultural use of marshlands around Lake Kivu, which is a sensible agricultural policy.[2] But draining wetlands typically leads to high carbon losses. A small, though not trivial, portion of Amazonian deforestation occurs through actions of smaller landowners, sometimes with the support of the Brazilian government in response to the landless movement. According to researchers at the International Institute for Applied Systems Analysis, rising global temperatures are likely to make coffee growing unsuccessful at most of its present altitudes in Africa, which will require farmers to deforest upper elevation forests, absent some other adaptation technique.[3] Many small farmers would benefit from road building and improved access to inputs and markets, but road building is also a major incentive for land clearing. Additionally, efforts to sequester carbon that involve taking farmland out of production have the potential to restrict farmers' access to land.

Of course, degradation of natural resources also has negative implications for small and larger farmers - not only through global warming, but also potentially through local and regional affects. Loss of wetlands will diminish fish supplies. One important study estimates that African deforestation could have extremely adverse climate effects in Africa itself that are separate from the consequences of increasing atmospheric carbon because of changes to local albedo and regional rainfall.[4]

In short, while there are trade-offs for individuals and among competing interests, it would be naive to believe that the protection of natural resources always benefits small farmers locally.

Apart from land-use protection, adverse consequences on food production and small farmers could flow from any mitigation activity that focuses on absolute emissions, or emissions per hectare, rather than emissions per unit of food, because one way to reduce agricultural emissions on any single farm is to produce less food. The solution developed below, supported by major international institutions, focuses on measuring emissions per unit of food.

3. SIGNIFICANCE TO CLIMATE AND PRODUCTION OF SMALL FARMER EMISSIONS

One of the factors that should influence policy toward small farmer mitigation is the importance of their emissions to climate change and food security. In this

2 Republic of Rwanda, Strategic Plan for the Transformation of Agriculture in Rwanda: Phase II, Final Report (Kigali, 2009).

3 Personal communication with Michael Obersteiner (Oct. 2011).

4 H. Paeth et al., "Regional Climate Change in Tropical and Northern Africa due to Greenhouse Forcing and Land Use Change," *J. Climate* 22 2008:114-132.

section, I describe the importance of climate change to food production in developing countries, the importance of agricultural mitigation to addressing climate change, and the importance of small farm production to agricultural mitigation.

3A. Importance of Climate to Agricultural Production in Developing Countries

Despite high uncertainty about details, there is no reason to doubt the general importance of greenhouse gas mitigation for addressing the concerns of the hungry and of small farmers in the developing world. According to the consensus view, net worldwide effects of rising temperatures on food production are uncertain up to two degrees Celsius and could possibly balance, but that is because warmer temperatures in northern areas, along with the crop benefits of higher carbon dioxide (CO_2), could balance the negative effects in the southern hemisphere. In 2007, the Intergovernmental Panel on Climate Change (IPCC) stated that "agricultural production, including access to food, in many African countries is projected to be severely compromised . . . [and will] further adversely affect food security and exacerbate malnutrition,"[5] and recent evidence has only confirmed this view. One paper by researchers at Stanford University showed that a broad range of climate models indicate a 90 percent chance that *average* summer temperatures by the end of the century will exceed the highest record summer temperatures for the entire 106 year period of 1900 to 2006.[6] The authors estimate on average a 10 percent decline in grain yields for each rise in temperature of one degree Celsius. Another statistical analysis of past yield responses to temperature predicted yield losses (absent adaptation) in the period 2046 to 2065 of 20-40 percent in many sub-Saharan African countries for maize, millet, groundnuts, and millet.[7] A 2009 paper using crop models by the International Food Policy Research Institute estimated that by 2050 average rice, wheat, and maize yields will decline in the region by up to 14 percent, 22 percent, and five percent and, without major additional investments in agriculture, would reduce calorie availability per person in sub-Saharan Africa by 21 percent.[8] An even more recent paper examined how temperature has affected maize yields in African field studies and estimates that a rise of even a single degree Celsius is likely to lead to maize yield losses of 20 to 30 percent in much of the region.[9]

5 Pete Smith et al., *Climate Change 2007: Mitigation of Climate Change* (Geneva: IPCC, 2007). A review of studies since that date finds that they confirm the conclusion.
C. Müller et al., "Climate Change Risks for African Agriculture," *PNAS* 108 2011:4313-4315.

6 D. S. Battisti and R.L.Naylor, "Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat," *Science* 323 2009:240-244.
N. Hockley et al., "Risks of Extreme Heat and Unpredictability," *Science* 324 2009:177-178.

7 W. Schlenker and D. B. Lobell, "Robust Negative Impacts of Climate Change on African Agriculture," *Environmental Research Letters* 5 2010.
G. Nelson et al., "Food Security, Farming and Climate Change to 2050: Scenarios, Results, Policy Options," (IFPRI, Washington, D.C., 2010).

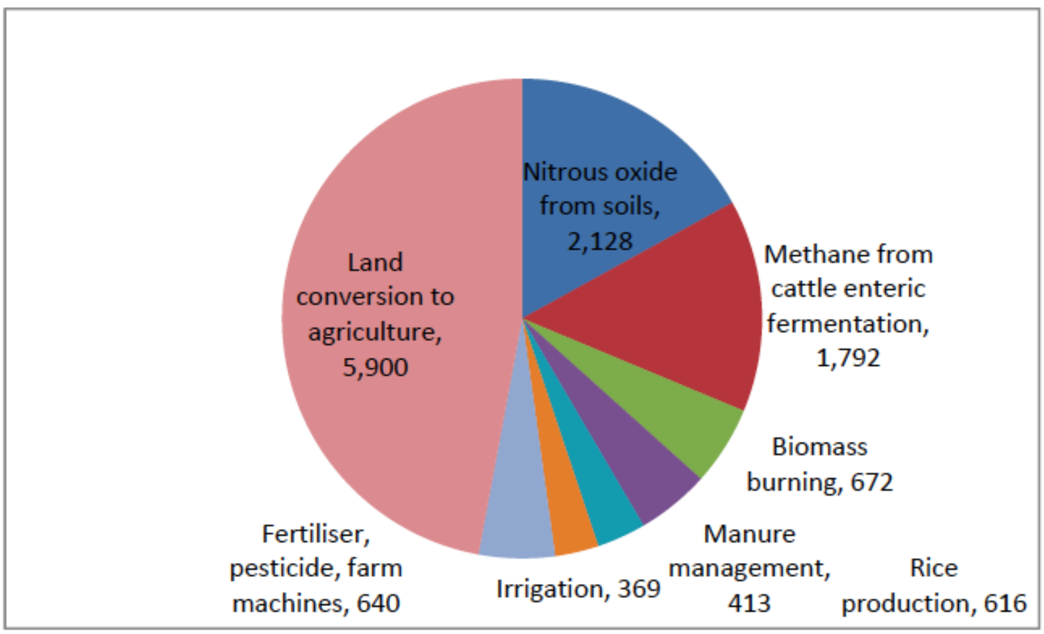
8 Nelson 2010.

9 . D. B. Lobell et al., "Nonlinear Heat Effects on African Maize as Evidenced by Historical Yield Trials," *Nature Climate Change* 1 2011:42-45.

3B. The Importance of Agricultural Mitigation to Climate Change

The IPCC estimated agricultural emissions from nitrous oxide and methane in 2005 at roughly 12 percent of world greenhouse gas emissions, and energy use involved in agricultural production at another two percent.[10] Estimates of land-use change emissions vary – and so-called bookkeeping approaches estimate higher emissions than satellite estimates -- but best estimates for 2005 might be on the order of at least another ten percent. [11] Nearly all emissions attributed to land-use change are those associated with conversion of forests or peat lands to agricultural use. Figure 1 reproduces a graphic from a previous Oxfam report identifying the general scope of different basic categories of agricultural emissions – although recent estimates would modestly lower those from land-use change.

Figure 1. Basic Sources of GHGs from Agriculture, Copied from Wright 2010.[12]



Source: Bellarby et al, 2008; HM Treasury, 2006.

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10 Smith 2007.
J. Bellarby, "Cool Farming: Climate Impacts of Agriculture and Mitigation Potential (Amsterdam: Greenpeace International, 2008).

10 Y. Malhi, "The Carbon Balance of Tropical Forest Regions, 1990-2005," *Current Opinion in Environmental Sustainability* 2 4 2010: 237-244.;
G. R. Van der Werf et al., "C02 Emissions from Forest Loss," *Nature Geoscience* 2 11 2009: 737-738.

11 Y. Pan et al., "A Large and Persistent Carbon Sink in the World's Forests," *Science* 333 6045 2011:988-993.
Malhi 2010
Van der Werf 2009.

12 J. Wright, "Feeding Nine Billion in a Low Emissions Economy: Challenging but Possible," (Oxfam, 2010).

At perhaps a quarter of world emissions, agriculture and land-use change are obviously less significant than energy emissions, but their significance looks different as part of a complete strategy for stabilizing the climate. Estimates vary by model and stabilization temperature, but a commonly accepted goal in Europe calls for reducing emissions in 2050 to half of 1990 levels, or a total of 20 gigatons of CO_2 equivalent. If emissions from land-use change remain the same at roughly five gigatons of CO_2, and agricultural emissions otherwise grow under business as usual under at least some projections to roughly ten gigatons,13 combined emissions would reach 15 gigatons. It is impossible to imagine a stabilization strategy with 75 percent of allowable emissions from the land-use sector that would generate less than five percent of world GDP at that time.

3C. The Significance and Sources of Emissions from Small Farmers in the Developing World

Figures 2 and 3 present separate regional estimates and projections of agricultural production emissions, excluding energy emissions, by the IPCC and researchers at the Potsdam Institute.[14] According to the IPCC, three quarters of agricultural production emissions occur in developing countries, and this share will probably rise above 80 percent by 2050, since nearly all emissions growth under business as usual will occur in developing countries.[15] As conventionally counted – although there is a case for counting forestry as an additional source of emissions – reported emissions from land-use change all result from conversion of tropical forest and tropical peat lands to another use.[16] In nearly all cases, those additional uses will be agricultural, although data challenges sometimes make this difficult to show.[17] The developing world is therefore the focus of agricultural greenhouse gas emissions.

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13 A. Popp et al., "Food Consumption, Diet Shifts, and Associated Non-CO2 Greenhouse Gases from Agricultural Production," *Global Environmental Change* 20 2010:451-62.

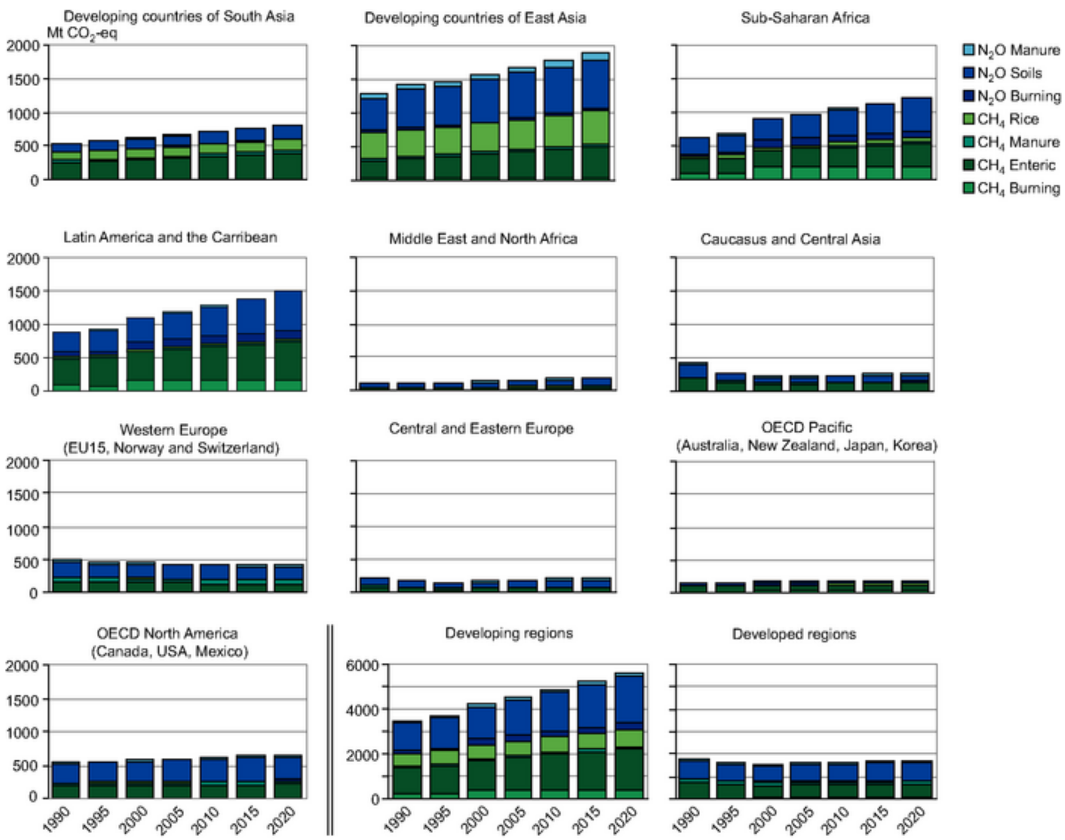
14 Smith 2007.
Popp 2010.

15 Smith 2007.

16 T. Searchinger, "The Food, Fores,t and Carbon Challenge," *National Wildlife Federation* 2011. Although emissions from forest harvesting are real and counted under the UNFCCC, standard methods of reporting global emissions from land-use change net out these emissions against regrowth from forest harvests in decades past, which leaves few net emissions. Yet because this regrowth from past harvesting would occur regardless of present harvests, present harvests do lead to increases in atmospheric carbon until and unless forests regrow from present harvests.

17 According to FAO data, decreases in forest area do not always show up in corresponding increases in agricultural land. This discrepancy is likely due primarily to large problems in FAO data for changes in agricultural land, for which changes or errors of definition or weak country estimates probably play a large role.

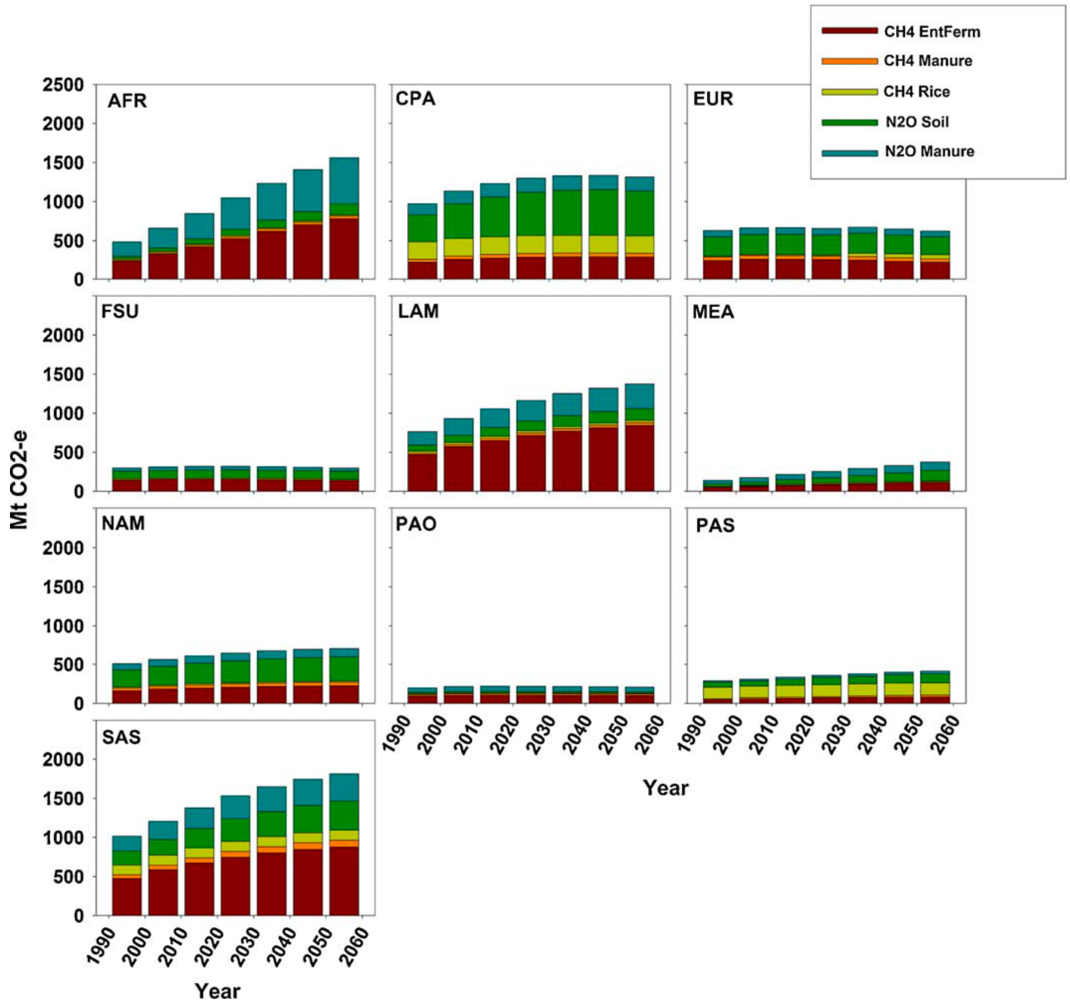
Figure 2.



Note that full scope of livestock emissions is obscured by failure to segregate N20 between grazing land and cropland.

Source: IPCC 2007.

Figure 3. Estimated Regional Agricultural Emissions



AFR – Africa; CPA – Centrally Planned Asia (i.e., China, Vietnam, Laos), LAM – Latin America (including Mexico), FSU – Former Soviet Union, NAM – North America, PAO – Pacific OECD (Japan, Australia, New Zealand), PAS – Pacific Asia, SAS (South Asia (e.g. India, Pakistan, Bangladesh).

Livestock sources are those labeled "EntFerm," enteric fermentation, "CH_4 manure," and "N20 Manure," which, in Potsdam's tabulation, includes not merely emissions from centralized manure management, but also all waste deposits on grazing land.

Source: Postdam Institute 2010.

Livestock

Livestock emissions are represented primarily by CH_4 - Enteric, which is the methane produced in the stomachs of ruminants (cattle, sheep, and goats) – poultry and pigs do not generate substantial methane in this way. Manure management emissions for both methane (CH_4) and nitrous oxide (N_20) result from the manure of confined livestock, to which pigs and cattle both are major contributors but not poultry, as poultry wastes are handled dry and do not emit much methane. Grazing animals also generate N_20 from their deposits of urine and manure; according to current IPCC methods, this nitrogen turns into N20 at higher rates than crop nitrogen. One reason the full scope of livestock emissions has been underappreciated is that the IPCC has included N_20 emissions from urine and manure deposited on grazing land under soil management, which also includes fertilizer emissions (Figure 2). By contrast, Figure 3 from the Potsdam Institute includes nitrous oxide on grazing land under N_20 manure, and, when combined with methane from manure and enteric fermentation (the methane generated in ruminant stomachs), shows livestock to provide the bulk of production emissions overall.

Livestock emissions are even more prominent in developing countries according to the Potsdam analysis, constituting roughly 70 percent of production emissions from both sub-Saharan Africa and the Indian subcontinent. These emissions are globally significant, and small farmers contribute their share. In these continents, livestock ownership appears to be widespread in rural areas, and, among households holding livestock, the number of livestock held is remarkably constant in many countries.[18] In India, small and marginal farmers own 60 percent of female cattle and buffaloes.[19] Latin America, however, is an exception, as livestock ownership is highly concentrated.

Crop Fertilization

Nitrous oxide results from the addition of nitrogen, either from synthetic fertilizer or nitrogen fixation. This figure is best seen from the Potsdam paper, and it represents roughly half of emissions in Europe and North America and slightly more than half in China and Vietnam. Africa uses little fertilizer and therefore has few emissions in this category.

Overall, and depending on the definition, small farmers are probably substantial contributors to these emissions in China, India, and possibly other parts of Asia, but not in Latin America. Farms in Asia are generally small. According to FAO data, within India, farms smaller than five hectares hold 68 percent of all farm areas, and all farms fewer than ten hectares occupy 84 percent of all cropland (See Table 1). The FAO does not provide data for China, but a separate study by Chand identifies the average farm size in China at 0.6 hectares, and in India at 1.2 hectares.[20] In addition, within Asia, the production emissions profile of small farms is probably similar to, or perhaps even greater than, those of larger farms as measured per hectare. China has the world's highest fertilizer use by far per hectare,[21] and, as its farms are overwhelmingly small, there is no reason

18 U. Pica-Ciamarra et al., "Livestock Assets, Livestock Income and Rural Households: Cross-country Evidence from Household Surveys" (Joint paper of the World Bank, FAO, AU-IBAR, ILRI 2011).

19 M. Punjabi, " Emerging Changes in the Indian Dairy Industry (FAO, New Delhi, 2008), <http://www.aphca.org/reference/Workshops_chiangmai_25-29-08/Presentation/Day1/2_Emerging%20Changes%20in%20the%20Indian%20Dairy%20Industry.pdf>.

20 R. Chand, "Farm Size and Productivity: Understanding the Strengths of Smallholders and Improving their Livelihoods," *Economic and Political Weekly* 46 2011:5-11. <http://www.syngentafoundation.org/db/1/983.pdf>.

21 UK-China Sustainable Agriculture Innovation Network, "Improved Nutrient Management in Agriculture: A Neglected Opportunity for

to believe that farm emissions are disproportionate from larger farms. The Chand study cited earlier uses Indian agricultural census data to show that, in general, small farms in India are more intensive than large farms as measured by fertilizer use, which was almost double the use of large farms per hectare, or use of irrigation or high-yielding seeds, which was also higher per hectare.

Although small farms are significant, definitions matter, and the smallest farms do not occupy a proportionate share of land. Table 1 shows that, within India, 80 percent of farms are smaller than two hectares, but they occupy only 25 percent of cultivated area. The smallest and poorest farmers are therefore less substantial contributors. Within both Asia and Africa, according to Chand, farm sizes have actually been declining, with farm size in India declining from an average of 1.84 hectares in 1980-81 to 1.32 hectares 20 years later.

By contrast, farm sizes in Latin America are much larger, so smaller farms are likely to be less significant sources of cropland emissions. Crop farm sizes in Africa are generally small, but African fertilizer use is extremely low at less than 6-7 kg/ha,[22] and it represented only 3.8 percent of world nitrogen use overall in 2008 (see Table 1 below). Many small farmers use no fertilizer at all, so what fertilizer is used must occur disproportionately on Africa's larger, commercial farms.

Rice Methane

Annual methane emissions from paddy rice equal three quarters of a gigaton of emissions (CO_2 equivalent) (roughly 1.5% of total global emissions), nearly all in developing countries and with Asia as the dominant region. By 2050, almost three quarters of rice methane emissions from cropland will occur in China, India and the rest of Asia, where farms are small (Figure 2, emissions for rice and soil nitrous oxide). For this reason, small farmers are probably the dominant generators of rice methane.

Biomass Burning Methane (CH_4) and Nitrous Oxide (N_20)

According to the IPCC, emissions from biomass burning are roughly 0.67 gigatons per year in the form of methane and nitrous oxide. (Carbon dioxide emitted is considered recycled from plant growth.) This figure mostly encompasses deliberate burning of grasslands and savannas for grazing purposes or as part of shifting agriculture.[23] The estimates are very rough. To the extent they are assignable to human causes, small farmers are probably significant contributors in Africa and Asia. Despite their common identification, it is not clear how many of these emissions should be considered human-induced. Savanna and grassland landscapes deliberately burned by people would

China's Low Carbon Growth Plan," *Policy Brief No. 1*. Rothamsted Research et al. 2011.

22 J. Pretty et al., "Sustainable Intensification in African Agriculture," *International Journal of Agricultural* Sustainability 9 2011:5-24.

23 F. Mouillot et al., "Global *Carbon Emissions from Biomass Burning in the 20th Century," Geophysical Research Letters* 33 L01801 2006.

generally burn naturally as well, and the human impact should only be any increase in methane and nitrous oxide emissions above the natural background, an analysis no one has generated. Burning emissions due to shifting agriculture and outright agricultural conversion are subject to mitigation efforts, but there is virtually no literature suggesting mitigation measures reducing emissions from burning savannas and grasslands.

Table 1. Agricultural Area by Size of Holding, Censuses since 1995

Continent/ Country	1-2 ha (%)	2-5 ha (%)	< 5 ha (%)	5-10 ha (%)	<10 ha (%)	10-20 ha (%)	20-50 ha (%)	50-100 ha (%)	100-200 ha (%)	Over 200 ha (%)
AFRICA	**16.1**	**21.4**	**37.6**	**17.0**	**54.5**	**17.6**	**15.6**	**5.2**	**5.9**	**1.1**
Ethiopia	45.7	44.8	90.5	7.6	98.1	1.9	0.0	0.0	0.0	0.0
Guinea	39.2	41.2	80.4	19.6	100	0.0	0.0	0.0	0.0	0.0
Namibia	12.7	57.6	70.3	23.9	94.2	3.6	1.2	1.1	0.0	0.0
Togo	21.8	48.0	69.8	23.6	93.4	6.0	0.5	0.0	0.0	0.0
Egypt	20.6	35.3	55.9	15.0	70.9	29.1	0.0	0.0	0.0	0.0
Senegal	5.8	25.8	31.6	34.5	66.1	25.0	8.8	0.0	0.0	0.0
Reunion	5.1	19.9	25.0	30.2	55.1	14.8	30.0	0.0	0.0	0.0
Morocco	10.6	11.8	22.4	22.1	44.5	22.0	17.8	6.8	8.9	0.0
Cote D'Ivoire	10.7	11.2	21.9	23.3	45.2	28.4	26.4	0.0	0.0	0.0
Algeria	1.9	8.6	10.5	14.3	24.9	22.6	29.6	11.1	6.3	5.5
Tunisia	1.7	8.7	10.4	14.5	24.9	18.4	22.8	12.2	21.7	0.0
ASIA	**19.6**	**32.8**	**52.4**	**20.6**	**73.1**	**13.5**	**9.3**	**2.5**	**0.7**	**1.0**
Sri Lanka	100.0	0.0	100.0	0.0	100	0.0	0.0	0.0	0.0	0.0
Laos	34.4	65.6	100.0	0.0	100	0.0	0.0	0.0	0.0	0.0
Nepal	48.8	39.2	88.0	8.6	96.7	3.3	0.0	0.0	0.0	0.0
India	24.8	38.4	63.2	20.5	83.7	10.2	6.1	0.0	0.0	0.0
Philippines	18.5	35.6	54.0	21.6	75.7	13.5	10.8	0.0	0.0	0.0
Myanmar	12.4	28.5	40.8	34.5	75.3	22.0	2.6	0.0	0.0	0.0
Pakistan (5)	10.3	29.6	40.0	20.2	60.2	17.3	10.2	12.3	0.0	0.0
Kyrgystan	12.6	12.6	25.2	10.4	35.5	8.7	10.1	4.2	3.5	38.1
Jordan	7.0	15.9	22.8	15.7	38.5	15.4	18.3	9.7	7.1	11.0
Turkey	4.1	16.2	20.3	21.0	41.2	24.1	23.1	6.2	3.0	2.3
Iran	3.8	13.8	17.6	18.7	36.3	22.0	21.6	9.0	4.8	6.3
SOUTH AMERICA	**0.4**	**1.0**	**1.4**	**1.7**	**3.1**	**3.2**	**7.8**	**8.5**	**9.7**	**67.7**
Guatemala	9.2	6.1	15.3	6.9	22.1	6.9	9.6	12.5	12.5	36.3
Ecuador	1.3	4.3	5.5	5.6	11.2	8.3	19.3	18.3	13.6	29.3
Colombia	1.7	1.8	3.5	4.0	7.5	6.2	13.6	14.8	15.0	42.9
Venezula	0.3	1.2	1.5	1.6	3.1	2.5	5.0	6.0	8.1	75.2
Brazil (3)	0.2	0.7	0.9	1.3	2.2	2.8	7.2	7.8	9.3	70.8
Chile	0.4	0.4	0.8	1.3	2.2	2.5	5.1	4.9	5.1	80.2
Uruguay	0.0	0.0	0.1	0.4	0.5	0.9	2.6	4.2	8.2	83.6

Continents are the acre-weighted average of country data available.

Source: FAO International Censuses of Agriculture, various years.

Energy Use

Estimates of emissions from energy use (and other input emissions) in agricultural production, shown only in Figure 2 as emissions from irrigation and most of the emissions from fertilizer production and farm machinery, lie in the order of one gigaton of CO_2 equivalent per year. Compared to roughly five to six gigatons of nitrous oxide and methane emissions, the role of emissions from energy use in agricultural production itself is small. Many studies of total emissions from the consumption of food products assign a much larger role to energy emissions, but those studies incorporate emissions from processing, transportation, retail, and sometimes even home cooking.[24] Fertilizer emissions primarily occur from the energy used to produce them, but also include substantial quantities of nitrous oxide emitted during the production process. These emissions are obviously heavily concentrated in the regions that use fertilizer most freely, which include OECD countries, China, and substantial other portions of Asia.

Land-Use Change

Figures 2 and 3 exclude emissions from land-use change, and there is a fair level of uncertainty in those total emissions, but best estimates today might be around five gigatons (See footnote 10). As conventionally calculated, these emissions nearly all arise from conversion of forests to alternative land uses in the tropics.

The largest emissions from land-use change come from expanding ranching operations in Latin America and oil palm, rubber, and tree plantations in Southeast Asia. Although older papers assigned a large role to small farmers, a consensus has emerged that large-scale commercial farming and ranching is now the driving force behind deforestation.[25] Even so, this consensus is based on impressions rather than any true field analysis, and small-scale farmers probably still play a meaningful, if subordinate, role in land clearing even in Latin America and Asia.

In Africa, however, agricultural land expansion has, at least until recently, occurred more at the hands of smaller farmers. Cash cropping of high value products contribute, and are often produced in plantation, but cash crops constitute only 12 percent of total crop area in sub-Saharan Africa.[26] Countries like Tanzania are now reporting deforestation at the level of 400,000 hectares per year, and only some of that is triggered by large operations.[27] Estimates of the resulting emissions range from roughly 0.55 to 0.89 gigatons of CO_2 per year.[28]

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24 T. Garnett, "Where are the Best Opportunities for Reducing Greenhouse Gas Emissions in the Food System (Including the Food Chain)," *Food Policy* 36 2011:S23-S32.
E. Audsley et al., *How Low Can We Go? An Assessment of Greenhouse Gas Emissions from the UK Food System and Scope for Reduction by 2050* (WWF-UK, 2010).

25 T. Rudel et al., "Changing Drivers of Deforestation and New Opportunities for Conservation," *Conservation Biology* 23 2009:1396-1405.

26 T. Searchinger et al., "Synergies in the Solutions to Africa's Climate and Food Security Challenges," *Filling in the Gaps: Critical Linkages in Promoting African Food Security: An Atlantic Basin Perspective*. Ed. J. Guinan et al. (Washington D.C.: German Marshall Fund 2011). 67-106.

27 United States Agency for International Development, "U.S. AID Feed the Future Program: Tanzania FY 2010 Implementation Plan," *USAID: Agriculture* 2010, April 11, 2012 <http://www.usaid.gov/our_work/agriculture/pdfs/2010/FTF_2010_Implementation_Plan_Tanzania.pdf>.

28 Searchinger 2011.

A recent report found deforestation in the Congo from 2005-2010 was occurring at roughly four-times the rate of 1990-2000.[29]

Because deforestation could contribute to future agricultural climate problems in ways other than its contribution to carbon dioxide, small farmer deforestation in Africa could play a more important role in climate change for Africa. The FAO projected in 2006 that Africa would lose 30 percent of its forests by 2050, and a model group at the University of Bonn analyzed what that loss would do to Africa's own regional climate when combined with different levels of global warming.[30] According to their model, the effect is to increase temperatures, and probably rainfall effects, enough that the best climate scenario analyzed by the IPCC becomes equivalent to the world scenario for Africa. Such changes would have particularly harsh effects on the region's most productive farmland belt stretching from West to Central Africa, which feeds the region's largest populations.

3E. Summary of Emissions and Small Farmer Discussion

The importance of agricultural emissions overall to climate stabilization suggests that those emissions will and should be a focus of climate mitigation efforts. If this approach works through incentives, the exclusion of small farmers from policy focus would hurt rather than help them. Based only on the role of small farmers in contributing to important emissions, the focus would be cattle and other livestock emissions everywhere, fertilizer use and other emissions from nitrogen among small farmers in Asia, rice farmers (congregated in Asia), and the avoidance of land-use change emissions everywhere.

4. CARBON SEQUESTRATION AND SEQUESTRATION OFFSETS

Until recently, nearly all discussion of agricultural climate mitigation, and virtually all projects, has focused on carbon sequestration measures with the expectation of funding them as offsets for energy emissions, either through the Clean Development Mechanism (CDM) or voluntary markets. Not surprisingly, carbon sequestration measures have therefore also been the focus of papers about the trade-offs between adaptation and mitigation, barriers to adoption, monitoring, and other administrative costs.[31] Carbon sequestration differs from other forms

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29 Central African Forest Commission, *Forests of the Congo Basin: The State of the Forests* 2012, summarized in R. Butler, "Deforestation Increases in the Congo Rainforest," *Conservation and Environmental Science News* March 22, 2012, April 6, 2012, <http://news.mongabay.com/2012/0320-congo_basin_deforestation.html>.

30 Paeth 2008.

31 W. Srang-iam,. "Fighting Global Climate Change, Securing Local Livelihood: The Paradox of Carbon Reduction and Agricultural Vulnerability in Thailand," (Colorado Conference on Earth System Governance, 2011).

L. Lipper, *Climate Change Mitigation Finance for Smallholder Agriculture: A Guide Book to Harvesting Soil Carbons Sequestration Benefits* of mitigation in that it does not reduce emissions but creates a carbon sink. If carbon credits are sold to industrial emitters, the offsets are credited to industrial emitters and therefore cannot also be counted as reducing net agricultural emissions. Although carbon sequestration is a technical mitigation option, and offsets provide only one means of achieving them, their interaction shapes the trade-offs and synergies of carbon sequestration for small farmers.

This section argues that most carbon sequestration measures could provide some benefit to small farmers, but that they should be deemphasized because technical potential has been overemphasized, because most carbon sequestration measures that are likely to work still generate variable and uncertain carbon results, and because many practical challenges exist for small farmers to engage in carbon sequestration efforts in particular. Offset funding mechanisms exacerbate these challenges. Agroforestry stands out as a likely exception.

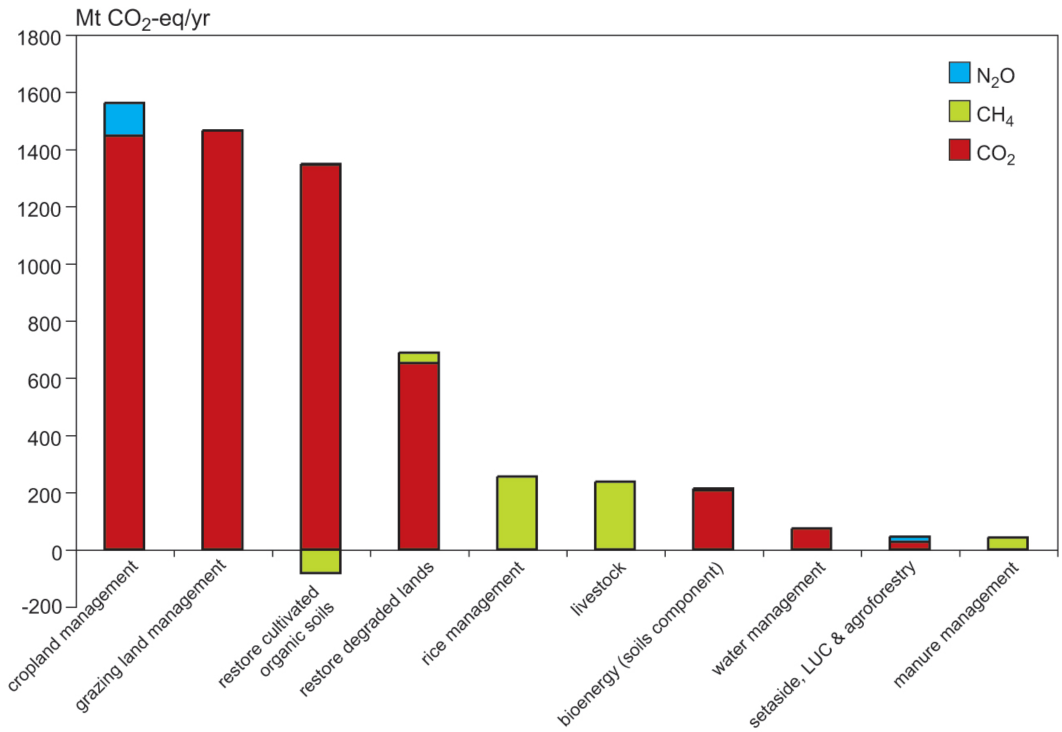
4A. IPCC Estimates of Carbon Sequestration Potential

The 2007 IPCC report on agricultural mitigation gave a strong endorsement to carbon sequestration efforts by estimating that various forms of carbon sequestration provided 90 percent of the mitigation potential for agriculture at up to \$100/ton of CO_2 (See Figure 4). Carbon sequestration usefully divides into four broad categories: soil carbon efforts in croplands, including restoration of degraded lands; soil carbon efforts in grazing lands; agroforestry, which can store carbon above ground as well as soils; and the reforestation or rewetting of agricultural lands, which typically removes them from agricultural production. The IPCC chart (Figure 4) does not include reforestation, whose estimates were included in a separate chapter, but does include the restoration of wetlands ("organic soils"), which removes agricultural lands from production.

(Rome: FAO, 2011)

A. De Pinto et al. "Potential of Carbon Markets for Small Farmers: A Literature Review," (IFPRI, Washington D.C., July 2010),

Figure 4. Estimates of Mitigation Potential in Agriculture



Source: IPCC 2007.

4B. Crop Soil Carbon Sequestration Technical Potential, Synergies, and Trade-offs

Among carbon sequestration opportunities, most of the agricultural focus has been on soil carbon sequestration through changed agricultural management practices. A recent article by David Powlson and other researchers at Rothamsted Research provides an excellent summary of the scientific doubts about the carbon actually sequestered, which in turn cast doubt on the willingness of funders to support these measures.[32]

Reduced plowing, including "no-till" farming, has formed an important part of the carbon sequestration strategy on the theory that tillage breaks up soil in such a way as to facilitate the decomposition of carbon by microorganisms. Yet, as Powlson summarizes, several papers have questioned whether measured increases in soil carbon in the top few centimeters, which are generally the soil layers assessed by no-till studies, are offset by reduced carbon at deeper soil depths. This literature is controversial because of limited data and a variety of statistical challenges, but even if soil carbon gains occur, there is also evidence,

32 D. Powlson et al., "Soil Carbon Sequestration to Mitigate Climate Change: A Critical Re-examination to Identify the True and the False," *European Journal of Soil Science* 62 2011:42-55.

summarized by Powlson, that no-till often generates warming from nitrous oxide in excess of its carbon reductions for at least several years. That is a big problem because even in the U.S., where no-till farming is advanced, only a small fraction of no-till farming occurs without occasional tillage, and the common view is that carbon benefits will be lost if tillage even occurs occasionally.[33] The combination of higher nitrous oxide emissions and limited sustained carbon gains, if any, implies a net increase in greenhouse gas emissions.

Another problem is that many means of adding carbon to soils, such as by adding mulch or manure, do not directly add to overall carbon storage as much as move carbon around, with unclear net gains. Some measures truly add carbon, such as returning residues to the soil or planting cover crops, but they often come with high opportunity costs because they sacrifice use of residues for animal feed or fuel, and because cover crops require labor and inputs and sometimes intrude on production in other growing seasons.[34]

Much of the interest in subsidizing soil carbon projects grows out of the expectation that such measures can boost yields, particularly in parts of Africa that have lost much of their soil carbon. Because soils with higher carbon content hold water better, building carbon can also enhance resilience to climate change. That is certainly true, however these benefits are hard to quantify, and yield gains from carbon growth are likely to occur slowly. Experience has shown that poor farmers are rarely in a position to focus on such strategies unless the same measures produce gains more rapidly in some other way.

A recent FAO paper by McCarthy et al. summarizes the substantial economic trade-offs, which fall into several categories: (1) upfront investment; (2) maintenance/variable costs; (3) opportunity costs (including labor); (4) transactions costs, including access to information but also challenges such as addressing communal grazing practices or privileges on agricultural land; and (5) risk. Summarized costs vary from rotational grazing costs of $105 per hectare up-front in South Africa and $27 per hectare maintenance, which are not trivial costs for dry lands, to $1,052 upfront costs for grazing land improvement in Ethiopia and maintenance costs of $126 per hectare (See Table 2). The authors summarize:

> "The very rosy net present value figures for many sustainable land management (SLM) practices, that increase carbon sequestration and reduce emissions found in such sources as McKinsey (2008) are not likely to be relevant in the most developing country contexts, since they do not capture the significant financing barriers associated with these practices and appear to be seriously underestimating both direct and indirect costs of adoption."

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33 I. Gelfand et al., "Carbon Debt of Conservation Reserve Program (CRP) Grasslands Converted to Bioenergy Production," *PNAS* 108 2011:13864-13869.

34 K.E. Giller et al., "Conservation Agriculture and Smallholder Farming in Africa: The H View," *Field Crops Research*, 114 2008:23-34.

On a more optimistic note, the science remains robust that overall yield gains tend to result in more soil carbon. As yields improve, so do residues and roots. For this reason, improved water capture, as through low berms on hillside to capture water (bunds), increased fertilization through fertilizer or nitrogen-fixing crops, and use of improved seeds are all means of increasing soil carbon.[35] The rates are probably modest per hectare from a climate standpoint, but this science suggests a direct synergy between measures that increase agricultural livelihoods and carbon gains.

Table 2. Examples of Establishment and Maintenance Costs of Land-based Agricultural Mitigation Options[36]

Technology options	Practices	Case study	Establishment costs (US$/ ha)	Average maintenance costs (US$/ha/ year)
Agroforestry	Various agroforestry practices	Grevillea agroforestry system, Kenya	160	90
		Shelterbelts, Togo	376	162
		Different agroforestry systems in Sumatra, Indonesia	1,159	80
		Intensive agroforestry system (high input, grass barriers, contour ridging), Colombia	1,285	145
Soil and water conservation	Soil and water conservation	Small-scale conservation tillage, Kenya	0	93
		Minimum tillage and direct planting, Ghana	220	212
		Medium-scale no-till technology for wheat and barley farming, Morocco	600	400
	Improved agronomic practices	Natural vegetative strips, the Philippines	84	36
		Grassed *Fanya juu* terraces, Kenya	380	30
		Konso bench terrace, Ethiopia	2,060	540
	Integrated nutrient management	Compost production and application, Burkina Faso	12	30
		Tassa planting pits, Niger	160	33
		Runoff and floodwater farming, Ethiopia	383	814
Improved pasture and grazing management	Improved pasture management	Grassland restoration and conservation, Qinghai province, China *	65	12
	Improved grazing management	Rotational grazing, South Africa	105	27
		Grazing land improvement, Ethiopia	1,052	126

Source: Compiled by Esther Velasco for this paper

35 G. Branca et al., *Climate-smart Agriculture: A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management* (Rome: FAO, 2011).

36 Compiled by Esther Velasco from H. Liniger and W. Critchley, eds, *Where the Land is Greener – Case Studies and Analysis of Soil and Water Conservation* (Nairobi: United Nations Environment Programme, 2007)); H. Linigeret al., *Sustainable Land Management in Practice: Guidelines and Best Practices for Sub-Saharan Africa* (Rome: FAO 2011); O. Cacho, "Economics of Carbon Sequestration Projects Involving Smallholders," *Natural Resource Management and Policy* 31 2009: 77-102.

4C. Grazing Land Soil Carbon

Although the IPCC identified grazing management as having the largest potential for carbon sequestration, the efficacy of grassland carbon management is a bit of an enigma.[37] On one hand, there is strong evidence that many grazing lands have lost carbon, and that changes in management practices can increase soil carbon.[38] On the other, scientific results are highly variable, as summarized by Lipper et al.[39]

> "Comparison of carbon sequestration levels on optimally grazed lands with ungrazed or overgrazed lands yields inconsistent results, because of the diversity of the ecological conditions. . . . Clearly stocking rates do matter, but the grazing pressure and its timing and duration at any given time, as well as plant recovery periods, are of more consequence than long-term average stocking rates."

Adding further complexity, overgrazing in semi-arid environments often results in increases in shrubs and small trees, which increases carbon stocks although it reduces livestock output.[40] The emerging synthesis, more nuanced than the analysis that motivated the IPCC,[41] concludes that somewhat wetter areas are more prone to overgrazing, and that the opportunities for carbon sequestration mainly exist where overgrazing has contributed to true replacement of perennial grasses with more annual vegetation or caused large-scale soil erosion.[42]

The trade-offs of improved grazing practices depend on the nature of the project. For replanting of degraded land, the trade-off includes the high cost of plantings and the temporary exclusion in many cases of grazing animals during the restoration effort. For most projects, the restoration is based on reducing stocking rates. Proponents assume that a better balance of animals to forage should result in a higher conversion efficiency of forage to meat and milk outputs, and the science supporting this principle overall is the success of New Zealand-style rotational grazing, for which these kinds of calculations have been brought to a fine art. However, there is less literature establishing these gains in drier climates. There is also evidence that many pastoral societies are already efficient grazers. For example, studies of grazing in Mali showed total production

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37 N. MacCarthy et al., "Climate Smart Agriculture: Smallholder Adoption and Implications for Climate Change Adaptation and Mitigation" (Working paper 2011).

38 R. T. Conant and K. Paustian, "Potential Soil Carbon Sequestration in Overgrazed Grassland Ecosystems," *Global Biogeochem. Cycles* 16 2002:90-99.

39 L. Lipper et al., "Supplying Carbon Sequestration from West African Rangelands: Opportunities and Barriers," *Rangeland Ecology & Management* 63 2011:155-166.

40 G. Asner and S. Archer, "Livestock and the Global Carbon Cycle," *Livestock in a Changing Landscape*. Ed. H. Steinfeld et al. (Washington D.C.: Island Press 2010). 69-82.

41 R.T. Conant et al., "Grassland Management and Conversion into Grassland: Effects on soil carbon," *Ecological Applications* 11 2001:343-355.

42 McCarthy 2011. J. D. Derner and G. E. Schuman, "Carbon Sequestration and Rangelands: A Synthesis of Land Management and Precipitation Effects," *J. Soil Water Cons.* 62 2007:77-85. For example, a study of grazing intensities in the western Sahel on drier, low-carbon lands found no response in carbon content to grazing intensity. O. Badini et al., "A Simulation Based Analysis of Productivity and Soil Carbon in Response to Time-Controlled Rotational Grazing in West African Sahel Region," *Agricultural Systems* 94 2007: 87-96.

of substantially higher protein per hectare than generated in the U.S. for lands of comparable productivity.[43]

The degraded grasslands of northwest China appear to provide an example of the opportunities for "ecosystem services" to support pastoralists. In May of 2011, China announced a $2 billion/year program to reduce overgrazing, largely through compensations to grazers to reduce grazing pressures and to install remote watering facilities. A summary paper and presentation by Dr. Paul Kemp of Charles Stuart University at a recent Consultative Group on International Agricultural Research (CGIAR) Science Conference in Beijing in October offers substantial evidence that such efforts can work.[44] Yet, there is reason to doubt

Table 3. FAO Estimated Costs and Payback of Grazing Improvements in Western China[45]

Size of herd	Baseline net income ($/ha/yr)	NPV/HA over 20 years ($/ha)	Number of years to positive cash flow	Number of years to positive incremental net income compared to baseline net income
Small	14.42	118	5	10
Medium	25.21	191	1	4
Large	25.45	215	1	1

Source: L. Lipper et al. *Climate Change Mitigation Finance in Smallholder Agriculture*. Rome: FAO, Nov. 2011.

that carbon benefits are playing or will play a critical role. The FAO has been exploring the potential of financing a sustainable grazing management project involving restoration of degraded grazing lands through the use of carbon finance, but a recent book-length compilation of studies about the opportunities in the region makes little or no reference to soil carbon.[46] The willingness of the Chinese to invest such substantial funds probably results less from a desire to sequester carbon than from a response to the dust storms created by degraded grasslands, which become a powerful nuisance with serious health consequences in late winter each year in Beijing. Because of the various scientific uncertainties, as well as other practical challenges with carbon projects

43 C. de Haan et al. , "Structural Change in the Livestock Sector." *Livestock in a Changing Landscape*. Ed. H. Steinfeld et al., (Washington D.C.: Island Press, 2010). 3.1.

44 K. McGhee, "Restoring China's Grasslands," Australian Centre for International Agricultural Research, CP19 2008, April 12, 2012 <http://aciar.gov.au/files/node/10949/China%20Grassland.pdf> .

45 A. Wikes in *Climate Change Mitigation Finance in Smallholder Agriculture*. L. Lipper et al. (Rome: FAO, Nov. 2011).

46 D. R. Kemp, and D. L. Michalk, eds., "Development of Sustainable Livestock Systems on Grasslands in Northwestern China," (Australian Center for International Agricultural Research Proceedings 134, Canberra, 2011).

in general discussed below, external funds for improved grazing management seem more likely to result from a desire to promote ecosystem services other than carbon.

4D. Forest Plantings and Wetland Restoration

By far the easiest way to sequester carbon is to plant trees on some form of agricultural land. There is no doubt about the potential of such measures to sequester carbon (although some of the estimates from particular projects may be excessive). In the case of wetland restoration, particularly of drained peatlands, the potential carbon gains are enormous. (This potential exists above all in Russia and parts of Southeast Asia.). Wetland restoration is a highly cost-effective mitigation strategy where such drained wetlands lands are not currently in use. But the IPCC estimate of mitigation cost. It did not assume use of abandoned land, yet it did not address the potential emissions from leakage as crops are replaced elsewhere, and costs were also based on a very limited scenario.[47]

Simply removing land from agricultural use does not generally help small farmers and, by itself, would not generally increase food availability. One set of alternatives might be projects that combine restoration of little used, highly degraded lands with improvements in agricultural production. For example, an FAO publication describes project in Chiapas, Mexico and Cambodia, designed to combine forest restoration and agricultural improvements on shifting agricultural lands that could, in theory, improve both production and carbon.[48] The paper also describes another project aimed at restoring Andean peatlands, a possible a situation where carbon losses are dramatically out of proportion to food gains, so that win/win solutions should be feasible. These types of projects might contribute to livelihood gains.

Some of the concern with carbon sequestration projects has focused on efforts by large-scale commercial interests to gain credit for establishing forest plantations. For example, some forestry companies have attempted to gain credit for these activities even in the peat lands of Southeast Asia that they have deforested, typically at the expense of local people.[49] Groups such as Forestwatch have identified afforestation projects that they claim are often in good grasslands, not degraded lands, and are displacing local pastoralists and other land users.[50] One paper cites an example in Uganda where there were reports of commercial plantations generating carbon offsets that threatened to

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47 There was no documentation of these cost estimates. Pete Smith, the lead author of the study, told this author that they were based on cost estimates at the time of removing average wheat land in the U.S. from crop production. This analysis also did not account for the land-use implications of replacing food production for land removed from production.

48 C. Seeberg-Elverfeldt and M. Tapio-Biström, *Global Survey of Agricultural Mitigation Projects* (Rome: *FAO*, 2010).

49 D. Murdiyarso and R. Pirard, “Pulpwood Plantations as Carbon Sinks in Indonesia: Methodological Challenge and Impact on Livelihoods,” *Carbon Forestry, Who Will Benefit?* Ed. D. Murdiyarso and H. Herawati (Bogor Barat: CIFOR 2005).

50 *CDM Carbon Sink Tree Plantations: A Case Study in Tanzania*, dir. B. Karumbidza and W. Menne 2009.

evict local people from their customary rights for farming, grazing, fishing, and timber collection.[51] In theory, CDM rules require that social criteria be met that would preclude this kind of displacement, but obviously that may not always occur.

4E. Agroforestry

Policy interest in agroforestry has been growing, primarily as a result of successful projects and documentation by the World Agroforestry Center, along with the powerful example of "parkland" restoration in Niger. Agroforestry is sometimes grouped under "conservation agriculture" with other carbon sequestration techniques, but it deserves special attention because it also sequesters carbon above ground, which is easier to monitor and generally builds faster.[52] From a carbon perspective, agroforestry techniques can be divided between (1) shifting to tree-based crops in whole or in part; (2) intercropping of trees or shrubs to increase nitrogen, wood, carbon residues, or fodder; and (3) planting shrubs during fallow periods to increase soil quality when they are plowed back into the soil.

The World Agroforestry Center has documented large yield gains from use of these techniques and has shown how various project designs can encourage adoptions.[53] The greatest success involves the planting of roughly five million hectares of "parklands" in Niger, where trees are planted at up to 160 trees per hectare, with cropping underneath. The literature on the actual carbon gains from agroforestry is somewhat lacking. Estimates are broad. But with potential gains of one to eight tons of carbon dioxide equivalent per hectare per year for at least twenty or thirty years with different practices, the carbon gains could serve as a potential additional financial incentive for up-front investments.[54] For example, at two tons of CO_2 per year for 20 years, that would be worth $500 per hectare at a relatively discounted carbon price of $15.00 per ton (assuming that carbon prices rise at least at the discount rate of money).

Most of the interest in agroforestry truly lies in its potential economic gains. The trees can add soil fertility, provide a source of livestock fodder, wood, and medicine, and increase crop yields.[55] Similar practices have been developed for South and East Africa, with the World Agroforestry Centre particularly

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51 B. Swallow and R. Meinzen-Dick, "Payment for Environmental Services: Interactions with Property Rights and Collective Action," *Institutions and Sustainability*. Ed. V. Beckmann and M. Padmanabhan (Dordrecht: Springer 2009). 4.

52 For good overall summaries, see F. Place et al., "Tree-based and Other Land Management Technologies for Landscape Restoration in Africa: Background Paper for the Investment Forum on Mobilizing Private Investment in Trees and Landscape Restoration," (Nairobi: World Agroforestry Center, 2011); D. Garrity et al., eds., *World Agroforestry into the Future* (Nairobi: World Agroforestry Center, 2006).

53 W. Makumba et. al., "The Long-Term Effects of a Gliricidia-Maize Intercropping System in Southern Malawi, on Gliricidia and Maize Yields, and Soil Properties," *Agriculture Ecosystems and Environment* 116 0.5 2006:85-92.
E. K. Asaah et al., "Trees, Agroforestry and Multifunctional Agriculture in Cameroon," *International Journal of Agricultural Sustainability* 9 1 2011:110-119.

54 S. J. Kandji et al., "Opportunities for Linking Climate Change Adaptation and Mitigation through Agroforestry Systems." *World Agroforestry into the Future*. Ed. D. Garrity et al. (Nairobi: World Agroforestry Centre 2006). 113-123.

55 . D. P.Garrity et al., "Evergreen Agriculture: A Robust Approach to Sustainable Food Security in Africa," *Food Sec*. 2 2010:197-214.

encouraging a nitrogen-fixing acacia species *Faidherbia albida* because it sheds its leaves at the start of the rainy season and regrows them at the end, allowing the leaves to provide a nitrogen mulch while still allowing light to penetrate to crops. Other permanent agroforestry techniques involve planting shrubs to generate high protein forages for dairy cows and growing trees in cocoa plantations, where their shape helps increase growth rates of young cocoa trees. In wetter pastures, silvopastoral systems can provide wood revenue sources while generating shade to remove stress on livestock in hot climates.

Despite this literature, there is a quiet debate about how widespread these techniques can truly become.[56] The success in Niger, although supported by NGO efforts starting in the 1990s, in effect reestablished a kind of agricultural practice that was traditional in the area and also took advantage of returning higher rainfall to the Sahel. There is every reason to believe it can be replicated in millions of hectares of other similar Sahelian lands, but there is no comparable proof that agroforestry can expand as strongly in other regions. Gaps include a lack of sound comprehensive guidance on where agroforestry truly helps rather than hurts, as trees can sometimes depress yields through competition for water and air and lack of access to seedlings.[57] Keeping up-front investments costs low and providing quick, tangible economic returns are the key to expansion.[58]

4G. Use of Offsets for Carbon Sequestration

Much of both the hope and concern with agricultural mitigation has focused on private offsets. In part, many development advocates have assumed that offsets are likely to generate the bulk of potential funding and have hoped to use offsets to boost agricultural development, with the assumption that such efforts would focus on soil improvements. In turn, advocates for climate legislation in developed countries have viewed agricultural offsets as a way in which a cap and trade system can financially benefit agriculture and therefore generate political support both domestically and abroad, as well as a way of generating cheaper credits for industry to help reduce its opposition. Estimates of cheap mitigation in the agricultural sector by such authorities as the IPCC, McKinsey, the U.S. Environmental Protection Agency, and the Stern Report, have helped to fuel this latter interest.[59]

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56 S. Franzelet al., "Scaling Up the Impact of Agroforestry: Lessons from Three Sites in Africa and Asia," *Agroforestry Systems* 61-62 2000 2004: 329-344.
O. C. Ajayiet al., "Agricultural Success from Africa: The Case of Fertilizer Tree Systems in Southern Africa (Malawi, Tanzania, Mozambique, Zambia and Zimbabwe)," *International Journal of Agricultural Sustainability* 9 1 2011:129– 136.
F. Place et al., "Improved Fallows in Kenya: History, Farmer Practice, and Impacts," (IFPRI, Washington D.C., 2003).

57 S. Hauser et al., "What Role Can Planted Fallows Play in the Humid and Sub-humid Zone of West and Central Africa," *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Ed. A Bationo et al. (Netherlands: Springer, 2007). 647-668.

58 Among the skeptics, count Ken Giller, who runs a large Gates-funded project on nitrogen-fixation in Africa. Interview with Ken Giller, Beijing, Oct. 2011.

59 N. Stern, *TheStern Review: Economics of Climate Change* (Cambridge: Cambridge University Press, 2006).
J. Creyts et al. "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?," McKinsey Company, 2007.

Three related offset programs permit offsets from developing countries:

- The CDM allows credits purchased from developing countries to be certified and to count toward meeting Kyoto targets for OECD countries;
- An emissions trading program set up by the EU's Emissions Trading System, which permits the purchase of CDM credits;
- Various voluntary carbon markets.

In 2008, CDM constituted roughly 90 percent of offset carbon traded with a market valuation of $6.5 billion, based on 389 million tons of CO_2 equivalent,[60]

To date, agricultural mitigation projects have been limited by restrictions at both the CDM level and the EU. CDM must approve each type of mitigation project, and, with one exception, pure agricultural projects focus on the capture of methane, such as digesters from livestock waste. The exception is an inoculant on legumes on acidic soils to reduce CO_2 emissions from production of nitrogen fertilizer. The restrictions are based on concerns about scientific uncertainty, verifiability, and permanence. CDM has allowed credits for forest plantings on degraded lands, and they have provided nearly all of the land-based emissions credits.[61] A list by FAO of Bio-Carbon projects shows the same.[62]

Voluntary carbon markets have proved a little more forgiving of agricultural mitigation projects. The Chicago Climate Exchange accepted a variety of agricultural practices, particularly no-till agriculture, but the Exchange closed at the end of 2010. Only a modest number of projects focused on agricultural soils, and land-based credits provided only sixteen and eleven percent of total credits in 2007 and 2008 respectively, and only 5.6 million tons of CO_2 overall in those years.[63]

Offsets have certain inherent limitations. Because offsets allow regulated factories and power plants to reduce emissions less through their own efforts, the accountability requirements for offsets must inevitably be tighter than, for example, the use of foreign aid to promote mitigation. That need implies a more conservative approach to the science, closer monitoring, and concerns about leakage, i.e., the extent to which activities such as replanting of forests in one location simply shift emissions to another. The great conceptual and often practical challenge is the establishment of "additionality," the proof that a

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<http://www.mckinsey.com/clientservice/sustainability/greenhousegas.asp>.
United States Environmental Protection Agency, "EPA Preliminary Analysis of the Waxman-Markey Discussion Draft: The American Clean Energy and Security Act of 2009 Request for Analysis," *Environmental Protection Agency*, 2009.
<http://www.epa.gov/climatechange/economics/pdfs/WM-Analysis.pdf>.

60 De Pinto, IFPRI 2010.

61 A. Vasa and K. Neuhoff, "The Role of CDM Post-2012: Carbon Pricing for Low-carbon Investment Project" (Climate Policy Initiative, Berlin, 2011).

62 L. Lipper 2011.

63 DePinto, IFPRI, 2010.

mitigation measure would not occur anyway but instead results from the payment of the mitigation credit. To establish additionality, CDM requires an analysis that the measure would not otherwise be economical and customary. That proof increases transactions costs, but despite complaints about those costs, there is serious dispute that most CDM projects truly meet the additionality test.[64] Ironically, the more economical a mitigation measure – and therefore the more desirable and likely to be successful – the less likely it is to be additional. The additionality problem is so fundamental that many researchers and some policymakers have called for abolishing it altogether and replacing the whole approach with an alternative that rewards countries for holding emissions below a projected baseline.[65]

4H. Administrative Costs of Carbon Offset Projects

One of the central concerns with carbon offsets is that administrative costs, including monitoring, will absorb too much of the funds from carbon payments. As presently estimated, administrative costs are not exceptionally high, but consume a high percentage of project revenues mainly because payment rates are low due to low demand for these types of credits, and new laws in developed countries could increase that demand. However, one reason demand is low is that the indirect methods of measuring carbon necessary to maintain low administrative costs leave a high level of uncertainty about benefits.

Information on actual administrative costs for carbon offset projects is limited as cost estimates are often presented per project rather than per ton of carbon,[66] or the pure transactions costs are discussed only qualitatively.[67] From the data of forestry projects, the transactions costs vary but are not enormous. A 2002 paper by CIFOR, based on interviews of estimated costs for CDM-like projects in early stages of implementation, estimated costs from only \$0.4/t CO_2 to \$1/t CO_2, which included monitoring costs. Yet some categories for many projects showed no costs, such as administration, and the estimates excluded landholder transaction costs, so the overall estimates were probably low.[68] Estimates for different categories of projects by a Dutch agency were somewhat higher at \$0.42 to \$4.56/t CO_2. Similarly, an estimate in a more recent paper of a project designed to sequester carbon in fast-growing trees put cost estimates at \$3.27/t. CO_2 [69] These cost estimates assume that farmers would do the monitoring themselves. Because there are almost no functioning soil carbon sequestration projects in the developing world, it is very hard to judge the merits of these estimates. For a future market that might pay at the true alternative costs of

64 Vasa 2011.

65 B. Haya, "Measuring Emissions Against an Alternative Future: Fundamental Flaws in the Structure of the Kyoto Protocol's Clean Development Mechanism," (University of California at Berkeley, 2009). April 11, 2012 <http://erg.berkeley.edu/working_paper/index.shtml>.

66 De Pinto, IFPRI, 2010.

67 McCarthy 2011.

68 M. Milne, "Transaction costs of forest carbon projects" (CIFRO, Bogota, 2002).

69 Cacho 2009.

carbon sequestration of $25 or more per ton, these transactions costs would not seem exorbitant – and CDM credits in 2011 fluctuated from around $17 to $12 ton.

These costs probably appear exorbitant to some critics because the value of carbon sequestration credits has been so low. For example, the Institute for Agriculture and Trade Policy has criticized the Kenya Agricultural Carbon project set up by the World Bank because it promises to pay only $2.48 million to farmers over 20 years, which works out to only $1 per farmer per year, yet the project expects to incur $1.04 million in transaction costs.[70] This criticism does not seem necessarily fair as these kinds of projects are in their infancy, necessitating high transaction costs at this time, while payment rates for carbon sequestration offsets are low.

Even so, these payments are low in part because Europe, which provides the primary market for offset credits, has so far rejected all soil carbon sequestration offsets due to uncertainty and impermanence, and those concerns are likely to remain in place. The quality of monitoring that is affordable and reflected in the cost efforts above is not sufficient to overcome these doubts. The costs of direct carbon sampling are prohibitive (e.g. estimated at almost $700 per plot to sample ten samples by one study),[71] and although much work is occurring on remote sensing methods, they are not capable now of providing meaningful estimates at the resolution required, nor can they assess carbon at depth.[72] Any soil carbon gains must therefore be based on assumed average relationships in response to practices. For example, one recent paper on soil carbon sequestration through no-tillage in the Punjab estimated administrative costs, including monitoring, at less than ten percent of project returns, assuming payments of at least $25/t CO_2, but the monitoring would solely assess implementation of the practice and not direct measurements of soil carbon.[73]

In short, to date, the problem is not the size of transaction costs but the low carbon payments and ineligibility of soil carbon projects on the European market. On the other hand, providing a higher level of monitoring to overcome some of the doubts behind that European refusal to fund soil carbon sequestration projects would be cost-prohibitive.

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70 K. Hansen-Kuhn, "Soil Carbon Sequestration for Carbon Markets: The Wrong Approach to Agriculture," *Institute for Agriculture and Trade Policy*. April 11, 2012 <http://www.iatp.org/documents/soil-carbon-sequestration-for-carbon-markets-the-wrong-approach-to-agriculture>.

71 R. Makipaa et al., "The Costs of Monitoring Changes in Forest Soil Carbon Stocks," *Boreal Environmental Research* 13 2008: 120–30.

72 A. Chatterjee and R. Lal, "On Farm Assessment of Tillage Impact on Soil Carbon and Associated Soil Quality Parameters," *Soil and Tillage Research* 104 2 2009:270–277. < http://linkinghub.elsevier.com/retrieve/pii/S0167198709000828>,

73 P. Grace et al., "Soil Carbon Sequestration and Associated Economic Costs for Farming Systems of the Indo-Gangetic Plain: A Meta-analysis," *Agriculture, Ecosystems and Environment* 146 2012:137-146.

4I. Particular Challenges for Carbon Offsets Facing Small Farmers and Pastoralists

Small farmers face particular challenges in participating in carbon sequestration offset projects. Transaction costs are higher because more farmers must band together. Small farmers are often unable to spare land for tree planting.

Tenure presents another frequent problem. If small farmers do not have full land ownership rights, they have less reason to invest in any system designed to provide financial rewards in the future that accrue to whoever controls the land at that time. Carbon sequestration projects obviously fit this description, but so do any improvements to production based on up-front investments. In different forms, this tenure problem should affect small farmers broadly: in China, where land ownership is technically by the state; in Africa, where the same is true but where land ownership is also modified by customary rights; and in Latin America, where small farms at the frontier in particular may not have established rights.

Tenure also presents a substantial administrative challenge for offset projects where communal property is involved. As only one example, Roncoli et al. describe how the complex interactions of private and communal lands in a part of Mali would make it difficult to allocate carbon sequestration benefits among the multiple resource users and even among jurisdictions.[74]

Various time factors probably provide the greatest difficulties. Many offset projects only pay based on success, or after several years of operation, but many small farmers lack access to the capital necessary for up-front investments and cannot take the risk of failure. They also reasonably fear the multi-year commitments required by project designers, as those commitments reduce opportunities to adjust to changing personal, weather, or market realities.[75]

4J. Potential Challenges and Opportunities Facing Women Farmers

Women farmers in general face these disadvantages to an even greater degree than men: they have less access to capital, less access to technical information, and less capacity to bargain with outsiders. Many women are laborers.

Tenure issues can also prove particularly problematic. Although they do most of the farming, women in Africa may lose property control if their husbands die, or may lose control to additional wives. One study cited by Meinzen-Dick found that insecurity of tenure limited women’s willingness to plant trees, and that, in some situations, women can even lose control of land by planting trees.

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74 C. Roncoli et al., “Carbon Sequestration from Common Property Resources: Lessons from Community-Based Sustainable Pasture Management in North-Central Mali,” *Agricultural Systems* 94 1 2007:97-109. <http://linkinghub.elsevier.com/retrieve/pii/S0308521X06001132>.

75 De Pinto, IFPRI Discussion Paper 2010.

"Rather than simple 'ownership' of resources, we often find separate bundles of rights; for example, one person may have the right to plant a tree and use its fruits, another to grow an annual crop on the land around the trees, and a third to graze their flocks on the land in the dry season. I n other situations, one person has the right to use the land, but another holds the controlling or decision-making rights. The different rights may be held by different households (landlord and tenant), or even by different members within a household (husband, wife and children). The duration of rights also varies, from a growing season (or less) to the long term." [76]

Although climate mitigation programs can lead to problems for women if not addressed, Meinzen-Dick also notes that with proper focus, they can enhance women's rights and access to resources, and even lead to changes in property ownership customs and laws.

4G. Summary of Carbon Sequestration and Offsets

Overall, these complex considerations support a variety of conclusions:

1. The technical opportunities, trade-offs and synergies for carbon sequestration present a different question from the question of whether offsets provide a suitable funding mechanism. But there are particular technical challenges presented by pursuing carbon sequestration through offsets.

2. For many farmers, efforts at soil carbon sequestration do hold the promise for long-term productivity gains, but techniques that involve adding carbon from external sources (such as mulching) may not generate true carbon savings, and techniques that involve increased retention of residues often have substantial costs. Tenure and cultural issues present practical obstacles for many small farmers and particularly women to participate in agroforestry and other beneficial carbon projects. Considering labor and investment constraints, the most promising synergies involve efforts to boost yields that simultaneously boost soil carbon over time, for example through water harvesting techniques, improved fertilization, and terracing.

3. Agroforestry provides a particular opportunity. It may generate rapid enough economic returns to justify the efforts of small farmers, and those agroforestry systems that involve increases in above-ground carbon likely have the potential scope and verifiability to justify subsidies based on the carbon alone. Even so, impermanence remains a major obstacles to the use of offset financing.

76 R. Meinzen-Dick "Women, Land and Trees," *World Agroforestry into the Future*. Ed. D. Garrity et al. (Nairobi: World Agroforestry Center, 2006). 174. See also R. Meinzen-Dick et al., "The Role of Collective Action and Property Rights in Climate Change Strategies," *CGIAR CAPRI Policy Brief* 7 2010: 174.

4. Projects that combine yield enhancement with reforestation of more marginal areas should hold promise in theory but are in early stages. Plantation forestry, although probably beneficial in some locations, most likely provides the major area of social risk among carbon projects, and Oxfam would be wise to look at these projects in more detail.

5. Offset funding imposes a set of problematic limitations on carbon projects for small farmers. Carbon sequestration offsets are unlikely to work unless there is a separately funded intermediary willing to help meet up-front costs and probably to find some way of increasing flexibility in performance and land use for individual farmers over time. The scientific uncertainties and these practical challenges greatly reduce the potential of offsets to support carbon sequestration projects.

6. Because of the challenge of "additionality," there is serious reason to doubt whether present style CDM offsets will survive or should survive over the long-term. The "additionality" problem also explains why it would be particularly difficult to use "offsets" to support carbon sequestration through measures that boost yields, as those measures should be desirable anyway.

7. Despite these practical challenges, there is no general reason from the standpoint of small farmers to oppose carbon offsets. It is true that the limitations of many small farmers on ownership or political control of natural resources presents some risk, but that risk is no higher for carbon offset projects than for any other land-use decisions, and most projects aimed at carbon enhancement should benefit small farmers.

5. TECHNICAL POTENTIAL, SYNERGIES AND POTENTIAL FOR OTHER FORMS OF GREENHOUSE GAS MITIGATION

The lengthy discussion of carbon sequestration reflects its dominance of the agricultural mitigation discussion, but, as its limitations are becoming more appreciated, awareness of other opportunities has grown. In particular, researchers have increasingly shown that simple improvements in agricultural productivity tend to lower emissions per kilogram of food. These opportunities may not exist for all types of small farms, but properly estimated, they exist for many. One critical variable involves how greenhouse gas calculations take account of the carbon cost of land, and this paper devotes particular attention to that topic.

5A. Livestock Mitigation and Tradeoffs

Livestock generate the substantial majority of all world agricultural production emissions. The great bulk of emissions result from methane from the enteric fermentation of feed that occurs in the guts of ruminants (cattle, sheep, buffalo, goats) and nitrous oxide from cattle and other ruminants, with emissions from manure management of concentrated livestock a distant third.[77]

Although livestock mitigation in the developed world focuses on feed additives and possible vaccines against methane, the developing world has simpler options so long as emissions are judged per kilogram of meat or milk: become more productive by improving the quality of feed, or the health and breeding of animals. A study by the FAO published last year found that dairy production on average in sub-Saharan Africa generated 7.5 kilograms of greenhouse gas emissions per kilogram of raw milk of a globally average quality (reflecting fat and protein content), while dairies in the United States generated only 1.3 kilograms, less than one fifth.[78] Dairies in Asia generated about 2.5 kilograms. The emissions in the developing world are high in part due to low yields of beef and milk. Africa has 14 percent of the world's dairy cows but only two percent of the world's dairy production[79] due to poor nutrition, poor health care, lower yielding varieties, lower birth and higher death rates. As a result, more of the feed used to support dairy production is used to keep cows alive and less is directed into the milk output, which results in more emissions of methane, and NO2 per kilogram of milk.[80] The poor quality of the feed and forage consumed by cows also results in more methane for each ton of feed. In general, the lower the energy value of feed, the more of the feed that is converted in guts into methane and the less that is absorbed for energy by the animals.

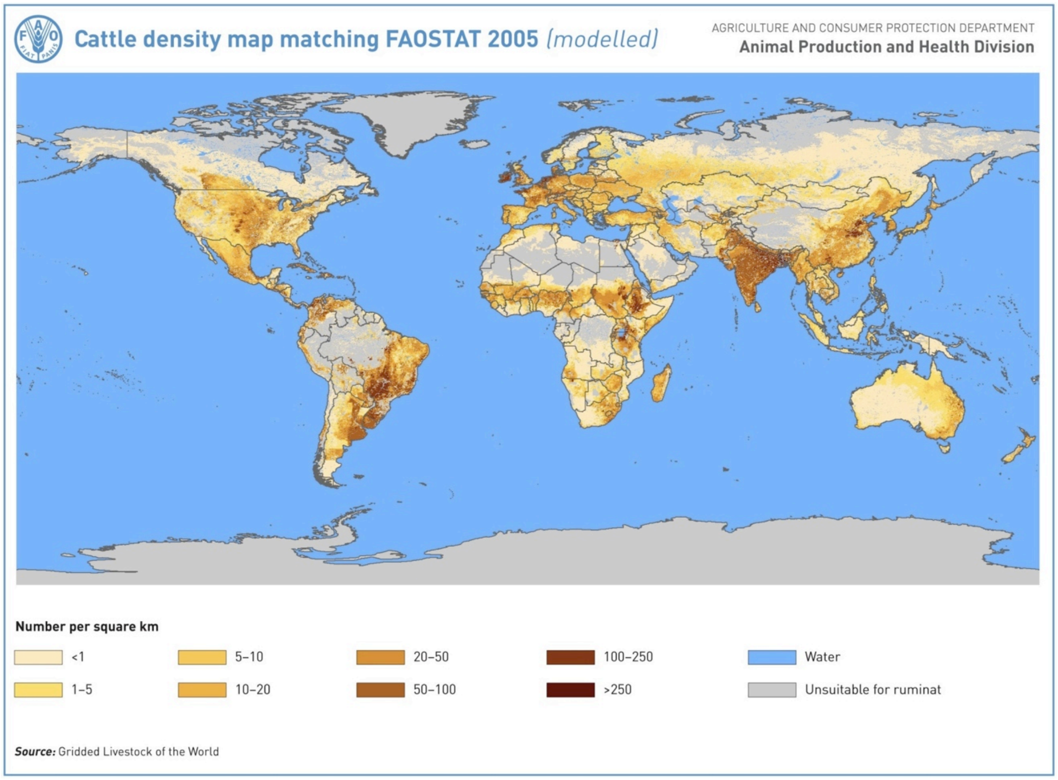
77 Smith 2007.

78 P. Gerber et al., *Greenhouse Gas Emissions from the Dairy Sector: A Lifecycle Assessment*, (Rome: FAO, 2010). <http://www.fao.org/docrep/012/k7930e/k7930e00.pdf>.

79 H. Menzi et al., "Impacts of Intensive Livestock Production and Manure Management on theEnvironment," *Livestock in a Changing Landscape: Drivers, Consequences and Responses*. Ed. Steinfeld et al. Washington D.C.: Island Press, 2010. 140.

80 P. K. Thornton and M. Herrero, "Potential for Reduced Methane and Carbon Dioxide Emissions from Livestock and Pasture Management in the Tropics," *PNAS* 107 46 2010:19,667-19,672.

Figure 5: World Cattle Density



Source: FAO 2005.

Improvements do not have to approach industrial agricultural levels to improve yields and reduce emissions. The FAO paper found that a ten-percent increase in the digestibility of feed in an extensive system resulted in a 19-percent reduction in greenhouse gas emissions per liter of milk.[81] A separate paper by Thornton and Herrero focused only on methane emissions but, using more specific calculations and data for different parts of Africa, found a reduction in methane emissions from feasible feeding improvements that ranged from 57-77 percent per liter of milk or per kilogram of meat for the producing animals.[82] Those techniques included relatively modest increases in the use of supplemental grains, high-protein forage shrubs, planting of improved forage grasses, or use of cereal grains that generate more digestible residues for feeding animals.

The opportunities for emissions reduction from other livestock are less clear, since pigs and chickens in general generate far fewer emissions. Much of the focus has been on the greater use of digesters to turn manure into useable

81 Gerber 2010.

82 Thornton 2010. Unlike the FAO study, this paper did not estimate overall lifecycle emissions, but only the emissions from animals actually producing milk or meat; this paper also assumes that improved feed would be provided to these animals.

gases, and such “biodigesters” can even be eligible for CDM credits. But the actual emissions savings depend heavily on the gas leakage rates, about which there is little data. Use of wastes for energy instead of firewood could also be part of a reforestation strategy, which this paper discusses below.

Although obviously beneficial, livestock improvement strategies also have a few potential trade-offs. For example, any efficiency gain places pressure on farmers, who cannot always continue to match this gain. The emergence of medium-sized or large dairies, which is likely to cause reductions in milk prices for hungry non-farmers, might be another outcome of this strategy (although it could also emerge without any effort to help small dairy farmers). Helping mixed crop-livestock farmers could also help these farmers expand into land used by pastoralists, who are often even poorer.

5B. Yield Improvements for Land-Use Savings

Emissions from land use change are usually presented as a problem for forest protection and REDD, not agriculture. But in general, if a hectare of forest can be saved by yield gains or a hectare of land can be reforested because of yield gains, there would be large carbon gains. In sub-Saharan Africa, in theory, a doubling of yield, if translated into a hectare of land savings, might plausibly save 100 tons per hectare of pure carbon,[83] which works out to savings of roughly 18 tons of CO_2 per year if spread out over 20 years. As illustrated by one fairly simple recent paper, increasing yields in Tanzania through increases in fertilizer would reduce emissions substantially compared to the alternative of clearing more land to provide the same food.[84] Following this logic, yield gains by themselves provide a form of climate mitigation, and the gains need not occur only in crops. In Latin America, a recent paper submitted by Bernardo Strassbourg et al. estimates that Brazil could easily produce all the additional food now expected by 2030 by achieving very reasonable percentages of pasture intensification on already cleared agricultural land.[85]

Unfortunately, yield gains do not translate automatically into land savings on a local basis. There is an extensive literature on this subject, which I believe has a more straightforward summary. As I argue in a recent paper, yield gains almost certainly save land on a global basis, but yield gains in the tropics, which tend to have the highest intact carbon stocks, often lead to agricultural expansion in the tropics as agriculture becomes more profitable.[86] Yield gains are therefore only a reliable contributor to savings from land-use change if they are achieved in

83 Gibbs (2008) op cit. estimates above-ground carbon for season and humid forests and savannas in Africa at 51 to 204 tons per hectare, depending on whether the lands are shrub or forest, disturbed or undisturbed, with potential soil conversion losses of 10 to 19, assuming that conversion loses 25 percent of soil carbon.

84 C. Palm et al., “Identifying potential synergies and trade-offs for meeting food security and climate change objectives in sub-Saharan Africa,” *PNAS* 107 46 2010:19,661-19,666.

85 B. Strassbourg, National Wildlife Federation Conference on Land Sparing, University of San Diego, Sept. 7-9, 2011.

86 Searchinger, “The Food, Forest and Climate Challenge,” 2011.

coordination with land protection – a distinction which suggests an opportunity to integrate agricultural improvement strategies into REDD. As discussed above, a few of the existing carbon projects in effect aim for this balance by reforesting marginal areas while trying to improve production on core agricultural lands.

As an example of one specific project, the World Wildlife Fund helped some communities that were encroaching on a national park in northern Madagascar to improve the productivity of their existing agricultural lands, including rice production areas, in order to draw agriculture away from park areas. Rachel Kramer, a student at the Yale Forestry School, has compared the results with those of other communities around the park that did not receive this support, and found the project to be highly successful. One reason for success may be that the area was remote, agriculture existed to meet local needs, and farmers did not have the opportunity to take advantage of higher productivity to clear more lands to produce food for market trade.

Shifting agriculture may present a similar situation generally. According to one recent book, "traditional shifting cultivation with short cropping periods and long secondary forest fallow periods is now rare." In a broader sense, however, roughly 37 million people are involved in some form of shifting cultivation in the tropics, affecting millions of hectares of land, of which only a small portion is under cultivation at any time.[87] Africa is a major center of long-term rotations in this sense. In theory, boosting yields and protecting forests should provide an alternative that provides large carbon savings.

One challenge with this approach is that, at least on a local basis, more intensive agriculture will often lead to more deforestation, or the replacement of mosaics of agriculture, forest, and transitional areas with monocultures.[88] The environmental costs of swidden agriculture can also become an excuse for supporting the lease or sale of land to larger, more intensive operations.

No methodology exists for linking yield gains with carbon protection from natural areas, whether on a project, regional, or national basis, and the closest related work is that involving REDD. But, in theory, this linkage provides perhaps the most critical synergy between agricultural improvements and carbon gains.

5C. Rice Management

Rice methane contributes roughly 0.8 gigatons of greenhouse gas emissions per year in nearly all in developing regions, and more than 80 percent in Asia.[89]

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87 P. A. Sanchez et al., "Alternatives to Slash and Burn: Challenges and Approaches of an International Consortium," *Slash-and-Burn Agriculture: The Search for Alternatives*. Ed. Cheryl A Palm et al. (New York: Columbia University Press, 2005). 3-41.

88 Several articles describe the environmental effects of replacing shifting agriculture in Southeast Asia with rubber plantations or other forms of intensive agriculture.

A. Ziegleret al., "The Rubber Juggernaut," *Science* 324 5930 2009:1024-1025.

D. Schmidt-Vogt, "An Assessment of Trends in the Extent of Swidden in Southeast Asia," *Human Ecology* 373 2009:269-280.

89 Smith 2007.

Producing rice generates, on average, roughly four times the emissions per ton of wheat and maize.[90] Although African rice emissions are low today, rice consumption is growing at six percent per year in sub-Saharan Africa and a Coalition for African Rice Development seeks to double Africa's rice production by 2020 alone. Japan's development agency spurs this effort, with the support of groups such as the Alliance for a Green Revolution in Africa and Oxfam, because rice is highly nutritious, loved by consumers, and can generate high yields, and because Africa already imports more than $1 billion in rice per year.[91] The flooding of fields for paddy rice creates the perfect conditions for bacteria to generate methane and, depending on how the water is managed, N20 as well. One study estimates that rice emissions will grow to roughly 200 million tons per year by 2050 in sub-Saharan Africa.[92]

A variety of methods exist to reduce rice emissions both per hectare and per unit of food. Emissions per hectare, according to standard IPCC methodology for a hectare that is continuously irrigated for 180 days, are roughly five tons of CO_2 equivalent per year, but multiple periods of aeration cut those emissions roughly in half.[93] Other techniques that affect emissions include the removal of rice straw, drying paddies out of season and rotating with other crops, and the addition of potassium to some soils.[94] Drawdowns and potassium can both increase crop yields – although the situation is apparently soil-specific. Rice straw now has limited economic uses and is broadly burned in the Punjab, but varied practical research has long explored ways of treating rice straw to increase its economic use, for example as an animal feed.[95] Another way to reduce emissions per unit of food is to use appropriate rice cultivars that attain higher yields without increasing inputs. Increasing yields provides an even simpler method, since it does not generally cause methane emissions to rise per hectare. The Central Rice Research Institute in India has, in specific situations, found 40-percent increases in yields for the correct rice cultivar, 20-percent increases in grain yield for the application of potassium in some fields, and up to three-fold increases in net profit for certain rotations that also greatly reduced emissions.[96]

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90 B. Linquist et al., "An Agronomic Assessment of Greenhouse Gas Emissions from Major Cereal Crops," *Global Change Biology* 181 2011: 194–209.

91 Africa Rice Center, "Nerica – New Rice for Africa," *CGIAR*, 2003. April 12, 2012 <http://www.warda.cgiar.org/NERICA%20flyer/NERICA%20on%20the%20move.pdf>.

92 Popp 2010.

93 IPCC, "2006 IPCC Guidelines for National Greenhouse Gas Inventories," Vol. 4, Table 5.12.

94 X. Yan et al., "Statistical Analysis of the Major Variables Controlling Methane Emission from Rice Fields," *Global Change Biology* 11 7 2005:1131-1141. <http://www.blackwell-synergy.com/doi/abs/10.1111/j.1365-2486.2005.00976.x>.
X. Yan et al., "Global estimations of the inventory and mitigation potential of methane emissions from rice cultivation conducted using the 2006 Intergovernmental Panel on Climate Change Guidelines," *Global Biogeochemical Cycles* 23 2 2009: 1-2, <http://www.agu.org/pubs/crossref/2009/2008GB003299.shtml>.
Tapan Adhya, Presentation provided to the author, Central Rice Institute, Cuttack, India, June, 2011.

95 A.M. Nour, "Rice Straw and Rce Hulls in Feeding Ruminants in Egypt," *Plant Breeding and the Nutritive Value of Crop Residues, Proceedings of a Workshop held at ILCA, Addis Ababa, Ethiopia*. Ed. Jess D. Reed, Brian S. Capper, and Paul J. H. Neate. Addis Ababa: International Livestock Centre for Africa, 1988. 4. <http://www.fao.org/wairdocs/ILRI/x5494E/x5494e07.htm>.

96 Adhya June 2011.

For new rice fields, avoiding deep organic soils reduces emissions not only from land-use change, but also from methane emissions. Here there may well be trade-offs, as more organic, rich bottomlands provide high yields and better prospects for irrigation and water control, but will lead to greater carbon loss. Upland rice has lower yields but has been growing substantially in Africa since the invention of New Rice for Africa (NERICA), a cross between African and Asian rice varieties first achieved in the 1990s. By 2006, this variety had spread to 200,000 hectares. Uganda increased its rice production by 50 percent, achieving yields by experienced farmers of 2.5 tons per hectare without fertilizer.[97] Such yields are modest compared to Asian or U.S. yields of paddy rice, which are more than three times as high, but these yields are still high compared to average sub-Saharan Africa cereal yields of around 1.2 tons per hectare. Some studies have estimated that relatively modest rates of fertilizer by world standards – although high by standards of sub-Saharan Africa -- increases even upland rice yields to four tons per hectare.[98]

Oxfam has strongly promoted the System of Rice Intensification (SRI), pioneered in Madagascar, as a yield-boosting technique with other environmental benefits. SRI refers to a variety of different techniques, the most significant of which involves the repeated irrigation for saturation of soils, rather than continuous irrigation, and disking of soils to keep them irrigated. SRI also involves planting one or fewer seedlings per hill than conventionally recommended and using organic material rather than synthetic fertilizer. In general, studies by supporters report large yield gains, sometimes by more than 50 percent, and similar-sized reductions in water use.[99] The potential impacts on greenhouse gas emissions are discussed less frequently, although reductions have been reported.[100]

The International Rice Research Institute (IRRI) has not been a supporter of SRI, and has gone so far as to perform comparison studies of SRI versus conventional rice-farming techniques in China. In one of these studies, IRRI demonstrates extremely similar yields on general high-yielding rice on fertile land[101] and argues persuasively that at least some of the reported yields in Madagascar were not possible and must be in error. The paper also challenges

97 Y. Kijimaet al., "How Revolutionary is the 'NERICA Revolution'? Evidence from Uganda," *Developing Economies* 44 2 2006:252-267. <http://onlinelibrary.wiley.com/doi/10.1111/j.1746-1049.2006.00016.x/pdf>.

98 Sylvester Oikeh et al., "Soil Fertility and Nerica Rice Nutrition." *AfricaRice*, April 6. 2012 <http://www.africarice.org/publications/nerica-comp/module%207_Low.pdf>. The fertilizer rates used to achieve these yields were 60 kg nitrogen, 13 kg phosphorus and 25 kg potassium per hectare.

99 Africare et al, "More Rice for the People, More Water for the Planet: System of Rice Intensification (SRI)." Oxfam Research Report. Aug. 13, 2010. <http://www.oxfamamerica.org/files/more-rice-for-people-more-water-for-the-planet-sri.pdf>.

100 S. Hidayah et al., "Intermittent Irrigation in System of Rice Intensification, Potential as an Adaptation and Mitigation Option of Negative Impacts of Rice Cultivation in Irrigated Paddy Field," *Experimental Station for Irrigation*, Indonesia. April 12, 2012 <www.rid.go.th/thaicid/_6_activity/Technical-Session/SubTheme2/2.10-Susi_H-Dewi_AA-Marasi_DJ-Soekrasno.pdf>.
Tapan Adhya, Personal communication, Central Rice Research Institute, Cuttack, India, May 2011.

101 J. E. Sheehy et al., "Fantastic Yields in the System of Rice Intensification: Fact or Fallacy," *Field Crop Research* 88 1 2004: 1-8. <http://linkinghub.elsevier.com/retrieve/pii/S0378429004000036>.

some of the SRI claims on agronomic grounds, such as the relationship between size of grain and number of panicles.

In a follow-up interview, IRRI Director Achim Doberman indicates that some of these disputes revolve around what is and is not new. Doberman supports planting of young seedlings, alternative wetting and drying, and mechanical aeration of soils as useful techniques depending on soils and area, but takes exception to branding them as SRI. Doberman also suggests limitations, including large quantities of labor for SRI and a need for excellent irrigation control, and argues that these techniques alone do not provide ultimate savings in water use on a regional basis, since conserved water is sometimes lost when fields are drained. In summary, there is support for the core SRI techniques -- whether or not they are labeled SRI -- but these techniques are more likely to boost yields in lower yielding areas, such as Africa, rather than in generally higher yielding areas, such as much of Asia.

As with many new practices, mitigation measures may also cause tradeoffs. They may include added labor and, in many cases, infrastructure costs for improving water management. A critical tradeoff involves the location of new rice fields, particularly in places, like Africa, where they are expanding. Placing new rice fields in river bottoms will generally result in the highest yields but will also incur the highest costs from land-use change. Synergistic benefits will also be greatest if alternative uses can be developed for rice straw, and if water savings on a field-by-field basis can translate into regional gains, a possibility which depends on the details of water management.

5D. Fertilizer Production and Use

The International Fertilizer Industry Association, the source typically used for this figure, estimates global greenhouse gas emissions from fertilizer production and use at 1.25 gigatons of CO_2 equivalent (roughly 2.5 percent of world GHG emissions in 2005). Of these emissions, roughly 500 million tons occur during production and distribution (nearly all production), and 750 million tons occur through N20 emissions from soils (plus some CO_2 from the carbon component of some nitrogen fertilizers).[102] Although fertilizer use is highly uneven, it is now high in Asia as well as in OECD countries, and East Asia and South Asia together use 45 percent of all nitrogen, according to FAO data (Table 5). China consumes roughly one third of the total nitrogen fertilizers in the world,[103] and, due to primary reliance on coal, the production of fertilizer generates ten percent of China's fossil fuel emissions.[104] According to a UK-funded scientific

102 International Fertilizer Association, *Fertilizers and Climate Change: Enhancing Agricultural Productivity and Reducing Emissions* (Paris: IFA, 2009). <http://www.fertilizer.org/ifa/HomePage/LIBRARY/Publication-database.html/Fertilizers-and-Climate-Change.-Enhancing-Agricultural-Productivity-and-Reducing-Emissions.html>.

103 X. Wang et al., "Regional Distribution of Nitrogen Fertilizer Use and N-saving Potential for Improvement of Food Production and Nitrogen Use Efficiency in China," *Journal of the Science of Food and Agriculture* 91 11 2011:2013-2023.

104 UK-China Sustainable Agriculture Innovation Network 2011.

collaboration of U.K. and Chinese scientists, Chinese farmers also greatly overuse nitrogen fertilizer by an astounding 30 to 60 percent, and eliminating this overuse would cut total Chinese GHG emissions by two percent without reducing yield. [105] Although nitrogen overuse is far greater in China, there is a sense that parts of India and other areas in Asia also overuse nitrogen fertilizer, although the topic is less studied.

Table 4. Nitrogen Fertilizer Use by Region

Region	Percentage of global use
Africa	3.80
Central Europe	4.15
Eastern Europe and Central Asia	15.94
East Asia	34.58
Latin America	4.62
North America	10.69
Oceania	1.20
South Asia	11.00
West Asia (Midle East)	6.64
West Europe	7.38
Grand Total	**100.00**

Source :Author's elaboration from FERTISTAT

The International Fertilizer Development Corporation, a non-profit offshoot of the Tennessee Valley Authority, has long emphasized the opportunities of shifting fertilizer application to a compact form of urea, which look like small golf balls, that farmers can make themselves and directly place in paddies next to the rice plant. The technique is spreading in Bangladesh, and has been estimated to increase yields by 17 to 33 percent while decreasing nitrogen application by 33 percent.[106] Although not directly studied, this reduced nitrogen application should translate into fewer greenhouse gas emissions. While this technique has been highly successful in Bangladesh, at least one major research group in China has not found comparable yield benefits locally, perhaps because Chinese farmers apply extraordinary levels of nitrogen fertilizer.[107] By interview, Achim Doberman of IRRI also expresses doubt about the workload involved in this fertilizer application, which is more labor intensive than broadcast nitrogen.

More efficient use of fertilizer therefore appears to be a legitimate opportunity for mitigation, with potential economic benefits, although the opportunities must be

105 Ibid.

106 Data provided by International Fertilizer Development Corporation (IFDC). The opportunities and challenges for using supergranules vary according to a variety of conditions. S. K. Mohanty et al., "Nitrogen Deep-placement Technologies for Productivity, Profitability, and Environmental Quality of Rainfed Lowland Rice Systems," *Nutrient Cycling in Agroecosystems* 53 1999: 43-57. According to the IFDC, which invented and has promoted this technique, impediments from high labor requirements discussed in that article have been reduced by improved planting techniques.

107 X. Yan, Personal communication, Institute of Soil Science, Chinese Academy of Sciences, Nanjing, Oct., 2010.

explored more carefully by farm type and region. This is not an opportunity in Africa, which greatly underutilizes fertilizer. In Africa, the goal is to increase fertilization in a balanced way, so that nitrogen, which emits large quantities of greenhouse gases, is combined with other needed fertilizer to assure that yields respond fully.

Additional discussion focuses on the opportunity to replace nitrogen fertilizer with nitrogen fixing crops or to cover crops of some kind. Using a legume to increase nitrogen for non-legume crops does not by itself appear to reduce nitrous oxide emissions: IPCC guidance calls for the same "Tier 1" application factor. But legumes have two other benefits. They eliminates the energy cost of fertilizer use, which makes up roughly half of total emissions from nitrogen use and perhaps more in China. In addition, according to science accepted by the IPCC, nitrogen that is fixed and converted into the crops does not lead to meaningful levels of nitrous oxide-- suggesting potential to reduce overall emissions through increased use of nitrogen-fixing crops. These crops, such as beans, tend to be high in protein but have low yields relative to cereals.

The experience of promoting these crops is long and complicated. Part of the challenge is technical. Legumes have not been as successful in Africa for fixing nitrogen because of pest problems, lack of phosphate and incompatible nitrogen-fixing bacteria in soils. Recent work has focused on inoculating soils with nitrogen-fixing bacteria that interact well with higher yield legumes, with promising results.[108] Much of the issue is also practical. Ken Giller provides a good summary of the challenges and opportunities and summarizes: "There are a number of exciting examples where development of new varieties of N2-fixing grain and fodder legumes has led to widespread adoption by farmers. Legumes are unlikely to be widely adopted purely for their benefits in soil improvement, but need to bring additional benefits in labor-saving due to weed control, or other products such as food and fodder."[109]

The potential benefits of more efficient use of nitrogen range from reducing fertilizer costs for farmers in China to increasing yields in Bangladesh. One study in Malawi found that, because legumes have lower yields, farmers would not produce them unless the farmers were large and efficient enough to guarantee their calorie needs through maize, so legumes became a dietary improvement or cash crop.[110] In all cases, we must assume that there are at least some costs in the form of added labor or perception of risk.

108 T. Paul Cox, "Helping Legumes Become Africa's Nitrogen Factories," *New Agriculturalist*. Nov. 2010. April 11, 2012 <http://www.new-ag.info/en/focus/focusItem.php?a=1785>.

109 K. E. Giller, Nitrogen Fixation in Tropical Cropping Systems (Wallingford: CABI Publishing, 2001), 2nd ed.

110 G. van den Brand, "Towards Increased Adoption of Grain Legumes among Malawian Farmers: Exploring Opportunities and Constraints Through Detailed Farm Characterization" (MSc thesis, Utrecht University, Wageningen University, 2011).

5E. Coffee Production

Coffee and tea production are major cash crops for small farmers, with some estimates of 25 million coffee farmers worldwide. A report by Frontline estimated that small farmers produce roughly half of the world's coffee.[111] According to FAO data, Brazil produces roughly one third of the world's coffee and Vietnam another eighth; substantial quantities of coffee are also produced in sub-Saharan Africa, Indonesia, and other countries in Central America.[112]

The Cool Farm Tool, developed by researchers with Sustainable Food Labs and the University of Aberdeen, identifies two mitigation opportunities for coffee farms. One involves better use of coffee-tree residues, which are now commonly piled on the edge of fields to decompose. The Cool Farm Tool estimates that composting this material and incorporating it to reduce addition of synthetic fertilizer could reduce emissions by roughly 600 kg CO_2 equivalent per hectare. These estimates assume that piled tees generate methane as if they were stored in landfills, and the estimated reductions are not large relative on a per-hectare basis. The other opportunity involves the introduction of shade trees. A critical question for shade-grown coffee is the impact on yields. One summary indicates that yield findings are highly varied: impacts on yields at a shade level less than 50 percent appeared to be favorable or unchanged, although farmers perceive a negative relationship.[113]

Overall, these mitigation opportunities, at least up to the point of any adverse yield effects, would appear favorable from a livelihood standpoint but, in a substantial tradeoff, require additional labor.

5F. Irrigation Energy Savings

Many small farmers do not use much machinery, and only some use extensive fertilizer, as discussed above; a notable exception is the gains in irrigation energy efficiency. An IFPRI report also estimates that diesel pumping emissions themselves constitute 3.7 percent of GHG emissions throughout India.[114] In general, there seems to be a broad consensus that diesel pumps are not particularly efficient. Although perhaps overstated, a fact sheet produced by a department of the Indian Ministry of Environment and Forest estimates that relatively simple adjustments to diesel pumps in India could cut energy use in

111 Kelly Whalen, "Your Coffee Dollar" *Public Broadcasting Service*. Nov. 28, 2012 <http://www.pbs.org/frontlineworld/stories/guatemala.mexico/coffee1.html>.

112 United States Government, "Coffee: World Markets and Trade,." *USDA Foreign Agricultural Service*, June 2010, April 12, 2012 <www.fas.usda.gov/htp/coffee/2010/June%202010/2010__June_Coffee.pdf>.

113 I. Perfecto et al., "Biodiversity, Yield and Shade Coffee Certification," *Ecological Economics* 54 4 2005: 435-446. <http://linkinghub.elsevier.com/retrieve/pii/S092180090400401X>.

114 G. Nelson et al., "Greenhouse Gas Mitigation: Issues for Indian Agriculture" (International Food Policy Research Initiative, Washington D.C., 2009). The paper also did an analysis of potential greenhouse gas savings by increasing the price of electricity, which found that a doubling of the electricity price would reduce GHG emissions from diesel pumping by 16 percent, essentially by transferring sources of irrigation water from less efficient to more efficient wells. I do not find this report particularly persuasive as it is based on simple assumptions. However, the paper did highlight the emissions from diesel pumps.

half, indicating that programs to improve diesel-pump efficiency can also improve livelihoods.[115]

Some forms of irrigation efficiency improvement may not only reduce costs, but also increase water availability, which would provide other gains. However, experts caution that many increases in irrigation efficiency may not ultimately result in water savings on a regional basis, since inefficiently applied water may come back into the system as return flows to be used by other farmers.[116] Because some water is truly lost into deep groundwater, however, or evaporated in dry areas through excess application, and because energy is used to pump water around, there is a general view that improvements in irrigation efficiency are highly achievable. Still, this area of potential savings remains under-investigated.

5G. Research and New Technologies

Technologies ultimately have massive consequences for the evolution of agriculture. Had Brazil not developed appropriate seed varieties and other techniques for raising soybeans, its agricultural landscape would be dramatically different. Farmers generally respond to available technologies when the economic advantages are strong. Over time, technological development and therefore research has enormous implications on which types of farming expand and where. For example, one prominent scholar of the Green Revolution has made a convincing case that Africa fell behind Asia in significant part because Africa has much more restricted availability of high-yielding seeds.[117]

Substantial research examines techniques for reducing greenhouse gas emissions from agriculture. Initially spurred on by New Zealand, thirty-two countries now participate in the Global Research Alliance for Agricultural Greenhouse Gases. The bulk of this research, however, is directed at agriculture in more developed countries. As a counter example, New Zealand recently announced the first round of 16 million New Zealand Dollars of funding for research to reduce livestock emissions in grazing systems in developing countries; still, this funding is a fraction of what is needed.

Additional research is needed to explore more the detailed elaboration of the strategies discussed above, based on fundamental knowledge. For different soil types and water management capacity, for example, efforts at the country level are necessary to analyze the merits of different rice strategies both to increase production and reduce greenhouse gas emissions. While the CGIAR network has developed grains with more digestible stovers, conversations with an expert

115 "Chinese Motor Pumps," *Envis Centre: Development Alternatives*, Nov. 28, 2012 <http://www.daenvis.org/chinesemotor3.htm>.

116 J. Faures et al., “Reinventing Irrigation,” *Water for Food, Water for Life*. Ed. D. Moden. (London: Earthscan;; Columbo: International Water Management Institute, 2007.

117 R. E. Evenson and D. Gollin, “Assessing the Impact of the Green Revolution, 1960 to 2000,” *Science* 300 5260 2003: 758-762.

in Rwanda indicate that these grains were little known or tested there.[118] Other research is more fundamental. For example, there is almost no data about nitrous oxide emissions in Africa, and there is extremely limited data on African wetland soil carbon content.

Although there are many other purely political factors, sustained funding for synergistic agricultural mitigation will require a substantial foundation in science. Oxfam may wish to work with other appropriate organizations to develop a specific research agenda and a strategy for encouraging its pursuit.

5H. Challenges for Small and Women Farmers with These Forms of Mitigation

These forms of mitigation nearly all involve improvements in agricultural efficiency. The challenges faced by small farmers in general are therefore the same challenges these farmers face in making any other improvements. They include challenges of uncertain tenure, economies of scale, insufficient access to capital, poor transportation networks, and eroded extension networks.

For women, all of these challenges tend to be greater, and because the challenges are context-specific, there is no one simple solution. In general, successful mitigation programs for women farmers must do the following: (1) specifically target women to provide resources and knowledge; (2) address the shortages of female farmers' time and labor; (3) remain aware of tenure rules and cooperative rights and how they affect women's ability both to engage in mitigation practices and to take advantage of financial incentives; and (5) strive to enhance women's tenure rights.

5I. Summary of Best Opportunities and Trade-offs

There are abundant potential synergies between agricultural improvements achievable by small farmers and agricultural mitigation. In virtually all cases, yield gains alone can count if coupled with natural resource protection and, in some cases, restoration of degraded, unproductive lands. Feasible gains in livestock feeding and rearing efficiency are also widespread, and improvements in energy efficiency and nitrogen use are likely available to many small farmers in Asia. None of these efforts are without risks, and all face the general challenges involved in improving agriculture for small farmers generally. None of these agricultural practices are inherently more available to small rather than large-scale farmers. But the less efficient agriculture is today, the greater the opportunities for mitigation through resource-efficiency gains.

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118 Cyprian Ebong, Personal communication, Rwanda Agricultural Board, Oct. 2011.

6. ALTERNATIVE FUNDING MECHANISMS FOR AGRICULTURAL MITIGATION: A METHOD OF IMPLEMENTING NAMAS WITH AN INTERMEDIATE LEVEL OF ACCOUNTABILITY

Government-generated funding for mitigation can come in many forms. One could occur through fairly standard overseas development assistance (ODA). Typical ODA funds are not tied to any particular degree of progress and, to date, have not been tied to quantifiable greenhouse gas reductions. Among other challenges, this funding approach for mitigation would need to overcome traditional skepticism about ODA, and it would be difficult to avoid a situation in which climate funding competed with traditional ODA for other purposes. At the other end of the spectrum, offsets have the highest level of accountability. This section analyses the challenges of offsets as applied to reducing emissions from production emissions, and then suggests an intermediate form of accountability between offsets and ODA that builds on NAMAs. "Intermediate" refers to a lesser level of proof that GHG reductions have occurred or will occur than is required for offsets, but unlike ODA, dollars would be based on an expectation and eventual, reasonable demonstration of GHG reductions.

6A. Offsets

Offsets have three principal potential strengths as a means of generating and distributing mitigation funds. First, they are politically easier to sell because they do not require direct public funding and taxation in developed countries. Once a developed country has established a cap, the offset actually becomes a means of reducing the costs of compliance with that cap. Second, offsets assure some level of accountability for greenhouse gas reductions. Finally, as private transactions, offsets provide a means of circumventing corrupt or inefficient governments.

Each of these features is also a cost. Offsets replace rather than add to GHG reductions required in developed countries; because of this fact, they require a high level of certainty and verifiability. Project-specific efforts make additionality even harder to judge.

The challenges for offsets discussed above in the context of carbon sequestration apply mostly, but not entirely, to offsets for other mitigation measures.

- Permanence: Permanence is far less of a concern with changes in production emissions than with carbon sequestration. Savings in methane and nitrous oxide occur in the year of production and are permanent. The abandonment of an agricultural practice reduces the long-term payoff from the mitigation investment but does not reverse the original savings.

- Tenure: Uncertain tenure presents a particular challenge for small farmers making long-term commitments to carbon sequestration; for this reason, tenure problems should be less of an obstacle for mitigation offsets involving production emissions. Yet tenure will often remain an issue in the generic sense that limited tenure rights are often an obstacle to agricultural investments for small farmers.

- Need for Up-Front Payments: Because mitigation measures require up-front investments, the general practice of paying for offsets only after savings occur would also be a major impediment to the use of offsets for production mitigation.

- Uncertainty and Verification: Scientific uncertainty will remain a major challenge in using offsets for production mitigation. Virtually all of the mitigation measures outlined above involve measures with a high degree of confidence for substantial savings across all farm types, but with a high degree of variability.

- Additionality: Additionality is likely to be an even greater challenge in establishing offsets for production emissions using measures that also enhance food supply. The offsets' very economic benefits make it more difficult to demonstrate that they would not occur anyway. For reasons discussed above, the generic problem of additionality also raises the question of whether traditional offsets can and even should survive.

- Baseline: In many situations, production mitigation measures will not reduce absolute emissions from those participating because these measures should result in increases in total production. For example, a measure to improve the feed quality of animals on a particular farm will probably increase the emissions from that farm overall, while decreasing emissions per kilogram of milk or meat. The measure contributes to mitigation only by comparison with an alternative baseline that included this level of production but in an inefficient way. Calculating emissions reductions in this way would represent a major departure for offset accounting and would create vexing issues for establishing the baseline. In some cases, if mitigation strategies result in low-carbon development but the alternative is no development, mitigation may not even result in reduced emissions on a global basis.

In summary, while permanence and tenure challenges have less consequence for mitigation by reducing production emissions than by sequestering carbon, other problems remain with the use of offsets, such as uncertainly, and the need for up-front payment. Meanwhile additionality problems become even more of a challenge. For these reasons, while some offset opportunities may exist, Oxfam should not primarily pursue offsets as the methodology for funding agricultural production emissions.

6B. Building on Nationally Appropriate Mitigation Activities, or NAMAs.

The widely held consensus of experts working on climate mitigation and agriculture in developing countries – including interviewees requested by Oxfam[119] -- is that mitigation efforts should focus on measures that that are already justified by their success in alleviating poverty and hunger and have sufficient economic potential for farmers to maintain their uses. In part, these views reflect the missions of these organizations and individuals, but they also reflect, for the most part, the various practical challenges described in this paper. In particular, agricultural activities that minimize emissions will likely only occur if they are self-sustaining and in the self-interest of developing countries. Overall, agricultural mitigation in developing countries fits more neatly into the framework of low carbon development than into greenhouse gas offsets – suggesting NAMAs as an obvious framework for encouraging this kind of mitigation.

The international framework established at Copenhagen in 2009 provided that developing countries would develop NAMAs, some of which developing countries would undertake on their own and others that they would undertake only with external financial support. Countries submitted their NAMAs quickly, and, as one review correctly observes, "The NAMAs submitted to the UNFCCC are usually emission reductions and the type and level of support needed are specified only in exceptional cases. The submissions so far do not yet constitute 'bankable' activities."[120] Countries are aware of the vagueness of the Copenhagen framework and are working to further develop NAMA proposals. Interestingly, although agriculture was measured broadly in the general NAMAs, one 2011 review found that transport is dominating the development of more specific NAMAs.[121]

The contours of NAMA's are largely up for grabs. While many developing countries undoubtedly wish for funding with few strings that they can administer themselves, developed countries will probably not be willing to provide funds on such a loose basis as officials will need to garner political support and show to voters that funds are put to good use. Nor should Oxfam necessarily support such wide discretion. The opportunity exists to develop a framework for NAMAs that could support agricultural mitigation using a mid-point standard of accountability between typical ODA and offsets. The funding would be designed to stimulate win/win solutions that have a substantial likelihood of being self-

119 Among interviewees advocating these perspectives are: Lini Wollenberg of CCAFS; Leslie Lipper and Marya-Lissa Tapio-Bistrom of FAO; Ruth Meinzen-Dick and Gerald Nelson of IFPRI; and Patrick Verkooijen and Juergen Voegele of the World Bank.

120 F. Röser et al., "The Status of Nationally Appropriate Mitigation Actions," (UNEPSBCI 2011 Symposium on Sustainable Buildings, May 24, 2011, Leverkusen, Germany).

121 Röser 2011.

sustaining. The following sections sketch out such a system, using livestock improvements and rice management as examples.

What Would Be Funded?

In general, plans could set forth a series of improvements in agricultural practices that would lead to greenhouse gas reductions in agriculture. For example, in the case of livestock, the plan could set forth a series of measures designed to improve the feeding and health of ruminant livestock that would be estimated to reduce emissions per unit of livestock. Funded measures could be any measures that would contribute to an overall plan of action, from the planting of improved grass seeds to improved marketing facilities. In the case of rice, the measures might include changes in water management, which would require infrastructure improvements as well as actual farmer management changes. A program might offer farmers guarantees for trying such management for two or three years to encourage adoption. Critically, the funding would support investments to adopt measures that farmers would have the incentive to continue to practice on their own.

Quantification, Benchmarks, and Verification

The plan of action would include plans for degree of adoption and sufficient details of the adoption to estimate greenhouse gas mitigation to a reasonable level of confidence. Such programs could require a fair level of proof that the agricultural measures would reduce greenhouse gas emissions, as wells as offering a reasonable quantification. The plan would have certain quantified benchmarks for progress that are not directly tied to actual greenhouse gas reductions -- such as degree of progress in developing refrigeration systems for livestock or benchmarks for improving water management systems to enable mid-season drawdowns of rice. The core of the plan, however, would be benchmarks setting forth practical proxy criteria for estimating and establishing greenhouse gas reductions. Additional work is necessary to establish those proxies. In the case of livestock, it might be possible to establish greenhouse gas reductions based on a ratio between numbers of animals and outputs of meat and dairy. In the case of rice, it might be possible to use aerial photographs taken at the right season to determine degree of implementation of water level drawdowns or degree of removal of rice straw from paddies. The benchmarks should include negative conditions that would undermine the degree of greenhouse gas reduction. Those conditions might include criteria against conversion of native habitats and associated releases of carbon.

Additionality

Additionality would be based on improvements above an expected baseline for farms in an area or sector. For example, by estimating rates of progress in an area in livestock productivity improvements, it would be possible to reward projects for achieving greater rates of improvement.

Who Would Be Paid?

If the system works through NAMAs, national government endorsement would be required at some level. But this system could accommodate a variety of methods for allocating funds to people, organizations, and efforts. National or local governments and local organizations including farmer groups could organize projects. As for any other general aid project, funding could support what makes sense, from common infrastructure to research and support groups to direct incentives for farmers. In keeping with other assistance programs, performance incentives would be wise.

When Would Funds Be Provided

The system could provide some funds up-front, some as progress occurs, and, perhaps, some as an ultimate reward for success.

Non-Performance or Subsequent Changes

While there are a number of possible options for the timing of funding, any system should recognize the need for up-front funding for small farmers and the practical reality that original investments cannot be returned for ultimate non-performance. Despite these limitations, systems could encourage performance. They might reward organizations and countries that achieve benchmarks with more funding, and withdraw future funding from those that do not.

Intersection with Food Security Funding

In addition to new global climate funding, countries have increased their direct development assistance for agriculture. In a 2009 meeting, Group of Eight countries promised to provide $20 billion in aid over three years for a global food security initiative. Many countries have been moving to expand funding, including the U.S. and Canada. As part of the U.S. initiative, countries must develop national food security plans: plans for fourteen African countries, along with three regional plans, are now posted, as well as for three Asian countries and three Latin American countries. [122] While these plans seem like reasonable and balanced approaches to boosting agricultural production, they include only vague discussion of adaptation and limited discussion of mitigation. For example, the Tanzania plan addresses climate mitigation only by calling for assistance to help Tanzania enforce various existing codes that would limit Tanzania's rate of 400,000 hectares of deforestation annually. In theory, food

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122 United States Agency for International Development, "USAID Feed the Future FY 2010 Implementation Plans," *USAID: Agriculture*. April 6, 2010 <http://www.usaid.gov/our_work/agriculture/ftf_implementation_plans.htm>.

security and climate mitigation funds should be able to leverage each other and achieve greater progress toward each goal.[123] For climate purposes, greater detail would be needed on the rate of deforestation and other issues.

For this new approach to NAMAs to come into existence, a number of basic research steps are necessary, followed by pilot projects. In particular, there is a need for greater scientific guidance on the benchmarks and verification steps that would be adequate for providing reasonable confidence of a range of quantified levels of greenhouse gas reductions. IPCC guidance at the national level provides methods for estimating likely GHG reductions from certain basic agricultural measures, but the guidance is often limited for practical use to evaluating the benefits of changes in practices. For example, measures for estimating methane emissions from ruminant livestock require a degree of knowledge of production methods and feed quality that most countries are unlikely to have at a sufficient detail to support the quantification suggested here. Meanwhile, guidance on methane emissions from water-level management is probably too crude to be broadly accepted in the scientific community. Careful analysis by a credible group of researchers is necessary to develop guidance on how to shape NAMAs in ways that allow for credible, verifiable benchmarks and give confidence to donor countries that promised mitigation is scientifically valid.

Funding

In the Copenhagen agreement, developed countries committed collectively to provide $30 billion for mitigation and adaptation to developing countries by 2012, and $100 billion per year by 2020. Although countries agreed in Durban to develop a new fund under the authority of the United Nations to replace the Global Environmental Facility (which has disbursed roughly $9 billion over twenty years for a variety of environmental protections), most of the details remain to be negotiated, and it is by no means clear what percentage of funding would go through such a fund, or what the source of funding might be. One source of funds might be a tax on international shipping, which Oxfam has supported. With so much remaining to be negotiated, the kind of "accountable" NAMA framework described here could play a role in the structuring of such funds.

7. INTEGRATION WITH REDD

Agricultural improvements translate into greenhouse gas savings if they result in land sparing, but because of regional expansion, agricultural improvements may also encourage land conversion. The best way to assure that the two go hand in hand – thus bringing additional funds into agricultural improvements for mitigation – is to integrate such efforts with forest protection, which now means REDD.

123 USAID 2010.

Norway and other interests promoting REDD have started to focus on the drivers of deforestation, including agricultural improvement. Most issues regarding REDD remain unresolved, including the key question of who will actually receive funding for forest protection. One possibility would be for funds to be directed toward agricultural improvements, particularly among small farmers.

Some REDD advocates believe that developed country funders should provide funding to countries for achieving a certain level of forest protection, and should not attempt to influence who obtains funds. Regardless of whether or not payments will ultimately prove so disinterested, Oxfam and others could try to influence spending at the national level. In addition, one of the potential consequences of protecting any particular forest area is that agriculture may clear more other forests. Simultaneously boosting agricultural yields and protecting forests helps guard against this kind of leakage and subsequently merits additional compensation.

This kind of leakage is also the means by which pure productivity gains can translate into greenhouse gas savings through avoided deforestation. Ideally, agricultural NAMA programs and deforestation would move forward together. As a first step toward making this happen, Oxfam might wish to support the development of some model-integrated plans.

8. GETTING THE GREENHOUSE GAS ACCOUNTING RIGHT

Judgments about agricultural mitigation in the developing world will inevitably turn on some form of "lifecycle analyses," which indirectly estimate the GHG consequences of changed production or management measures. It is not technically possible to monitor emissions of nitrous oxide and methane as they occur. And because developing countries will not generally be subject to caps, some form of analysis is necessary to assure that a measure that reduces certain kinds of emissions in certain locations does not also increase emissions elsewhere. In turn, the details of lifecycle analyses become extremely important, and poor analyses can result in distorted incentives. There are two particularly important conceptual issues that have dominant potential influence on calculations.

8A. Emissions per Hectare or per Unit of Food

Typically, mitigation opportunities are estimated per hectare. As a result, reductions in food production save greenhouse gas emissions, and increases in production can increase greenhouse gas emissions even when they result in much higher greenhouse gas efficiency ("intensity"). When combined with typical treatment of land, discussed below, this type of approach generally favors lower over higher intensity. This approach would likely also disqualify much developing world agriculture from mitigation consideration because of growing populations, food demands, and total agricultural production.

Intensity, or estimating emissions per unit of food, is a better approach. Estimating emissions per unit of food will generally encourage more productive agriculture, up to a point. For example, one impressive recent meta-analysis of nitrous oxide emissions found that, overall, these emissions were smallest at fairly high nitrogen application rates (180-190 kilograms per hectare), but then increased rapidly thereafter.[124] Factoring in potential savings in land use would make the analysis stronger. For the reasons discussed above, improvements in resource efficiency are viable for small-scale farmers practicing agriculture at low intensity, as well as for more intensive farmers.

For these reasons, participants in the various world meetings on climate and agriculture nearly always discuss emissions on an intensity basis. Yet, because such approaches fit badly into offset systems, many continue to develop accounting systems that are not intensity based. For example, the FAO recently proposed a new standard for carbon sequestration for degraded grasslands to the Voluntary Carbon Standard, and this approach is based on calculating emissions per hectare (or over a general land area) rather than per unit of food.[125] The version submitted in June of 2012 calculates increases or decreases in methane or nitrous oxide emissions due to changes in the number of grazing animals, even though number alone does not alter emissions per unit of meat or milk.

Many agricultural greenhouse gas calculators, such as the Cool Farm Tool, are working on a per unit food basis. With many parameters still uncertain, putting such an approach into practice will require a degree of scientific scrubbing and consensus building. There are also important baseline issues or points of comparison, as the following examples demonstrate.

- Should funding support agriculture that reduces emissions per unit food compared to a local average, a world average, or any improvement on the farm in question? For example, even reductions in emissions per unit of food within Tanzania may involve increases in production at a higher emissions rate than those involved in importing food from the northern hemisphere.
- What is the unit of food? For example, even if grazing improvements reduce emissions per unit of beef, those emissions would likely remain larger than emissions per unit of protein generated by poultry or vegetarian diets.

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124 J. W. Van Groeningen et al., "Towards an Agronomic Assessment of N2O Emissions: A Case Study for Arable Crops," *European Journal of Soil Science* 61 6 2010: 903-913. <http://doi.wiley.com/10.1111/j.1365-2389.2009.01217.x>.

125 FAO. *Methodology for Sustainable Grassland Management, Version 01*,)Proposed to Voluntary Carbon Standard, June 2011.

- What is the probable future baseline from which to judge emissions? Changes in production levels and in the world at large will result in changing emissions intensity. In theory policy should encourage reductions from whatever might otherwise be expected.

7B. Calculating Emissions or Savings from Land Use

Lifecycle analyses are inconsistent in the ways they address emissions from land use. When analyses focus on a particular farm, they assign emissions or credits based on changes in that farm's own carbon stocks; however, these analyses almost never account for offsite gains or losses in carbon due to increased or reduced farm production. Lifecycle calculations of a final end product, such as dairy, may assign emissions if they use feed from Brazil, where land use change is occurring, but not if they use soybean meal from a region that is not experiencing land-use change.[126] Another potential approach, generally followed only for biofuels, assigns emissions from land-use change based on a world model of estimated emissions from land-use change due to increases in consumption. In theory, that approach assigns emissions appropriately for consumption decisions and could be used to reward improvements in productivity for the implicit land-use saved, however the models are highly uncertain and varied.

Each approach has large potential impacts on life-cycle assessment (LCA) results and farming incentives. If emissions are assigned based on regional land-use effects -- such as treating Brazilian soybeans as high emissions, but not those from the U.S. -- the tropics are penalized at the expense of temperate zone agriculture. More fundamentally, if emissions are only assigned to those farms that actually convert new land, there is no GHG reward or penalty for increasing or decreasing yields on existing land, and that whole area of potential mitigation is mostly ignored.

My own recommendation is two-part. First, in general, LCAs should recognize the carbon opportunity cost of land, so any production that uses land sacrifices potential carbon sequestration, and any agricultural activity that increases yield, increases that potential. Second, this opportunity cost should receive one score in general, and a higher score where it is tied to local forest protection, so that the potential is realized in actual sequestration. This approach will generally favor efforts to improve agricultural production in developing countries.

While accounting issues quickly become vexing, complicated, and sometimes abstruse, they are absolutely critical to the greenhouse gas and other policy implications of mitigation policies.

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126 Gerber 2010.

9. INFLUENCING INTERNATIONAL INVESTMENT

Private agricultural investment in the developing world, even in Africa, will likely dwarf public investment. I discuss three ways in which considerations of climate change mitigation may bear on these investments in ways that affect small farmers.

9A. Land Grabs

Although it is hard to confirm, the purchase or long-term lease of large land areas in the developing world appears to have large-scale effects on many small farmers. A number of reports have noted the frequent evictions of rural inhabitants from their land due to large-scale acquisitions of land and water, although some of these acquisitions were made by elites within developing countries.[127] The environmental and climate implications have been less thoroughly discussed. As demonstrated by the site visits featured in a new book by journalist Fred Pearce, many and probably most major acquisitions are relatively natural areas, including forests and savannas, wetlands, areas used for grazing, areas only cropped in the past, and even long abandoned plantations that have likely recouped substantial natural vegetation.[128] Farmers and other rural people use these lands, but their conversion to more intensive agriculture would undoubtedly release large quantities of carbon as well as have other biodiversity effects. Increased attention to carbon implications may provide one means of influencing these deals.

9B. State Agricultural Investment

Although statistics are hard to come by, China now appears to be the biggest single investor in Africa and one the biggest builders of infrastructure, and its trade has exceeded $100 billion per year.[129] One website, developed by a group at Macquarie University in Australia, that tracks Chinese investments indicated that less than one percent of China's direct investments in Africa was in agriculture, and that China remains a minor player in land acquisitions.[130] Even so, by the end of 2009, the country's capital investment in African agriculture had

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127 W. Anseeuw et al., *Land Rights and the Rush for Land: Findings of the Global Commercial Pressures on Land* (Rome: International Land Coalition, 2001).

E. O'Brien, *Irregular and Illegal Land Acquisition by Kenya's Elites: Trends, Processes, and Impacts of Kenya's Land-grabbing Phenomenon*. Rome: International Land Coalition, 2011..

L. Mehtaet al., "Special Issue: Water Grabbing: Focus on the (Re)Appropriation of Finite Water Resources," *Water Alternatives* 5 2012:193-542.

128 F. Pearce, *The Land Grabbers: The New Fght over who Owns the Earth* (Boston: Beacon Press, 2012).

129 H. French, "The Next Empire," *The Atlantic*, May 2010, April 6, 2012 <http://www.theatlantic.com/magazine/archive/2010/05/the-next-empire/8018/>.

130 "More Support for Chinese Agricultural Investment Abroad as Manufacturing Investment Matures," *Exporting China's Development to the World*, April 6, 2012 <http://mqvu.wordpress.com/2011/05/15/more-support-for-chinese-agricultural-investment-abroad/>.

reached $1.5 billion.[131] Chinese officials recently announced that agriculture would be an investment priority and would receive subsidies, and that aid programs would focus on establishing demonstration centers, including new centers in the cotton-producing countries of Northwest Africa.[132] As of 2010, China was building agricultural technology centers in fourteen countries of sub-Saharan Africa.[133] China is making more direct land investments in Southeast Asia. Direct investment in Africa is likely to dwarf agricultural aid, and policies to influence this investment are therefore important potential tools. A scientifically accepted process for estimating the carbon consequences of various agricultural improvements, undertaken with the collaboration of scientific researchers, may help to influence these investment strategies.

9C. Carbon Labeling, Certification Programs, and Purchasing Policies

Although several initiatives to place carbon labels on food emerged a few years ago, the movement now appears to be slowing. Tesco, the UK's largest retailer, announced plans in 2007 to label 500 products: as of June of 2011, it had labeled only 100 of its own brand products,[134] and it abandoned the effort add more labels in January of 2012.[135] Tesco blamed the failure on the cost of carbon labeling plus the failure of other food sellers to pick up the effort. The French retailer Casino has labeled 500 items. France initially proposed mandatory carbon labeling on all products but replaced this program with a one-year, voluntary pilot program in July 2011.[136] A number of other companies including Unilever, Pepsi, and Nestle, have announced goals for reducing their greenhouse gas emissions.

Such approaches could adversely affect small farmers in developing countries in a number of ways: (1) they may actually generate more emissions per unit of food in some circumstances; (2) they may unfairly be branded as causing such emissions, due to a flawed system of calculations; and (3) particularly under certification approaches, they could impose administrative costs that are disproportionate for small farmers. One paper has argued that developing countries will often be at a disadvantage for two reasons: they are still clearing land, unlike developed countries, and lower yields imply high emissions per unit of crop.[137] Such costs are blamed for marginalizing small horticultural producers under Global GAP, a program started by European retailers to establish basic

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131 X. Tan, "China's Investments in Africa's Agriculture" (WRI PowerPoint Presentation, April 2011).

132 "Exporting China's Development to the World," *Exporting China's Development to the World*, April 6, 2012 <http://mqvu.wordpress.com/>.

133 Tan 2011.

134 "Carbon Footprints: Following the Footprints," *The Economist*, June 2, 2012. April 6, 2012 <http://www.economist.com/node/18750670>.

135 A. Vaughan," Tesco drops carbon-label pledge," *The Guardian*, Jan. 30, 2012, Nov. 28, 2012 <http://www.guardian.co.uk/environment/2012/jan/30/tesco-drops-carbon-labelling >.

136 S. Baddeleyet al., "Trade Policy Implications of Carbon Labels on Food," *Estey Center Journal of International Law and Trade Policy* 13 2012: 59-93.

137 Baddeley 2012.

environmental standards for agricultural products.[138] In general, however, lifecycle analyses that find higher emissions from imported, rather than European, food typically involve vegetables transported by air freight.[139]

Labeling standards, such as those of the Rainforest Alliance, already incorporate social criteria. The greenhouse gas focus is legitimate and can potentially help or hurt small farmers. For the reasons discussed above, Oxfam should initially focus on the details of the accounting.

10. OXFAM INTERESTS BEYOND SMALL FARMERS

Small farmers constitute a large fraction of the rural poor. Promoting economic opportunities for these farmers is therefore an important development and anti-hunger strategy. However, only a minority of the world's hungry is made up of small farmers, while roughly half of the world's hungry are urban, as illustrated, on a country basis, by Figure 6.[140] In rural areas, the poorest and hungriest people are often landless or have such sufficiently small holders that much of their income derives off-farm.[141] For example, although the data is somewhat old, surveys have found that those with half a hectare of land or less receive between 30 and 90 percent of their income off-farm.[142] The poorest 20 percent of the population in developing countries typically consists of net food buyers,[143] typically including at least half of all farm buyers. As a 2008 Oxfam paper summarizes:

> A recent FAO study shows that most rural households in Bangladesh, Pakistan, Viet Nam, and Malawi are net consumers. In most of the African countries that have been studied, only 25-30 percent of producers are net sellers, and in Vietnam and Cambodia the proportion rises only to about 40 percent. Figures for most Latin American countries are even lower.[144]

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138 Brenton et al., "Carbon Labeling and Low-income Country Exports: A Review of the Development Issues," *Development Policy Review* 27 2009: 243-267. <http://dx.doi.org/10.1111/j.1467-7679.2009.00445.x>.

139 Breton 2009.

140 A. U. Ahmed et al., "The World's Most Deprived: Characteristics and Causes of Extreme Poverty and Hunger," *Food Policy Report*, 43 Oct. 2007: 130.

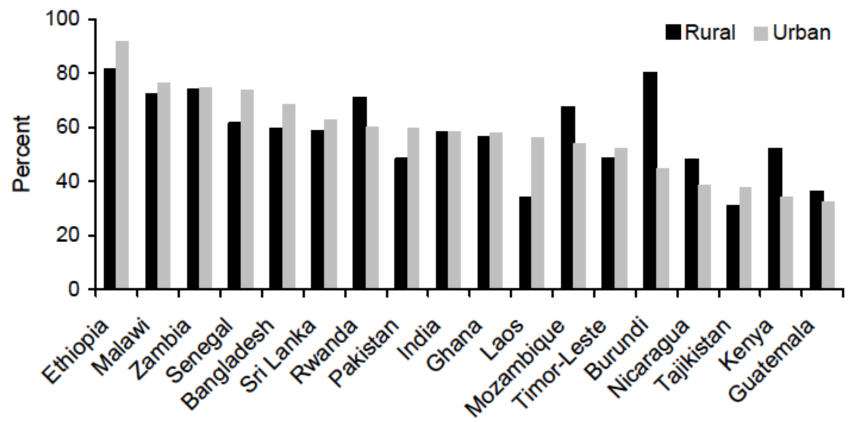
141 P. Hazell and L. J. Haddad, *Agricultural Research and Poverty Reduction* (Washington, D.C.: International Food Policy Research Institute, 2001).

142 Hazell 2001.

143 FAO, *The State of Food Insecurity in the World: How Does International Price Volatility Affect Domestic Economies and Food Security* (Rome: FAO, 2011): 1-50.

144 Oxfam International, "Double-Edged Prices: Lessons from the Food Price Crisis: 10 Actions Developing Countries Should Take," *Oxfam International Briefing Paper* 121 2008: 1-46.

Figure 6. Distribution of the hungry between urban and rural areas



Note: The hunger incidences represent the sum of the incidences for the subjacent, medial, and ultra hungry.

Figure 6: Reprinted from Ahmed et al. 2007.

For this reason, economists have long found that benefits for the poor from agricultural productivity gains largely derive from lower food prices, and much of the remainder derives from rural employment opportunities generated by the multipliers of increasing agricultural revenue.[145] Female-headed households suffer particularly from high food prices because they are even less likely to have food surpluses and are usually poorer in general.[146] The Oxfam 2008 paper does an excellent job of summarizing the challenges: women own much less land, have holdings only 20-35 percent of the size of male holdings, occupy worse land, and engage in agriculture to a substantial extent as laborers. In South Asia, most rural women are as unpaid contributing family members.

This paper, as requested, has focused on synergies and trade-offs between small farmers and climate mitigation. But agricultural improvements (or damage) also affect the hungry through overall production and labor demand, and Oxfam's interest in the synergies and trade-offs should therefore extend beyond the direct impacts on small-scale farming.

11. PROPOSED UNFCCC LANGUAGE

For several recent conferences of the parties, New Zealand and other countries have been pushing to include language that would call for the Secretariat to undertake a work plan to evaluate mitigation opportunities. Much of the motivation lies in the belief that similar work for forest protection led to

145 Hazell 2001. A. De Janvry et al., "Technological Change in Agriculture and Poverty Reduction" (Concept paper for the WDR on Poverty and Development 2000-01, University of California, 2000).

146 Janvry 2000.

momentum to provide funding for REDD, as well as the apparent hope that this process will lead to increased funding for the agricultural sector. In personal conversations, officials at the World Bank have stated that this official endorsement will make it easier for the Bank to focus efforts in this area; presumably the same will apply to other international institutions.

On the other hand, there is no obvious legal reason such language is necessary. The Cancun agreement explicitly calls for countries to develop plans for Nationally Appropriate Mitigation Activities and Nationally Appropriate Adaptation Activities, and encourages related technical work to support such measures, including the establishment of guidelines for measuring their progress, which is to be the basis for reporting. Both NAMAs and NAPAs may include agricultural activities. The Cancun agreement called for the development of modalities and accounting systems to support NAMAs, and the African Ministerial communiqué called for the African Union to undertake a work plan on climate smart agriculture.

Although this language seems to offer some potential good, there is no reason to wait for this language to undertake the analytical work and NAMA development necessary for positive mitigation work to go forward. Because official processes such as the UNFCCC also tend to work best when they are filtering, rather than inventing new material, Oxfam may also wish to support private efforts to elaborate the technical and economic opportunities in greater depth.

12. SUMMARY OF FINDINGS AND POLICY RECOMMENDATIONS

12A. Support those carbon sequestration efforts that provide direct economic returns but deemphasize other measures and deemphasize carbon offsets.

In particular, policy should deemphasize the focus on traditional offsets for carbon sequestration because of the myriad challenges of offset projects (additionality, permanence, and high proof requirements), the scientific uncertainty about many soil carbon sequestration efforts, and the challenges for small farmers in participating in such projects. Oxfam should look particularly carefully at plantation forest projects. However, some offset opportunities may exist and should be embraced, particularly in the field of agroforestry. Oxfam should also support opportunities to boost soil carbon through various yield improvements using tools beyond offsets.

12B. Focus on the major opportunities for mitigating emissions that have the potential both to generate relatively rapid economic benefits and become economically self-sustaining.

Those opportunities involve livestock improvement, intensification with forest protection, nitrogen management in parts of Asia, rice management, and agroforestry efforts that enhance production, for example, by fixing nitrogen or providing high quality dairy fodder.

12C. Create a framework through NAMAs for agricultural mitigation programs that have an intermediate level of scientific certainty and results-monitoring for GHG reductions between offsets and pure foreign aid.

Such programs would require a fair level of proof that the agricultural measures would reduce greenhouse gas emissions, and should offer a reasonable quantification, but they should permit up-front funding and use practicable methods of verification.

12D. Integrate agricultural mitigation projects with REDD.

Agricultural improvements will nearly always reduce emissions if they do not result in local expansion of the agricultural area. REDD is also the first international climate effort "moving out," and Norway and other interests promoting REDD have started to focus on the drivers of deforestation, including agricultural improvement. One of the key questions REDD has yet to address is who will actually receive funding for forest protection. Ideally, small farmers would receive a fair share of the funds for agricultural improvements.

12E. Support accounting and climate strategies that focus on emissions per unit of food and that incorporate the opportunity costs of land.

Any accounting that calculations emissions per hectare would perversely reward reductions in food production.

12F. Support analytical work to get specific.

Substantial technical and economic questions surround every technical opportunity for reducing greenhouse gas emissions from agriculture in general and for small farmers in particular. In order for these efforts to move forward, and for them to truly reduce emissions and boost farm income, additional analysis is needed at multiple levels. Ultimately, it is through the details of specific plans that adverse potential effects of mitigation efforts on small farmers can be avoided, and beneficial effects promoted. Oxfam's country-level programs can work on plans at a country level. This work can also provide a basis for influencing international investment.

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