STRATEGIES FOR

Mitigating Climate Change in Agriculture

Recommendations for Philanthropy

Executive Summary

April 2014

CLIMATEFOCUS

CEA California Environmental Associates

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SUGGESTED CITATION:

Dickie, A., Streck, C., Roe, S., Zurek, M., Haupt, F., Dolginow, A. 2014. "Strategies for Mitigating Climate Change in Agriculture: Recommendations for Philanthropy – Executive Summary." Climate Focus and California Environmental Associates, prepared with the support of the Climate and Land Use Alliance. Report and supplementary materials available at: www.agriculturalmitigation.org

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WEB PLATFORM:

www.agriculturalmitigation.org contains a copy of this executive summary, the full report, the abridged report, the technical annex as well as various supplementary materials including:

Background analyses of the global agricultural sector

- Finance
- Institutions
- Mitigation practices
- Sources of emissions
- Trade

Agricultural sector and policy profiles for specific countries / regions:

- Brazil
- China
- European Union
- India
- United States

This work has been made possible by the generous support of the Climate and Land Use Alliance. It is intended to help a range of organizations with strategic planning for greenhouse gas mitigation in the agricultural sector. The findings presented and any errors incurred should only be attributed to the authors. Although it has been written with a specific audience in mind, this report is in the public domain and the authors encourage the circulation of this report as widely as possible.

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EXECUTIVE SUMMARY

Agriculture contributes substantially to global climate change. The sector accounts for roughly a fifth of greenhouse gas (GHG) emissions when one considers the full life cycle of production including agriculture's role in deforestation.[1] This is a massive number, comparable in scale to the transportation sector. Further, this ratio can be even higher in developing countries where the agriculture and forestry sectors together often account for a majority of total emissions. Yet, historically, climate negotiators and policy makers have paid relatively little attention to the agricultural sector in the global effort to slow climate change.

A constructive debate on agriculture and climate change is hampered by a false dichotomy between food security and environmental health. Civil society often approaches agriculture with an overarching mission of *either* improving food security and strengthening smallholder livelihoods *or* reducing the environmental degradation caused by agricultural systems. The option of supporting productive, low-emissions agricultural systems often falls through the cracks of these agendas. There is also little discussion about the opportunities provided by reducing emissions through shifting diets as well as the reduction of food loss and waste. The specter of mitigation practices that risk reducing yields may be preventing a useful integration of the food security and livelihoods agenda with that of the climate and environmental community. Given the likely impacts of climate change on poor and vulnerable communities, we cannot afford to approach agriculture from these silos any longer.

In recent years there have been a number of developments which indicate a positive shift towards incorporating climate into a broader agricultural agenda. Examples include the creation of the Global Research Alliance on Agricultural Greenhouse Gases; the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS); the support of Climate Smart Agriculture by international organizations (World Bank, FAO); Brazil's Low Carbon Agriculture program (Agricultura de Baixa Emissão de Carbono, ABC); and Animal Change (a European Commission funded research effort).

Yet, still more resources need to be brought to bear on the intersection of agriculture and climate change, particularly as there are multiple, complex challenges in addressing this nexus. Production is exceedingly diffuse, the demand for carbon intensive meat is increasing, there are research needs and challenges to mitigating agricultural emissions, and there are very high levels of uncertainty associated with the mitigation potential of various interventions. While it will be a persistent challenge, we have the resources needed to create agricultural systems that are more productive and less GHG intensive. Moving quickly towards higher productivity, lower emissions agricultural systems is in the long-term interest of stakeholders throughout the agricultural sector, including national governments, agribusinesses, multi- and bi-lateral financial institutions, and most importantly, farmers.

Summary of Recommendations

This report was commissioned to identify GHG mitigation options in the agricultural sector. Our analysis provides a snapshot of the global mitigation potential in the year 2030, compared to a hypothetical baseline in which no additional mitigation from agriculture is attempted, beyond current adoption and intensification trends. Our recommendations focus on GHG mitigation options while also supporting the food security and climate resiliency needs. We concentrate on mitigation options that reduce the GHG intensity of agriculture, both by changing production practices without harming yields and by shifting demand to lower-GHG intensive products. At its heart, this report has four overarching recommendations:

1. **Shift consumption patterns.** We will be unable to reverse growing agricultural emissions trends unless we address their root cause: rising demand for agricultural products, particularly those that are carbon intensive. Agricultural GHG emissions cannot be addressed simply as a problem of inefficient production on the supply-side. A spotlight must be cast on the pressures that inefficient, unsustainable consumption patterns pose to global climate and land use. This report estimates that nearly 3 gigatonnes of carbon dioxide equivalents (Gt CO_2e) per year could be mitigated through changes in diets and reductions in food waste in 2030 compared with a business as usual scenario.[2] About 75 percent of this mitigation potential comes from changes in diet and the other 25 percent from reductions in food loss and waste. These major shifts in demand for agricultural products represent an emissions reduction of roughly 55 percent of direct agricultural emissions in 2030.

2. **Focus on key agricultural producers that can achieve major productivity gains.** Demand-side interventions need to be paired with efforts to improve the efficiency of production. One of the largest challenges in containing the growth of agricultural GHG emissions is the diffuse nature of production. While there are countless mechanisms that could reduce GHG emissions, there are only a limited number of countries and sectors that can yield meaningful reductions (i.e., at least 40 to 50 million tonnes (Mt) CO_2e reductions per year by 2030) with practices that would be beneficial to producers and to yields. In the aggregate, the emissions reduction potential of the agricultural sector through supply-based approaches is nearly 2 Gt CO_2e per year by 2030, including efficiencies gained in fertilizer production in China.[3] These emissions reductions represent about a 30 percent reduction from 2030 levels. In most cases, these interventions would yield productivity gains and ought to be in the best interest of farmers and governments.

   Priority focus areas should include: reducing enteric fermentation emissions from the largest cattle herds that are not produced as efficiently as they could be (e.g., Brazil's cattle population and India's dairy herd), increasing the efficiency of nutrient use on China's croplands, securing major industrial inefficiencies in China's fertilizer production, reducing rice emissions in Southeast Asia, and improving stored manure practices in industrialized livestock systems.

   Interventions need to be designed on a case-by-case basis, specific to country-level conditions. Common interventions for encouraging changes in agricultural practices include expanding extension capacity, expanding the availability of subsidized loans, providing financial incentives, and working directly with producer groups.

3. **Pursue catalytic, cross-cutting interventions.** Achieving high productivity, low emissions agriculture across the globe will require that mitigation practices be incorporated into the daily business of actors across the agricultural sector. Agricultural ministries, agribusinesses, and financial institutions and donors all need to create and adopt best practices for an integrated climate and productivity agenda in agriculture. High leverage opportunities that are already gaining traction include: standards and guidelines for low emissions agricultural investments, greater transparency and accountability in corporate supply chains, removal of barriers to agricultural mitigation measures in both the United Nations Framework Convention on Climate Change (UNFCCC) and World Trade Organisation (WTO), and reform of agricultural subsidies in major agricultural economies.

4. **Take a rational approach to agricultural carbon sequestration.** Of the many debates on agricultural mitigation, perhaps none has endured as many fluctuations in recent years as the discussion surrounding the role of carbon sequestration in agricultural soils and above-ground biomass. This report estimates a global carbon sequestration potential of between 700 and 1,600 Mt CO_2e per year by 2030.[4] The mitigation, yield, and economic impacts of sequestration are not well understood for all practices, and there are complicating factors such as the impermanent nature of carbon stocks. Given these challenges, agricultural carbon sequestration should not be embraced or pursued *in lieu* of other mitigation opportunities. However, long-term management and preservation of soil carbon is critical for agricultural productivity because it increases soil fertility,

reduces erosion, and increases moisture retention. Maintaining soil organic matter is vital for farmers and ranchers everywhere, regardless of the potential to measure or monetize sequestration.

Summary of methodology

This report was designed to address mitigation opportunities in the agricultural sector. The analysis is intended to help readers understand the relative magnitude and feasibility of mitigation opportunities. It draws a tight boundary around the agricultural sector and omits a number of mitigation opportunities connected to agriculture such as: reduced deforestation, restoration of abandoned lands, restoration of peatlands, fossil fuel offsets from bioenergy, emissions fluxes related to land use change driven by increases or decreases in biofuels and bioenergy, and energy and industrial efficiency along the agricultural supply chain (with the exception of fertilizer production in China). Many of these opportunities are worthy of exploration and support.

The quantitative analysis included in this report provides an overview of the technical potential for GHG mitigation in the agricultural sector in the year 2030, compared with a baseline projection, calculated by country and emitting sector. Technical mitigation potential represents the emissions reductions or carbon sequestration possible with current technologies, ignoring economic and political constraints. This analysis represents a synthesis of existing published literature and data. We used a range of approaches to determine the mitigation potential for the main categories of interest: enteric fermentation, manure management, rice management, fertilizer application to crops, carbon sequestration on croplands, grazing lands and in agroforestry systems, and changes in demand. In some cases we cited published analyses directly. In other cases, we developed our own assessments based on existing data. In a select number of cases, we relied on unpublished work shared with us by leading scientists in the field.

For a full description of the methodology and sources used, please see Annex 3 of the full report.

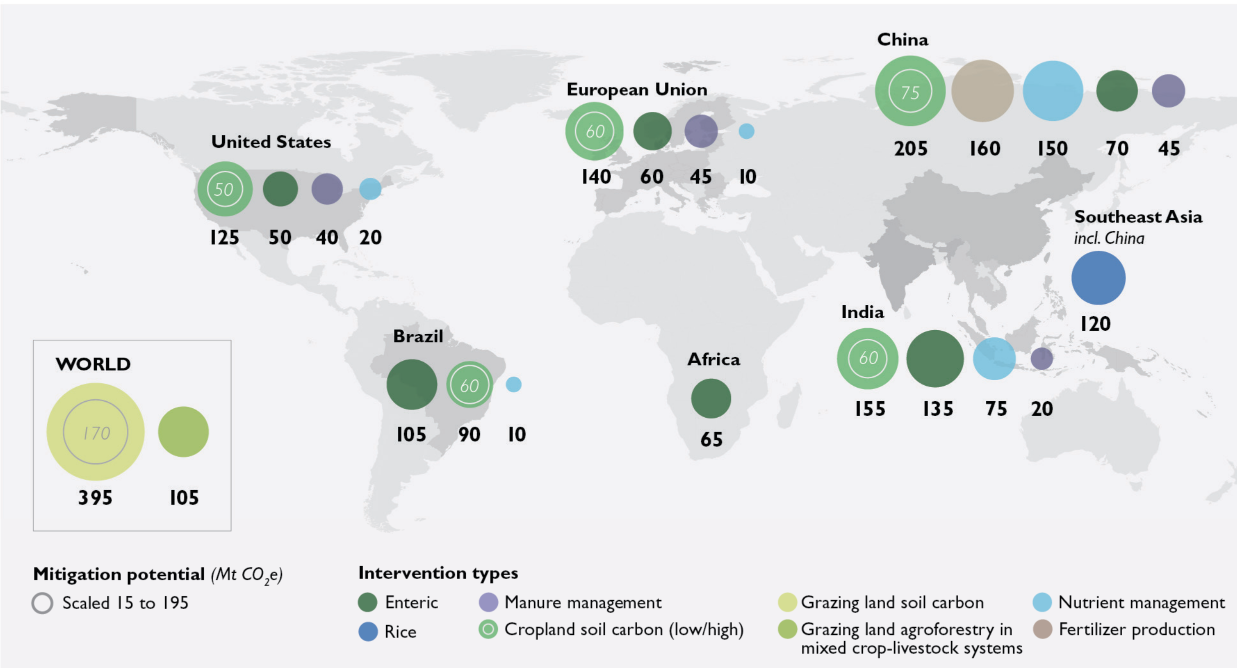
Summary of priority areas

The pressures on land, natural resources, climate, and people continue to grow. Win-win solutions exist and must be pursued aggressively by all factions that are collectively charting the course for agriculture in the 21st century. The map below shows mitigation potential and priority areas for interventions.

Global mitigation opportunities (technical potential)

Setting aside economic and political constraints, the greatest technical opportunities to reduce agricultural greenhouse gases from direct agricultural are centered on a few key geographies: U.S., E.U., China, India, and Brazil.

There is a high level of uncertainty in estimates of carbon sequestration on croplands and grazing lands. In this analysis we have provided an upper estimate and a lower estimate of mitigation potential based on different assumptions and/or different analyses. The two circles show the mitigation potential using the high and low estimates.



United States

125. Croplands: *Soil carbon sequestration (biochar), high*

50. All ruminants: *Enteric fermentation reduction*

40. All livestock *Stored manure management*

20. All crops *Nutrient management*

Brazil

105. All ruminants: *Enteric fermentation reduction*

90. Croplands: *Soil carbon sequestration (biochar), high*

10. All crops: *Nutrient management*

European Union

140. Croplands: *Soil carbon sequestration (biochar), high*

60. All ruminants: *Enteric fermentation reduction*

45. All livestock: *Stored manure management*

10. All crops: *Nutrient management*

India

155. Croplands: *Soil carbon sequestration (biochar), high*

135. All ruminants: *Enteric fermentation reduction*

75. All crops: *Nutrient management*

20. All livestock: *Stored manure management*

China

205. Croplands: *Soil carbon sequestration (biochar), high*

160. Supply chain: *Fertilizer production*

150. All crops: *Nutrient management*

70. All ruminants: *Enteric fermentation reduction*

45 All livestock: *Stored manure management*

Southeast Asia (incl. China)

120. Rice: *Water and rice straw management*

Greater Horn of Africa

65. All ruminants: *Enteric fermentation reduction*

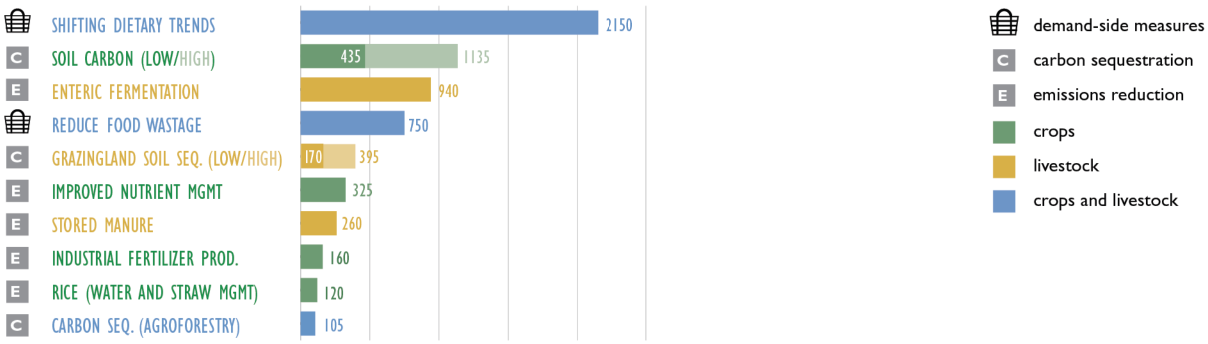
World

395. Grazing Lands: *Soil carbon sequestration, high*

105. Grazing Lands: *Agroforestry in mixed crop-livestock systems*

Source: CEA analysis based on multiple sources. See Annex 3 for methodology and sources.

Mitigation opportunities by sector and country in 2030 (Mt CO2e)



MITIGATION CATEGORY	REGION / COUNTRY	DETAILS

SHIFTING DIETARY TRENDS

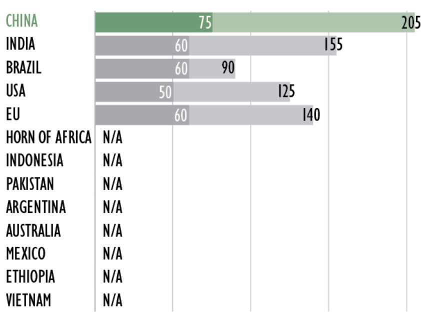
WORLD 2,150

Meat and dairy, especially from ruminants, are high carbon products and consumption of these commodities are rapidly increasing.

The carbon intensity of food items varies dramatically. Meat and dairy, especially from ruminants, are high-carbon products and consumption of these commodities is rapidly increasing due to increasing income and populations in emerging countries. Efforts to reduce demand, shift meat consumption to lower carbon alternatives (e.g., from beef to poultry), or curtail growth should be explored in both developed and emerging economies. This mitigation estimate assumes that the entire global population adopts a "healthy diet" based on recommendations from Harvard Medical School which prescribe 90 grams of protein per day. Although there are major portions of the global population that do not eat this much meat, and large portions of the global population that are unlikely to adopt such meat heavy diets for cultural and/or religious reasons, these totals are significantly lower than the current global average.

SOIL CARBON SEQUESTRATION FROM BIOCHAR APPLIED TO CROPLANDS

WORLD 435 (low) / 1,135 (high)

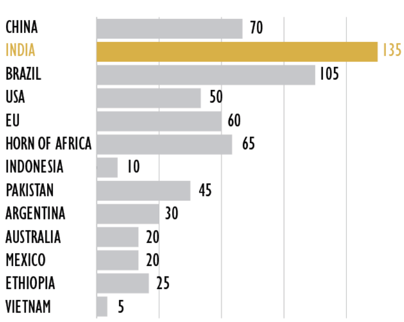


This report relies on an analysis of the mitigation potential from global adoption of biochar to provide estimates for soil carbon sequestration potential on croplands. Two estimates are shown, using different assumptions about available feedstocks and the inclusion of avoided emissions in the life-cycle calculations. According to this analysis, the largest opportunity for GHG mitigation from biochar is through the use of rice residues. Sugar cane residues is also an important feedstock. China and Brazil are regions with particularly strong potential for biochar. In terms of broader attention to soil carbon sequestration, Sub-Saharan Africa is critical region because of the strong links between soil fertility and food security.

ENTERIC FERMENTATION

All ruminants

WORLD 940



Brazil: Brazil's large cattle populations provide one of the most cost effective opportunities to reduce enteric methane emissions. Improving the forage quality on grazing lands in Brazil could increase the stocking densities, increase the productivity of the herd and thus reduce the number of animals needed to support a given level of production (thus reducing emissions). Additional carbon sequestration on these lands would be a co-benefit.

India: The mitigation potential shown here reflects the opportunity for all of India's ruminant population. However, India's large and growing population of dairy livestock (both cattle and buffalo) provides a particularly ripe opportunity for enteric methane emissions. The mitigation potential in the dairy sector alone is 70 Mt COe_2 per year. For the dairy sector, access to better quality stover and other feed is the priority (as the animals are rarely grazed). Improved diets will increase the productivity of these animals.

EU and US: While there is still fairly significant potential to reduce enteric fermentation in cattle across Europe and the US, these systems are highly industrialized already; cattle are fed high quality diets and are produced very efficiently. Additional gains require high-cost additives and supplements which typically do not increase productivity and, in some cases, have negative impacts.

Sub-Saharan Africa: Although there are sizable livestock populations across Sub-Saharan Africa which are typically fed low-quality diets, the opportunity for mitigation is low in this region because so many of these animals are not grown for market but rather kept for financial security, labor, and subsistence. Improving feed would likely not reduce the size of the herds.

MITIGATION CATEGORY	REGION / COUNTRY	DETAILS

REDUCED FOOD WASTAGE

WORLD 750

Food wastage is largely a byproduct of inefficiency and there are vast opportunities for cost savings and emissions reductions along the entire supply chain.

In the energy and transportation sectors, there has been a tremendous amount of attention placed on improving the efficiency of the systems. A comparable effort has not been initiated in the agricultural sector, but is desperately needed since food postharvest loss and consumer waste of food across the supply chain is over 30 percent in most countries.[i]

i) Godfray et al., 2010.

GRAZINGLAND SOIL CARBON SEQUESTRATION

WORLD 170 (low) / 395 (high)

The countries with the biggest opportunities for mitigation are those that have large areas of grazing land that are important to their agricultural economy (e.g. Brazil, China, Kenya, Ethiopia, Mongolia).

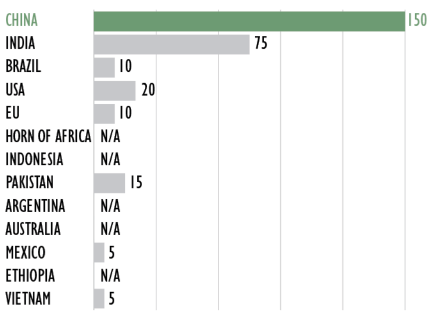
This report provides two estimates of mitigation potential from soil carbon sequestration in grazing lands, drawing from multiple sources in the scientific literature. The carbon sequestration potential of grazing lands is one of the most uncertain areas of agricultural mitigation. The lower estimate shown here only estimates the soil carbon sequestration potential associated with rehabilitating overgrazed grasslands. It should be considered a conservative estimate because there are opportunities for soil carbon sequestration on grazinglands that are not degraded.

There is soil carbon sequestration potential in grazing lands in many regions of the world. The countries with the biggest opportunities for mitigation are those that have large areas of grazing land that are important to their agricultural economy (e.g. Brazil, China, Kenya, Ethiopia, Mongolia).

Brazil: In Brazil there is an enormous amount of pasture that is already managed, but is marginally productive. Productivity on these grazing lands could improve a lot with a change in management practices. The potential productivity gains mean that pasture improvements are inline with producer incentives. Any effort to improve the carbon sequestration of grazing lands in Brazil dovetails well with efforts to reduce enteric fermentation emissions through improved forages (see above).

IMPROVED NUTRIENT MANAGEMENT

WORLD 325



China: Over the last few decades, China has become the global hotspot for overuse of synthetic fertilizers. Most farmers in China could reduce fertilizer application rates by 30-60% without harming yields.[ii] Aggregate nutrient use efficiency rates across China could double.

India: India is an emerging hotspot for over application of fertilizer. Although there are many parts of India where access to fertilizer is still limited and fertilizer is still under-applied, increasingly it seems to be following the path of China in terms of over-application.

US: Although American farmers are relatively efficient with fertilizer inputs per unit of output, roughly 65% of croplands have potential for better timing, rate, or method of nutrient application.[iii]

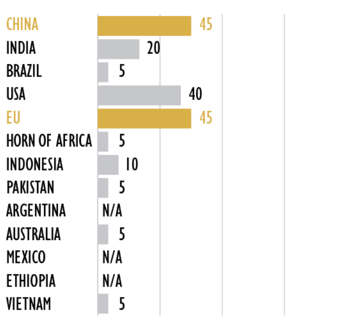
Sub-Saharan Africa: Most croplands across Sub-Saharan Africa receive too little fertilizer. Increasing rates of fertilizer use across the region would greatly benefit yields, without much of an increase in emission. With increased yields, higher volumes of crop residues would be available for soil carbon sequestration and increased soil fertility.

ii) Ju et al., 2009
iii) Ribaudo, M. (2011) "Reducing agriculture's nitrogen footprint: are new policy approaches needed?" United States Department of Agriculture: Economic Research Service.

EMISSION REDUCTIONS FROM STORED MANURE

All livestock

WORLD 260



China: The opportunity for reducing emissions from stored manure is significant in China, where management practices have not yet been widely implemented in concentrated feeding operations and where massive growth is anticipated in confined pig and poultry populations.

EU and US: There is significant opportunity to reduce emissions from stored manure in the US, which has been slow to adopt mitigation measures such as methane digesters. There is still room for improvement in the EU, although this region has probably already addressed the low hanging fruit as it has been faster to adopt digesters.

Although there are some low-cost and low-tech mitigation practices for better management of stored manure, the best options are costly and do not improve the productivity of livestock sectors. There are some low-cost and low-tech mitigation practices for better management of stored manure, but the best options are costly and do not improve the productivity of livestock sectors. However, there are very significant co-benefits of improved treatment of stored manure in any country, most notably water quality improvements. Further, both methane digesters and compost facilities can create valuable products (bioenergy or biogas, and soil enhancements, respectively). In some markets, these products will be profitable enough to warrant the upfront investment. However, in most markets some kind of subsidy will be required.

MITIGATION CATEGORY	REGION / COUNTRY	DETAILS

EMISSIONS REDUCTIONS FROM INDUSTRIAL FERTILIZER PRODUCTION

REGION / COUNTRY	
WORLD	N/A
CHINA	160[iv]

China: In China, emissions from fertilizer production are particularly high because coal is used as a feedstock (as opposed to natural gas) and equipment is largely outdated and inefficient. Vast improvements could be made over time by investments in new equipment and industry consolidation.

iv) Zhang et al., 2013

WATER AND STRAW MANAGEMENT

Irrigated rice systems

REGION / COUNTRY	
WORLD	120
CHINA	25
INDIA	15
BRAZIL	0
USA	0
EU	0
HORN OF AFRICA	N/A
INDONESIA	10
PAKISTAN	5
ARGENTINA	N/A
AUSTRALIA	N/A
MEXICO	N/A
ETHIOPIA	N/A
VIETNAM	10

Southeast Asia: Rice has one of the highest carbon footprints of any crop because of the methane generated from cultivating in wet systems. Mid-season drainage in irrigated systems and improved management of rice straws can provide significant emissions reductions and are cost effective where water is expensive.

CARBON SEQUESTRATION FROM AGROFORESTRY

WORLD 105

Agroforestry systems may well have adoption potential across a wider range of agricultural systems, however data on the mitigation potential for agroforestry is limited.

This report includes an assessment of the carbon sequestration potential from agroforestry systems adopted in mixed crop-livestock systems in humid and tropical highland areas of the developing world. Agroforestry systems may well have adoption potential across a wider range of agricultural systems, however data on the mitigation potential for agroforestry is limited. Agroforestry may be particularly appropriate for grazing lands or mixed crop-livestock systems as they can provide shade and nutritional benefits for livestock and are less likely to displace crops.

1) A detailed discussion of the methodology employed for all of these estimates is provided in Annex 3;
2) This report does not provide country-level estimates for carbon sequestration on grazinglands, agroforestry, fertilizer production outside of China, or demand side measures. It also only provides country level estimates for biochar application for some countries;
3) This report does not provide estimates for soil carbon sequestration on croplands for practices other than biochar application and agroforestry in mixed systems because of data limitations and because of potential double-counting between these practices and biochar. Table 2 in Annex 3 provides additional information on country and regional carbon sequestration potential.

Source: CEA analysis based on multiple sources. See Annex 3 for methodology and sources.

SUMMARY OF INTERVENTIONS

This report details 12 strategies and 41 interventions for philanthropy to address climate change mitigation in the agricultural sector, organized by supply-side, demand-side and cross-cutting strategies.

Supply-side Strategies

A large number of practices can be deployed to reduce GHG emissions associated with the production of crops and livestock. Multiple intervention options are available for every source of emissions, and the effectiveness of any single intervention will depend greatly on the specifics of the relevant agricultural system. Interventions that reduce the emissions intensity of production are typically in line with productivity gains and/or cost savings, and are thus often in the best interest of the farmers. However, emissions intensification practices also carry the risk of environmental or social trade-offs. In other cases, mitigation practices do not have an impact on productivity, but may help farmers meet other objectives (e.g., water quantity savings from mid-season drainage in rice systems or water quality improvements from better management of stored manure).

SUSTAINABLE INTENSIFICATION

Increasing the efficiency of land and resource-use will be essential to meet rising demand for agricultural products and to improve food security for a growing global population. Closing yield gaps for crops, and especially for livestock, increases the emissions efficiency of production (e.g., lower emissions per unit of product) and can decrease land use change emissions by decreasing pressure on forests. Because there are some trade-offs and social and environmental risks to intensification, the challenge is to support 'sustainable intensification'. Sustainable intensification is a concept broadly aimed at increasing yield and meeting future demand by optimized efficiency of agricultural production across social, environmental and ethical dimensions of sustainability.

Specific interventions:

- Assess mitigation effectiveness of intensification strategies for REDD+ finance
- Develop assessment tools to identify mitigation opportunities with high co-benefits and low / manageable tradeoffs

IMPROVING NITROGEN MANAGEMENT AND PRODUCTION

Nitrous oxide emissions stem from nitrogen fertilizers (both synthetic and organic) on croplands that have not been absorbed by plants, and leach instead into the environment. Fertilizer run-off contaminates surface and ground water quality and creates GHG emissions in the form of nitrogen oxide. To better manage fertilizer application, the basic approach is to increase the nitrogen use efficiency within the cropping system by better matching the nitrogen supply from fertilizers with the nitrogen demands of the crops. Although there are many practices that are effective in improving nutrient use efficiency, and most of them are low-cost, they also tend to be labor and/or knowledge intensive. China is believed to have the greatest overuse of fertilizer globally. Simple measures can greatly reduce GHG emissions from fertilizer application in China without harming yields. In fact, in China, reduced fertilizer application would benefit yields and long-term soil fertility in most cases. In addition, securing major industrial inefficiencies in China's fertilizer production would yield very significant GHG reductions.

Specific interventions:

- Evaluate the Soil Testing and Fertilizer Recommendation program in China and additional measures to reduce fertilizer application

- Support efforts in knowledge dissemination to farmers on correct fertilizer management
- Improve fertilizer production by engaging the fertilizer industry through investment or outreach

REDUCING EMISSIONS FROM ENTERIC FERMENTATION

Enteric fermentation accounts for nearly half of direct agricultural emissions. It is part of the digestive process in herbivorous animals ('ruminants' such as cows, buffalos, goats, and sheep). These animals have a rumen, a large four-compartment stomach with a complex microbial environment, which allows these animals to digest complex carbohydrates, a process that produces methane as a byproduct. Ultimately, the best way to reduce enteric fermentation emissions is to reduce ruminant populations. When animals are held in unproductive systems, or are kept for purposes other than meat production, they are kept alive for a long time. When it takes a long time for a single animal to reach slaughter weight, not only does that animal have high emissions per unit of product, but a larger herd is needed to support a given level of production. There are three main ways to reduce enteric fermentation emissions per unit of meat or milk: 1) improving the quality and digestibility of feed; 2) providing supplements and additives and reduce methane; and, 3) optimizing the health and reproductive capacity of the herds. Both feeding and herd management practices are targeted at lowering the number of animals necessary to sustain a given level of production. Some of the world's largest livestock herds are managed at low productivity levels, with suboptimal diets, nutrition and herd structure. Holding production levels constant, lower emissions could be achieved by improving the diets of these animals. Because these interventions are in line with productivity gains, reductions in enteric fermentation emissions for many of the world's animal populations provide some of the most cost-effective mitigation potentials in agriculture.

Specific interventions:

- Improve grazing lands management in beef production in Brazil by promoting awareness and capacity of cattle ranchers through outreach and vertical integration of the supply chain
- Increase effectiveness of the Low Carbon Agriculture program in Brazil (Agricultura de Baixa Emissão de Carbono; ABC) to reduce agricultural emissions
- Improve feeding practices in dairy production in India by making a business case and supporting outreach campaigns to processors, producers and farmers

SEQUESTERING CARBON IN AGRICULTURAL SYSTEMS

There are numerous land and crop management practices that can increase the soil organic carbon in agricultural soils, including protecting existing carbon in soils by slowing decomposition of organic matter and reducing erosion (e.g. reduced tillage or no tillage, cover crops, contour strops), increasing the amount of carbon in soils (e.g., retention of crop residues, biochar), add carbon to the agricultural system through above ground biomass (e.g. agroforestry or silvopasture), and increasing carbon stores in grazing lands (e.g. managing stocking rates, timing and rotation of livestock, introduction of grass species or legumes with higher productivity, and application of biochar, compost, fertilizer, or irrigation to increase productivity).

As noted above, there is a justified concern from a sizable segment of the scientific community that an over-emphasis on the benefits of soil carbon sequestration may detract from other measures in the agricultural sector which are at least as effective in combating climate change.[5] However, most practices that increase the carbon content in agricultural soils are good agricultural practices anyway and lead to increased yields and water retention. Considering the need to intensify agricultural production, an active consideration of increasing soil carbon within existing agricultural programs requires comparatively little effort with potential significant benefits.

One way to prioritize support for increased soil carbon sequestration is to identify those geographies where soil carbon content is particularly low and where the links to food security, poverty reduction, and productivity gains are strongest. This report focuses on the croplands of Sub-Saharan Africa and the grazing lands of Brazil as two geographies where carbon sequestration would support broader efforts to improve soil fertility and forage productivity, for the long-term benefit of producers. Additionally, this report recommends continued, long-term investments in research and development of promising new practices, specifically biochar, as well as improved data on soil types, soil carbon contents and fluxes, specifically in Sub-Saharan Africa.

Specific interventions:

- Make the case for silvopastoral systems in Brazil by initiating and supporting research and dialogue to establish better practices
- Support awareness campaigns targeted at producers to communicate best practice in Brazil
- Increase below and above-ground carbon sequestration in agricultural systems in Sub-Saharan Africa (SSA) by facilitating the development of methods and decision support tools for trade-off assessment
- Support scientific network to collect and analyze long-term data series of SSA soil carbon stocks and fluxes
- Support the development of biochar by testing and scaling-up biochar production and use in key markets (e.g. China, Brazil)
- Enhance credibility and knowledge on biochar by promoting standards in biochar production

REDUCING METHANE EMISSIONS FROM RICE CULTIVATION

Rice is one of the most important cereal crops in the world, grown on more than 140 million hectares and consumed more than any other staple food.[6] Close to 90 percent of rice is grown in Asia, and of that, 90 percent is grown in flooded or partially flooded paddy fields.[7] When fields are flooded, the decomposition of material depletes oxygen in the soil and water, causing anaerobic conditions that generate methane. The water management system of rice cultivation is therefore one of the most important factors affecting and causing GHG emissions. Other factors, including soil type, tillage management, residues, and fertilizer, also play a role. Methane emissions from rice production account for 11 percent of GHG emissions from the agricultural sector and a third of emissions from crops in 2010,[8] making it the crop with the highest GHG footprint. Asia is the main region where rice is produced globally (90 percent) and therefore represents the main opportunity for interventions. The top rice producing countries—China, India, Indonesia, Bangladesh, Vietnam, and Thailand—account for more than 75 percent of global rice production.[9] Many of the interventions used to reduce rice emissions (e.g. improved water management, improved rice straw management, and more precise nutrient management) are complementary with productivity gains. For example, adding irrigation to better control water, which allows for double cropping.

Specific interventions:

- Scale up sustainable rice intensification systems that integrate climate mitigation by building a model for resource-use efficiency practices in rice production with proven mitigation effect; and scale up application in ASEAN countries
- Build a mitigation component into food security projects on rice

MANAGING MANURE

Manure and urine can cause both nitrous oxide and methane emissions. They cause nitrous oxide emissions when deposited on pastures by grazing animals, used as a fertilizer on croplands, or stored in dry agricultural systems. Manure and urine stored in wet (anaerobic) systems create methane emissions. Although mitigation options exist for manure on pasture, they are often very difficult to implement because of the dispersed nature of the deposits. Thus, this report focuses exclusively on manure in stored systems. Although stored manure accounts for a relatively small amount of direct agricultural emissions, it is technically possible to mitigate a very high percentage of these emissions (as much as 70 percent for most systems).[10] Mitigation practices include anaerobic digesters, converting manure into compost, better timing and application of manure onto croplands, and a number of simple, low-cost ways to improved storage and handling. When managed effectively, manure can reduce the need for synthetic fertilizers, displace fossil fuels, create profitable products for producers, and increase the productivity of croplands and pastures. Further, while mitigation interventions that target stored manure management do not benefit livestock productivity, they also present no serious food security risks and have other co-benefits (e.g., water quality).

Specific interventions:

- Reduce emissions from stored manure systems in China by supporting spatial planning for industrial livestock facilities
- Reduce emissions from stored manure systems in the U.S. by supporting biogas production subsidies in key states

Demand-side Strategies

The discussion on food security and agriculture mitigation over the last two decades has almost exclusively focused on ways to increase productivity and reduce net GHGs emissions from production. However, as the global population grows and incomes rise, we will also need to pay attention to the demand-side of the equation, including which products we consume, how much we consume, and how much food we waste. Major demand shifts have the technical potential to reduce overall emissions associated with agriculture by roughly 55 percent by 2030, compared with a baseline. Although the potential to reduce the GHG footprint of the agricultural sector through changes to consumption patterns is enormous, the certainty around the mitigation estimates is very poor and the literature on this topic is only beginning to emerge.

REDUCING FOOD LOSS AND WASTE

According to FAO estimates, approximately one third of all food intended for human consumption is lost or wasted in the value chain (production, handling and storage, processing and packaging, distribution and market, and consumption).[11] Food loss happens before it reaches the consumer through spoilage, spilling or other unintended consequences due to limitations in agricultural infrastructure, storage and packaging. Food waste refers to food that is intentionally discarded, usually during distribution (retail and food service) and consumption. ‘Food wastage’ in this report refers to both food loss and waste. In the developing world, losses mainly occur postharvest as a result of financial and technical limitations in production techniques, storage and transport. In contrast, losses in the developed world are mostly incurred by end consumers. Simplistically calculated, cutting current food wastage levels in half has the potential to close the 70 percent gap of food needed to meet 2050 demand by roughly 22 percent,[12] potentially making the reduction of food wastage a leading strategy in achieving global food security. China and the U.S. appear to provide the largest opportunities for GHG mitigation from consumption practices.[13]

Specific interventions:

- Reduce consumer food waste in the U.S. by revising food date labeling practices
- Support consumer education of food waste through communication campaigns in China and the U.S.
- Measure food waste in food companies along the supply chain
- Reduce food loss in the value chain by improving handling and storage practices in South/Southeast Asia and Sub-Saharan Africa by providing technical and financial support to farmers

SHIFTING DIETARY TRENDS

As detailed in Chapter 2, livestock production also has a large carbon footprint, accounting for approximately 50 to 70 percent of direct agricultural GHG emissions. When the full life cycle emissions of meat is considered, livestock account for 14.5 percent of total global GHG emissions, or a total of 7.1 Gt CO_2e per year.[14] While numerous researchers and institutions around the world are focused on reducing the carbon footprint of livestock production (supply), little has been done about the viability of curbing growth trajectories of meat consumption (demand). It is important to address rising meat consumption, particularly beef. Beef has roughly six times the carbon footprint per kg of food than poultry, and poultry's carbon footprint is roughly ten times that of any of the major cereal crops.[15] Beef is also the least resource-efficient meat to produce per kilo than any other meat, requiring large amounts of water, energy, feed and land.

If global populations adopt U.S. consumption patterns, the associated emissions would be enormous. Interventions that can help curtail major increases in beef consumption both in industrialized countries and in emerging economies will be critical over the next few decades. Given the established links between diet-related diseases and high levels of meat consumption, keeping global average per capita meat consumption at reasonable levels will have important health benefits as well.

Specific interventions:

- Leverage existing food and resource security policies to reduce beef production and imports, and promote alternative proteins in China
- Promote public health policies that incentivize healthy diets and healthy levels of protein intake in the U.S.
- Curb future demand of beef in China and decrease per capita meat consumption in the U.S. through media and outreach campaigns

Cross-cutting Strategies

No one single strategy or recommendation can address the full mitigation potential of the agricultural sector. This suggests that a coordinated philanthropic strategy should consist of a diversified portfolio. The reduction of GHG emissions at the source (supply) and through shifts in consumption (demand) are essential pillars of such a strategy. However, there are a number of cross-cutting measures that can facilitate the uptake of new practices and spur innovation. This chapter will review a number of such measures, with a particular focus on those that help to channel public or private funds into mitigation, or that allow for better accounting of the GHG footprint of the agricultural sector.

SUBSIDIES AND TRADE

Access to finance, availability of financial support, and access to markets all play a key role in facilitating the transition to climate-smart agriculture. Government subsidies are the most common form of incentives in the agricultural sector. Currently only a small percentage of such subsidies are well-aligned with climate or other environmental goals. Reform of agricultural subsidies in major agricultural economies, particularly the E.U. and U.S., would be enormously valuable. Advocacy around these programs may be worth the effort, even if they are long-term strategies.

International trade is increasingly important for global food security, in particular where productive capacities are impaired as a result of climate change. However, badly designed mitigation policies can also distort trade, with negative impacts on food accessibility and availability. Agricultural trade issues are stymied in both the United Nations Framework Convention on Climate Change (UNFCCC) and World Trade Organisation (WTO) proceedings due to presumed jurisdictional limitations of each intergovernmental body. Targeted analysis might be able to break the gridlock, potentially removing barriers and allowing incentives for agricultural mitigation measures in both the WTO and UNFCCC.

Specific interventions:

- Establish financial incentives for soil management in the U.S. and the E.U. through subsidies reform
- Protect, strengthen and expand conservation programs supported through the U.S. Farm Bill
- Support farmer advisory programs in the U.S. and the E.U.
- Remove barriers and create incentives for GHG mitigation under the WTO and UNFCCC and support a formal or informal process to examine the trade and clime change interface in the WTO

FINANCE AND INVESTMENTS

Large private and public agricultural investments are required to meet projected agricultural demand. In 2009, FAO estimated investment needs of USD 9.2 trillion by mid-century (USD 210 billion annually from 2005–2050).[16] These projections embody a broad range of capital items related to primary livestock and crop production, as well as a number of activities in downstream support services, but do not account for climate change impacts or other constraints.[17] Compared to these numbers, climate finance flowing into agriculture is expected to be marginal.[18] It is therefore essential that baseline financial flows into agriculture be re-directed towards low emitting, carbon rich and sustainable agricultural models.

Specific interventions:

- Steer donor support away from high emitting agricultural activities, especially beef production
- Include GHG data in investment appraisal and program evaluation
- Channel climate finance towards agriculture by incorporating climate-smart agriculture in the design and implementation of the Green Climate Fund

CORPORATE SUPPLY CHAINS

Across supply chains it is becoming increasingly difficult to assure the availability and quality of raw materials. Security of supply is becoming a key concern for business, especially in the food and agricultural sectors. Companies sourcing from areas affected by climate change are particularly vulnerable. To mitigate climatic, environmental, and social risks, companies increasingly look for strategies to better ensure a sustainable supply of raw materials.[19] At the same time, consumers, especially those in developed countries, but increasingly those in emerging economies as well, have become more concerned about the environmental and social impacts of agricultural production. As a result, down-stream, consumer-facing companies have been under increasing pressure to improve the sustainability of their products across the full supply chain, particularly with respect to deforestation.

Sustainability can be improved at any stage, from fertilizer production to consumer waste handling, and through various leverage points, depending on the scope and integration of the supply chain. Examples of supply chain initiatives range from multi-stakeholder dialogues, information disclosures, and corporate social responsibility reports and strategies, to technical assistance, guidelines for better practices, standards, certification schemes and industry commitments. Greater transparency and accountability in corporate supply chains would strengthen the climate-oriented investments and commitments of major food and agribusinesses.

Specific interventions:

- Embed climate change mitigation in certification systems
- Make the business case for certification with climate mitigation component
- Mobilize support of certification with farmers
- Advocate for government engagement in sustainable sourcing
- Reach out to traders and engage them in sustainable supply chain efforts

TRACKING EMISSIONS IN AGRICULTURE

Measuring and monitoring GHG emissions is fundamental for managing emissions effectively. A robust understanding of how much carbon can be sequestered, or how much GHG emissions can be reduced by different practices, is central to making informed decisions about the most appropriate mitigation strategies. However, significant gaps continue to exist, particularly in developing countries where there are still many questions related to the sources of agricultural emissions, as well as an absence of methods and methodologies that allow the monitoring of emissions through supply chains and the evaluation of GHG impacts of investments. Many of the available methods for emission quantification and monitoring are expensive and complex.[20] And there are still large uncertainties associated with measurements of livestock, rice, and nitrogen fertilizer emissions.[21] Considering the relevance of tracking emissions for any valuable mitigation action, and the particular characteristics of philanthropic support, GHG monitoring, reporting and verification (MRV) improvement for governments, the private sector, and NGOs must be a priority action.

Specific interventions:

- Develop GHG monitoring frameworks in in developing countries
- Develop simple on-farm monitoring tools
- Increase the traceability of GHG emissions along the supply chain by supporting the development of robust emissions tracking systems across supply chains
- Develop tools that allow investors to assess the GHG impact of their investments

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[1] CEA analysis based on: Harris et al., 2012.; FAOSTAT 2008; EDGAR 4.2, Vermeulen et al., 2012; Bellarby et al., 2008; Chen and Zhang, 2010; Lal, 2004; Smith et al., 2007; Steinfeld et al., 2006; Van Oost et al. 2012; Wakeland et al., 2012; Weber and Matthews, 2008.

[2] See Annex 3 of the full report for methodology.

[3] See Annex 3 of the full report for methodology.

[4] See Annex 3 of the full report for methodology.

[5] Powlson, D., Whitmore, A., Goulding, K. (2011). Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. *European Journal of Soil Science, 62,* 42–55.

[6] Wassmann, R., Hosen, Y., Sumfleth, K. (2009). *Agriculture and Climate Change: Reducing Methane Emissions from Irrigated Rice.* Washington, D.C.: 2020 Vision for Food, Agriculture, and the Environment.

[7] Ibid.

[8] Food and Agriculture Organization of the United Nations. (2013). FAOSTAT. Retrieved 2013-14, from http://faostat.fao.org.

[9] International Rice Research Institute (IRRI). Retrieved 2013-14, from http://www.irri.org/index.php?option=com_k2&view=item&id=9151&Itemid=100480&lang=en

[10] Hristov, A., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkinds, J., Rotz, A., Dell, C., Adesogan, A., Yang, W., Tricarico, J., Kebreab, E., Waghorn, G., Oosting, S. (2013). *Mitigation of greenhouse gas emissions in livestock production – A review of technical options for non-CO_2 emissions.* Rome, Italy: Food and Agriculture Organization of the United Nations Animal Production and Health.

[11] Food and Agriculture Organization of the United Nations. (2013). *Food wastage footprint: Impacts on natural resources.* Rome, Italy; Food and Agriculture Organization of the United Nations.

[12] Searchinger, T., Hanson, C., Ranganathan, J., Lipinski, B., Waite, R., Winterbottom, R., Dinshaw, A. (2013). *Creating a Sustainable Food Future: Interim Findings.* Washington, D.C.: World Resources Institute.

[13] Ibid.

[14] Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., and Tempio, G. (2013). *Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities.* Rome, Italy: Food and Agriculture Organization of the United Nations.

[15] Gonzalez, A., Frostell, B., Carlsson-Kanyama, A. (2011). Protein efficiency per unit energy and per unit greenhouse gas emissions: Potential contribution of diet choices to climate change mitigation. *Food Policy, 36,* 562-570

[16] Schmidhuber, J., J.Bruinsma, G. Boedeker. (2009). *Capital requirements for agriculture in developing countries to 2050.* Rome, Italy: United Nations Food and Agriculture Organization Economic and Social Development Department.

[17] USD 210 billion gross if accounting for replacement costs of depreciating capital goods; all estimates in constant 2009 U.S. dollars.

[18] As an example: The Global Environment Facility (GEF) to the UNFCCC show that over the 4th replenishment period of the Fund, out of a total of 228 approved projects, 33 related (partly) to agricultural activities (with USD 825million of GEF funding for all projects) and approximately USD 81million out of this for agriculture-related projects, excluding co-financing. The method of selecting whether projects solely or partly focus on agriculture is based on project outlines set out in GEF reports.

[19] Steering Committee of the State-of-Knowledge Assessment of Standards and Certification. (2012). *Toward Sustainability. The roles and limitations of certification.* Washington, D.C.: RESOLVE, Inc.

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