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Climate and Agriculture

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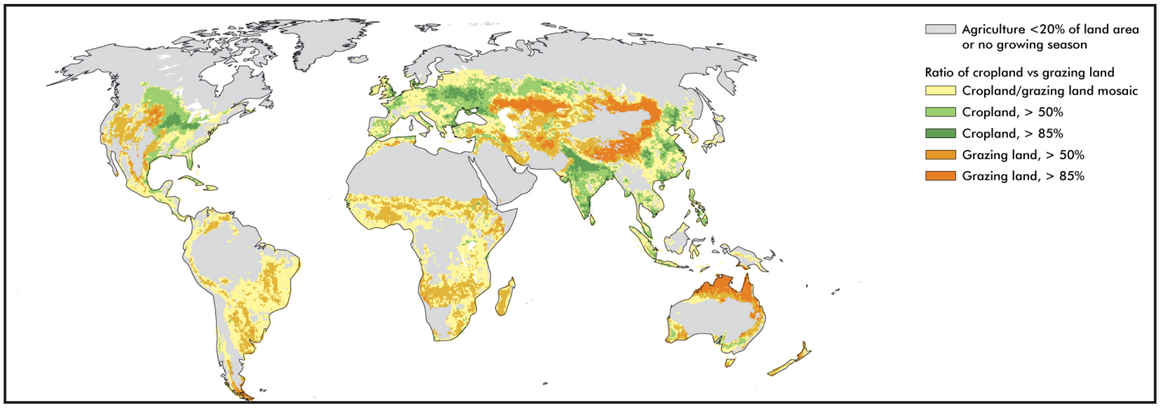
Agriculture and Climate—The Critical Connection

Documented increases in global air and sea temperatures over the last century have demonstrated unequivocally that our planet is warming. Most climatologists agree that the warming trend will continue, and at an accelerating pace unless the causes of global warming are addressed immediately. This reality, and the urgent need for action, is finally being recognized by society and governments around the world. Policies at local, national and international levels are being developed and debated right now—aimed at reducing greenhouse gas (GHG) emissions. Yet until recently, agriculture has been little discussed in climate policy, much less a focus of or major participant in policy negotiations. Considering agriculture's susceptibility to the effects of global warming, its critical importance for food production, its impacts on land, water and energy use and production, and perhaps most importantly, the key role it could play in mitigation and adaptation, this needs to change.

Sustainable farming systems can reduce agriculture's greenhouse gas emissions and be a primary vehicle in stabilizing and reversing climate change while continuing to provide food, feed, fiber and energy in a changing climate. But getting to these climate-friendly agricultural systems requires a shift in focus, research and investment away from industrialized, input and fossil fuel–intensive agricultural practices toward low-input, resilient agricultural systems that increase carbon sequestration in the soil and lessen output of greenhouse gases. For these systems to succeed, we not only need a different approach to climate and agricultural policy, but also new thinking on food, energy and trade policies.

Agriculture and the Climate Crisis

Agriculture, our primary source of food, is critical for human survival, but its importance for the environment and climate is less recognized. Farming, including crop and pasture land, covers 40 percent of the globe, accounts for 70 percent of consumptive water use, and employs approximately 40 percent of the population worldwide.[1] This makes clear that any changes in agriculture, whether caused by humans or the climate, will resonate throughout the global environment and economy.



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Written by Jim Kleinschmit, December 2009 2105 First Avenue South Minneapolis, Minnesota 55404 USA iatp.org

MAJOR SOURCES OF DIRECT AGRICULTURAL GHG EMISSIONS

SOIL EMISSIONS: Nitrous oxide emissions account for about 60 percent of total agricultural sector emissions. Nitrous oxide is produced naturally in soils through the microbial processes of nitrification and de-nitrification, but the large increase in use of nitrogen fertilizer for the production of high nitrogen-consuming crops like corn has increased emissions.

ENTERIC FERMENTATION: During digestion, microbes in the animal's digestive system ferment feed. This process, called enteric fermentation, produces methane, a powerful greenhouse gas, as a by-product which can be emitted by the exhaling and belching of the animal. Cows and other ruminants have higher methane emissions than pigs and poultry because of their unique digestive systems.

MANURE MANAGEMENT: Methane is also produced by the anaerobic (without oxygen) decomposition of manure. When manure is handled as a solid or deposited naturally on grassland, it decomposes aerobically (with oxygen) and creates few methane emissions. However, manure stored as a liquid or slurry in lagoons, ponds, tanks or pits decomposes anaerobically and creates methane emissions.

CO2 FROM FOSSIL FUEL CONSUMPTION: These emissions are primarily from combustion of gasoline and diesel to fuel farm equipment, including tractors, combines, irrigation pumps, grain dryers, etc., but also include emissions related to the production of fertilizers, pesticides and herbicides, which are primarily derived from fossil fuels.

RICE CULTIVATION: Much of the world's rice is grown in flooded paddies. The flooding (used to provide water to the crop and to help protect the rice crop from pests and weed pressure) means that the manure, soils and other organic matter on the fields are in an anaerobic environment, and decomposition of these materials and the soil emissions result in methane being produced and released into the atmosphere.

The relationship between agriculture and climate is complex. While most GHG emissions can be traced to fossil fuel use for energy, such as burning of coal and other fossil fuels for electricity and combustion of gasoline in cars, agriculture also plays a contributing role. Agriculture has always contributed some direct emissions—methane from animals and carbon dioxide from soils, for example—but changes in how animals are fed, raised and how much land is cultivated have resulted in increased quantities of these gases being emitted. A relatively new greenhouse gas threat is nitrous oxide, which occurs naturally, but has increased markedly as a result of the growing use of synthetic fertilizers. Together, direct emissions related to agriculture worldwide are estimated to make up 13.5 percent of all GHG emissions, and about 6 percent of U.S. emissions.[2]

But those aren't the only greenhouse gases connected to agriculture. According to the Food and Agriculture Organization (FAO), deforestation worldwide, mostly linked to expansion of agricultural areas, is estimated to be responsible for 17.4 percent of GHG emissions. If these land use changes are added to agriculture's GHG toll, the sector's climate impact rises significantly.[3] Much of this expansion into existing forests and natural areas is in the form of industrial cattle and crop production (such as soybeans, corn and palm oil) intended for export by large agribusiness to wealthier countries. Of course, these numbers reflect only current deforestation and land use changes, mostly in the developing areas of Africa, South America and Asia. What are not included are the tremendous historical changes in land use and forestation that have already occurred in Europe, North America and other "developed" areas.

A Shifting Climate's Impacts on Agriculture

Climate change's effect on agricultural production is of utmost concern. A number of factors determine crop yields, primarily temperature and precipitation. Although in some regions temperature and precipitation changes will have limited production benefits, agricultural experts agree that in general a changing climate will result in overall lower agriculture yields.[4,5] When crops are exposed to high temperatures, crop development slows. In the U.S., studies predict that a 1.2 C increase from the current mean (which is what the Intergovernmental Panel on Climate Change predicts will occur over the next three decades) would cause yield decreases of 4 percent in corn, 6.7 percent in wheat, 12 percent in rice and 5.7 percent in cotton.[6,7] Soybeans have a higher optimum temperature range, which means that Midwest soybean yields could possibly increase, but decline in the southern United States.

Many regions will see increases in heat extremes, extended heat waves and intense precipitation events leading to yield reduction, soil erosion and increased flooding. At high latitudes, annual river runoff and water availability will increase, while many semi-arid regions, including the Western U.S., Mediterranean Basin, southern Africa and northeast Brazil, will see a decrease in water availability.[8] Already, changes in weather patterns have had demonstrable effects on agriculture globally, as droughts and heavy precipitation have inflicted crop damage and decreased yields.[9]

Weed, disease and pest pressures will also increase as a result of climate change. Many weeds and insect pests that thrive in warm weather will gain hold in regions previously too cool to support their growth, and increased carbon dioxide levels will likely benefit weeds more than food crops.[10,11] Monoculture crop systems that make up the bulk of U.S. agriculture will be particularly at risk from increases in weed and pest pressures, as well as changing microclimates. Unlike polyculture systems, where a diversity of crop types planted together, or in close proximity, ensures some protection against devastation from pests or weather, monocultures are highly vulnerable systems that can be wiped out entirely from a single pest, blight or weather event.

Animal agriculture will be negatively affected as well. Higher levels of animal disease and parasites are predicted with increased temperatures, and this will likely result in greater costs for disease control and higher levels of livestock mortality. Further, the decline in grain yields and resulting decreased grain availability could lead to increased feed costs and overall livestock production costs, especially for industrial confinement systems.

All of these changes will have profound effects on farmers' ability to raise crops and feed animals, and therefore to feed, clothe and fuel a growing population. The effects will differ greatly by crop and region, and will likely affect farmers in lower latitudes, particularly sub-Saharan Africa, most severely. These regions are also where technology and information transfer is the lowest, where a majority of livelihoods depend on agriculture, and where the most food insecure peoples live—pointing not only to a coming climate crisis, but also to growing concerns about food security and economic development.[12]

Agriculture and the Climate Solution

Farming as it is increasingly practiced today—industrial, monocultural and fossil fuel–intensive—is both a cause and victim of climate change. However, there are other ways to farm that can significantly lower greenhouse gas emissions, store additional carbon from the atmosphere in the soil, and reduce vulnerability to the effects of climate change.

First, agriculture can reduce its own level of emissions. One of the biggest opportunities for reduction is in the area of synthetic fertilizer use. Made from natural gas, nitrogen-based fertilizers are energy and greenhouse gas intensive to produce, and increased use of these fertilizers has been linked to increased greenhouse gas emissions from soils.[13] A great percentage of fertilizer needs can be met by increased use of animal manures, compost (especially from food and organic materials in the waste stream), green manure crops that are plowed into the soil to provide nutrients and organic matter, and resource-conserving crop rotations that include legumes, which fix nitrogen in the soil. While these practices may not fully replace synthetic fertilizer use, especially with nitrogen-dependent crops such as corn, they can significantly reduce the need for these fertilizers while at the same time providing soil and water quality benefits.

A more permanent solution to the synthetic fertilizer dilemma may be found in more perennial cropping systems. These crops provide multiple advantages from a climate perspective, including eliminating or significantly reducing the need for tillage; deeper root systems that both protect and build soil; better drought tolerance; and lower fertilizer and pesticide requirements. Markets already exist for perennial crops such as grasses and alfalfa for animal fodder, and much of the focus for sustainable bioenergy and biofuel feedstocks is on perennial crops. But there are currently fewer options for perennial substitutes for many of our food crops, especially grains and oilseeds. Wes Jackson and the Land Institute in Salina, Kansas, are working to change that through efforts at perennializing primary food crops such as wheat, sorghum, sunflowers and others.[14]

Another area of possible agriculture emissions reductions is in the livestock sector. Enteric fermentation, primarily a concern for ruminant animals such as cattle, sheep, goats, buffalo, etc., is one of the biggest emission sources. The way these animals digest grasses and feed produces methane, which has been calculated to account for 5 to 10 percent of overall human-caused GHG emissions.[15] As one might expect, these emissions are harder to reduce or mitigate than those of many other sectors. However, diet does have an influence, and recent

CROP YIELD INCREASES AND GENETIC ENGINEERING—A FALSE TRUTH?

Many cite increased crop productivity as the key to reducing agriculture's overall climate impacts. Often, they promote biotechnology as the primary mechanism for increasing crop yields. But is it correct to attribute increases in crop productivity to biotechnology? A recent report from the Union of Concerned Scientists suggests that this may not be the case.[29]

In "Failure to Yield: Evaluating the Performance of Genetically Engineered Crops," scientist Doug Gurian-Sherman reviews the available research on the overall yield impacts of crop transgenic modification after more than 20 years of research and 13 years of commercialization in the United States. He finds that although crop yields for corn, soybeans and cotton have increased substantially over this period, none of the yield increases for soybeans, and only modest yield improvements for corn, could be linked to genetically engineered (GE) traits. What has made a difference, says Gurian-Sherman, are traditional plant breeding techniques and improved agronomic practices. And when it comes to climate, GE crops have a serious strike against them: they've led to significant increases in pesticide use, according to a recent report by the Organic Center, Union of Concerned Scientists and Center for Food Safety.[30] Nearly all synthetic pesticides are derived from fossil fuels. Increasing their use—GE crops required 27 percent more pesticides than non-GE in 2008—increases agriculture's climate impact.[31]

Rather than focusing our agricultural research dollars on genetic engineering, Gurian-Sherman's report helps show there may be more productive approaches that could better meet our goals. These approaches include modern methods of conventional plant breeding; participatory plant breeding, in which crops are bred for the specific conditions under which they will be grown and with grower participation; and organic and other sophisticated low-input farming practices.

These recommendations align with the findings of the IAASTD, which concluded that biotechnology would be of little help to farmers globally if not coupled with conventional breeding and other agricultural research that considers the ecological, economic, political and scientific needs of different regions and crops.[32]

BENEFITS OF INCREASED SOIL ORGANIC MATTER

- Increased surface residue forms a physical barrier to wind and water erosion.
- Higher residue rotations and cover crops contribute more organic matter and nutrients to the soil.
- Less soil disturbance means lower organic matter losses.

Soil properties change

- Surface structure becomes more stable and less prone to crusting and erosion.
- Water infiltration increases and runoff decreases when soil structure improves.
- Soil organic matter holds 10 to 1,000 times more water and nutrients than the same amount of soil minerals.
- Beneficial soil organisms become more numerous and active with diverse crop rotations and higher organic matter levels.

Air quality, water quality, and agricultural productivity improve

- Dust, allergens and pathogens in the air immediately decline.
- Sediment and nutrient loads decline in surface water as soon as soil aggregation increases and runoff decreases.
- Ground and surface water quality improve because better structure, infiltration and biological activity make soil a more effective filter.
- Crops are better able to withstand drought when infiltration and water holding capacity increase.
- Organic matter may bind pesticides, making them less active. Soils managed for organic matter may suppress disease organisms, which could reduce pesticide needs.
- Crop health and vigor increase when soil biological activity and diversity increase.
- Wildlife habitat improves when residue management improves.

From: USDA NRCS http://soils.usda.gov/sqi/concepts/soil_organic_matter/som_work.html

research conducted by Danone, Stoneyfield Farm and participating dairy farmers has shown that by changing the cow's diet to include more omega-3 rich feeds like alfalfa, flax, hemp and grasses, enteric emissions can be reduced significantly (up to 18 percent), while also improving the nutritional value of the milk.[16]

In addition to enteric emissions, there are other areas where the trend towards concentrated animal feeding and production systems have resulted in large climate impacts on both "ends" of the animal—feed and manure. Grain production for animal feed can be quite carbon intensive, and has been demonstrated that livestock diet has a strong influence on enteric emissions from the cattle.[17] This problem is then often compounded in the emissions from the manure, as what goes into the cow has a major influence in what comes out, including GHG emissions from the manure.

And as this manure is generally stored in an anaerobic setting, the result is much more potent methane emissions than carbon dioxide that would result from the manure being dispersed on the field or composted. While much focus has been on capturing this methane for energy production, most of the gas could be avoided entirely through grass-based farming, especially rotational grazing systems, which eliminate or significantly reduce both the feed and manure-related emissions, while also contributing to increased carbon storage in the soil.

This brings us to agriculture's most critical function in countering climate change: carbon. Enemy number one in the atmosphere, it is conversely one of the most important ingredients for soil health. Carbon is a primary component of soil organic matter (SOM), which enhances water and nutrient holding capacity and improves soil structure.[18,19] Putting more carbon in the soil can help reduce the damaging levels of these gases in the atmosphere and mitigate some of the harmful impacts on agricultural production of our already changing climate. For example, as noted earlier, climate change is expected to produce more severe storms and heavier single-event precipitation, as well as longer and more frequent periods of drought. Researchers have shown that increasing SOM by just one percent improved the available water holding capacity in the soil by 3.7 percent.[20] SOM also helps increase water infiltration, protects soil from erosion (which is likely to increase with more severe weather events), and reduces the need for some fertilizers, pesticides and herbicides; all of which contribute—in production and/or use—to greenhouse gas emissions.

The potential role of agriculture in sequestering carbon is still being debated, but it could be quite significant—up to 25 to 40 percent of carbon from fossil fuel emissions annually by some optimistic estimates, depending on the agricultural systems employed.[21] Practices that increase carbon sequestration will also increase agriculture's ability to handle the changing climate and its impacts on water availability, soil, air and water quality, and wildlife habit, to name a few examples.

Some of agriculture's potential contributions to the climate solution are accounted for in other sectors where agricultural products are refined, processed and consumed. This is particularly true of local food and bio-based energy systems, which have been held up as "silver bullets" for addressing climate change. But the reality is much more complex—local food production can still be very carbon intensive throughout its lifecycle, while bio-based energy created from input-intensive feedstocks may not be any better through its lifecycle than the fossil fuels they seek to replace. But that does not mean there are not opportunities for these sectors to contribute positively to the climate crisis; only that food and energy feedstocks need to be produced, processed, transported and consumed in ways that reduce GHG emissions throughout the lifecycle.

Local Food Systems and Climate

Local food has been identified both as a key opportunity and a false solution for climate change. The difference between these dichotomous conclusions generally turns on the production practices used to produce the food in the first place. In one of the most noted examples, the New York Times in 2007 published an op-ed which discussed a study by researchers at Lincoln University in New Zealand on greenhouse gas emissions from different food sources. These researchers found that lamb produced in New Zealand and shipped to Great Britain had a lower carbon foodprint than lamb raised in Great Britain.[22] The conclusion of the op-ed writer and many others was that food miles and local food production did not matter. But lost in the discussion was the real reason for the difference: production practices. British lamb is generally raised on grain and produced with synthetic fertilizers, while New Zealand lamb is raised primarily on grass, which typically not only requires many fewer inputs, but also has greater carbon sequestration potential than annual row crops. When compared, emissions from transporting the lamb from New Zealand to Britain were less than the high GHG emissions associated with British production practices.

It is true that agricultural transportation, in almost all cases, is a smaller part of the carbon foodprint than production. According to some U.S. researchers, overall transport (including both from producer/processor to point of sale and other upstream transportation miles) accounts for only about 11 percent of the food systems emissions.[23] And the type of transport does matter—long distance shipping, generally by ship or rail, is usually more climate friendly than much of the local transport, from farm to farmers market, for example, which is primarily done by truck and automobile.

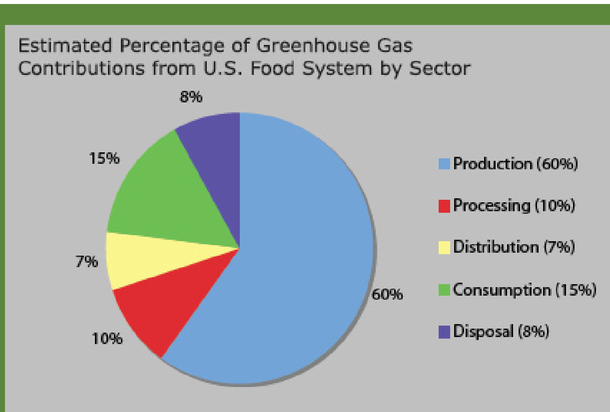
But what these studies show most definitively is that our primary focus for reducing food-related greenhouse gas emissions needs to be on what type of foods we produce, and how we produce them. According to most researchers, agricultural production accounts for the bulk of the food system's greenhouse gas emissions: somewhere between 50 and 83 percent of emissions occur before food even leaves the farm gate.[24] The type of food is very important—generally, foods higher up the food chain such as red meat and dairy are, not surprisingly, higher in GHG emissions. Reducing consumption of these foods, especially in the protein-rich diets of developed countries, could go a long way toward food-related greenhouse gas emissions reductions. But how the food is produced is equally important. Food produced in fossil-fuel heated greenhouses or using input-intensive grain feed will have high greenhouse gas emissions, whether it is vegetables or meat.

Waste—whether at the farm, at the retailer or in one's kitchen—also plays a role in food's climate impact, as it is estimated that up to 50 percent of food globally is lost, wasted or discarded.[25] This problem is often compounded from a climate perspective, as much of this organic matter gets put in landfills, especially in developed countries like the U.S., where it breaks down into methane emissions.[26] Solutions to these emissions require smarter actions on the part of consumers in their food purchasing and ensuring that food and other organic waste goes to composting systems that turn the material and remaining carbon into a valuable soil amendment.

Reducing production-related emissions will require alternative practices, such as organics, grazing systems for livestock, and others that are detailed in this report. Because these types of production practices are often used by farmers who market their food as "local," it is likely that local food can be better for the climate—in both production and transport—but one needs to know more than whether it is produced locally to be sure.

Bioenergy

In the same way, viewpoints differ about the role bioenergy (including biofuels and biomass-based power and heat generation) plays in addressing climate change. Initially, many thought bioenergy was unequivocally positive for the climate, as it provided a "carbon neutral" substitution for fossil fuels (since the plants absorbed carbon from the atmosphere in their production). But as the bioenergy sector began to grow, analyses of overall impacts across their lifecycles became more sophisticated. Concerns about fossil fuel inputs to crop production and carbon emissions from forest and grassland destruction for bioenergy crop production, as well as the diversion of land used for food production in many countries, have tempered enthusiasm for this sector's value in addressing the climate crisis.



The percent of GHGs that are contributed from each stage of the food chain was adapted from Weber and Matthews (2008). However, that study did not separate the processing stage from production, and it did not include the food consumption and disposal stage. Therefore, additional information was collected to separate out the processing stage (Garnett 2007, Van Hauwermeiren et al. 2007, Dutilh and Linnemann 2004, Pimentel et al. 2008) and to add on end-of-life contribution (Carlsson-Kanyama et al. 2003, Büsser 2008, Dutilh and Linnemann 2004, Garnett 2007). These numbers are estimates and are based on a review of existing literature, not a comprehensive analysis. They should serve as a compass for future climate and food policy work, but should not be interpreted to represent a "typical" food item or the U.S. food system in aggregate.

But similar to local food production, the reality of bioenergy's value for reducing greenhouse gases depends upon how and where the bioenergy feedstocks are grown and processed, what form of energy (liquid fuel, heat, etc.) is produced, and how it is used. In general, biomass production of heat and/or electricity is more efficient, and therefore results in better GHG performance, than liquid fuels. The type and amount of energy needed to process the bioenergy feedstocks also matters. But, as one would suspect, the type of feedstock and the way it is produced is a primary determinant of bioenergy's overall carbon footprint.

Bioenergy produced from industrial monocultural feedstock crops that require heavy inputs of fossil fuels are unlikely to provide much benefit to the climate, and if their production results in stored soil carbon releases (which happen when natural lands are plowed), then they may even be a source of overall greenhouse gas emission increases. This type of land use change related to bioenergy feedstock production, both directly and indirectly, lies at the heart of current scientific and political debates about whether most biofuels and bioenergy developments are actually beneficial from a climate perspective.[27]

But if that same bioenergy is produced from low-input crops like perennial grasses or sustainably harvested crop and forest residues, especially when produced and used on a community scale, it does have real potential to reduce greenhouse gas emissions from both the agricultural and energy sectors, while providing economic and rural development opportunities for rural communities.[28] Of course, real optimization of biofuels and bioenergy requires simultaneous efforts to significantly conserve fuel and energy economy-wide, including higher efficiency vehicles and technology, and reduction of miles driven and energy consumed.

Getting to Climate-Friendly Agricultural Systems

While many aspects of the climate solution are still being determined for other sectors, the answers for agriculture are increasingly clear. Climate-friendly agricultural systems are needed worldwide to help fight global warming and to ensure that we continue to have the food, fiber, energy and natural resources that we depend upon. We know that agriculture as a sector can both significantly reduce its emissions and be a major sink for greenhouse gases already in the atmosphere. And we know that with this carbon sequestration and shift to low-input agricultural systems, we can actually improve the resiliency of our soil, water systems and environment in a changing climate, while reducing our dependence upon fossil fuels. These points provide the needed direction for future agricultural development from both adaptive and mitigative perspectives.

But this necessary adoption of sustainable agricultural systems worldwide will not occur without a major shift in climate and agricultural policy and development. Efforts currently underway to craft international and national climate policies need to recognize agriculture's unique and valuable role, and to provide appropriate and sufficient resources and policy direction to ensure that farming is a major part of the climate solution, without sacrificing its other necessary functions. One of the most important ways to achieve this would be to prioritize funding and support for agricultural systems that are both adaptive and mitigative, rather than promoting approaches that only address one of these equally-important goals in isolation. This will be especially important in developing countries confronting drops in yields due to global warming. This approach is consistent with the findings of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) and other analyses, which emphasize the importance of enhancing and disseminating knowledge, science, technology and development focused on low-input sustainable agriculture systems.

Put into practice, this approach would require major changes in agricultural policies worldwide. Research and farmer education would need to be refocused on optimizing sustainable agricultural production and the most promising ways at reducing and sequestering greenhouse gas emissions within these multifunctional systems. Investment by governments would need to be shifted away from proprietary seed and crop technologies towards enhancing traditional plant breeding, integrated livestock production and low-input fertilization systems. Intensive and extensive work would be needed to provide education, access to credit and technology, and other forms of support for farmers worldwide to shift to sustainable agricultural systems that meet their local needs and resources. And other policies, especially energy and trade, would need to be modified to ensure that they are supporting, and not impeding, this shift in agricultural development, including much more support for distributed food and energy systems.

Considering the gravity of our climate crisis, it is incumbent upon us to find ways that all sectors of the economy can help. Agriculture—done right—can be a major part of that complex solution. By moving agricultural development towards more climate-friendly systems, farmers worldwide can contribute to the climate solution and environmental protection while continuing to feed and supply us with needed food, materials and energy in a changing climate.

Principles for a Responsible and Climate-Friendly Approach to Agriculture

- Climate policy must adopt an integrated and coherent approach that acknowledges and supports the importance of sustainable agriculture to long term sustainable development. The agricultural sector both depends upon and impacts the natural environment. Because of this, agriculture has a unique and substantial role to play as a steward of our natural resources and ecosystems.

- All agricultural systems are not equal in their impacts upon the environment and in their contribution to climate change. Addressing climate change in the agricultural sector requires recognition of historical differences among different types of agriculture, and different country contributions to the problem of climate change. This means that actions to reverse climate change in agriculture must acknowledge differences in the respective economic and technical capacities of farmers (both within countries and internationally) in accordance with the principle of common and differentiated responsibility.

- Agriculturally based climate mitigation and adaptation efforts must complement, not impede, the production of a safe and healthy food system. A system of sufficient and safe food production for all people on the planet is paramount. Climate-friendly agriculture practices must also ensure abundant food production.

- Climate mitigation must include a fair international system that rewards farmers for their contributions to mitigation, including carbon sequestering activities and renewable energy services.

- Climate change solutions must build the capacity for farmers to create healthy and resilient communities and ecosystems, including safeguarding water systems.

Further reading on Agriculture and Climate

This paper provides an overview of some of the issues related to agriculture and climate change. For more in-depth reading, consult these resources:

- Agriculture at a Crossroads, International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) www.agassessment.org

- National Sustainable Agriculture Coalition "Agriculture and Climate Change: Impacts and Opportunities at the Farm Level" http://sustainableagriculture.net/wp-content/uploads/2008/08/nsac_climatechange-policypaper_final_2009_07_16.pdf

- Agriculture, Climate Change and Carbon Sequestration, NCAT http://attra.ncat.org/attra-pub/PDF/carbonsequestration.pdf

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