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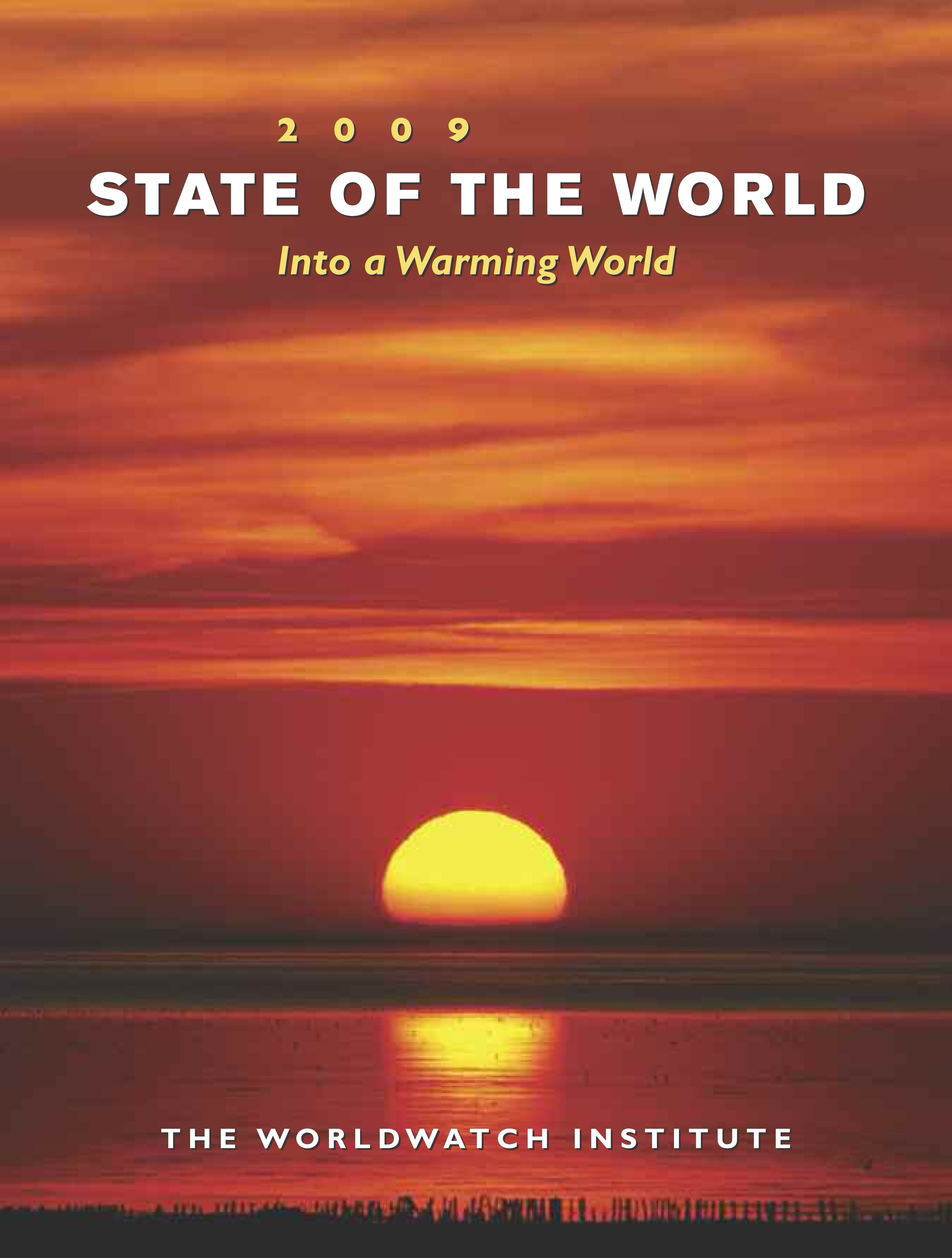
STATE OF THE WORLD

Into a Warming World



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STATE OF THE WORLD
Into a Warming World

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Farming and Land Use to Cool the Planet

Sara J. Scherr and Sajal Sthapit

For more than a decade, thousands of low-income farmers in northern Mindanao, the Philippines, who grow crops on steep, deforested slopes, have joined landcare groups to boost food production and incomes while reducing soil erosion, improving soil fertility, and protecting local watersheds. They left strips of natural vegetation to terrace their slopes, enriched their soils, and planted fruit and timber trees for income. And their communities began conserving the remaining forests in the area, home to a rich but threatened biodiversity. Yet these farmers achieved even more—their actions not only enriched their landscapes and enhanced food security, they also helped to "cool" the planet by cutting greenhouse gas emissions and storing carbon in soils and vegetation. If their actions could be repeated by millions of rural communities around the world, climate change would slow down.[1]

Indeed, climate change and global food security are inextricably linked. This was made abundantly clear in 2008, as rioters from Haiti to Cameroon protested the global "food crisis." The crisis partly reflected structural increases in food demand from growing and more-affluent populations in developing countries and short-term market failures, but it was also in part a reaction to increased energy costs, new biofuel markets created by legislation promoting alternative energy, and climate-induced regional crop losses. Moreover, food and fiber production are leading sources of greenhouse gas (GHG) emissions—they have a much larger "climate footprint" than the transportation sector, for example. Degradation and loss of forests and other vegetative cover puts the carbon cycle further off balance. Ironically, the land uses and management systems that are accelerating GHG emissions are also undermining the ecosystem services upon which long-term food and fiber production depend—healthy

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watersheds, pollination, and soil fertility.[2]

This chapter explains why actions on climate change must include agriculture and land systems and highlights some promising ways to "cool the planet" via land use changes. Indeed, there are huge opportunities to shift food and forestry production systems as well as conservation area management to mitigate climate change in ways that also increase sustainability, improve rural incomes, and ease adaptation to a warming world.

The Need for Climate Action on Agriculture and Land Use

Land is one fourth of Earth's surface and it holds three times as much carbon as the atmosphere does. About 1,600 billion tons of this carbon is in the soil as organic matter and some 540–610 billion tons is in living vegetation. Although the volume of carbon on Earth's surface and in the atmosphere pales in comparison to the many trillions of tons stored deep under the surface as sediments, sedimentary rocks, and fossil fuels, surface carbon is crucial to climate change and life due to its inherent mobility.[3]

Surface carbon moves from the atmosphere to the land and back, and in this process it drives the engine of life on the planet. Plants use carbon dioxide (CO_2) from the atmosphere to grow and produce food and resources that sustain the rest of the biota. When these organisms breathe, grow, die, and eventually decompose, carbon is released to the atmosphere and the soil. Carbon from this past life provides the fuel for new life. Indeed, life depends on this harmonized movement of carbon from one sink to another. Large-scale disruption or changes on land drastically alter the harmonious movement of carbon.

Land use changes and fossil fuel burning are the two major sources of the increased CO_2 in the atmosphere that is changing the global climate. (See Box 3–1.) Burning fossil fuel releases carbon that has been buried for millions of years, while deforestation, intensive tillage, and overgrazing release carbon from living or recently living plants and soil organic matter. Some land use changes affect climate by altering regional precipitation patterns, as is occurring now in the Amazon and Volta basins. Overall, land use and land use changes account for around 31 percent of total human-induced greenhouse gas emissions into the atmosphere. Yet other types of land use can play the opposite role. Growing plants can remove huge amounts of carbon from the atmosphere and store it in vegetation and soils in ways that not only stabilize the climate but also benefit food and fiber production and the environment. So it is imperative that any climate change mitigation strategy address this sector.[4]

Extensive action to influence land use is also going to be essential to sustain food and forest production in the face of climate change. Agricultural systems have developed during a time of relatively predictable local weather patterns. The choice of crops and varieties, the timing of input application, vulnerability to pests and diseases, the timing of management practices—all these are closely linked to temperature and rainfall. With climate changing, production conditions will change—and quite radically in some places—which will lead to major shifts in farming systems.

Climate scenarios for 2020 predict that in Mexico, for example, 300,000 hectares will become unsuitable for maize production, leading to estimated yearly losses of $140 million and immense socioeconomic disruption. And in North America, the areas with the optimum temperature for producing syrup from maple trees are shifting northward, leaving farmers in the state of Vermont at risk of

Box 3–1. Greenhouse Gas Emissions from Land Use

Carbon dioxide (77 percent), nitrous oxide (8 percent), and methane (14 percent) are the three main greenhouse gases that trap infrared radiation and contribute to climate change. Land use changes contribute to the release of all three of these greenhouse gases. (See Table.) Of the total annual human-induced GHG emissions in 2004 of 49 billion tons of carbon-dioxide equivalent, roughly 31 percent—15 billion tons—was from land use. By comparison, fossil fuel burning accounts for 27.7 billion tons of CO_2-equivalent emissions annually.

Deforestation and devegetation release carbon in two ways. First the decay of the plant matter itself releases carbon dioxide. Second, soil exposed to the elements is more prone to erosion. Subsequent land uses like agriculture and grazing exacerbate soil erosion and exposure. The atmosphere oxidizes the soil carbon, releasing more carbon dioxide into the atmosphere. Application of nitrogenous fertilizers leads to soils releasing nitrous oxide. Methane is released from the rumens of livestock like cattle, goats, and sheep when they eat and from manure and water-logged rice plantations.

Naturally occurring forest and grass fires also contribute significantly to GHG emissions. In the El Niño year of 1997–98, fires accounted for 2.1 billion tons of carbon emissions . Due to the unpredictability of these events, annual emissions from this source vary from year to year.

Land Use	Annual Emissions (million tons CO_2 equivalent)	Greenhouse Gas Emitted
Agriculture	6,500	
Soil fertilization (inorganic fertilizers and applied manure)	2,100	Nitrous oxide*
Gases from food digestion in cattle (enteric fermentation in rumens)	1,800	Methane*
Biomass burning	700	Methane, nitrous oxide*
Paddy (flooded) rice production (anaerobic decomposition)	600	Methane*
Livestock manure	400	Methane, nitrous oxide*
Other (e.g., delivery of irrigation water)	900	Carbon dioxide, nitrous oxide*
Deforestation (including peat)	8,500	
For agriculture or livestock	5,900	Carbon dioxide
Total	15,000	

** The greenhouse gas impact of 1 unit of nitrous oxide is equivalent to 298 units of carbon dioxide; 1 unit of methane is equivalent to 25 units of carbon dioxide.*
Source: See endnote 4.

losing not only their signature product but generations of culture and knowledge.[5]

The Gangotri glacier in the Himalayas, which provides up to 70 percent of the water in the Ganges River, is retreating 35 meters yearly. Once it disappears, the Ganges will become a seasonal river, depriving 40 percent of India's irrigated cropland and some 400 million people of water. The frequency, intensity, and duration of rainfall are also likely to change, increasing production risks, especially in semiarid and arid rainfed production areas. Monsoons will be heavier, more variable, and with greater risk of flooding. An increased incidence of drought threatens nearly 2 billion people who rely on livestock grazing for part of their livelihoods, particularly the 200 million who are completely dependent on pastoral systems. The incidence and intensity of natural fires is predicted to increase. [6]

The poorest farmers who have little insurance against these calamities often live and farm in areas prone to natural disasters. More-frequent extreme events will create both a humanitarian and a food crisis.

On the other hand, climatic conditions may improve in some places. In the highlands of East Africa, for example, rains may become more reliable and growing seasons for some crops may expand. The growing season in northern latitudes in Canada and Russia will extend as temperatures rise. Even in these situations, however, there will be high costs for adapting to new conditions, including finding crop varieties and management that are adapted to new climate regimes at this latitude. The impacts on pest and disease regimes are largely unknown and could offset any benefits. For instance, the Eastern spruce budworm is a serious pest defoliating North American forests. Changing climate is shifting the geographic range of the warblers that feed on the budworms, increasing the odds for budworm outbreak.[7]

Many of the key strategies described in this chapter for agricultural, forest, and other land use systems to mitigate climate change—that is, to reduce GHG emissions or increase the storage of carbon in production and natural systems—also will help rural communities adapt to that change. Mobilizing action for adaptation in these directions rather than relying only on other types of interventions, such as seed varieties or shifts in market supply chains, could have significant success in slowing climate change.

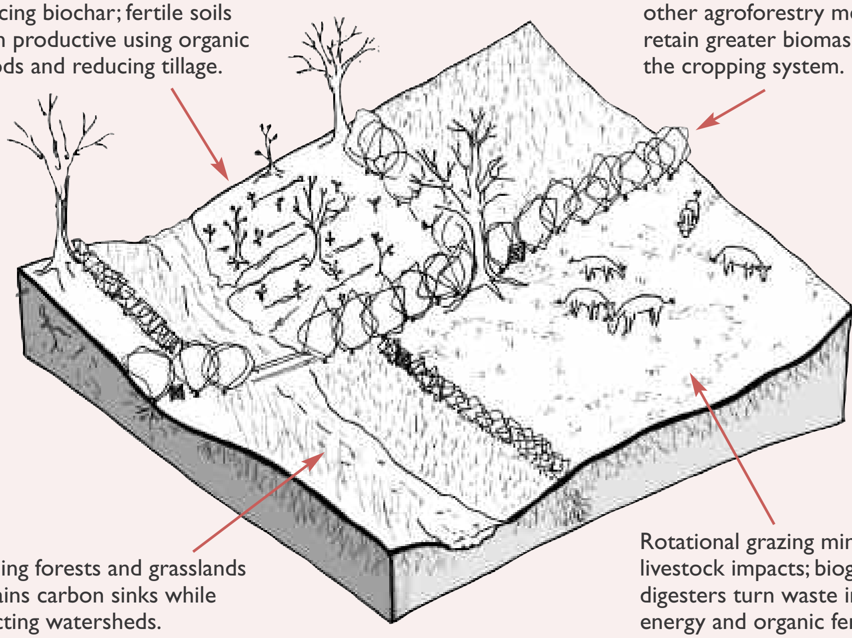
Making Agriculture and Land Use Climate-friendly and Climate-resilient

An agricultural landscape should simultaneously provide food and fiber, meet the needs of nature and biodiversity, and support viable livelihoods for people who live there. In terms of climate change, landscape and farming systems should actively absorb and store carbon in vegetation and soils, reduce emissions of methane from rice production, livestock, and burning, and reduce nitrous oxide emissions from inorganic fertilizers. At the same time, it is important to increase the resilience of production systems and ecosystem services to climate change.[8]

Many techniques are already available to achieve climate-friendly landscapes. None is a "silver bullet," but in combinations that make sense locally they can help the world move decisively forward. This chapter describes five strategies that are especially promising: enriching soil carbon, creating high-carbon cropping systems, promoting climate-friendly livestock production systems, protecting existing carbon stores in natural forests and grasslands, and restoring vegetation in degraded areas. (See Figure 3–1.) Many other improvements will also be needed for production systems to adapt to climate change while meeting growing food needs and commercial demands, such as adapted seed varieties. But these five strategies are highlighted because of their powerful advantage in mitigating climate change as well as contributing broadly to more-sustainable production systems and other ecosystem services.[9]

Moreover, these strategies can help mobi-

Figure 3–1. Multiple Strategies to Productively Absorb and Store Carbon in Agricultural Landscapes



lize a broad political coalition to support climate action by meeting the urgent needs of farmers, grazers and rural communities, the food industry, urban water users, resource-dependent industries, and conservation organizations. They can help meet not only climate goals but also internationally agreed Millennium Development Goals and other global environmental conventions.

Many of these approaches will be economically self-sustaining once initial investments are made. It is important to implement this agenda on a large scale in order to have significant impacts on the climate. Key roles that governments need to play are to mobilize the financing and social organization needed for these initial investments, develop additional incentives for activities that are more time-consuming or costly yet offer no particular benefits to farmers or land managers, and invest in the development of technologies and management systems that are especially promising but not yet ready for widespread use.

Enriching Soil Carbon

Soil has four components: minerals, water, air, and organic materials—both nonliving and living. The former comes from dead plant, animal, and microbial matter while the living organic material is from flora and fauna of the soil biota, including living roots and microbes. Together, living and nonliving organic materials account for only 1–6 percent of the soil's volume, but they contribute much more to its productivity. The organic materials retain air and water in the soil and provide nutrients that the plants and the soil fauna depend on for life. They are also reservoirs of carbon in the soil.[10]

In fact, soil is the third largest carbon pool on the planet. In the long term, agricultural practices that amend soil carbon from year to year through organic matter management rather than depleting it will provide productive soils that are rich in carbon and require fewer chemical inputs. New mapping tools, such as the 2008 Global Carbon Gap Map produced by the Food and Agriculture Organization, can identify areas where soil carbon storage is greatest and areas with the physical potential for billions of tons of additional carbon to be stored in degraded soils.[11]

Enhance soil nutrients through organic methods. Current use of inorganic fertilizers is estimated at 102 million tons worldwide, with use concentrated in industrial countries and in irrigated regions of developing nations. Soils with nitrogen fertilizers release nitrous oxide, a greenhouse gas that has about 300 times the warming capacity of carbon dioxide. Fertilized soils release more than 2 billion tons (in terms of carbon dioxide equivalent) of greenhouse gases every year. One promising strategy to reduce emissions is to adopt soil fertility management practices that increase soil organic matter and siphon carbon from the atmosphere.[12]

Numerous technologies can be used to substitute or minimize the need for inorganic fertilizers. Examples include composting, green manures, nitrogen-fixing cover crops and intercrops, and livestock manures. Even improved fertilizer application methods can reduce emissions. In one example of organic farming, a 23-year experiment by the Rodale Institute compared organic and conventional cropping systems in the United States and found that organic farming increased soil carbon by 15–28 percent and nitrogen content by 8–15 percent. The researchers concluded that if the 65 million hectares of corn and soybean grown in the United States were switched to organic farming, a quarter of a billion tons of carbon dioxide could be sequestered.[13]

The economics and productivity implications of these methods vary widely. In some very intensive, high-yield cropping systems, replacing some or all inorganic fertilizer may require methods that use more labor or require costlier inputs, but there is commonly scope for much more efficient use of fertilizer through better targeting and timing. In moderately intensive systems, the use of organic nutrient sources with small amounts of supplemental inorganic fertilizer can be quite competitive and attractive to farmers seeking to reduce cash costs.[14]

Improvements in organic technologies over the past few decades have led to comparable levels of productivity across a wide range of crops and farming systems. The question of whether organic farming can feed the world, as some claim, remains controversial. And more research is needed to understand the potentials and limitations of biologically based soil nutrient management systems across the range of soil types and climatic conditions. But there is little question that farmers in many production systems can already profitably maintain yields while using much less nitrogen fertilizer—and with major climate benefits.

Minimize soil tillage. Soil used to grow crops is commonly tilled to improve the conditions of the seed bed and to uproot weeds. But tilling turns the soil upside down, exposing anaerobic microbes to oxygen and suffocating aerobic microbes by working them under. This disturbance exposes nonliving organic matter to oxygen, releasing carbon dioxide. Keeping crop residues or mulch on the surface helps soil retain moisture, prevents erosion, and returns carbon to the soil through decomposition. Hence practices that reduce tillage also generally reduce carbon emissions.[15]

A variety of conservation tillage practices accomplish this goal. In nonmechanized systems, farmers might use digging sticks to plant seeds and can manage weeds through mulch and hand-weeding. Special mechanized systems have been developed that drill the seed through the vegetative layer and use herbicides to manage weeds. Many farmers combine no-till with crop rotations and green manure crops. In Paraná, Brazil, farmers have developed organic management systems combined with no-till. No-till plots yielded a third more wheat and soybean than conventionally ploughed plots and reduced soil erosion by up to 90 percent. No-till has the additional benefit of reducing labor and fossil fuel use and enhancing soil biodiversity—all while cycling nutrients and storing carbon.[16]

In Paraná, Brazil, no-till plots yielded a third more wheat and soybean than conventionally ploughed plots and reduced soil erosion by up to 90 percent.

Worldwide, approximately 95 million hectares of cropland are under no-till management—a figure that is growing rapidly, particularly as rising fossil fuel prices increase the cost of tillage. The actual net impacts on greenhouse gases of reduced emissions and increased carbon storage from reduced tillage depend significantly on associated practices, such as the level of vegetative soil cover and the impact of tillage on crop root development, which depends on the specific crop and soil type. It is projected that the carbon storage benefits of no-till may plateau over the next 50 years, but this can be a cost-effective option to buy time while alternative energy systems develop.[17]

Incorporate biochar. Decomposition of plant matter is one way of enriching soil carbon if it takes place securely within the soil; decomposition on the surface, on the other hand, releases carbon into the atmosphere as carbon dioxide. In the humid tropics, for example, organic matter breaks down rapidly, reducing the carbon storage benefits of organic systems. Another option, recently discovered, is to incorporate biochar—burned biomass in a low-oxygen environment. This keeps carbon in soil longer and releases the nutrients slowly over a long period of time. While the burning does release some carbon dioxide, the remaining carbon-rich dark aromatic matter is highly stable in soil. Hence planting fast-growing trees in previously barren or degraded areas, converting them to biochar, and adding them to soil is a quick way of taking carbon from the atmosphere and turning it into an organic slow-release fertilizer that benefits both the plant and the soil fauna.

Interestingly, between 500 and 2,500 years ago Amerindian populations added incompletely burnt biomass to the soil. Today, Amazonian Dark Earths still retain high amounts of organic carbon and fertility in stark contrast to the low fertility of adjacent soils. There is a global production potential of 594 million tons of carbon dioxide equivalent in biochar per year, simply by using waste materials such as forest and milling residues, rice husks, groundnut shells, and urban waste. Far more could be generated by planting and converting trees. Initial analyses suggest that it could be quite economical to plant vegetation for biochar on idle and degraded lands, though not on more highly productive lands.[18]

Most crops respond with improved yields for biochar additions of up to 183 tons of carbon dioxide equivalent and can tolerate more without declining productivity. Advocates calculate that if biochar additions were applied at this rate on just 10 percent of the world's cropland (about 150 million hectares), this method could store 29 billion tons of CO_2-equivalent, offsetting nearly all the emissions from fossil fuel burning.[19]

Creating High-carbon Cropping Systems

Plants harness the energy of the sun and accumulate carbon from the atmosphere to produce biomass on which the rest of the biota depend. The great innovation of agriculture 10,000 years ago was to manage the photosynthesis of plants and ecosystems so as to dependably increase yields. With 5 billion hectares of Earth's surface used for agriculture (69 percent under pasture and 28 percent in crops) in 2002, and with half a billion more hectares expected by 2020, agricultural production systems and landscapes have to not only deliver food and fiber but also support biodiversity and important ecosystem services, including climate change mitigation. A major strategy for achieving this is to increase the role of perennial crops, shrubs, trees, and palms, so that carbon is absorbed and stored in the biomass of roots, trunks, and branches while crops are being produced. Tree crops and agroforestry maintain significantly higher biomass than clear-weeded, annually tilled crops.[20]

Although more than 3,000 edible plant species have been identified, 80 percent of world cropland is dominated by just 10 annual cereal grains, legumes, and oilseeds. Wheat, rice, and maize cover half of the world's cropland. Since annual crops need to be replanted every year and since the major grains are sensitive to shade, farmers in much of the world have gradually removed other vegetation from their fields. But achieving a high-carbon cropping system, as well as the year-round vegetative cover required to sustain soils, watersheds, and habitats, will require diversification and the incorporation of a far greater share of perennial plants.[21]

Perennial grains. Currently two thirds of all arable land is used to grow annual grains. This production depends on tilling, preparing seed beds, and applying chemical inputs. Every year the process starts over again from scratch. This makes production more dependent on chemical inputs, which also require a lot of fossil fuels to produce. Furthermore, excessive application of nitrogen fertilizer is a major source of nitrous oxide emissions, as noted earlier.[22]

In contrast, perennial grasses retain a strong root network between growing seasons. Hence, a good amount of the living biomass remains in the soil instead of being released as greenhouse gases. And they help hold soil organic matter and water together, reducing soil erosion and GHG emissions. Finally, the perennial nature of these grasses does away with the need for annual tilling that releases GHGs and causes soil erosion, and it also makes the grasses more conservative in the use of nutrients. In one U.S. case, for example, harvested native hay meadows retained 179 tons of carbon and 12.5 tons of nitrogen in a hectare of soil, while annual wheat fields only retained 127 tons of carbon and 9.6 tons of nitrogen. This was despite the fact that the annual wheat fields had received 70 kilograms of nitrogen fertilizer per hectare annually for years.[23]

Researchers have already developed perennial relatives of cereals (rice, sorghum, and wheat), forages (intermediate wheatgrass, rye), and oilseeds (sunflower). In Washington state, some wheat varieties that have already been bred yield over 70 percent as much as commercial wheat. Domestication work is under way for a number of lesser known perennial native grasses, and many more perennials offer unique and exciting opportunities.[24]

Shifting production systems from annual to perennial grains should be an important research priority for agriculture and crop breeding, but significant research challenges remain. Breeding perennial crops takes longer than annuals due to longer generation times. Since annuals live for one season only, they give priority to seeds over vegetative growth, making yield improvement in annuals easier than in perennials that have to allocate more resources to vegetative parts like roots in order to ensure survival through the winter. But in the quest for high-carbon agricultural systems, plants that produce more biomass are a plus. Through breeding, it may also be possible to redirect increased biomass content to seed production.

A Billion Tree Campaign launched in 2006 shattered initial expectations and mobilized the planting of 2 billion trees in more than 150 countries.

Agroforestry intercrops. Another method of increasing carbon in agriculture is agroforestry, in which productive trees are planted in and around crop fields and pastures. The tree species may provide products (fruits, nuts, medicines, fuel, timber, and so on), farm production benefits (such as nitrogen fixation for crop fertility, wind protection for crops or animals, and fodder for animals), and ecosystem services (habitat for wild pollinators of crops, for example, or micro-climate improvement). The trees or other perennials in agroforestry systems sequester and store carbon, improving the carbon content of the agricultural landscape.

Agroforestry was common traditionally in agricultural systems in forest ecosystems and is being newly introduced into present-day subsistence and commercial systems. The highest carbon storage results are found in "multistory" agroforestry systems that have many diverse species using ecological "niches" from the high canopy to bottom-story shade-tolerant crops. Examples are shade-grown coffee and cocoa plantations, where cash crops are grown under a canopy of trees that sequester carbon and provide habitats for wildlife. Simple intercrops are used where tree-crop competition is minimal or where the value of tree crops is greater than the value of the intercropped annuals or grazing areas, or as a means to reduce market risks. Where crops are adversely affected by competition for light or water, trees may be grown in small plots in mosaics with crops. Research is also under way to develop low-light-tolerant crop varieties. And in the Sahel, some native trees and crops have complementary growth patterns, avoiding light competition all together.[25]

While agroforestry systems have a lower carbon storage potential per hectare than standing forests do, they can potentially be adopted on hundreds of millions of hectares. And because of the diverse benefits they offer, it is often more economical for farmers to establish and retain them. A Billion Tree Campaign to promote agroforestry was launched at the U.N. climate convention meeting in Nairobi in 2006. Within a year and a half the program had shattered initial expectations and mobilized the planting of 2 billion trees in more than 150 countries. Half the plantings occurred in Africa, with 700 million in Ethiopia alone. By taking the lead from farmers and communities on the choice of species, planting location, and management, and by providing adequate technical support to ensure high-quality planting materials and methods, these initiatives can ensure that the trees will thrive and grow long enough and large enough to actually store a significant amount of carbon.[26]

Tree crop alternatives for food, feed, and fuel. In a prescient book in 1929, Joseph Russell Smith observed the ecological vulnerabilities of annual crops and called for "A Permanent Agriculture." This work highlighted the diversity of tree crops in the United States that could substitute for annual crops in producing starch, protein, edible and industrial oils, animal feed, and other goods as well as edible fruits and nuts—if only concerted efforts were made to develop genetic selection, management, and processing technologies. Worldwide, hundreds of indigenous species of perennial trees, shrubs, and palms are already producing useful products for regional markets but have never been subject to systematic efforts of tree domestication and improvement or to market development. Since one third of the world's annual cereal production is used to feed livestock, finding perennial substitutes for livestock feed is especially promising.[27]

Exciting initiatives are under way with dozens of perennial species, mainly tapping intra-species diversity to identify higher-yielding, higher-quality products and developing rapid propagation and processing methods to use in value-added products. For example, more than 30 species of trees, shrubs, and liane in West Africa have been identified as promising for domestication and commercial development. Commercial-scale initiatives are under way to improve productivity of the Allanblackia and muiri (*Prunus africanus)* trees, which can be incorporated into multistrata agroforestry systems to "mimic" the natural rainforest habitat. Growing trees at high densities is not, however, recommended in dry areas not naturally forested, as this may cause water shortages, as has happened with eucalyptus in some dry areas of Ethiopia.[28]

Shifting biofuel production from annual crops (which often have a net negative impact on GHG emissions due to cultivation, fertilization, and fossil fuel use) to perennial alternatives like switchgrass offers a major new opportunity to use degraded or low-productivity areas for economically valuable crops with positive ecosystem impacts. But this will require a landscape approach to biofuels planning in order to use resources sustainably, enhance overall carbon intensity in the landscape, and complement other key land uses and ecosystem services.[29]

Promoting Climate-friendly Livestock Production

Domestic livestock—cattle, pigs, sheep, goats, poultry, donkeys, and so on—account for most of the total living animal biomass worldwide. A revolution in livestock product consumption is under way as developing countries adopt western diets. Meat consumption in China, for example, more than doubled in the past 20 years and is projected to double again by 2030. This trend has triggered the rise of huge feedlots and confined dairies around most cities and the clearing of huge areas of land for low-intensity grazing. Livestock also produce prodigious quantities of greenhouse gases: methane (from fermentation of food in the largest part of an animal's stomach and from manure storage), nitrous oxide (from denitrification of soil and the crust on manure storage), and carbon (from crop, animal, and microbial respiration as well as fuel combustion and land clearing).[30]

Livestock now account for 50 percent of the emissions from agriculture and land use change. Remarkably, annual emissions from livestock total some 7.1 billion tons (including 2.5 billion tons from clearing land for the animals), accounting for about 14.5 percent of emissions from human activities. Indeed, a cow/calf pair on a beef farm are responsible for more GHG emissions in a year than someone driving 8,000 miles in a mid-size car.[31]

Serious action on climate will almost certainly have to involve reducing consumption of meat and dairy by today's major consumers and slowing the growth of demand in developing countries. No such shift seems likely, however, without putting a price on the cost of emissions. Meanwhile, some solutions are at hand to reduce emissions of greenhouse gases by existing herds.

Intensive rotational grazing. Innovative grazing systems offer alternatives to both extensive grazing systems and confined feedlots and dairies, greatly reducing net GHG emissions while increasing productivity. Conventional thinking says that the current number of livestock far exceeds the carrying capacity of a typical grazing system. But in many circumstances, this reflects poor grazing management practices rather than numbers.

Research shows that grasslands can sustainably support larger livestock herds through intensive management of herd rotations to allow proper regeneration of plants after grazing. By letting the plants recover, the soil organic matter and carbon are protected from erosion, while livestock productivity is maintained or increased. For example, a 4,800-hectare U.S. ranch using intensive rotational grazing tripled the perennial species in the rangelands while almost tripling beef production from 66 kilograms to 171 kilograms per hectare. Various types of rotational grazing are being successfully practiced in the United States, Australia, New Zealand, parts of Europe, and southern and eastern Africa. Large areas of degraded rangeland and pastures around the world could be brought under rotational grazing to enable sustainable livestock production.[32]

Rotational grazing also offers a viable alternative to confined animal operations. A major study by the U.S. Department of Agriculture compared four temperate dairy production systems: full-year confinement dairy, confinement with supplemental grazing, outdoor all-year and all-perennial grassland dairy, and an outdoor cow-calf operation on perennial grassland. The overall carbon footprint was much higher for confined dairy than for grazing systems, mainly because carbon sequestration in the latter is much higher even though carbon emissions are also higher. The researchers concluded that some of the best ways to improve the GHG footprint of intensive dairy and meat operations are to improve carbon storage in grass systems, use higher-quality forage, eliminate manure storage, cover manure storage, increase meat or milk production per animal, and use well-managed rotational grazing.[33]

Feed supplements to reduce methane emissions. Methane produced in the rumen (the first stomach of cattle, sheep, and goats and other species that chew the cud) account for about 1.8 billion tons of CO_2-equivalent emissions. Nutrient supplements and innovative feed mixes have been developed that can reduce methane production by 20 percent, though these are not yet commercially viable for most farmers. Some feed additives can make diets easier for animals to digest and reduce methane emissions. These require fairly sophisticated management, so they are mainly useful in larger-scale livestock operations (which are, in any case, the main sources of methane emissions).[34]

Advanced techniques being developed for methane reduction also include removing specific microbial organisms from the animal's rumen or adding other bacteria that actually reduce gas production there. Research is also under way to develop vaccines against the organisms in the stomach that produce methane.[35]

Biogas digesters for energy. Manure is a major source of methane, responsible for some 400 million tons of CO_2-equivalent. And poor manure management is a leading source of water pollution. But it is also an opportunity for an alternative fuel that reduces a farm's reliance on fossil fuels. By using appropriate technologies like an anaerobic biogas digester, farmers can profit from their farm waste while helping the climate. A biogas digester is basically a temperature-controlled air-tight vessel. Manure (or food waste) is fed into this vessel, where microbial action breaks it down into methane or biogas and a low-odor, nutrient-rich sludge. The biogas can be burned for heat or electricity, while the sludge can be used as fertilizer.[36]

Some communities in developing countries are already using manure to produce cooking fuel. By installing anaerobic digesters, a large pile of manure can be used to produce biogas as well as fertilizer for farms. Even collecting the methane and burning it to convert it to carbon dioxide will be an improvement, as methane has 25 times the global warming potential of carbon dioxide, molecule for molecule, over a 100-year period. And the heat this generates can be used to produce electricity. By thinking creatively, previously undervalued and dangerous wastes can be converted into new sources of energy, cost savings, and even income. Biogas digesters involve an initial cash investment that often needs to be advanced for low-income producers, but lifetime benefits far outweigh costs. This technology could be extended to millions of farmers with benefits for the climate as well as for human well-being through expanded access to energy.[37]

Biogas can even contribute to commercial energy. In 2005, for instance, the Penn England dairy farm in Pennsylvania invested $141,370 in a digester to process manure and $135,000 in a combined heat and power unit, with a total project cost of $1.14 million to process the manure from 800 cows. Now the farm makes a profit by using the biogas to generate 120 kilowatt-hours of electricity to sell back to the local utility, at 3.9¢ per kilowatt-hour. The system also produces sufficient heat to power the digester itself, make hot water, and heat the barns and farm buildings.[38]

Protecting Existing Carbon Stores in Natural Forests and Grasslands

The world's 4 billion hectares of forests and 5 billion hectares of natural grasslands are a massive reservoir of carbon—both in vegetation and root systems. As forests and grasslands continue to grow, they remove carbon from the atmosphere and contribute to climate change mitigation. Intact natural forests in Southeast Australia hold 640 tons of carbon per hectare, compared with 217 tons on average for temperate forests. Thus avoiding emissions by protecting existing terrestrial carbon in forests and grasslands is an essential element of climate action.[39]

Reduce deforestation and land clearing. Massive deforestation and land clearing are releasing stored carbon back into the atmosphere. Between 2000 and 2005, the world lost forest area at a rate of 7.3 million hectares per year. For every hectare of forest cleared, between 217 and 640 tons of carbon are added to the atmosphere, depending upon the type of vegetation. Deforestation and land clearing have many different causes—from large-scale, organized clearing for agricultural use and infrastructure to the small-scale movement of marginalized people into forests for lack of alternative farming or employment opportunities or to the clearing of trees for commercial sale of timber, pulp, or woodfuel. In many cases the key drivers are outside the productive land use sectors—the result of public policies in other sectors, such as construction of roads and other infrastructure, human settlements, or border control.[40]

Current international negotiations are exploring the possibility of compensating developing countries for leaving their forests intact or improving forest management.

Unlike many of the other climate-mitigating land use actions described in this chapter, protecting large areas of standing natural vegetation typically provides fewer short-term financial or livelihood benefits for landowners and managers, and it may indeed reduce their incomes or livelihood security. The solution sometimes lies in regulation, where there is strong enforcement capacity, as with Australia's laws restricting the clearance of natural vegetation. But in many areas the challenge is to develop incentives for conservation for the key stakeholders.

Several approaches are being used. One is to raise the economic value of standing forests or grasslands by improving markets for sustainably harvested, high-value products from those areas or by paying land managers directly for their conservation value. Current international negotiations are exploring the possibility of compensating developing countries for leaving their forests intact or improving forest management. During the Conference of the Parties to the climate convention in Bali in December 2007, governments agreed to a two-year negotiation process that would lead to adoption of a mechanism for Reducing Emissions from Deforestation and Degradation (REDD) after 2012. Implementation of any eventual REDD mechanism will pose major methodological, institutional, and governance challenges, but numerous initiatives are already under way to begin addressing these.[41]

A second incentive for conservation is product certification, whereby agricultural and forest products are labeled as having been produced without clearing natural habitats or in mosaic landscapes that conserve a minimum area of natural patches. For example, the Biodiversity and Agricultural Commodities Program of the International Finance Corporation seeks to increase the production of sustainably produced and verified commodities (palm oil, soy, sugarcane, and cocoa), working closely with commodity roundtables and their members, regulatory institutions, and policymakers. While the priority focus is on conservation of biodiversity, this initiative will have significant climate impacts as well, due to its focus on protecting existing carbon vegetative sinks from conversion, developing standards for sustainable biofuels, and establishing certification systems.[42]

A third approach is to secure local tenure rights for communal forests and grasslands so that local people have an incentive to manage these resources sustainably and can protect them from outside threats like illegal commercial logging or land grabs for agriculture. A study in 2006 of 49 community forest management cases worldwide found that all the initiatives that included tenure security (admittedly a small number) were successful but that only 38 percent of those without it succeeded. Diverse approaches and legal arrangements are being used to strengthen tenure security and local governance capacity.[43]

Reduce uncontrolled forest and grassland burning. Biomass burning is a significant source of carbon emissions, especially in developing countries. Controlled biomass burning in the agricultural sector, on a limited scale, can have positive functions as a means of clearing and rotating individual plots for crop production; in some ecosystems, it is a healthy means of weed control and soil fertility improvement. In a number of natural ecosystems, such as savanna and scrub forests, wild fires can help maintain biotic functions, as in Australia. In many tropical forest ecosystems, however, fires are mostly set by humans and environmentally harmful—killing wildlife, reducing habitat, and setting the stage for more fires by reducing moisture content and increasing combustible materials. Even where they can be beneficial from an agricultural perspective, fires can inadvertently spread to natural ecosystems, opening them up for further agricultural colonization.[44]

Systems are already being put in place to track fires in "real time" so that governments and third-party monitors can identify the people responsible. In the case of large-scale ranchers and commodity producers, better regulatory enforcement is needed, along with alternatives to fire for management purposes. For small-scale, community producers, the most successful approaches have been to link fire control with investments in sustainable intensification of production, in order to develop incentives within the community to protect investments from fire damage. These "social controls" have been effectively used to generate local rules and norms around the use of fire, as in Honduras and The Gambia.[45]

Manage conservation areas as carbon sinks. Protected conservation areas provide a wide range of benefits, including climate regulation. Just letting these areas stand not only helps the biodiversity within, it also stores the carbon, avoiding major releases in greenhouse gas emissions. Moreover, due to some early effects of climate change, important habitats for wildlife are shifting out of protected areas. Plants are growing in higher altitudes as they seek cooler temperatures, while birds have started altering their breeding times. Larger and geographically well distributed areas thus need to be put under some form of protection.

This need not always be through public protected areas. At least 370 million hectares of forest and forest-agriculture landscapes outside official protected areas are already under local conservation management, while half of the world's 102,000 protected areas are in ancestral lands of indigenous and other communities that do not want to see them developed. Conservation agencies and communities are finding diverse incentives for protecting these areas, from the sustainable harvesting of foods, medicines, and raw materials to the protection of locally important ecosystem services and religious and cultural values as well as opportunities for nature tourism income. Supporting these efforts to develop and sustain protected area networks, including public, community, and private conservation areas, can be a highly effective way to reduce and store greenhouse gases.[46]

Restoring Vegetation in Degraded Areas

Extensive areas of the world have been denuded of vegetation from large-scale land clearing for annual crops or grazing and from overuse and poor management in community and public lands with weak governance. This is a tragic loss, from multiple perspectives. People living in these areas have lost a potentially valuable asset for the production of animal fodder, fuel, medicines, and raw materials. Gathering such materials is an especially important source of income and subsistence for low-income rural people. For example, researchers found in Zimbabwe that 24 percent of the average total income of poor farmers came from gathering woodland products. At the same time, the loss of vegetation seriously threatens ecosystem services, particularly watershed functions and wildlife habitat.[47]

Efforts to restore degraded areas can thus be "win-win-win" investments. Although there may be fewer tons of CO_2 sequestered per hectare from restoration activities, millions of hectares can be restored with low opportunity costs and strong local incentives for participation and maintenance.

Revegetate degraded watersheds and rangelands. Hydrologists have learned that "green water"—the water stored in vegetation and filtrating into soils—is as important as "blue water" in streams and lakes. When rain falls on bare soils, most is lost as runoff. In many of the world's major watersheds, most of the land is in productive use. Poor vegetative cover limits the capacity to retain rainfall in the system or to filter water flowing into streams and lakes and therefore accelerating soil loss. From a climate perspective, lands stripped of vegetation have lost the potential to store carbon. Landscapes that retain year-round vegetative cover in strategically selected areas and natural habitat cover in critical riparian areas can maintain most, if not all, of various watershed functions, even if much of the watershed is under productive uses.[48]

With rapid growth in demand for water and with water scarcity looming in many countries (in part due to climate change), watershed revegetation is now getting serious policy attention. Both India and China have large national programs targeting millions of hectares of forests and grasslands for revegetating, and they see these as investments to reduce rural poverty and protect critical watersheds. In most cases, very low-cost methods are used for revegetation, mainly temporary protection to enable natural vegetation to reestablish itself without threat of overgrazing or fire. For example, in Morocco 34 pastoral cooperatives with more than 8,000 members rehabilitated and manage 450,000 hectares of grazing reserves. On highly degraded soils, some cultivation or reseeding may be needed. Two keys to success in these approaches are to engage local communities in planning, developing, and maintaining watershed areas and to include rehabilitation of areas of high local importance, such as productive grazing lands, local woodfuel sources, and areas like gullies that can be used for productive cropping.[49]

In Rajasthan, India, for example, community-led watershed restoration programs have reinstated more than 5,000 traditional *johads* (rainwater storage tanks) in over 1,000 villages, increasing water supplies for irrigation, wildlife, livestock, and domestic use and recharging groundwater. In Niger, a "regreening" movement, using farmer-managed natural regeneration and simple soil and water conservation practices, reversed desertification, increased tree and shrub cover 10- to 20-fold, and reclaimed at least 250,000 hectares of degraded land for crops. Over 25 years, at least a quarter of the country's farmers were involved in restoring about 5 million hectares of land, benefiting at least 4.5 million people through increased crop production, income, and food security. Extending the scale of such efforts could have major climate benefits, with huge advantages as well for water security, biodiversity, and rural livelihoods.[50]

Reestablish forest and grassland cover in biological corridors. Loss and fragmentation of natural habitat are leading threats to biodiversity worldwide. Conservation biologists have concluded that in many areas conservation of biodiversity will require the establishment of "biological corridors" through production landscapes, to connect fragments of natural habitat and protected areas and to give species access to adequate territory and sources of food and water. One key strategy is to reestablish forest or natural grassland cover (depending on the ecosystem) to play this ecological role. These reforestation efforts also have major climate benefits.

In Brazil's highly threatened Atlantic Forest, for example, conservation organizations working in the Desengano State Park struck a deal with dairy farmers to provide technical assistance to improve dairy-farm productivity in exchange for the farmers reforesting part of their land and maintaining it as a conservation easement. Milk yields tripled and farmers' incomes doubled, while a strategic buffer zone was established for the park.[51]

In northwestern Ecuador, two thirds of coastal rainforests have been lost due to logging and agricultural expansion, risking the survival of 2,000 plant and 450 bird species. The Chocó-Manabí corridor reforestation project is attempting to improve wild species' access to refuge habitats by restoring connectivity between native forest patches through reforestation efforts. This project is restoring 265 hectares of degraded pastures with 15 native trees species and as a result sequestering 80,000 tons of carbon dioxide. The opportunity for such investments is mobilizing new partnerships between wildlife conservation organizations, the climate action community, farmers, and ranchers.[52]

Market Incentives for Climate-friendly Agriculture and Land Use

All the strategies described in the preceding sections are already available or are well within technological reach at far lower cost than many climate solutions being discussed (such as geological storage of carbon). The challenge is shifting policy and investment priorities and supporting institutions to create incentives for farmers, pastoralists, forest owners, agribusiness, and all other stakeholders within the agriculture and forestry supply chains to scale up best practices and continue to innovate new ones. This will require concerted action by consumers, farmers' organizations, the food industry, civil society, and governments.

The central players in any response to climate change are the farmers and communities—those who actually manage land—and the food and fiber industry that shapes the incentives for the choice of crops, quality standards, and profitability. Some innovators are already showing the way. For example, the Sustainable Food Lab, a collaborative of 70 businesses and social organizations from throughout the world, has assembled a team of member companies, university researchers, and technical experts to develop and test ways to measure and provide incentives for low-carbon agricultural practices through the food supply chain, mainly by increasing soil organic matter, improving fertilizer application, and enhancing the capacity of crops and soil to store carbon.[53]

A key driver is consumer and buyer awareness. Consumers will take the needed steps once they realize that their choice of meat and dairy products, and their support for natural forests and grassland protection, can have as great an impact on the climate as how far they drive their cars. One immediate action is for consumers, processors, and distributors to adopt greenhouse gas footprint analysis for food and fiber products, addressing their full "life cycle," including production, transport, refrigeration, and packaging, to identify strategic intervention points.

In 2007, for instance, the Dole Corporation committed to establishing by 2021 a carbon-neutral product supply chain for its bananas and pineapples in Costa Rica. Their first step in this process was to purchase forest carbon offsets from the Costa Rican government equal to the emissions of its inland transport of these fruits. GHG impact is a key metric that can be used for evaluating new food and forest production technologies and for allocating resources and investments. Policymakers can then include incentives for reducing carbon emissions in cost structures throughout the food and land use systems, using various market and policy mechanisms.[54]

Product markets are also beginning to recognize climate values. The last 20 years have seen the rise of a variety of "green" certified products beyond organic, such as "bird-friendly" and "shade-grown," that have clear biodiversity benefits. Various certification options already exist for cocoa and coffee (through the Rainforest Alliance, Starbucks, and Organic, for example). The Forest Stewardship Council's certification principles "prohibit conversion of forests or any other natural habitat" and maintain that "plantations must contribute to reduce the pressures on and promote the restoration and conservation of natural forests," supporting the use of forests as carbon sinks. New certification standards are starting up that explicitly include impacts on climate, which will for the first time send clear signals to both producers and consumers.[55]

The rise of carbon emission offset trading could potentially provide a major new source of funding for the transition to climate-friendly agriculture and land use. (See Box 3–2.) A great deal can be done in the short term through the voluntary carbon market, but in the long run it will be essential for the international framework for action on climate change to fully incorporate agriculture and land use.[56]

Public Policies to Support the Transition

Governments can take specific steps immediately to support the needed transition by integrating agriculture, land use, and climate action programs at national and local landscape levels. Costa Rica is a leader in these efforts. The government has committed to achieving "climate neutrality" by 2021, with an ambitious agenda including mitigation through land use change. Costa Rica is a participant in the Coalition for Rainforest Nations, a group encouraging avoided-deforestation programs, and has already increased its forest cover from 21 percent in 1986 to 51 percent in 2006. The country is taking advantage of markets that make payments for ecosystem services and ecotourism to support these efforts.[57]

Currently, governments spend billions of dollars each year on agricultural subsidy payments to farmers for production and inputs, primarily in the United States ($13 billion in 2006, which was 16 percent of the value of agricultural production) and Europe ($77 billion, or 40 percent of agricultural production value) but also in Japan, India, China, and elsewhere. Most of these payments exacerbate chemical use, the expansion of cropland to sensitive areas, and overexploitation of water and other resources while distorting trade and reinforcing unsustainable agricultural practices. Some countries are beginning to redirect subsidy payments to agri-environmental payments for all kinds of ecosystem services, and these can explicitly include carbon storage or emissions reduction.[58]

Growth in commercial demand for agricultural and forest products from increased populations and incomes in developing countries and demand for biofuels in industrial

Box 3–2. Paying Farmers for Climate Benefits

Paying farmers and land managers to reduce carbon emissions or store greenhouse gases is a critical way to both mitigate climate change and generate ecosystem and livelihood benefits. The carbon market for land use has three main components: carbon emissions offsets for the regulatory market, as established by the Kyoto Protocol; offset activities in emerging U.S. regulatory markets operating outside the Kyoto Protocol; and the sale of voluntary carbon offsets coming from land use, land use change, and forestry, primarily to individual consumers, philanthropic buyers, and the private sector.

Developing countries can implement afforestation and reforestation projects that count toward emission reduction targets of industrial countries through the Clean Development Mechanism of the Kyoto Protocol. The treaty authorizes afforestation and reforestation but excludes agricultural or forest management, avoided deforestation or degradation, and soil carbon storage. However, each CDM project must address thorny issues of nonpermanence of carbon uptake by vegetation and soil, risks of potential displacement of emissions as deforestation just moves elsewhere, and sustainable development prospects in the host country that can limit implementation.

There is more innovation in the voluntary market, where buyers value multiple benefits. The value of forestry plus land use projects more than doubled from $35 million in 2006 to $72 million in 2007. Work is proceeding to lend more credibility, transparency, and uniformity in methods used for creating land-based carbon credits.

There are several ongoing initiatives to promote diverse types of land-use-based payments:

- The World Bank's $91.9-million BioCarbon Fund is financing afforestation, reforestation, REDD, agroforestry, and agricultural and ecosystem-based projects that not only promote biodiversity conservation and poverty alleviation but also sequester carbon.
- The Regional Greenhouse Gas Initiative in the northeastern United States will include afforestation and methane capture from U.S. farms.
- The trading system in New South Wales, Australia—the world's first—provides for carbon sequestration through forestry, including on-farm forest regeneration.
- The New Zealand government is investing more than $175 million over five years in a Sustainable Land Management and Climate Change Plan to help the agriculture and forestry sectors adapt to, mitigate, and take advantage of the business opportunities of climate change. This scheme will include specific cap-and-trade allocations to the dairy sector and will incorporate cash grants to encourage new plantings by landowners, increased research funding, technology transfer, and incentives to use more wood products and bio-energy.
- Rabobank, the world's largest agricultural financier, will pay farmers $83,000 to reforest, which will be sold as carbon offsets; the bank may use some of these credits to offset its own activities. This is the first transaction of its kind in Brazil's Xingu province, which has the country's highest deforestation rates. Soy and cattle farmers are targeted, and replanting is planned for riparian stretches through the region.
- REDD payments for avoided deforestation in Mato Grosso state alone in Brazil are estimated at $388 million annually.

Much larger initiatives are needed now to link carbon finance with investments to achieve rural food security by "re-greening" degraded watersheds, promoting agroforestry, restoring soil organic matter, rehabilitating degraded pastures, controlling fires, or protecting threatened forests and natural areas important for local livelihoods. If low-income landowners and managers are to benefit from payments for ecosystem services, they need secure rights, clear indicators of performance, and systems for aggregating buyers and sellers to keep transaction costs low.

Source: See endnote 56.

nations is stimulating investments by both private and public sectors. In 2003, African governments committed to increase public investment in agriculture to at least 10 percent a year, although only Rwanda and Zambia have done this so far. The World Bank and the Bill & Melinda Gates Foundation have committed to large increases in funding in the developing world. There is a major window of opportunity right now to put climate change adaptation and mitigation at the core of these strategies.[59]

This is beginning to happen in small steps. Brazil is crafting a diverse set of investment programs to support rural land users who invest in land use change for climate change mitigation and adaptation. The U.N. Environment Programme is initiating dialogues on "greening" the international response to the food crisis, linking goals of international environmental conventions with the Millennium Development Goals.[60]

Many available technologies and management practices could lighten the climate footprint of agriculture and other land uses and protect existing carbon sinks in natural vegetation.

But much more comprehensive action is needed. If not, this otherwise positive trend could seriously undermine climate action programs. A new vision is needed to respond to this food crisis that not only provides a short-term Band-Aid to refill next year's grain bins but also puts the planet on a trajectory toward sustainable, climate-friendly food systems.

National policy, however, is not enough. It is essential to invest in building capacity at local levels to manage ecoagricultural landscapes—to enable multistakeholder platforms to plan, implement, and track progress in achieving climate-friendly land use systems that benefit local people, agricultural production, and ecosystems.

Taking Action for Climate-friendly Land Use

Human well-being is wrapped up with how food is produced. Ingenious systems were developed over the past century to supply food, with remarkable reliability, to a good portion of the world's 6.7 billion people. But these systems need a fundamental restructuring over the next few decades to establish sustainable food systems that both slow and are resilient to climate change. Land-manager and private-sector action will determine the response, but public policy and civil society will play a crucial role in providing the incentives and framework for communities and markets to respond effectively.[61]

Food production and other land uses are currently among the highest greenhouse gas emitters on the planet—but that can be reversed. Although recent food price riots may discourage any actions that could raise costs, if action is not taken costs will rise anyway as local food systems are disrupted and as higher energy costs ripple through a system that has not been prepared with alternatives.

The strategy for reducing greenhouse gas emissions from agriculture and other land use sectors also must recognize the need for major increases in food and fiber production in developing countries to feed adequately the 850 million people currently hungry or undernourished, as well as continually growing populations. Investments must be channeled so that increased production comes from climate-friendly production systems rather than from systems that clear large areas of natural forest and grasslands, mine organic matter from the soil, strip vegetative cover from riparian areas, or leave soils bare for many months of the year.[62]

As described in this chapter, many available technologies and management practices could lighten the climate footprint of agriculture and other land uses and protect existing carbon sinks in natural vegetation and soils. Many more could become operational fairly quickly with proper policy support or adaptive research and with a more systematic effort to analyze the costs and benefits of different strategies in different land use systems. Other innovative ideas will emerge if leading scientists and entrepreneurs can be inspired to tackle this challenge. And many of the actions most needed in land use systems to adapt to climate change and mitigate GHG emissions will bring positive benefits for water quality, air pollution, smoke-related health risks, soil health, energy efficiency, and wildlife habitat. These tangible benefits can generate broader political support for climate action.

It is heartening that there are already so many initiatives to address climate change in the food and land use sectors, and these efforts have established a rich foundation of practical, implementable models. But the scale of action so far is dishearteningly small. With the exception of the recent REDD initiatives to save standing forests through intergovernmental action, which are still in an early stage, there are no major international initiatives to address the interlinked challenge of climate, agriculture, and land use.

A worldwide, networked movement for climate-friendly food, forest, and other land-based production is needed. This calls for forging unusual political coalitions that link consumers, producers, industry, investors, environmentalists, and communicators. Food, in particular, is something that the public understands. By focusing on food systems, climate action will become more real to people. It is realistic to expect that the prices of food and other land-based products will rise in a warming world, at least for a time. This must not be the result of scarcity caused by climate-induced system collapse but rather because new investment has been mobilized to create sustainable food and forest systems that also cool the planet.

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The Risks of Other Greenhouse Gases

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