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Agriculture and Forestry

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Agriculture and Forestry, by Blake Hudson*

I. Introduction

As this book demonstrates, the drivers of climate change are varied and multi-faceted. A wide array of sources contribute to greenhouse gas accumulation in the atmosphere. As is widely acknowledged, emissions from industrial, transportation, energy, residential, and commercial sectors are each significant sources of greenhouse gases (GHGs). Yet two additional sectors—agriculture and forestry—play a pivotal, dual role in climate change. They are both significant sources of GHGs and important GHG sinks that sequester emissions. Thus, agriculture and forestry both contribute to climate change and help to regulate it.

Agricultural lands occupy roughly 40-50% of the Earth's land surface, and include cropland, managed grasslands, pasturelands, and permanent crops such as agro-forestry or bioenergy crops.[1] Over twelve billion acres of the Earth's surface were used for agriculture in 2002, and agricultural lands are projected to increase globally by over one billion acres by 2020 to meet the demands of rising populations.[2] Feeding the earth's ever-growing population and driving a significant part of the global economy does not come without an environmental cost, however. Globally, agriculture accounts for about 10-12% of carbon emissions,[3] while in the U.S. it accounts for 20% of fossil fuel use[4] and 7% of GHG emissions.[5]

Forestlands occupy about one-quarter of the earth's ice-free land surface, and contain over half of the world's plant and animal species.[6] Though forests have traditionally been considered a predominantly local resource controlled and managed by individual property owners or local governments, the national and global importance of local forests are becoming increasingly apparent. On local scales, forests provide a broad array of goods and services: timber resources, watershed protection and purification, water flow regulation and flood prevention, air quality benefits, biodiversity and habitat protection, nutrient recycling, genetic resources, rainfall generation, disease regulation, ecosystem stability, recreational and cultural values, and increased residential and commercial energy efficiency.[7] On a global scale, forests sequester significant amounts of greenhouse gas that would otherwise exacerbate climate change. Even so, deforestation alone accounts for a full one-third of all carbon released into the atmosphere between 1850 and 1998,[8] second only to the energy sector. Over the last two decades, up to 20% of global annual carbon emissions resulted from forest destruction and degradation, more than the global transportation sector.[9] Though the U.S. has long been a stable forest sink, that status is in jeopardy as new threats may lead to significant deforestation over the next 50 years.

This chapter discusses both the GHG source and GHG sink potential of the agricultural and forest sectors. It also describes the governance and management frameworks for each sector and the GHG mitigation options available for each. The chapter concludes by highlighting future challenges for U.S. agriculture and forestry related to GHGs and climate.

II. Agriculture and Forestry as GHG Sources

Though the agricultural and forest sectors are distinct in a number of ways, their shared status as global sources of GHGs means they are intricately intertwined. As was the case in previous centuries in the developed world, today "the main driver of forest loss [in the developing world] is the conversion of new land on which to grow commodity crops and graze livestock."[10] Yet agriculture and forestry each uniquely contribute to GHG emissions in a variety of ways.

A. Agriculture

Three primary GHGs are associated with agriculture—carbon (CO_2), methane (CH_4), and nitrous oxide (N_2O). Though emitted in lesser quantities, methane and N_2O emissions are, respectively, 21 and 310 times more effective at trapping heat in the atmosphere than carbon.[11] These numbers represent "global warming potential" relative to carbon.[12]

Carbon emissions result primarily from microbial decay of crop residues, the sublimation of soil organic matter into the atmosphere, and the burning of plant litter and soil organic matter.[13] Crop land management, including tillage processes, have a significant impact on the quantity of carbon emissions related to soil carbon, though the clearing of forests and filling of wetlands to meet increased agricultural demand also contribute to carbon emissions related to agricultural soils.[14] Carbon emissions also arise from agricultural infrastructure—i.e. energy consumed during agricultural processes, including agricultural machinery used in the preparation of agricultural lands, the planting, cultivation, and harvesting of agricultural products, and the carbon-intensive cultivation and processing of livestock feed, pesticides, and fertilizers.[15]

In addition, carbon emissions arise from factory processing and refrigeration of agricultural products, and their transportation around the globe.[16] Increased international trade of agricultural products is projected to increase CO_2 emissions, though this can be offset in varying degrees by fuel efficiency gains in the transportation sector.[17] Though the overall impact on GHG emissions due to agricultural infrastructure is relatively low considering that agricultural fuel use is a small part of total U.S. fuel consumption, improved operational efficiency and no-till farming methods (which use less fuel) nevertheless can reduce fossil fuel-based agricultural emissions.[18]

Methane emissions result primarily from the decomposition of organic matter, livestock manures, and "fermentative digestion" in livestock, with varying levels of methane associated with particular diets. N_2O emissions result from microbial transformation of nitrogen in both soils and manures and from excess nitrogen presence through the application of ever-increasing quantities of fertilizer. Agriculture accounted for a full 56% of global non-carbon GHGs in 2005 and is expected to remain the largest contributor of non-carbon GHGs in 2030, by which time non-carbon GHG emissions are expected to have increased by another 45%.[19] Roughly 50% of total anthropogenic methane and 85% of N_2O are attributable to agriculture.[20] Agricultural methane emissions on the whole increased by 40% between 1970 and 2004,[21] and methane related to livestock production is expected to increase by up to 60% by 2030.[22] Similarly, Agricultural N_2O emissions increased by 50% between 1970 and 2004,[23] and are projected to increase by 35-60% by 2030 because of increases in fertilizer use and manure production.[24]

In the U.S., agriculture contributes roughly 70% of total N_2O emissions and 25% of total methane emissions.[25] Despite the high non-carbon GHG emissions from U.S. agriculture, the greatest GHG contribution from U.S. agriculture is loss of soil carbon, followed by enteric fermentation and manure management.[26] Though this may remain the case in the U.S. for some time, the agricultural activity with perhaps the greatest climate impact globally could very well become livestock production, as it will lead to ever increasing emissions of all types of GHGs (carbon, methane, and N_2O). Higher meat consumption in rapidly developing, populous countries like China will place concomitant stressors on forests and wetlands, which will be increasingly converted to agricultural lands. These conversions will both remove forests as a GHG sink and increase emissions through the cultivation of evermore feedstocks, while also increasing the methane and N_2O emissions associated with livestock digestive processes and their manure.[27]

B. Forestry

As noted, over recent decades deforestation and forest degradation have accounted for nearly 1/5 of global carbon emissions.[28] The increased recognition of the role of forests in regulating the global climate has placed global forest protection on the agenda of both international climate negotiations and negotiations related to establishing a global sustainable forest management regime.[29] These negotiations have mostly focused on Reduced Emissions from Forest Degradation and Destruction (REDD) programs, or what has become known as "REDD-plus."

REDD-plus seeks to curb forest destruction and degradation and enhance forest carbon stocks, and also promotes "conservation [and] sustainable management of forests in developing countries"[30] through programs aimed at alleviating rural poverty, conserving biodiversity, and sustaining ecosystem services.[31]

In the U.S., both the threats to forests, and their role in climate change mitigation are becoming increasingly clear, with scholars noting that "[p]rojections under the base case or business as usual scenario are that loss of [U.S.] forestland to other uses will be substantial, causing significant net release of GHGs (e.g., carbon dioxide) currently stored in those forests and also precluding much of their anticipated future GHG sequestration."[32] Between 1982 and 1997 over 22 million acres of U.S. forests were removed, with nearly 10 million acres going to developed uses. The deforestation rate accelerated between 1992 and 1997, increasing to nearly 1 million acres of forests converted to urban development yearly.[33] Due to reforestation or afforestation of other lands, however, forests on the whole have recently constituted no more than 1% of total U.S. GHG emissions.[34] Even so, economic drivers and population pressures in some regions of the U.S. are expected to compel future deforestation, with 23 million acres of forests projected to be developed or degraded over the next 50 years in the Southeast alone—an amount equal to 13% of all southern forestland.[35] As a result of these projections and concerns for forests in other parts of the U.S., avoiding deforestation to achieve GHG mitigation and other benefits is receiving increased attention.[36]

III. Agriculture and Forestry as GHG Sinks

Both the agricultural and forest sectors have significant potential as GHG sinks. Agriculture can sequester large amounts of carbon in soil and crops. Yet studies have shown that the GHG sink performance of the agricultural sector is far below its technical potential due primarily to high costs and other barriers to implementation of carbon sequestration projects.[37] Forests are currently playing a major role as a carbon sink both globally and in the U.S., even though deforestation continues worldwide. Not only does global forest destruction constitute a substantial *source* of atmospheric carbon, but one-third of global carbon emissions are absorbed by forests each year, making forests the most significant terrestrial carbon sink on the planet.[38] As a result, forest preservation has a magnified ameliorative effect on greenhouse gas mitigation, since forest preservation both avoids adding carbon to the atmosphere and prevents the loss of a significant carbon sink.

In the U.S., lands containing agricultural and forest operations sequester almost 830 teragrams of CO_2 equivalent (1 teragram equals approximately 1 million tons). Ninety percent of this carbon is sequestered in forests. In 2005, the Environmental Protection Agency (EPA) found that total forest and agricultural sinks offset 12% of carbon emissions from all other GHG-emitting sectors in the U.S.[39] Of course, the potential for U.S. agricultural and forest lands to serve as sinks must be offset by the emissions these sectors themselves generate; the agricultural sector in particular is a net source of GHGs. Thus, while agriculture accounts for approximately 7% of U.S. GHG emissions, carbon sequestered in agricultural soils offset only $1/10^{th}$ of these emissions.[40] After subtracting GHG source data from GHG sink data, agriculture and forests in the U.S. offset 6% of U.S. total GHG emissions in 2005.[41]

IV. The Regulatory Framework

As discussed in Part V. below, a variety of measures could mitigate U.S. agricultural and forestry GHG emissions and encourage utilization of these sectors as sinks. Such measures range from prescriptive regulations to voluntary and incentive-based programs, to a combination of the two in the form of cap-and-trade schemes that include agricultural and forest offsets. Regardless of the mechanisms used, it is important to first understand the regulatory framework within which U.S. agriculture and forestry currently are situated.

A. Agriculture

Federal involvement in agriculture began in 1933 with the Agricultural Adjustment Act,[42] which was "designed to save small farming in America and, to some, it signaled a return to the Jeffersonian ideal of an agrarian democracy."[43] Since 1933, Congress has passed at least 56 statutes "aimed at agricultural prices and production"[44] to preserve agricultural income, soil conservation, and food supply. Congress has continued to pass farm bills roughly once every 5 years.[45] The 1985 farm bill for the first time included numerous conservation programs, discussed below in Part V., as a response to agricultural erosion and the expansion of agricultural operations into marginal farmlands to meet "perceived" increase in demand.[46] These programs were thus aimed at preserving both financial and environmental aspects of agricultural lands.[47]

The 1990 farm bill further refined these programs, and added new ones particularly relevant to climate change mitigation, like the Wetlands Reserve Program, through which the federal government purchases conservation easements from, or enters into cost-share arrangements with, landowners who preserve wetland resources.[48] Congress also plays a role in crop emergency and insurance provision to assist in the event of floods, droughts, and other natural disasters.[49] A number of state and federal programs provide financial assistance to farmers to overcome barriers to entry into productive agricultural operations and assist with the adoption of technological enhancements.[50]

State governments maintain a wide range of tools to govern agricultural activities, particularly those related to their police power to regulate land use activities. The states most often exercise this authority through "right-to-farm" statutes (used, for example, to overcome nuisance claims brought by citizens living near farms) and agricultural zoning laws (to regulate the when, where, and how of agricultural production within a municipal unit).[51] States could also regulate GHG emissions from agriculture, although "[s]tates have generally refrained from regulating emissions from any agricultural sources."[52] As a result, the "regulatory framework" for agriculture in the context of climate change is largely non-regulatory, and consists primarily of financial incentive programs rather than prescriptive regulation. Many prescriptive federal statutes contain agricultural exemptions. Some statutes, like the Clean Water Act (CWA),[53] do not regulate agricultural activities that result in nonpoint source water pollution or the filling of wetlands that would otherwise act as carbon sinks. Such activities are considered to fall within the domain of land use regulation, which is traditionally reserved to state governments under the Constitution,[54] The states, in turn, are reticent to prescriptively regulate a variety of activities related to agricultural greenhouse gas emissions. As a result, subsidy programs, tax policy, and market driven instruments are the primary means of shaping agricultural policy in the context of climate change mitigation at both the federal and state levels.

B. Forestry

The federal government maintains regulatory authority over the approximately 35% of forestland that it owns, while state governments are currently responsible for regulating the remaining 60% of forests owned by private individuals and 5% owned by subnational governments.[55] States have vigorously guarded against federal intrusions into subnational forest management.[56] The federal role is mostly limited to statutes that primarily regulate other resources, like water pollution under the CWA and species conservation under the Endangered Species Act (ESA).

Both federal and subnational forest policy options in the U.S. can be situated along a spectrum, reflecting both the scope of forest values protected and the stringency of regulatory standards. The scope of forest management standards can range from virtually non-existent (in many states), to very basic (focusing primarily on timber extraction and fundamental silvicultural[57] practices like clear cutting and riparian buffer zone protection), to those that seek to protect the full range of values provided by forests, including biodiversity or carbon sequestration and other climate mitigation values. Forest management standard stringency might range from voluntary substantive[58] or procedural[59] guidelines, to incentive-based programs,[60] to prescriptive regulation.[61]

V. Mitigation Measures[62]

Scholars have argued that "[i]t is increasingly clear that no strategy for mitigating global climate change can be complete or successful without addressing the widespread emissions from agriculture and forestry, also known as the land use sector. Yet so far, land-based, or 'terrestrial,' carbon has been largely ignored in climate mitigation initiatives, including at the highest levels."[63] Among the reasons for this oversight is undoubtedly the lack of uniformly applicable mitigation practices in these sectors. This in turn is the result of the complex web of agricultural and forestry GHG sources; horizontal geographic distinctions and ecological conditions; and both horizontal and vertical jurisdictional challenges that make designing and implementing global mitigation measures difficult. Mitigation is further complicated because mitigation measures aimed at one type of GHG can actually increase other types of GHGs.[64] Furthermore, mitigation measures that are effective in one location may be less effective or counterproductive in others, and the effectiveness of mitigation measures can vary over time.[65]

The Intergovernmental Panel on Climate Change (IPCC) divides agricultural and forestry mitigation options into three basic categories: 1) options that avoid CO_2 emissions by preserving existing pools or sinks of carbon in tree biomass and soils (e.g., forest or agricultural lands preservation); 2) options that enhance the removal of atmospheric CO_2 through sequestration (e.g., creation and preservation of sinks through afforestation, adjustment of agricultural management practices, etc.); and 3) options that directly reduce fossil fuel-related CO_2, or methane and N_2O emissions.[66] So while mitigation of carbon emissions in agriculture and forestry depends upon the net difference between carbon sequestration and carbon emissions within the sector, N_2O and methane mitigation depends solely on emissions reductions.[67]

Importantly, studies demonstrate that different mitigation options become more or less attractive depending upon a wide range of potential prices for carbon, which of course are in turn affected by regulatory or voluntary policies that influence carbon pricing.[68] In other words, these studies show that the price of carbon, whether high or low, and the design of regulatory or voluntary policies aimed at making carbon credits of value to farmers and forest owners, has a substantial effect on the degree to which agricultural policies will tip toward carbon sink and away from carbon source. They also impact the amount of forest that is preserved or replanted. These studies find that "carbon payments, [for example] in the form of CO_2 pricing, have the largest overall impacts on the forest and agricultural sectors."[69]

As noted earlier, forests currently account for 90% of the carbon sink in the U.S., demonstrating that agriculture is not currently a significant GHG sink. Yet, scholars have noted that actual levels of GHG mitigation in the agricultural sector are far below the technical potential, and the "[g]ap between technical potential and realized GHG mitigation occurs due to costs and other barriers to implementation."[70] If these barriers can be removed, through carbon pricing, assistance with methane and N_2O reduction technologies, or otherwise, then agriculture can supplement forest sinks by constituting a far greater GHG sink, in the case of carbon, or a far less significant source, in the case of methane and N_2O.

Policies that can harness forests to sequester carbon range from payments to incentivize the storing of forest carbon to regulatory restrictions on the replacement of forests for development or agriculture.[71] Similarly, agricultural mitigation policies may be incentive-based and aimed at the preservation of soil carbon or prevention of methane or N_2O emissions, or regulatory restrictions aimed at addressing each. A variety of GHG mitigation options for the agricultural and forestry sectors are discussed below.

A. Land Conservation, Preservation, and Enhancement Regulations and Incentive Programs[72]

Land conservation and preservation provide perhaps the most efficient mechanism for both reducing sources of GHGs as well as creating sinks for them—*if* carbon sequestration or GHG emissions prevention is the primary policy objective. Yet, this can be challenging because, as scholars have noted, "protecting large areas of standing natural vegetation typically provides fewer short-term financial or livelihood benefits for landowners and managers. It may even reduce their incomes or livelihood security."[73] While regulation may certainly be an option to achieve preservation objectives in areas where it can be successfully crafted and effectively enforced, equally important—and perhaps more important given the difficulties in prescribing limits on the use of land—are non-regulatory incentives that could induce landowners to preserve lands.

In agriculture, the most effective mechanism for increasing carbon storage and reducing emissions from N_2O, methane, and carbon, not surprisingly, is to facilitate the reversion of cropland to native vegetation. This can be done either through preservation of large plots of decommissioned agricultural lands or in a localized fashion embedded within the agricultural operation, such as by incorporating grassed waterways, field margins, or shelterbelts.[74] Converting croplands back to wetlands can result in rapid carbon sequestration gains, as can planting trees through agro-forestry,[75] afforestation, or reforestation.[76] Even a change of vegetative species type can have an effect, as some grasses send carbon into deeper root systems.[77]

Forestland protection comes in two primary forms. The first is conservation oriented programs which keep forestland in the hands of foresters rather than convert it to some other developed use. These forests may be subject to forestry activities, including extraction, which can have a significant sink effect, as long as they are continually reforested or otherwise managed under carbon-sensitive policies. Regardless, at the very least maintaining forest operations ensures against a major loss of a carbon sink as would occur if forests were developed, and which might be exacerbated by the potential fossil fuel use-intensive uses to which the property may then be put. The second primary form of forestland protection is preservation oriented—policies that simply preserve forests free of forestry operations.

One way in which either forest operations conservation or forest preservation can occur is through afforestation, which is, according to the IPCC, the establishment of new forests on lands that have historically not contained them.[78] Total forest acreage in the U.S. has rebounded from early losses to cover about 1/3 of the U.S. today.[79] Given a historical baseline of 45% forest coverage, 12% of U.S. land theoretically could be replanted via afforestation. Restoring the full 12% may be unrealistic, since much of the relevant land remains locked up in agricultural or other land uses. Nonetheless, some of this land has been taken out of commission as agricultural land, and thus might be suitable for replanting. Indeed, between 1982 and 1997, 14 million acres of former agricultural lands were converted to forest. Notably, however, a significant acreage of private forests was converted to agricultural or developed lands during the same time period.[80] In addition, there may be some lands not historically forested that could be planted in forest cover.

1. Federal

a. Federal Regulations

At the federal level, there is very little prescriptive regulation aimed specifically at land preservation aside from policies that apply to federally owned lands, which make up nearly 1/3 of the U.S. land base. In the forestry context, for example, national parks, wilderness areas[81] and forests subject to the U.S. Forest Service's roadless rule[82] are *de facto* conservation/preservation areas. Of course, such policies could change in the future, but they currently protect a vast quantity of resources crucial to combating climate change—for example, nearly one-third of the land administered by the U.S. Forest Service is designated as wilderness.[83]

At least two federal statutes do prescriptively regulate private land conservation, however. The ESA indirectly serves to preserve land in at least some circumstances, as a result of its mandate to protect at-risk species and their critical habitat. The statute with perhaps even greater potential to conserve land is the CWA, with its section 404 permitting program which governs the dredging and filling of wetlands. The 404 program, overseen by the U.S. Army Corps of Engineers, can facilitate federal government conservation or preservation of carbon-loaded wetlands, including the many forested wetlands along the nation's coast and a variety of other wetlands filled for agricultural operations. Yet this remains a potential only—the Corps of Engineers approves the overwhelming majority of applications for wetland fill permits, despite the potential of wetlands to sequester substantial quantities of carbon.[84]

According to the IUCN, coastal wetlands sequester fifty times more carbon in their soil per unit of area than tropical forests and ten times more than temperate forests.[85] Coastal wetlands have great potential for carbon sequestration since their continual accretion and burial of nutrient-rich sediments accumulates carbon over longer time periods and at higher rates than other ecosystems.[86] Even so, coastal wetlands are under tremendous strain, primarily related to commercial and residential development activities in the coastal zone[87] as well as agricultural, industrial, and energy development along the coast.[88]

A significant amount of U.S. coastal wetlands have already been developed,[89] with total wetland losses accelerating in recent years.[90] The state of Louisiana is losing 6,600 acres of coastal wetlands a year,[91] and in only the last fifteen years Florida has lost 84,000 acres of wetlands to urban development—a rate of 5,600 acres a year.[92] Coastal watersheds in the Great Lakes, Atlantic Ocean and Gulf of Mexico lost 59,000 acres each year from 1998 to 2004.[93]

The primary reason that the 404 program has not been utilized to address climate change is that the administration of the CWA does not explicitly contemplate impacts on climate. Rather, the program focuses on water quality impacts, allowing dredge and fill of wetlands when there is no practicable alternative that is less damaging to aquatic resources or when the nation's waters would not be significantly degraded.[94] Importantly, however, the program does require wetland offsets that could become significant carbon sinks.[95] Additionally, other adjustments in policy would allow the 404 permit requirements to play a greater role in preserving wetlands. Currently the 404 program exempts "normal" agricultural operations.[96] Some scholars argue that eliminating this exemption "could protect many jurisdictional wetlands that are currently allowed to be plowed with impunity," and that, "without the exemption for those wetlands that are impacted, mitigation would be required to offset the functions impacted by the agricultural activities, as is required for other types of activities that impact jurisdictional wetlands."[97]

In the future, Congress may pass federal statutes aimed at private forest or agricultural lands conservation or preservation, but it has yet to do so. Accordingly, the primary mechanisms by which the federal government seeks to influence agricultural and forest conservation and preservation are incentive programs and subsidies.

b. Federal Incentive Programs and Subsidies

A variety of existing federal programs could be used to incentivize agricultural or forest conservation and preservation, discourage GHG emitting activities, or facilitate information dissemination to achieve mitigation goals. These programs might also be used to facilitate the purchase or creation of conservation easements to preserve carbon sinks, or to make outright property purchases. Of course, many of these programs are largely subsidized by federal tax dollars, making their implementation vulnerable to budget cutbacks during times of fiscal restraint.

One healthy program, the farm bill, has consistently expanded its budget, with the 2008 version topping out at $284 billion.[98] Still, commentators have speculated that as a result of challenging economic times, even the farm bill will suffer. The "number and scope of new programs is likely to be far smaller" in the next farm bill, and "funding for any new programs will likely have to be offset by reductions to existing programs."[99] In addition, countervailing subsidies can undermine existing GHG mitigation programs. The U.S. is one of the greatest subsidizers of agriculture in the world, paying billions each year in subsidies, many of which are for GHG intensive commodity crop production[100] and which give rise to a number of other environmental harms.[101]

Despite inconsistent government support and economic constraints, some programs remain effective at fostering agricultural or forest land protection; and some may be good models for devising new incentive programs. Perhaps one of the most well-known such initiatives is the Conservation Reserve Program (CRP), which typically pays farmers to retire land from production for ten to fifteen years if the land is of particular environmental importance or is environmentally vulnerable.[102] In 2008, more than 34 million acres were enrolled in CRP, though the 2008 Farm Bill capped the amount of acreage that could be enrolled to 32 million (around 7 million acres lower than the previous cap).[103] The program has been described as "the largest environmental program on private lands in the United States," sequestering 48 million more metric tons of CO_2 than under the business as usual scenario, according to the U.S. Department of Agriculture (USDA).[104] The 2008 Farm Bill "expanded [CRP] eligibility to include management practices on private forest lands and other natural resource areas,"[105] and has funded projects to, for example, plant up to 500,000 acres of bottomland hardwoods, some of the most productive forestlands for sequestering carbon.[106] Still, as Professor Angelo has observed, "the amount of money devoted to…conservation programs pales in comparison to the money expended on commodity subsidy programs . . . approximately 1.5 billion dollars per year is spent on the [Conservation Reserve Program] as compared to the 20 billion dollars per year spent on the commodity subsidy programs."[107]

Another incentive-based initiative, the Wetlands Reserve Program,[108] assists landowners in restoring and maintaining wetlands through cost sharing or the creation of easements for restoring wetlands on agricultural land.[109] Landowners have three options. First, a perpetual conservation easement granted to the USDA may allow them to receive payment for the full cost of restoration, or second they may grant a thirty year easement to the USDA and receive three-quarters of the restoration cost. Finally, a landowner may enter into a cost-sharing agreement with the federal government to restore or enhance wetland functions.[110] Nearly $230 million has been spent under the program to enroll more than 2 million acres of wetlands.[111]

In the forestry sector, the Forest Legacy Program[112] enlists the Forest Service and state forestry agencies in preventing the conversion of private forestlands to non-forest uses, primarily through the purchase of conservation easements. The federal government may fund up to 75% of project costs, while the remaining 25% comes from private, state or local sources. Landowners also benefit from reduced taxes associated with the restrictions placed on land use.

The U.S. Department of Agriculture offers a variety of other voluntary, incentive-based programs to promote conservation or preservation of agricultural or forested lands. These include the Environmental Quality Incentives Program,[113] the Conservation Stewardship Program,[114] the Agricultural Management Assistance Program,[115] the Healthy Forests Reserve Program,[116] the Conservation of Private Grazing Lands Program,[117] the Farm and Ranch Lands Protection Program,[118] and the Grassland Reserve Program.[119] The responsible government agencies might use these measures more aggressively than they currently do, or conceivably might adjust them administratively to focus more explicitly on GHG mitigation.[120] For its part, Congress could also adjust existing programs or develop other subsidy programs designed specifically to target GHG emissions reductions and sequestration.

Finally, the U.S. Congress could provide disincentives for carbon intensive agricultural or forestry activities, or coerce adoption of carbon sequestration policies. Indeed, Congress could require administrative agencies to do so *through* existing subsidy policies. The federal government could take an instructive cue from the European Union, which in 2003 began requiring that certain environmental requirements must be met before agricultural interests could receive subsidies.[121]

c. Federal Cap-and-Trade + Carbon Offsets: a Combined Regulatory and Incentive-Based Approach

A potentially significant mechanism for encouraging forestland and agricultural conservation and preservation is offset programs, either stand-alone or coupled with a regulatory cap-and-trade or carbon taxation system. These programs work by allowing industries to meet their emissions cap or taxation requirements (or public relations goals) by offsetting emissions through agricultural or forestry carbon sequestration projects. Though not gaining traction to date, most iterations of proposed domestic climate legislation in the U.S. have provided for carbon offset projects driven by investment in, or credit purchases from, approved sequestration projects—primarily those related to forests.[122]

These programs have potential in part because policies aimed at reducing emissions alone from the agricultural and forest sectors may not be as attractive as those that both reduce emissions and increase the productivity of operations.[123] Increasing productivity may occur through expanding and adjusting existing agricultural and forestry operations, causing more carbon to be sequestered, or by establishing new GHG offset projects that allow industry to defer costs associated with emissions reduction expenses.

As discussed in greater detail in Part V below, commentators have called for incorporating farming and land use offset investments into cap-and-trade programs or for establishing voluntary offset programs.[124] In addition to forestry projects, the U.S. government has considered agricultural offset or payment programs to encourage conservation tillage, reduction of nitrogen fertilizer, change in manure management practices, and conversion of agricultural lands to forests or grasslands.[125]

2. State and Local Initiatives

a. State and Local Regulations

State and local governments may use their land use regulatory authority to zone for the conservation or preservation of agricultural or forest lands. An example is Washington County, Maryland's Forest Conservation Ordinance,[126] implementing the Maryland Forest Conservation Act.[127] This Act requires all counties in Maryland with less than 200,000 acres of forest cover to adopt ordinances to conserve forests.[128] Washington County's ordinance provides that development of land expected to remove 40,000 square feet or more of forest must submit a mitigation plan to the county planning commission.[129] Funds generated by mitigation requirements are used for conservation easement purchases and forest planting in sensitive environmental areas.[130]

State and local governments may also develop purchase or transfer of development rights programs (PDR and TDR programs). These allow governments to directly purchase development rights to maintain forest and agricultural lands, or they may prohibit development of lands in one area and allow the transfer of those rights to areas elsewhere that may otherwise be subject to zoning restrictions prohibiting the development sought.[131] Similarly, state and local governments may develop urban growth boundaries to protect agricultural and forest lands. Oregon, for example, maintains a comprehensive growth boundary plan,[132] and protects rural lands outside the boundary including non-urban agricultural and forested lands.[133]

b. State Incentive Programs and Subsidies

State conservation and land management programs very similar to those at the federal level exist in most states, and include programs aimed at cost-sharing, technical assistance, or tax policy. Various states have specific programs aimed at GHG emissions mitigation or sequestration.[134] A number of states have designed agricultural district programs to preserve agricultural land from "indiscriminate conversion to nonagricultural uses . . . ."[135] Property owners voluntarily sign contracts agreeing to maintain their land in agricultural use for a set period and receive a range of benefits in return, from differential tax assessments to deferred assessments to protection from eminent domain, annexation, or anti-agricultural statutes.[136] Other states have focused on ecosystem service programs. The Florida Ranchlands Environmental Services Project,[137] for example, provides ecosystem service payments to ranchers to achieve water storage, phosphorus retention and wetland habitat enhancement through mechanisms other than man-made public works projects.[138]

c. State Cap-and-Trade + Carbon Offsets

Though a federal cap-and-trade program for carbon emissions has not materialized as of 2013, California has created just such a scheme, and it includes an offset program that covers the agricultural and forestry sectors.[139] The Global Warming Solutions Act of 2006,[140] also known as AB 32, seeks to cap and reduce GHG emissions to 1990 levels by the year 2020 and achieve an 80% reduction from 1990 levels by 2050.[141] AB 32 provides a GHG offset program for certain types of agricultural (livestock-related) and forestry (including urban forestry) projects. Entities may use offset credits to meet up to 8% of its triennial compliance obligation under the program.[142]

In addition to offset programs driven by GHG emissions regulation, there are a variety of voluntary carbon offset markets where carbon credits may be purchased by businesses, individuals or interest groups seeking to reduce their "carbon footprint," perhaps for public relations or other purposes or in anticipation of future climate regulation. Some of these programs have focused directly on agricultural offsets.

By mid-2009, 10,000 farmers across nearly 35 states had allocated more than 10 million acres to offset projects, though that number may have dropped as hopes of a federal carbon cap-and-trade program have waned.[143] Even so, entities like the Pacific Northwest Direct Seed Association[144] have provided 30,000 tons of CO_2 offset credits to Entergy, an energy company. These credits were generated by farmers who agreed to use a "direct seed" agriculture method for at least 10 years.[145] Other programs include the National Farmers Union and the Iowa Farm Bureau, the Illinois Conservation and Climate Initiative, the Indiana Environmental Credit Corporation, and the Upper Columbia Resource Conservation and Development Council.[146] The scope of these and similar programs cover no-till crop management, conversion of cropland to grass, managed forests, grasslands, and rangelands, new tree plantings, anaerobic digesters and methane projects, wind, solar, or other renewable energy use, and forest restoration.[147]

B. Changing Agricultural Methods[148]

Changes in agricultural methods through adjustments in crop cultivation and livestock production could by some estimates offset one quarter of yearly global emissions from fossil fuel use—especially if driven by the right economic incentives.[149] In the U.S., studies estimate that between 257 and 807 million tons of CO_2 equivalent (up to 11% of U.S. 2007 emissions) can be sequestered in the country's agricultural soils each year.[150] Importantly, "agricultural GHG mitigation options are found to be cost competitive with non-agricultural options (e.g., energy, transportation, forestry [GHG mitigation options]) in achieving long-term (i.e., 2100) climate objectives."[151]

Agricultural methods can be adjusted to mitigate GHG emissions in one of two ways. First, a variety of improvements related to crop cultivation may facilitate GHG mitigation, both with regard to carbon (through tillage, crop residue management, restoration of organic soils drained for crop production, restoration of degraded lands, and changes in the type of agricultural operation engaged in, such as conversion of cropland to grassland) as well as methane and N_2O (through nutrient use and fertilization methods).[152] Second, adjustments in livestock operations can mitigate GHGs, primarily related to grazing, manure management, methane capture for biogas production, and improved diet through the use of specific feeds and feed additives.[153] Intensity and timing of grazing can influence carbon accrual in soils,[154] and rotational grazing of livestock can both provide the soil carbon benefits of perennial crops and increase beef production.[155]

C. Forest Management Practices and Linkage of Forests with Other Sectors

As with agricultural operations, forestry practices can be adjusted where forest operations remain in place. Afforestation, reforestation, stand density, forest road standards, riparian buffer zone expansion,[156] and annual allowable cut requirements may be utilized to increase carbon sequestration in forest operations. In addition, harvesting long-term wood products, reduced-impact logging, forest certification scheme participation, reducing fertilizer usage, and agro-forestry[157] can reduce emissions and/or sequester carbon.[158] Though fertilizer is a source of GHG emissions, and controlled burning of forest lands can emit carbon during burning events, these mechanisms may also be used in forests to enhance carbon sequestration and forest productivity and contribute to forests being a greater GHG sink overall. Delaying rotation of forest stocks to allow for more carbon sequestration can be of further benefit.[159]

D. Biofuels: Substituting Agricultural or Forestry Feedstock for Fossil Fuels

The use of grains, crop residue, cellulosic crops like switchgrass, sugarcane, or trees for energy in lieu of fossil fuels releases CO_2, but has the potential, in theory, to create a closed loop system whereby carbon emitted from biofuels is continually "re-sequestered" during the process of renewing these fuel sources.[160] This is unlike the open-ended use of non-renewable fossil fuels.[161] Importantly, of course "the net benefit to atmospheric CO_2 [ ] depends on energy used in growing and processing the bioenergy feedstock."[162] Yet, concerns over impacts on other land uses, including for food production, biodiversity protection, and other environmental uses, make the overall effects of bioenergy uncertain.

A primary biofuel debate regards the relative benefit of using corn-based ethanol, considering that it is carbon-intensive to cultivate and creates stress on the food sector. The use of cellulosic ethanol from wood-based and other products, on the other hand, provides some potentially significant advantages over corn-based ethanol in terms of relative GHG emissions.

At least one study has found that the use of cellulosic ethanol results in a 65% reduction in GHG emissions relative to the use of corn ethanol.[163] A primary reason for this is that corn-based ethanol production requires more energy, water, and fertilizer use due to more frequent cultivation requirements. Cellulosic ethanol production, on the other hand, requires far less frequent cultivation inputs[164] (occurring a few times over 20 to 50 years for managed stands, less frequently for unmanaged stands).[165]

Second, cellulosic ethanol production has the potential to use virtually no fossil fuel in the conversion process, because waste biomass material can itself be used as a fuel to drive the process, rather than fossil fuels. In addition, cellulosic ethanol feedstocks sequester more carbon in the soil than do corn feedstocks, with switchgrass, for example, maintaining a root system that penetrates over 10 feet into the soil and weighs as much as an entire year's growth aboveground (6-8 tons per acre).[166] Perhaps most importantly, cellulosic ethanol does not place a corollary strain on food products and their prices like corn-based ethanol.

In fact, as the pulp and paper and timber industries continue to move overseas, the development of cellulosic ethanol markets would provide a market in which private forest owners may participate, and could be an important incentive to encourage them to maintain forest lands as carbon sinks, rather than to develop them for residential, commercial, or industrial development. Of course, scholars have cautioned against perceiving cellulosic ethanol as a "panacea," noting that the "concerns associated with planting large areas of plants for cellulosic biofuels depend in large part on what land uses they are replacing."[167] If cellulosic ethanol production operations "replace fields currently occupied by industrial commodity crops, the environmental and energy benefit could be significant. However, if the same acreage of industrial commodity crops continues to be grown and additional natural lands are converted to grow cellulosic biofuel crops, there would likely be additional environmental harms . . . ."[168]

Though the potential promise of biofuels is substantial, technological progress has yet to scale up biofuel use for industrial and commercial purposes and to meet the GHG mitigating potential of biofuels. Even so, a variety of federal programs are aimed at encouraging private, state, and local entities to perform research on and use forest biomass for energy, such as the Forest Biomass for Energy program[169] and the Community Wood Energy program.[170] The 2008 farm bill created the Biomass Crop Assistance Program to "assist in the development of renewable energy feedstocks, including cellulosic ethanol, and to provide incentives for producers to harvest, store, and transport biomass."[171] Renewable fuel or portfolio standards that require biofuel use may also be crafted at the national, state, and local levels.[172] Chapter 16 discusses U.S. biofuels policy in detail.

E. Barriers to Mitigation[173]

Though agriculture and forestry provide vast GHG mitigation promise due to their unique capacity to draw GHGs back in from the atmosphere, the sequestration opportunities they present special political and temporal implications that complicate reliance on these sectors. Most of these problems are related to saturation, additionality, leakage, and permanence, each of which will here be discussed in turn.

Saturation is the maximum storage capacity of agricultural and forested lands. Soils or terrestrial biomass subject to targeted carbon sequestration projects may fully saturate 15-60 years after project inception, though forests take longer to saturate, around 80 years.[174] One way to avoid saturation is to cultivate what would otherwise be a steady-state forest over time and selectively harvest and reforest over time to maintain forest succession.[175] This might be particularly effective in maximizing carbon sequestration over specified time frames if the forest products removed are ultimately used in semi-permanent uses, such as construction. As scholars note, "[e]ven if the forest is harvested, however, sequestration can be long lived if slow-growing older trees are processed to lumber used in construction of houses that last for decades."[176]

In addition, it can be difficult to ensure that forest or agricultural offsets are "additional" to what would have otherwise been achieved.[177] A related issue is the baseline used to judge agricultural or forest mitigation gains, an often difficult task.

Reversability, or permanence, presents another challenge. A sudden change in management may undermine gains, which may also result from natural or intentional disturbances like fires, insect blights (pine beetles, etc.), disease, or invasive species, just to name a few examples.

Uncertainty regarding both science and the practical mechanisms by which agricultural and forest GHGs are sequestered or limited presents additional hurdles. Much less is known about GHG mitigation from agriculture and forestry than from industrial activities, especially with regard to measurement, monitoring, and verification. Product life cycles present particular difficulties for measurement and monitoring. Carbon-based products, for example, can end up as short-term products like food or paper, or long term products like lumber construction. At the end of their life cycle, the products' carbon might be released very quickly (if burned for energy or disposal) or very slowly (if landfilled).

In addition, while the amount of carbon stored above ground in forests is relatively easy to measure, soil carbon is more difficult to assess. For example, measuring methane emissions from enteric fermentation is difficult, while measuring methane used for energy production out of manure management systems is relatively easy.[178] The variability between seasons and locations adds an additional layer of complexity.

The final three mitigation barriers are leakage, transaction costs, and property rights complications. Leakage results through displacement of emissions, whereby reduction of production in one area may be offset by increases in another area. Transaction costs may be substantial if administrative mechanisms are complex or poorly developed. Property rights can give rise to a basic tragedy of the commons scenario: unless the owners of agricultural and forest lands are compensated for the public environmental benefits that their land provides, they may have no incentive to preserve those benefits.

VI. Tipping Towards Source or Sink?: Future Issues for U.S. Agriculture and Forestry

Perhaps the greatest threat to the use of agriculture and forests as sinks to combat climate change is simply the loss of agricultural and forested lands to more remunerative use for development. Developed land in the U.S. increased by 25 million acres (34%) between 1982 and 1997, which "means that more than one-fourth of all of the land converted from rural to urban and suburban uses since European settlement occurred in only 15 years."[179] The 34% increase in land development corresponded with a population growth of only 15%; land consumption occurred more than twice as fast as population growth.[180] Furthermore, "the mismatch between land development and population growth is widening. Between 1982 and 1992, land was developed at 1.8 times the rate of population growth. Between 1992 and 1997, that multiple had grown to 2.5."[181]

This poses serious threats to the maintenance of lands as agricultural or forested landscapes. Indeed, the carbon sink potential of private forests in the U.S. is projected to drop by nearly two-thirds between 2010 and 2050.[182] As a result, "absent any policy interventions or unforeseen changes in natural, economic, or institutional phenomena, the forest sector's role in partly offsetting the country's GHG emissions will diminish."[183]

A. Agriculture and a Growing Population's Demand for GHG-intensive Food

The global population is expected to increase by nearly 20% by 2050, reaching nearly 9 billion, with a corresponding 70%-100% increase in agricultural demand due not only to population growth, but also to energy demands and higher incomes in developing countries.[184] It is true that technological advancements have facilitated an increase in the global average daily availability of calories per capita, despite the fact that per-capita agricultural land acreage has declined. Yet while growth in land productivity is expected to increase, it will do so at a declining rate, and any increased productivity will require increased demand for energy and GHG emissions-intensive irrigation and fertilizer use.[185]

Developing nations are expected to rely increasingly on more carbon-intensive food stocks, like meat. Meat demand in the developing world rose at an increasing annual growth rate from 1967-1997, primarily due to demand from China, and is projected to increase again by 57% between 2000 and 2020.[186] Indeed, in China alone meat consumption doubled over the past twenty years and is expected to double yet again over the next twenty.[187] Methane and N_2O emissions will rise along with demand for meat and dairy products, and as nations continue to move toward larger livestock production operations.[188]

Related to livestock production is the ever-increasing reliance of growing populations on corn-based products. The production of corn has been criticized for creating a variety of climate related harms. Corn is fed to virtually every type of livestock that is harvested, including cattle, poultry, pork, and fish, and is an ingredient in virtually every processed food for sale for human consumption. The United States is the leading producer of corn worldwide, growing nearly 40% of the global total.[189] Some of the more disturbing research has found that a majority of the carbon in American citizen tissues is derived from corn, most of which humans cannot even digest without carbon-intensive industrial processing.[190]

Not only is such processing GHG intensive, but corn "is one of the most energy-intensive, water-intensive, and pesticide and fertilizer intensive crops we grow."[191] In the U.S., "[i]t is only by virtue of America's market-distorting subsidy programs that farmers have a reason not only to grow corn, but to grow it in such a high-yield fashion requiring large inputs of fossil fuels and water which contribute to degradation of the environment."[192] Yet, global pressures for corn products will only rise under current projections. Corn crops "have faced increasing demand in the world market over the past ten years as they are sources of both human and animal food."[193]

Indeed, it seems clear that in the face of rising populations, a portfolio of strategies will be necessary to just keep agricultural GHG emissions at current levels, much less reduce them. Increasing crop yields, putting a price on agricultural GHGs, and the numerous other mitigation approaches discussed above will be crucial if agriculture is to tip toward being a part of the climate change solution, rather than increasingly tipping toward being a major contributor to GHG emissions and climate change.

B. Forests and a Growing Population's Demand for Land: a Southeastern Case Study

By far, the largest categorical contribution in agriculture and forestry to carbon sequestration in the U.S. is the preservation of forestland.[194] Yet even this bright spot in U.S. GHG mitigation is under threat. The U.S. Forest Service's "Southern Forest Futures Project" summary report (Futures Report) provides a case study of threats to U.S. forests as population, agricultural, and land development pressures rise. The Futures Report forecasts that the southeastern U.S. may lose up to 23 million acres (or 13%) of forests by 2060 due to urbanization, population growth, invasive species, and climate change. For perspective, consider that this amount would be roughly equivalent to clearing all of the forests within the entire state of Alabama.[195] This deforestation would be a huge blow not only environmentally, but economically, given the importance of the forestry sector to the southeastern U.S.[196]

The case of southeastern U.S. forests demonstrates that in the future deforestation will not be a potential problem limited to the Amazon, Indonesia, or other developing regions. Though U.S. forests have recovered from the historical lows of the early 1900s,[197] a return to a deforestation trajectory would be a significant setback for domestic forest resources and the local services they provide as well as the utilization of forests globally to combat climate change. Indeed, the Futures Report found that forest losses in the south would negatively impact carbon storage capacity in the region, with the amount of carbon sequestered in southern forests and their soils reaching a maximum in 2020,[198] and then declining over the next four decades.[199] This decline "would be a challenge for carbon mitigation policies, presenting a dynamic baseline where a first order policy objective would be to *stabilize* rather than expand forest carbon stocks."[200]

In other words, even if the political will could be garnered to pass forest carbon climate mitigation policies in the region, not only would southeastern forests be unable to sequester additional amounts of carbon, but it also would be exceedingly difficult to prevent southeastern forests from becoming an increasing source of atmospheric carbon. And all this is notwithstanding the seeming lack of political will in the southeastern U.S. to pass even basic forest management standards for timber extraction, much less for carbon sequestration.[201] Ultimately, some increased measure of federal or state regulatory or incentive-based inputs into private forest management will be needed to address increasing threats to these forests in the coming years.

VII. Conclusion

Both the agricultural and forestry sectors are potentially significant sources of global GHGs. Yet unlike most other sectors of the economy, both of these sectors maintain vast and potentially unmatched potential to be climate change mitigators, whether through sequestering carbon or using methane emissions or biofuels as substitutes for fossil fuels. Consider the forest sector.

Though the many ecosystem services provided by forests are well-known, many are related to climate change mitigation. Forests provide a renewable source of building materials and paper products and a means of regulating local ambient air temperatures in urban and rural areas during the summer, which in turn lowers fossil-fuel driven electricity usage and produces energy cost savings. Forests are also a source of renewable fuel in the form of cellulosic ethanol and renewable and biodegradable plastics, to name only a few examples. Perhaps most importantly forests are a global climate regulator and major carbon sink.

Yet as population and associated land development pressures increase—even pitting agriculture against forests as more land is needed to feed increasing populations—solutions aimed at conserving, preserving, and otherwise maximizing the GHG mitigation potential of agriculture and forestry are a necessity. These solutions may be regulatory, with greater federal or state guidance on agricultural and forest operations or sink preservation, or they may be incentive-based. To combat climate change effectively, we will need to harness the power of agriculture and forestry to feed the world, produce energy, *and* be a reservoir for GHGs emitted from all other sectors of the economy.

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[2] SARA J. SCHERR & SAJAL STHAPIT, WORLDWATCH INSTITUTE, REPORT 179, MITIGATING CLIMATE CHANGE THROUGH FOOD AND LAND USE 15 (Lisa Mastny ed. 2009) *available at* http://www.worldwatch.org/system/files/179%20Land%20Use.pdf.

[3] SMITH ET AL., *supra* note 1, at 498.

[4] Mary Jane Angelo, *Corn, Carbon and Conservation: Rethinking U.S. Agricultural Policy in a Changing Global Environment* 17 GEO. MASON L. REV. 593 (2010).

[5] RENÉE JOHNSON, CONGRESSIONAL RESEARCH SERVICE, RL33898, CLIMATE CHANGE: THE ROLE OF THE U.S. AGRICULTURE SECTOR 2-3 (2009), *available at* http://www.fas.org/sgp/crs/misc/RL33898.pdf; *see also* ENVIRONMENTAL PROTECTION AGENCY, EPA 430-R-12-001, *Agriculture*, *in* INVENTORY OF U.S. GREENHOUSE GAS

EMISSIONS AND SINKS: 1990-2010 (2012) [hereinafter EPA GREENHOUSE GAS INVENTORY REPORT]. The contribution of agriculture to U.S. GHG emissions may very well be higher once the life cycle of meat production is included. The EPA, however, adopts 8% as the contribution of agriculture to U.S. GHG emissions. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, *Sources of Greenhouse Gas Emissions*, http://www.epa.gov/climatechange/ghgemissions/sources.html.

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[7] *See id*. at 1206–09; CHARLIE PARKER, ET AL., GLOBAL CANOPY PROGRAMME, THE LITTLE REDD+ BOOK 16 (3d ed. 2009) *available at* http://unfccc.int/files/methods_science/redd/application/pdf/the_little_redd_book_dec_08.pdf; BASTIAAN LOUMAN ET AL., INT'L UNION OF FOREST RESEARCH ORGANIZATIONS, FOREST ECOSYSTEM SERVICES: A CORNERSTONE FOR HUMAN WELL-BEING, ADAPTATION OF FORESTS AND PEOPLE TO CLIMATE CHANGE—A GLOBAL ASSESSMENT REPORT 15, 16–20 (Risto Seppälä et al., eds., 2009), *available at* http://www.iufro.org/science/gfep/embargoed-release/download-by-chapter/ (follow "Download chapter 1" hyperlink).

[8] Ralph Alig, et al., *Mitigating Greenhouse Gases: The Importance of Land Base Interactions Between Forests, Agriculture, and Residential Development in the Face of Changes in Bioenergy and Carbon Prices*. 12 FOREST POL'Y & ECON. 67 (2010).

[9] CONSTANCE L. MCDERMOTT ET AL., GLOBAL ENVIRONMENTAL FOREST POLICIES: AN INTERNATIONAL COMPARISON 6 (2010).

[10] SCHERR, *supra* note 2, at 7.

[11] OFFICE OF ATMOSPHERIC PROGRAMS, CLIMATE CHANGE DIVISION, U.S. ENVIRONMENTAL PROTECTION AGENCY, DRAFT: GLOBAL ANTHROPOGENIC NON-CO2 GREENHOUSE GAS EMISSIONS: 1990 - 2030 1-2 (2011) [hereinafter GLOBAL ANTHROPOGENIC EMISSIONS] *available at* http://www.epa.gov/climatechange/Downloads/EPAactivities/EPA_NonCO2_Projections_2011_draft.pdf.

[12] OFFICE OF ATMOSPHERIC PROGRAMS, U.S. ENVIRONMENTAL PROTECTION AGENCY, GREENHOUSE GAS MITIGATION POTENTIAL IN U.S. FORESTRY AND AGRICULTURE 1-1 (2005) [hereinafter GREENHOUSE GAS MITIGATION POTENTIAL].

[13] SMITH ET AL., *supra* note 1, at 501.

[14] *Id.* at 499, 505.

[15] RONALD STEENBLIK & EVODKIA MÖISÉ, INTERNATIONAL FOOD & AGRICULTURAL TRADE POLICY COUNCIL, COUNTING THE CARBON EMISSIONS FROM AGRICULTURAL PRODUCTS: TECHNICAL COMPLEXITIES AND TRADE IMPLICATIONS 1 (2010) *available at* http://www.agritrade.org/events/documents/Steenlik_Moise_Counting_Carbon.pdf.

[16] *Id.* at 505.

[17] SMITH ET AL., *supra* note 1, at 503.

[18] JOHN HOROWITZ & JESSICA GOTTLIEB, U.S. DEPT. OF AGRICULTURE ECONOMIC RESEARCH SERVICE, THE ROLE OF AGRICULTURE IN REDUCING GREENHOUSE GASES 3 (US Department of Agriculture 2010) *available at* http://www.ers.usda.gov/media/140711/eb15_1_.pdf.

[19] GLOBAL ANTHROPOGENIC EMISSIONS, *supra* note 11, at 2-1 – 2-5.

[20] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 1-1.

[21] SOLOMON G. HAILE, ET AL., UNIVERSITY OF FLORIDA EXTENSION, THE INSTITUTE OF FOOD AND AGRICULTURAL SERVICES, GREENHOUSE GAS MITIGATION IN FOREST AND AGRICULTURAL LANDS: REDUCING EMISSIONS 2 (2008).

[22] SMITH ET AL., *supra* note 1, at 504.

[23] HAILE ET AL., *supra* note 21, at 2.

[24] SMITH, *supra* note 1, at 504.

[25] JOHNSON, *supra* note 5, at 4.

[26] HOROWITZ, *supra* note 18, at 2.

[27] SMITH ET AL., *supra* note 1, at 502-503.

[28] MCDERMOTT ET AL., *supra* note 9 at 6; PARKER, *supra* note 7 at 16.

[29] MCDERMOTT ET AL., *supra* note 9; s*ee also REDD and the Evolution of an International Forest Regime, Special Issue*, 10 THE INTERNATIONAL FORESTRY REVIEW 3 (2008). It should be noted, however, that international climate negotiations are nowhere near achieving a legally binding agreement on climate that includes forests. For more detail on international negotiations, see Chapter 2 in this volume.

[30] FOUNDATION FOR INTERNATIONAL ENVIRONMENTAL LAW AND DEVELOPMENT, GUIDE FOR REDD-PLUS NEGOTIATORS 4 (2011) *available at* http://www.field.org.uk/files/field_redd-plus_eng_may2011_web.pdf.

[31] PARKER, *supra* note 7, at 17.

[32] Alig et al., *supra* note 8 at 74.

[33] *Id.* at 67.

[34] JOHNSON, *supra* note 5 at 5.

[35] DAVID N. WEAR & JOHN G. GREIS, U.S. FOREST SERV., THE SOUTHERN FOREST FUTURES PROJECT: SUMMARY REPORT 26–31, 35 (2011), *available at* http://www.srs.fs.usda.gov/futures/reports/draft/summary_report.pdf.

[36] Alig et al., *supra* note 8, at 67.

[37] SMITH ET AL., *supra* note 1, at 522.

[38] News Release, UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE, *US Forest Service Finds Global Forests Absorb One-Third of Carbon Emissions Annually*, July 14, 2011, *available at* http://www.fs.fed.us/news/2011/releases/07/carbon.shtml.

[39] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at ES-1.

[40] JOHNSON, *supra* note 5; GLOBAL ANTHROPOGENIC EMISSIONS, *supra* note 11.

[41] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at ES-1.

[42] Angelo, *supra* note 4, at 623.

[43] William S. Eubanks II, *A Brief History of U.S. Agricultural Policy and the Farm Bill*, in FOOD, AGRICULTURE, AND THE ENVIRONMENT (forthcoming) (manuscript at 4) (on file with authors).

[44] DONALD B. PEDERSEN & KEITH G. MEYER. AGRICULTURAL LAW IN A NUTSHELL 11 (West Publishing 1995).

[45] Mary Jane Angelo & Joanna Reilly-Brown, *An Overview of the Modern Farm Bill*, in FOOD, AGRICULTURE, AND THE ENVIRONMENT (forthcoming) (manuscript at 1) (on file with authors).

[46] Allen H. Olson, *Federal Farm Programs—Past, Present, and Future—Will We Learn from our Mistakes, 6* GREAT PLAINS NAT. RES. L.J. 1, 17 (2001).

[47] Eubanks, *supra* note 43 at 11.

[48] UNITED STATES DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE, *Wetlands Reserve Program*, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/wetlands/.

[49] PEDERSEN, *supra* note 44, at 31.

[50] *Id*. at 48–50.

[51] *Id*. at 356–361.

[52] Viney P. Aneja, et al., *Effects of Agriculture upon the Atmospheric Environment of the United States: Research, Policy and Regulations*, 43 ENVTL. SCI. AND TECH. 4234 (2009).

[53] Clean Water Act, 33 U.S.C. § 1251 et seq. (1972).

[54] Some agricultural activities, like those associated with concentrated animal feeding operations, are now regulated as point sources under the CWA. NATIONAL CONFERENCE OF STATE LEGISLATURES, *Concentrated Animal Feeding Operations*, http://www.ncsl.org/issues-research/agri/concentrated-animal-feeding-operations.aspx. Professor Craig argues that Congress's operation "within constitutional federalism requirements" has caused it to misjudge the constitutionality of direct federal regulatory inputs into nonpoint pollution assumed to be the sole regulatory purview of the state and local governments. Robin Kundis Craig, *Local or National? The Increasing Federalization of Nonpoint Source Pollution Regulation*, 15 J. ENVTL. L. & LITIG. 179, 179-81 (2000). Craig notes that federal regulation of nonpoint source pollution would arguably engage the federal government in land use regulation "historically viewed as belonging almost exclusively to more local levels of government," and that federalism thus restricts Congress in regulating nonpoint sources of water pollution. *Id.* at 182, 186.

[55] U.N. ENV'T PROGRAMME, GLOBAL ENVIRONMENT OUTLOOK 3: PAST, PRESENT AND FUTURE PERSPECTIVES 110 (2002), *available at* http://www.unep.org/geo/GEO3/english/pdf.htm (follow "Forests" hyperlink).

[56] *See, e.g., Los Angeles County Flood Control District v. Natural Resources Defense Council, Inc., et al.*, United States Supreme Court, Pet'r's Amici Curiae Br. No. 11-460 (2012) *available at* http://www.bbklaw.com/88E17A/assets/files/Documents/SCOTUS-Stormwater-LACounty.pdf; *Doug Decker et al., v. Northwest Environmental Defense Center, et al.*, United States Supreme Court, Nos. 11-338, 11-347 (2012) *available at* http://www.bbklaw.com/88E17A/assets/files/Documents/SCOTUS-Stormwater-DeckerBrief.pdf.

[57] Silviculture is "a branch of forestry dealing with the development and care of forests." *Silviculture Definition*, MERRIAM-WEBSTER.COM, http://www.merriam-webster.com/dictionary/silviculture.

[58] *See generally*, MCDERMOTT ET AL., *supra* note 9. For example, some state governments only provide forest owners with *suggested* substantive standards of varying scope, such as suggestions that forest owners leave a thirty foot riparian buffer zone in forest watersheds or that forest owners not clearcut parcels over fifty acres in size.

[59] For example, some state governments only provide forest owners with information regarding suggested procedures, such as the development of forest management plans or environmental impact assessment methods. *See id.*

[60] Such programs might include ones like the Forest Legacy Program, described in the text accompanying *supra* note 112.

[61] For example, some state governments pass regulations *requiring* that forest owners implement substantive forest management standards related to riparian buffer zones and clear-cutting, or requiring that forest owners implement procedural forest management plans or undertake environmental impact assessments. *See generally*, MCDERMOTT ET AL., *supra* note 9.

[62] For a recent comprehensive report on mitigation measures for U.S. agriculture and forestry *see* KAROLIEN DENEF, SHAWN ARCHIBEQUE, & KEITH PAUSTIAN, ICF INTERNATIONAL, INTERIM REPORT TO USDA UNDER CONTRACT #GS-23F-8182H, GREENHOUSE GAS EMISSIONS FROM U.S. AGRICULTURE AND FORESTRY: A REVIEW OF EMISSION SOURCES, CONTROLLING FACTORS, AND MITIGATION POTENTIAL PAGE NUMBER (2011) *available at* http://www.usda.gov/oce/climate_change/techguide/Denef_et_al_2011_Review_of_reviews_v1.0.pdf.

[63] SCHERR, *supra* note 2, at 7.

[64] For example, conservation tillage can increase carbon sequestration, while also increasing N_2O. HOROWITZ, *supra* note 18, at 3.

[65] SMITH ET AL., *supra* note 1, at 511–13. For example, "[s]ome practices, like those which elicit soil carbon gain, have diminishing effectiveness after several decades; others, such as methods that reduce energy use, may reduce emissions indefinitely." *Id*. at 513.

[66] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 1-2. For a review of agricultural mitigation options, *see* Rattan Lal, *Carbon Emissions from Farm Operations*, 30 ENVIRONMENT INTERNATIONAL 981 (2004) *available at* http://cirit.osu.edu/clusterone/LASCANET/pdf%20files/Lal_3.pdf.

[67] SMITH ET AL., *supra* note 1, at 511.

[68] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 4-1 – 4-28; HAILE ET AL., *supra* note 21.

[69] Alig et al., *supra* note 8, at 74.

[70] SMITH ET AL., *supra* note 1, at 522.

[71] Alig et al., *supra* note 8, at 67.

[72]For a list of national, state, and local land preservation programs, *see* UNITED STATES DEPARTMENT OF AGRICULTURE, *National, State, and Local Land Preservation Programs*, http://www.csrees.usda.gov/nea/nre/in_focus/ere_if_preserve_programs.html.

[73] SCHERR, *supra* note 2, at 20.

[74] Shelterbelts are forested areas surrounding agricultural lands that reduce erosion, provide energy savings for facilities on agricultural lands, increase livestock feed efficiency and livestock lifespan, reduce pesticide drift, increase irrigation efficiency, provide wildlife habitat, and, of course, store carbon. UNITED STATES DEPARTMENT OF AGRICULTURE, *Conservation Practices that Save: Windbreaks/Shelterbelts*, http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_023631.pdf.

[75] Agroforestry systems are "land-use systems where trees are managed together with crops and/or animal production systems in agricultural settings," and may be used as a tool in "watershed management, non-wood forest products and enterprises, climate change mitigation and adaptation, waste water reuse, landscape restoration, food systems through integrated territorial development, urban agriculture, and trees outside forests assessments." FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, *Agroforestry*, http://www.fao.org/forestry/9469/en/.

[76] SMITH ET AL., *supra* note 1, at 508.

[77] *Id.* at 509.

[78] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 2-2.

[79] RASBAND, *supra* note 6, at 1198-1200.

[80] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 2-2 – 2-4.

[81] Brian Finegan, *Forest Succession*, 321 NATURE 109 (Nature Publishing Group 1984) *available at* http://www.planta.cn/forum/files_planta/finegan1_108.pdf.

[82] UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE, *Roadless Area Conservation*, http://www.fs.usda.gov/wps/portal/fsinternet/!ut/p/c4/04_SB8K8xLLM9MSSzPy8xBz9CP0os3gDfxMDT8MwRydLA1cj72BTFzMTAwjQL8h2VAQAJp-nEg!!/?ss=119930&navtype=BROWSEBYSUBJECT&navid=091000000000000&pnavid=null&ttype=roadmain&cid=FSE_003853&position=RELATEDLINKS&pname=Roadless-Home.

[83] UNITED STATES DEPARTMENT OF INTERIOR, NATIONAL PARK SERVICE, *Where is Wilderness?*, http://www.nature.nps.gov/views/KCs/Wilderness/HTML/ET_03_Where.htm.

[84] Of the Corps' 80,000 permit requests annually, only about 9% required to go through a "detailed evaluation for an individual permit." Of the 9% that must file for an individual permit, less than 0.3% are denied. Brandee Ketchum, Note, *Like the Swamp Thing: Something Ambiguous Rises From the Hidden Depths of Murky Waters—The Supreme Court's Treatment of Murky Wet Land in* Rapanos v. United States, 68 LA. L. REV. 983, 1011–12 (2008) (footnotes omitted). The EPA only exercised its power to veto the Corps wetland permitting eleven times between 1972 and 2007. CRAIG PITTMAN & MATTHEW WAITE, PAVING PARADISE: FLORIDA'S VANISHING WETLANDS AND THE FAILURE OF NO NET LOSS 167 (2009).

[85] INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES, THE MANAGEMENT OF NATURAL COASTAL CARBON SINKS, IUCN WORLD COMMISSION ON PROTECTED AREAS 49 (Dan d'A Laffoley & Gabrial D. Grimsditch, eds. 2009) [hereinafter IUCN WORLD COMMISSION] *available at* http://data.iucn.org/dbtw-wpd/edocs/2009-038.pdf.

[86] *See* Joy B. Zedler and Suzanne Kercher, *Wetland Resources: Status, Trends, Ecosystem Services, and Restorability*, 30 ANNUAL REVIEW OF ENVIRONMENT AND RESOURCES, 39, 55 (2005) (citing Eric C. Brevik & Jeffrey A. Homburg, *A 5000 Year Record of Carbon Sequestration from a Coastal Lagoon and Wetland Complex, Southern California, USA*, 57 CATENA 221 (2004) *available at* http://www.slc.ca.gov/Reports/Carlsbad_Desalinization_Plant_Response/Attachment_4.pdf); *see* Gail L. Chmura, Shimon C. Anisfeld, Donald R. Cahoon, & James C. Lynch, *Global Carbon Sequestration in Tidal, Saline Wetland Soils*, 17 GLOBAL BIOGEOCHEMICAL CYCLES, 22-1 (2003); A.H. Hussein, et al., *Modeling of Carbon Sequestration in Coastal Marsh Soils*, 68 SOIL SCIENCE SOCIETY OF AMERICA JOURNAL, 1786, 1786–87 (2004).

[87] IUCN WORLD COMMISSION, *supra* note 85, at 8–9.

[88] COASTAL LOUISIANA ECOSYSTEM ASSESSMENT & RESTORATION (CLEAR), REDUCING FLOOD DAMAGE IN COASTAL LOUISIANA: COMMUNITIES, CULTURE AND COMMERCE 2 (2006), *available at* http://www.clear.lsu.edu/pdfs/clear_newsletter_20081016112354.pdf.

[89] The U.S. as a whole has lost over half of its wetlands. David Moreno-Mateos, Mary E. Power, Francisco A. Comin, and Roxana Yockteng, *Structural and Functional Loss in Restored Wetland Ecosystems*, 10 PLOS BIOLOGY 1 (2012), *available at* http://www.plosbiology.org/article/info%3Adoi%2F10.1371%2Fjournal.pbio.1001247.

[90] SUSAN-MARIE STEDMAN & THOMAS E. DAHL, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL MARINE FISHERIES SERVICE, & U.S. DEPARTMENT OF THE INTERIOR FISH AND WILDLIFE SERVICE, STATUS AND TRENDS OF WETLANDS IN THE COASTAL WATERSHEDS OF THE EASTERN UNITED STATES 1998 TO 2004 (2008) *available at* http://www.habitat.noaa.gov/pdf/pub_wetlands_status_trends.pdf.

[91] ROBERT R. M. VERCHICK, FACING CATASTROPHE: ENVIRONMENTAL ACTION FOR A POST-KATRINA WORLD 19 (Harvard University Press, ed. 2010).

[92] Matthew Waite & Craig Pittman, *Louisiana Wetlands Serve as Warning, Experts Say*, ST. PETERSBURG TIMES, Sept. 6, 2005, at 10.A, *available at* http://www.sptimes.com/2005/09/05/Worldandnation/Katrina_offers_lesson.shtml.

[93] STEDMAN, *supra* note 90.

[94] ENVIRONMENTAL PROTECTION AGENCY, *Wetlands Regulatory Authority Fact Sheet*, EPA 843-F-04-001, http://water.epa.gov/type/wetlands/outreach/upload/reg_authority.pdf.

[95] Leonard Shabman & Paul Scodari, *The Future of Wetlands Mitigation Banking*, 20(1) CHOICES MAGAZINE 65, para. 1 (American Agricultural Economics Association Publication) (2005) *available at* http://www.choicesmagazine.org/2005-1/environment/2005-1-13.pdf.

[96] Clean Water Act, 33 U.S.C. § 1344(f).

[97] Angelo, *supra* note 4, at 642.

[98] Angelo, *supra* note 45, at 2.

[99] *Id.* at 27.

[100] Angelo, *supra* note 4, at 597.

[101] SCHERR, *supra* note 2, at 32.

[102] *See* PATRICK SULLIVAN ET AL., UNITED STATES DEPARTMENT OF AGRICULTURE ECONOMIC RESEARCH SERVICE, Agricultural Economic Report No. 834, *The Conservation Reserve Program: Economic Implications For Rural America*, 19 (2004) *available at* http://ageconsearch.umn.edu/bitstream/33987/1/ae040834.pdf.

[103] Food, Conservation, And Energy Act of 2008, Pub. L. No. 110-246, §§ 1102 -1104, 122 Stat. 923 -1525 (2008); Angelo, *supra* note 4, at 630.

[104] HOROWITZ, *supra* note 18, at 4.

[105] JOHNSON, *supra* note 5, at 20.

[106] *Id.* at 17.

[107] Angelo, *supra* note 4, at 632.

[108] UNITED STATES DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE, *Wetlands Reserve Program*, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/wetlands.

[109] Wetland Reserve Program, 16 U.S.C. § 3837-3837f (1994).

[110] Angelo, *supra* note 4, at 630.

[111] UNITED STATES DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE, *Wetlands Reserve Program FY 2007 Financial and Technical Assistance Dollars to States*.

[112] UNITED STATES DEPARTMENT OF AGRICULTURE, FOREST SERVICE, *Forest Legacy Program: Protecting Private Forest Lands from Conversion to Non-Forest Uses*, http://www.fs.fed.us/spf/coop/programs/loa/aboutflp.shtml.

[113] Environmental Easement Program, 16 U.S.C. § 3839 (1990).

[114] UNITED STATES DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE, *Conservation Stewardship Program*, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp.

[115] UNITED STATES DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE, *Agricultural Management Assistance*, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ama.

[116] UNITED STATES DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE, *Healthy Forests Reserve Program*, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests.

[117] UNITED STATES DEPARTMENT OF AGRICULTURE, NATURAL RESOURCES CONSERVATION SERVICE, *Conservation of Private Grazing Land*, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/cpgl.

[118] Farmland Protection Program, 16 U.S.C. § 3838h-j (1990).

[119] The Grassland Reserve Program, 16 U.S.C. § 3838n-q (1990).

[120] *See* UNION OF CONCERNED SCIENTISTS, THE HIDDEN COSTS OF CAFOS (2008) *available at* http://www.ucsusa.org/assets/documents/food_and_agriculture/cafo_issue-briefing-low-res.pdf.

[121] Daniel Bianchi, *Cross Compliance: The New Frontier in Granting Subsidies to the Agricultural Sector in the European Union*, 19 GEO. INT'L ENVTL. L. REV. 817 (2007).

[122] Lieberman-Warner Climate Security Act of 2007, S. 2191, 110th Cong. (2007); *see also* INSTITUTE FOR ENERGY RESEARCH, *Dingell-Boucher Cap-and-Trade Bill*, (Oct. 7, 2008) *available at* http://www.instituteforenergyresearch.org/2008/10/07/dingell-boucher-cap-and-trade-bill/; American Clean Energy and Security Act of 2009 (Waxman-Markey Bill), H.R. 2454, 111th Cong. (2009).

[123] SMITH ET AL., *supra* note 1, at 515.

[124] SCHERR, *supra* note 2, at 6. For a review of the offset potential of agriculture, *see* ROGER CLAASSEN & MITCH MOREHART, UNITED STATES DEPARTMENT OF AGRICULTURE ECONOMIC RESEARCH SERVICE, AGRICULTURE LAND TENURE AND CARBON OFFSETS, Economic Brief No 14 (2009).

[125] HOROWITZ *supra* note 18, at 1.

[126] WASHINGTON COUNTY, MARYLAND, FOREST CONSERVATION ORDINANCE (2008) *available at* http://www.washco-md.net/county_attorney/pdf/forestcn.pdf.

[127] The Maryland Forest Conservation Act, Md. Code Ann., Nat. Res. Art. §§ 5-1601–1612.

[128] *Id.* at § 5-1602(b)(10).

[129] Mitigation options available to property owners include: on-site retention or planting, off-site retention or planting, natural regeneration, and payment-in-lieu of planting or retention. *Id.*

[130] WASHINGTON COUNTY, MARYLAND, DEPARTMENT OF PLANNING AND ZONING, *Forest Conservation Ordinance*, http://www.washco-md.net/planning/forest.shtm.

[131] PEDERSEN, *supra* note 44, at 373–377.

[132] OREGON DEPARTMENT OF LAND CONSERVATION AND DEVELOPMENT, OREGON'S STATEWIDE PLANNING GOALS & GUIDELINES, GOAL 14: URBANIZATION, OAR 660-004-0040 (April 28, 2006) *available at* http://www.oregon.gov/LCD/docs/goals/goal14.pdf.

[133] OREGON DEPARTMENT OF LAND CONSERVATION AND DEVELOPMENT, *Rural Development in Oregon*, http://www.oregon.gov/LCD/pages/ruraldev.aspx#Rural_Development_in_Oregon.

[134] JOHNSON, *supra* note 5, at 21–23.

[135] PEDERSEN, *supra* note 44, at 369.

[136] *Id.* at 369–370.

[137] FLORIDA RANCHLANDS ENVIRONMENTAL SERVICES PROJECT (2012) http://www.fresp.org/.

[138] *See* Jacob T. Cremer, *Tractors versus Bulldozers: Integrating Growth Management and Ecosystem Services to Conserve Agriculture*, 39 ENVTL. L. REP. NEWS & ANALYSIS 10541, 10546 (2009) (citing Sarah Lynch & Leonard Shabman, *Valuing Ecosystem Services on Florida Ranchlands: Lessons Learned*, from *The Florida Ranchlands Environmental Services Project: Field Testing a Pay-for-Environmental Services Program*, 165 RESOURCES 17 (2007) http://www.waterinstitute.ufl.edu/symposium/downloads/92718559.pdf.

[139] A number of regional carbon cap-and-trade initiatives pre-dated the California scheme, including the Regional Greenhouse Gas Initiative, the Midwestern Regional GHG Reduction Accord, and the Western Climate Initiative. *See* CENTER FOR CLIMATE AND ENERGY SOLUTIONS, *North American Cap-and-Trade Initiatives*, http://www.c2es.org/us-states-regions/regional-climate-initiatives/north-america-cap-trade.

[140] California Global Warming Solutions Act of 2006, ch. 488, §§ 1–2, Cal. Legis. Serv. Ch. 488 (A.B. 32) (West).

[141] CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY, AIR RESOURCES BOARD, *Cap-and-Trade Program*, http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm.

[142] CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY, AIR RESOURCES BOARD, *Compliance Offset Program*, http://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm.

[143] JOHNSON, *supra* note 5, at 23.

[144] PACIFIC NORTHWEST DIRECT SEED ASSOCIATION, http://www.directseed.org/.

[145] This method "avoids soil losses from oxidation associated with traditional farming techniques and also reduces the growers' fuel use and soil erosion." CENTER FOR CLIMATE AND ENERGY SOLUTIONS, *Carbon Sequestration and Offsets Solutions*, http://www.c2es.org/business/belc/climate-energy-strategies/sequestration.

[146] JOHNSON, *supra* note 5, at 23.

[147] *Id.* at 24.

[148] For a comprehensive discussion of agriculture and carbon, *see* COALITION ON AGRICULTURAL GREENHOUSE GASES, CARBON AND AGRICULTURE: GETTING MEASURABLE RESULTS (April, 2010).

[149] SCHERR, *supra* note 2, at 6.

[150] EPA GREENHOUSE GAS INVENTORY REPORT, *supra* note 5; KEITH PAUSTIAN ET AL., AGRICULTURE'S ROLE IN GREENHOUSE GAS MITIGATION (Pew Center on Global Climate Change, 2006) *available at* http://www.c2es.org/docUploads/Agriculture%27s%20Role%20in%20GHG%20Mitigation.pdf.

[151] SMITH ET AL., *supra* note 1, at 499.

[152] *Id*.

[153] SCHERR, *supra* note 2, at 5.

[154] SMITH ET AL., *supra* note 1, at 508.

[155] CONSTANCE L. NEELY AND RICHARD HATFIELD, *Livestock Systems*, in FARMING WITH NATURE: THE SCIENCE AND PRACTICE OF ECOAGRICULTURE 121–42 (Sara J. Scherr and Jeffrey A. McNeely, eds. Washington, DC: Island Press, 2007).

[156] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 2-6.

[157] Agro-forestry is producing livestock or food crops on land that also grows trees for timber or other forest products. This increases the carbon stock above ground, but also may lead to increased soil carbon sequestration. SMITH ET AL., *supra* note 1, at 508. *See also* JOHNSON, *supra* note 5, at 21.

[158] JOHNSON, *supra* note 5, at 16.

[159] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 2-2.

[160] TEXAS STATE ENERGY CONSERVATION OFFICE, *Biomass Energy from Agriculture*, http://www.seco.cpa.state.tx.us/energy-sources/biomass/agriculture.php.

[161] SMITH ET AL., *supra* note 1, at 511; GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 2-9; *See also* ENERGY FUTURE COALITION, *The Benefits of Biofuels: Environment and Public Health* (2007) http://www.energyfuturecoalition.org/biofuels/benefits_env_public_health.htm.

[163] ENERGY FUTURE COALITION, *The Benefits of Biofuels: Environment and Public Health* (2007) http://www.energyfuturecoalition.org/biofuels/benefits_env_public_health.htm.

[164] Mark Murphey Henry et al., *A Call to Farms: Diversify the Fuel Supply*, 53 S.D. L. REV. 515 (2008); Rudolf M. Smaling, *Environmental Barriers to Widespread Implementation of Biofuels*, 2 ENVTL & ENERGY POL'Y J. 287 (2008); L. Leon Geyer et al., *Ethanol, Biomass, Biofuels and Energy: A Profile and Overview*, 12 DRAKE J. AGRIC. L. 61 (2007).

[165] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 2-4.

[166] ENERGY FUTURE COALITION, *supra* note 163.

[167] Angelo, *supra* note 45, at 22.

[168] *Id.* at 23.

[169] Farm Security and Rural Investment Act of 2001, 7 U.S.C. § 8112 (2002).

[170] *Id*. at § 8113.

[171] JOHNSON, *supra* note 5, at 20.

[172] HOROWITZ *supra* note 18, at 4. An example would be the Renewable Fuel Standard program administered by the federal government, which requires that "the volume of renewable fuel required to be blended into transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022." ENVIRONMENTAL PROTECTION AGENCY, *Renewable Fuel Standard*, http://www.epa.gov/otaq/fuels/renewablefuels/index.htm. This program is discussed in detail in Chapter 16.

[173] *See* SMITH ET AL., *supra* note 1, at 525; *see also* GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12.

[174] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 2-11, 2-4.

[175] Jeff Martin & Tom Gower, *Forest Succession*, 78 FORESTRY FACTS (University of Wisconsin Department of Forest Ecology and Management) (1996) *available at* http://woodlandinfo.org/sites/woodlandinfo.org/files/pdf/FEM/FEM_078.pdf.

[176] Luther Tweeten, et al., Assessing the Economics of Carbon Sequestration in Agriculture, Presented at Ohio University Conference on Assessment Methods for Soil Carbon Pools (November 2-4, 1998), at 7, *available at* http://nature.berkeley.edu/csrd/publications/pdf/tweeten_co2.pdf.

[177] Michael Gillenwater, *What is Additionality?* (Greenhouse Gas Management Institute Discussion Paper No. 001 January 2012) *available at* http://ghginstitute.org/wp-content/uploads/content/GHGMI/AdditionalityPaper_Part-1(ver3)FINAL.pdf.

[178] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 6-11.

[179] DANA BEACH, PEW OCEANS COMMISSION, *Coastal Sprawl* 3 (2002), *available at* http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Protecting_ocean_life/env_pew_oceans_sprawl.pdf.

[180] *Id.* at 4.

[181] *Id.*

[182] GREENHOUSE GAS MITIGATION POTENTIAL, *supra* note 12, at 3-18.

[183] *Id.* at 3-22.

[184] PAUL HEISEY, ET AL., UNITED STATES DEPARTMENT OF AGRICULTURE ECONOMIC RESEARCH SERVICE, PUBLIC AGRICULTURAL RESEARCH SPENDING AND FUTURE U.S. AGRICULTURAL PRODUCTIVITY GROWTH: SCENARIOS FOR 2010-2050, Economic Brief No. 17 (2011); *see also* Jennifer A. Burney, et al., *Greenhouse Gas Mitigation by Agricultural Intensification*, 107 PROC. OF THE NAT'L ACAD. OF SCI. 12052 (2010); SMITH ET AL., *supra* note 1, at 500; *See* Jason J. Czarnezki & Elisa K. Prescott, *Environmental and Climate Impacts of Food Production, Processing, Packaging, and Distribution*, in FOOD, AGRICULTURE, AND THE ENVIRONMENT (forthcoming) (manuscript at 4) (on file with authors).

[185] SMITH, *supra* note 1, at 504.

[186] SMITH ET AL., *supra* note 1, at 502.

[187] SCHERR, *supra* note 2, at 17.

[188] GLOBAL ANTHROPOGENIC EMISSIONS, *supra* note 11, at 5-12 – 5-13.

[189] Angelo, *supra* note 4, at 595-596.

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[190] *Id.* at 596.
[191] *Id.*
[192] *Id.* at 598.
[193] MADELINE PULLMAN & ZHAOHUI WU, FOOD SUPPLY CHAIN: ECONOMIC, SOCIAL, AND ENVIRONMENTAL PERSPECTIVES 67 (2011).
[194] HOROWITZ, *supra* note 18, at 2.
[195] WEAR, *supra* note 35, at 31, 35.
[196] *Id.* at 17, 29, 5.
[197] UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE, U.S. FOREST FACTS AND HISTORICAL TRENDS (2001) *available at* http://fia.fs.fed.us/library/briefings-summaries-overviews/docs/ForestFactsMetric.pdf.
[198] WEAR, *supra* note 35, at 34.
[199] Robert Hugget et al., *Forecasts of Forest Conditions*, *in* THE SOUTHERN FOREST FUTURES PROJECT, TECHNICAL REPORT 17 (2011), *available at* http://www.srs.fs.usda.gov/futures/reports/draft/Frame.htm (follow "Chapter 5" hyperlink).
[200] WEAR, *supra* note 35, at 34 (emphasis added).
[201] MCDERMOTT ET AL., *supra* note 9, at 327 tbl.10.7.