Statement of
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Thank you for the opportunity to testify at this important hearing. I will focus my testimony here on the science of the relation between global climate change, on the one hand, and agriculture and forestry, on the other.

<u>Introduction</u>

Climate is changing all across the globe. The air and the oceans are warming, mountain glaciers are disappearing, sea ice is shrinking, permafrost is thawing, and sea level is rising. And the consequences for human well-being are already being felt: more heat waves, floods, droughts, and wildfires; tropical diseases reaching into the temperate zones; vast areas of forest destroyed by pest outbreaks linked to warming; alterations in patterns of rainfall on which agriculture depends; and coastal property increasingly at risk from the surging seas.

We know the primary cause of these perils beyond any reasonable doubt. It is the emission of carbon dioxide (CO_2) and other heat-trapping pollutants from our factories, our vehicles, and our power plants, and from use of our land in ways that move carbon from soils and vegetation into the atmosphere in the form of CO_2 . We also know that failure to curb these emissions will bring far bigger impacts from global climate change in the future than those experienced so far. Devastating increases in the power of the strongest hurricanes, sharp drops in the productivity of farms and ocean fisheries, a dramatic acceleration of species extinctions, and inundation of low-lying areas by rising sea level are among the possible outcomes.

But we also know what we can and must do to avoid the worst of these possibilities. We can transform our technologies for supplying and using energy from polluting and wasteful to clean and efficient, using new incentives to accelerate the process and new agreements and forms of cooperation to bring the rest of the world along. We can halt and reverse deforestation, and we can modify farming practices in ways that increase rather than decrease the amounts of carbon stored in agricultural soils. Indeed, with care in choice of locations and methods, we can make our farms and our forests sustainable sources not only of food and fiber but of clean, renewable biofuels to help with the energy side of the solution. Finally, we can invest in countless ways to reduce our vulnerability to the changes in climate that we don't succeed in avoiding, for example by breeding heat- and drought-resistant crop strains, bolstering our defenses against tropical diseases, improving the efficiency of our water use, and starting to manage our coastal zones with sea-level rise in mind.

When we do all this, we will benefit not only by avoiding the worst damages from climate change, but also by reducing our perilous overdependence on petroleum, continuing to improve air quality in our cities, preserving our forests as havens for biodiversity and sources of sustainable livelihoods, reducing our vulnerability to the extreme weather events that occur from time to time even when climate is not changing overall, and generating new businesses, new jobs, and new growth in the course of getting it all done.

As is apparent already from the foregoing, the relation between farming and forestry and climate change is a multifaceted one. Farming and forestry practices are sources of some of the emissions that are driving global climate change, as well as points of particular vulnerability where climate change imperils human well-being by reducing the productivity of the land…and where adaptation efforts should be focused to reduce this harm. With appropriate management, on the other hand, farms and forests can become the locus of increased carbon storage that draws down the atmospheric load of CO_2, as well as serving as sources of low-carbon renewable biofuels. In what follows, I elaborate briefly on all of these aspects.

Vulnerability and adaptation of farms and forests under climate change

The conventional wisdom about effects of climate change on the productivity of farms and forests, up until a few years ago, was that modest increases in temperature accompanied by increases in atmospheric CO_2 (which is a plant nutrient as well as a heat-trapping pollutant) and rainfall (which increases in a warmer world because evaporation increases and what goes up must come down) would lead to increases in plant growth in many regions and thus to increases in crop yields and sustainable forest output. Only when the global average temperature increase reached 3.6 degrees Fahrenheit (2^{o}C) or more above the pre-industrial value, it was thought, would the effects of heat stress on plants offset the beneficial effects of increased CO_2 and increased rainfall in enough places to lead to declines in farm and forest productivity on a global basis.

Recent improvements in understanding of plant physiology, the ecology of plant pests and pathogens, and the implications of changes in average temperatures for temperature extremes and for changes in the patterns of precipitation and evaporation – all underpinned not just by theory and modeling but by observations – have changed this picture for the worse. It now seems that many plants are less helped by extra CO_2 and more hurt by heat stress than had been thought. In addition, increases in rainfall in a warming world come mainly in the form of an increase in deluges, a larger part of which rushes to the sea in storm runoff rather than soaking into the soil – a problem that's compounded by increased evaporation from the soil under increased heat. Thus drought conditions are expected to become more prevalent in a warming world, despite increased average rainfall and increased flooding.

Changes in atmospheric circulation patterns that are part of the climatic disruption driven by heat-trapping gases can make the situation even worse, as is already happening in India and China with changes in the monsoons on which agriculture in those countries is dependent. In those countries and many others where river flows are strongly affected by snowpack and the timing of snowmelt – true of course across the western United States – reductions in the snowpack coupled with earlier snowmelt are reducing water availability in the growing season, compounding the problem of low soil moisture that arises from higher evaporation rates.

Left out entirely of most of the earlier projections of the impact of climate change on farms and forests, moreover, have been the effects of climate change on plant pests and pathogens. These generally do better under warmer conditions. (That is a major reason why agriculture in the tropics has always been more challenging – and generally less productive – than agriculture in the temperate zones.) A stunning example of this vulnerability is provided by the millions of acres of spruce and pine trees in Alaska, British Columbia, and Colorado that have been killed by the spruce budworm and the pine bark beetle, whose numbers soared in the warming environment while drought weakened the ability of the trees to resist them.

Increased prevalence of drought in a warming world is also increasing the incidence of wildfires, impacting not just forests and woodlands but the homes people have built in these places. The average annual area burned by wildfires in the western United States, for example, has increased about four-fold in the past 30 years, and property losses from these events have likewise risen as would be expected.

These impacts and stresses on farms and forests are not projections. They are already being experienced today, in a world that has warmed, on the average, only about 1.4 degrees Fahrenheit (0.8°C) compared to 1900. If global emissions of heat-trapping gases continue to grow on what is often termed a "business as usual" trajectory, mid-range estimates are that the global average surface temperature increase compared to 1900 will grow to around 3.6 degrees F (2°C) by 2050 and 5.4 to 7.2 degrees F (3-4°C) by 2100. Considerably greater increases in average temperature in this century cannot be ruled out, moreover, because of uncertainties about the strengths of "positive feedbacks" in the climate system (such as CO_2 releases from warming seas and soils). And whatever the global-average increases turn out to be, we know on solid scientific grounds that the increases in mid-continent will be typically 2 times bigger, and those at high latitudes in the Northern Hemisphere can be larger still.

Although it is still the case today that climate change has benefitted farms and forests in some places while harming them in others, and this mixed pattern may persist for some years more, there can be little doubt that the far larger temperature increases expected by 2030 and beyond on the "business as usual" trajectory would put substantial stresses on farms and forests in most places. Such stresses can be alleviated to some extent by adaptation efforts of a variety of kinds, of course, including development of heat-, drought, and pest/pathogen-resistant crop strains and more efficient water management schemes for agriculture. We absolutely need to make well focused and effective investments in such measures.

But adaptation becomes more difficult, more costly, and less effective the larger are the changes in climate to which one is trying to adapt. The need to restrain climate change to a level with which affordable adaptation measures can plausibly cope is what has led so many analysts of this problem to conclude that every effort should be made to avoid exceeding a global average temperature increase of 3.6 degrees F (2°C). I note that President Obama's stated target for U.S. reductions in emissions of heat-trapping gases to 83% below 2005 emissions by 2050 is consistent with that aim, assuming that other industrialized countries perform similarly and that developing countries transition to declining emissions trajectories no more than a decade after the industrialized nations do.

Farms and forests as emitters and absorbers of heat-trapping gases

The Intergovernmental Panel on Climate Change (IPCC) estimated in its 2007 "Fourth Assessment" that human emissions of heat-trapping gases in 2004 were equivalent to about 50 billion metric tons of CO_2, of which 66% came from the energy sector and a bit over 30% from farms and forests. Carbon dioxide itself, which is by far the most important of the heat-trapping gases emitted by human activities, accounted for about three quarters of the CO_2-equivalent emissions, most of the rest coming from methane (CH_4) and nitrous oxide (N_2O) -- with a large part of the former coming from farm animals and a large part of the latter from the use of nitrogen fertilizer. Of the CO_2 contribution, around 75% is coming from fossil-fuel combustion and around 25% from deforestation, nearly all of the latter in the tropics.

For the United States, the EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2007* shows croplands accounting in 2007 for about 6% of total CO2-equivalent greenhouse-gas emissions, mainly by generating 72 percent of the country's nitrous oxide emissions and 32 percent of its methane emissions. On the other hand, U.S. agricultural lands and forests are a large net absorber of carbon dioxide: the *Inventory* estimate is that growing vegetation in the United States removed about 1 billion tons of CO_2 from the atmosphere and stored it as plant material and soil organic matter. (This figure is equivalent to about 17 percent of current U.S. CO_2 emissions from fossil-fuel combustion.)

Continuing rises in temperature and atmospheric CO_2 concentration will affect the emission/absorption balance in vegetation and soil organic matter in complicated, sometimes offsetting, and still not well quantified ways. It is clear enough despite the uncertainties, however, that stopping and reversing deforestation in the tropics, increasing reforestation and afforestation rates elsewhere, and managing agricultural soils to maximize carbon storage can and must play an important role in national and global strategies for limiting the build-up of CO_2 in the atmosphere.

With respect to the methane and nitrous oxide emissions from agriculture, there are many practical measures available for reducing them. Farmers can change the rate, timing, and form of nitrogen fertilizer applications and can use nitrogen inhibitors to slow the release of nitrogen into the soil. Dairies and hog operations can employ anaerobic digesters and can compost or apply manure at appropriate levels instead of relying on open pits and lagoons. Cattle operations can use feeds that reduce methane emissions. These changes in technologies and practices could mean, in many instances, new jobs and economic opportunity in rural communities.

The IPCC's 2007 report estimated the potential for the emissions reductions available globally by 2030 in the agricultural sector as 0.6 billion to 6 billion tons of CO_2-equivalent per year, the quantity depending on how much society is willing to pay per ton. Reductions available from the forestry sector worldwide were similarly estimated to be between 1.3 billion and 14 billion tons of CO_2-equivalent per year. These figures may be compared with current global emissions of heat-trapping gases in the range of 50 billion tons of CO_2-equivalent per year.

The figures presented here make clear that the agricultural and forestry sectors are large enough both in terms of the emissions they are contributing to the global problem and in terms of the emissions reductions (or the equivalent in increased absorption) that they could contribute to the solution that national and international strategies for addressing the climate challenges definitely must include means for dealing with these sectors. The fossil-fuel sector in total is larger, but emissions reductions large enough to give a good chance of holding the global average temperature increase to less than 3.6 degrees F (2°C) are not practical without getting some of those reductions from reduced emissions and increased absorption in farms and forests.

Renewable biofuels from agriculture and forestry

Expanding the use of fuels derived from recently grown (as opposed to fossil) plant material – i.e., biomass fuels – is of particular interest both as a means of reducing dependence on imported oil and as a way to reduce emissions of carbon dioxide from the fuel sector. The latter potential benefit arises because the growth of plant material removes from the atmosphere exactly the same amount of CO_2 as is returned to the atmosphere when the material is burned. As long as growing the biomass feedstock does not entail significant CO_2 emissions from associated land-use change or use of fossil fuels in the provision of inputs such as fertilizer and irrigation water and as long as the processing and transport steps do not entail significant use of fossil fuels, biofuels can emit substantially less GHG emissions over their lifecycles than fossil fuels. If the use of renewably supplied biofuels for power generation is combined with CO_2 capture and sequestration, it is possible that the operation could be "carbon negative" – i.e., could produce a net reduction of CO_2 in the atmosphere.

In 2008, biomass fuels accounted for an estimated 10% of primary energy supply worldwide. (The fossil fuels – oil, coal, and natural gas – together accounted for 82%, nuclear energy for 5%, and hydro and other non-biomass renewables for 3%.) Almost 90 percent of the very substantial biomass contribution, however, was in the form of direct combustion of fuelwood, charcoal, crop wastes, and dung in low-efficiency, high-polluting stoves and fireplaces, mostly in the rural sectors of developing countries. Only about 12% of the biomass total – thus 1.2% of global primary energy – was in the form of ethanol (from corn and sugarcane), biodiesel (from a variety of feedstocks), and wood fed to electric power stations.

While currently modest against the yardstick of global fuel use, production of fuel ethanol and biodiesel is growing very rapidly. Fuel ethanol production went from about 8 billion gallons (30 billion liters) in 2004 to almost 18 billion gallons (67 billion liters) in 2008.

Biodiesel production rose from 530 million gallons (2 billion liters) to 3.2 billion gallons (12 billion liters) in the same period. Together these two biofuels were equivalent to just over 1% of world oil production in 2008.

In the United States, nearly 4 percent of primary energy supply came from biomass fuels in 2007, more than half of it in the form of wood and organic wastes used in combined heat-and-power (CHP) and pure-electric power plants and the rest in the form of liquid biofuels for transport and solid biomass fuels for residential and commercial heating. U.S. fuel ethanol production reached 9 billion gallons (34 billion liters) in 2008 – about half of the world's production – and U.S. biodiesel production reached 700 million gallons (2.6 billion liters). Together these liquid biofuels were equivalent to about 2.3% of U.S. petroleum use in that year.

The Energy Independence and Security Act of 2007 (EISA) requires a substantial increase in the volume of biofuels consumed in the United States, from 9 billion gallons in 2008 to 36 billion gallons by 2022, including 21 billion gallons of advanced biofuels (comprising 16 billion gallons of cellulosic ethanol, 4 billion gallons of "other" advanced biofuels, and at least 1 billion gallons of biomass-based diesel). EPA has estimated that this renewable fuel standard will reduce transportation-related GHG emissions by an average of 150-160 million tons of CO2 equivalent per year-- equivalent to the annual emissions of 23 to 24 million vehicles.

Science needs for supporting climate policy relating to agriculture and forestry

As indicated in the foregoing, the roles of farming and forestry in the climate-change challenge include the emissions of heat-trapping gases that now emanate from those sectors, the potential for reducing those emissions, the opportunities for increasing the uptake of CO_2 from the atmosphere by farms and forests, and the potential of biofuels to reduce and in some instances even make negative the net CO_2 emissions from vehicles and powerplants that otherwise would be burning fossil fuels. All of these roles are sufficiently well understood scientifically to support implementation of policies and activities in the U.S., and related international agreements, that will help us get from the farm and forest sectors the contributions needed from them if the challenge is to be met.

At the same time, continuing to improve our scientific understanding of the relevant processes, including especially our capacity to measure and monitor them quantitatively on local to regional scales will be valuable in (a) increasing confidence that the performance specified in policy and agreements is indeed being achieved, (b) developing improved understanding of the some of the currently less well researched options in the agricultural and forest sectors for both mitigation and adaptation, such as biochar and emissions from wetlands, and (c) using insights from (a) and (b) to help refine our policies in the decades ahead.. In the remainder of this testimony I elaborate on some aspects of (a) and (b), namely (i) measuring emissions and uptake in the agricultural and forest sectors and (ii) improving quantitative understanding of the emissions-reduction potential of biofuel options.

Assessing emissions and uptake

A variety of policies can be employed to take advantage of emission-reduction and carbon-storage opportunities in agriculture and forestry, including incentives, voluntary programs, education, and market-based programs such as offsets. Offsets, if properly designed, reduce the costs of implementing a cap-and-trade program and engage farmers and land-owners profitably in the national effort to reduce emissions. Doing this properly requires that quantification and reporting systems be rigorous, verifiable, and transparent; that review and auditing systems be effective; and that uncertainties be accounted for, managed, and reduced over time. Greenhouse gas benefits accrued through terrestrial carbon sequestration will need to be monitored according to standard practices to ensure that the offsets satisfy requirements related to permanence, leakage, additionality, and verifiability.[1] Meeting these requirements has been and remains the focus of a range of major U.S. government efforts, including the National Greenhouse Gas Inventory and project-based monitoring approaches developed by USDA and EPA, drawing on the work of governmental, private-sector, and academic researchers over the last two decades.

Achieving the high confidence that decision-makers and the public will want concerning offsets and the reality of emissions reductions or uptake increases claimed for other initiatives in the agriculture and forestry sectors will require continuing effort to improve our understanding of and ability to measure stocks and flows of carbon and nitrogen at global, regional, and local scales. Currently, "bottom up" methods are available for calculating emissions and uptake at scales from projects to nations. The ability to verify these calculations using independent observation systems needs more work in some instances, however, in part because our current observation networks for carbon fluxes do not have sufficient density of coverage spatially or resolving power temporally. A continuing effort to strengthen our observation network of ground-based, air-based, ocean-based, and space-based measurements of the carbon cycle is therefore highly desirable. Combined with existing capabilities in the form of facility and site-specific measurements, carbon-cycle modeling, fossil-fuel emission inventories, and data on land use, a more robust carbon-cycle observation network would offer valuable additional information about progress on reducing emissions and increasing uptake.

The Obama Administration recognizes the importance of continuing to improve our measurement and monitoring capabilities and is addressing this need through a variety of interagency efforts engaging USDA, Interior/USGS, Commerce/NOAA, EPA, and NASA, among others, with coordination and integration from OSTP, the National Science and Technology Council, and the U.S. Global Change Research Program (USGCRP).

[1] The issue of "permanence" refers to the potential reversibility of carbon sequestration; to be effective, the carbon that is removed from the atmosphere and stored in plants and soils through an offsets market must remain out of the atmosphere. "Leakage" refers to the shifting of emissions from one place to another at the local, regional, national , or international level. The requirement for "additionality" means that carbon offset credits should not be awarded for actions that would have been taken even without an offsets policy, i.e., in a business-as-usual case.

Understanding the emissions-reduction potential of biofuels options

The array of options for deriving additional energy supplies from biomass fuels is large. In addition to the corn ethanol, use of wood and biomass wastes for combined heat and power, and use of wood for home heating that dominate the U.S. biofuels picture today, these options include a variety of approaches for producing ethanol, diesel fuel, and jet fuel from cellulosic biomass sources; the use of natural or genetically engineered strains of algae as sources of liquid and gaseous fuels for transport, buildings, and industry and for solid fuel for electric-power generation; and novel approaches for using fast-growing cellulosic biomass sources to co-fire with coal in conventional and integrated gasification combined cycle (IGCC) electric power plants, potentially in combination with CO_2 capture and storage to an extent that could make such power generation a net absorber of CO_2 from the atmosphere.

These approaches differ in state of technological development, efficiency of the conversions of solar energy to plant material and plant material to end-use energy form, requirements for land and water and other inputs such as fertilizers and pesticides, cost, net benefit in reducing greenhouse-gas emissions when all inputs as well as influences on soil and vegetation where the material is grown and elsewhere are taken into account, and other environmental and social impacts (positive as well as negative). While much is known about these factors, the technologies are evolving and so is our understanding of their full range of characteristics. I believe we know enough to define appropriate metrics to help with choosing options and with regulation, but we will get better at it as our scientific understanding of the details improves.

The question of "direct" and "indirect" land-use and emissions impacts of different approaches to producing biomass for energy is particularly important and also scientifically challenging. ("Direct" impacts refer to those that occur on the sites where the biomass is grown, process, and used; "indirect" impacts are those that occur at other sites as a result of commodity price changes that ensue from the allocation of significant amounts of farm and forest lands to biomass energy production.) There can be little doubt that large increases in production of biofuels production will have effects on land use in the United States and the rest of the world; the real issue is the magnitude of this effect.

To the extent that reduction in crop production because of conversion of cropland to biofules production is compensated by increased food crop yields on other cropland the expansion of cultivated area will be moderated. The conversion of pasture and forest to cropland will also depend on regional, national and local land-use policies, price sensitivities, and the constraints imposed by competing agricultural uses, such asgrazing. EISA requires the EPA to examine this issue, and other aspects of a full life-cycle analysis of biofuels production, and to develop a methodology that accounts for all of the important factors. A reasonable first cut at this can be and is being made on the basis of current understandings, but one may expect that the further development of the underlying science will lead to improvements in the approach over time.

Conclusion

The agriculture and forest sectors are important components of the global climate-change challenge posed by the accumulation of heat-trapping gases in the atmosphere from human activities. The importance of these derives from their significant role as both emitters and absorbers of these gases, from the risks that greenhouse-gas-induced climate change poses to the productivity of our farms and the economic and ecological services derived from our forests (and corresponding needs and opportunities for adaptation as an indispensable route to reducing these risks), and from their potential for an expanded contribution from renewable biofuels to displace part of the fossil fuels whose combustion is the largest driver of the problem.

The science needed to understand these roles, risks, and opportunities is well enough in hand to enable crafting a set of policies and strategies to move the United States and, one hopes, other major agricultural and forest nations in the right directions in terms of both the mitigation and adaptation dimensions of including farms and forests in the solution to the climate-change challenge. It is important to tailor these policies to our capabilities and understandings in relation to specific agricultural and land-use practices, moving forward aggressively on the ones that are well understood as we continue to work to improve our understanding of those we know less well.

Continuing to strengthen the science base for policies and strategies in this domain going forward will bring significant rewards in terms of our confidence in the performance of the approaches that are put in place, the ability to improve those approaches over time, and the capacity to develop additional options for farm- and forest-based climate-change mitigation and adaptation for the future. OSTP is energetically engaged -- together with the full range of relevant cabinet departments, other federal agencies, and White House offices, and with our partners in the wider research community and the Congress – in ensuring that this happens. My colleagues in the White House and I look forward to working with this Committee and the rest of the Congress to this end.

Thank you for your attention. I will be pleased to try to answer any questions you may have.