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Statement of
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before the

Subcommittee on Commerce, Justice, Science and Related Agencies
Committee on Appropriations
U.S. House of Representatives

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear today. My expertise is studying land vegetation using Earth orbiting satellites. I am assigned by NASA to the United States (US) Climate Change Science Program (CCSP) in Washington, where I co-chair the Observations Interagency Working Group. I have provided my resume for your information.

NASA's and NOAA's Earth orbiting satellites make measurements that enable our understanding of climate change and the global integrated Earth system. These satellites provide high accuracy, high-spatial and high-temporal resolution, global observations of the atmosphere, ocean, and land surface that cannot be acquired by any other method. To understand climate change, satellite observations must be of sufficient duration to distinguish long-term trends from short-term cycles created by processes such as extreme weather and El Nino.

Land vegetation is a critical aspect of the global carbon cycle because plants absorb carbon dioxide from the atmosphere via the process of photosynthesis and incorporate or store this carbon in wood and soil. In the global carbon cycle, carbon is exchanged among the biosphere, geosphere, hydrosphere, and atmosphere (Figure 1). The amount of carbon dioxide in the atmosphere is a direct result of the carbon cycle. This is a very important driver of climate and climate change, as the concentration of atmospheric carbon dioxide directly affects the Earth's temperature, through the "greenhouse" effect. I will address the land portion of the biosphere that directly affects the atmospheric carbon dioxide concentration and thus is extremely important for climate understanding, mitigation, and adaptation. Earth-viewing satellites provide the only means to measure global land vegetation with high accuracy and high resolution.

We are able to understand the land contribution to the carbon cycle by combining data recorded by Earth orbiting satellites with computer models. Our understanding of the land portion of the carbon cycle is founded on numerous small or local ground studies that have provided the knowledge to “scale up” from small studies. Satellite observations and computer models provide the means to scale up from local studies to an understanding of the global carbon cycle. Numerous federal agencies are involved in these activities and the CCSP coordinates their activities to maximize utilization of limited resources to gain knowledge of the global carbon cycle and hence global climate change.

The land portion of the global carbon cycle modulates the exchange of carbon between the carbon reservoirs on land, principally forests and their soils, the atmosphere, and the oceans. Earth-viewing satellites provide information on whether the land vegetation carbon reservoirs, overwhelmingly forests, are either releasing more carbon dioxide to the atmosphere than they are absorbing and storing or vice versa. Forests alone store approximately 85 percent of the planet's aboveground carbon in wood and store more than 70 percent of the planet's soil carbon (Houghton 2005, Janzen 2004). In addition, Arctic soils contain large amounts of carbon in peat. When warmed, peat has the potential for a methane release to the atmosphere equal to nearly 30 percent of all the carbon on land. Methane is a greenhouse gas similar to carbon dioxide. For these reasons, studying land vegetation and soils globally is vital to understand carbon storage and release. Earth-viewing satellites provide the only means to measure land vegetation and soils globally.

The current atmospheric carbon dioxide concentration is currently approximately 385 parts per million. By comparison, the total amount of carbon contained in the world’s forests is the equivalent of an additional 300 parts per million of atmospheric carbon dioxide. The soils of our planet contain the equivalent of an additional 750 parts per million of atmospheric carbon dioxide. For these reasons, the study of land vegetation and soils is directly linked to the carbon dioxide concentration of the atmosphere and hence our climate (Houghton 2005). Deforestation and conversion of forests to other non-forest land use is a major contributor to the present atmospheric carbon dioxide concentration.

There are three different satellite measurements of land vegetation and their soils that contribute fundamentally to understanding climate change:

(1) Land Use Change: Data from the series of Landsat satellites have been recorded continuously since 1972 to the present. Landsat enables detection of the conversion of forests to non-forest uses and quantification of land use change (Schneider et al. 2009; Hansen et al. 2008; Potapov et al. 2008; Goward et al. 2008). Landsat data are also very widely used for many societal benefits other than climate including aiding disaster management, mapping agricultural crops to determine global food production, geological mineral exploration, and protecting biodiversity (Williams et al. 2006). The land climate change community has guarded optimism that Landsat-5, now 25 years old, and Landsat-7, slightly impaired due to a mechanical problem, may have enough fuel and stamina to

operate until the NASA and USGS Landsat Data Continuity Mission (LDCM) is launched in December 2012.

(2) Photosynthesis Rates: Data from NASA's Moderate Resolution Imaging Spectrometer (MODIS) instruments, which are currently flying on NASA's Terra and Aqua satellites, quantify photosynthesis on the land (Zhang et al. 2008, Nemani et al. 2003). MODIS data, which started in 2000, are a substantial improvement over previous land photosynthesis estimates determined from Advanced Very High Resolution Radiometer (AVHRR) instruments on a series of NOAA polar-orbiting satellites that first began operating in 1981. Through scientific analysis, the AVHRR and MODIS data can be combined. The continuum of AVHRR and MODIS data provide a nearly 30-year data product of global land photosynthesis, which is important in understanding changes in the Earth's climate (Figure 2). The follow-on instrument to MODIS is the Visible Infrared Imager Radiometer Suite (VIIRS) instrument, which will be flown on the NOAA-Air Force funded National Polar-orbiting Operational Environmental Satellite System (NPOESS), first on NASA's NPOESS Preparatory Project (NPP) satellite and then in the series of operational NPOESS satellites.

It is vital that the VIIRS instruments continue the excellent climate change observations derived from MODIS. Without VIIRS, we will not be able to determine whether future increases in atmospheric carbon dioxide are due to increased deforestation, increased use of fossil fuels, increased forest fires, reduced photosynthesis on land, reduced photosynthesis in the oceans, or a combination of these. Data from the AVHRR-MODIS continuum are also very widely used for many other climate science purposes, including ocean's biology and chemistry, sea surface temperature, carbon dioxide emissions from forest fires, land surface temperature, and studies of the atmosphere.

(3) Vegetation Height: The third fundamental vegetation observation of climate change is the satellite measurement of vegetation height and its vertical profile from space using lasers aimed at the earth (Nelson et al. 2008). When the height of the planet's vegetation is combined with Landsat and MODIS data, a complete 3-dimensional view of vegetation emerges that is crucial to quantifying the role of vegetation in climate change. Research on satellite estimates of global vegetation canopy height was initiated with measurements from NASA's Ice, Cloud, and land Elevation Satellite (ICESat) that was launched in January 2003. Following recommendations in the 2007 National Research Council Decadal Survey for Earth science research and applications, NASA initiated pre-formulation concept studies of the ICESat-II and Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI) missions. The new missions will use different technologies to measure the height and vertical profile of land vegetation.

In summary, it is imperative for our understanding of the critical role of land vegetation in climate change that we mitigate a potential gap in Landsat observations, complete the VIIRS instrument for NPP to continue MODIS observations, and develop satellite instruments to measure the height of vegetation canopy.

I am pleased to note that NASA and USGS are proceeding with the Landsat Data Continuity Mission; that NASA is working with NOAA and the Air Force as part of the NPOESS program to overcome deficiencies associated with the VIIRS instrument on NPP; and that NASA is developing satellite laser capability for land vegetation height.

I would like to thank the Subcommittee for requesting that I testify on critical satellite observations to understand climate change. I focused my testimony on global land vegetation observations, my area of expertise. These critical climate change observations also provide information about global food and fiber production that sustains our planet's human population. These measurements also make a major contribution towards famine early warning, prediction of key food crop production worldwide, and other important societal benefits. They will also play an important role in climate change adaptation and mitigation.

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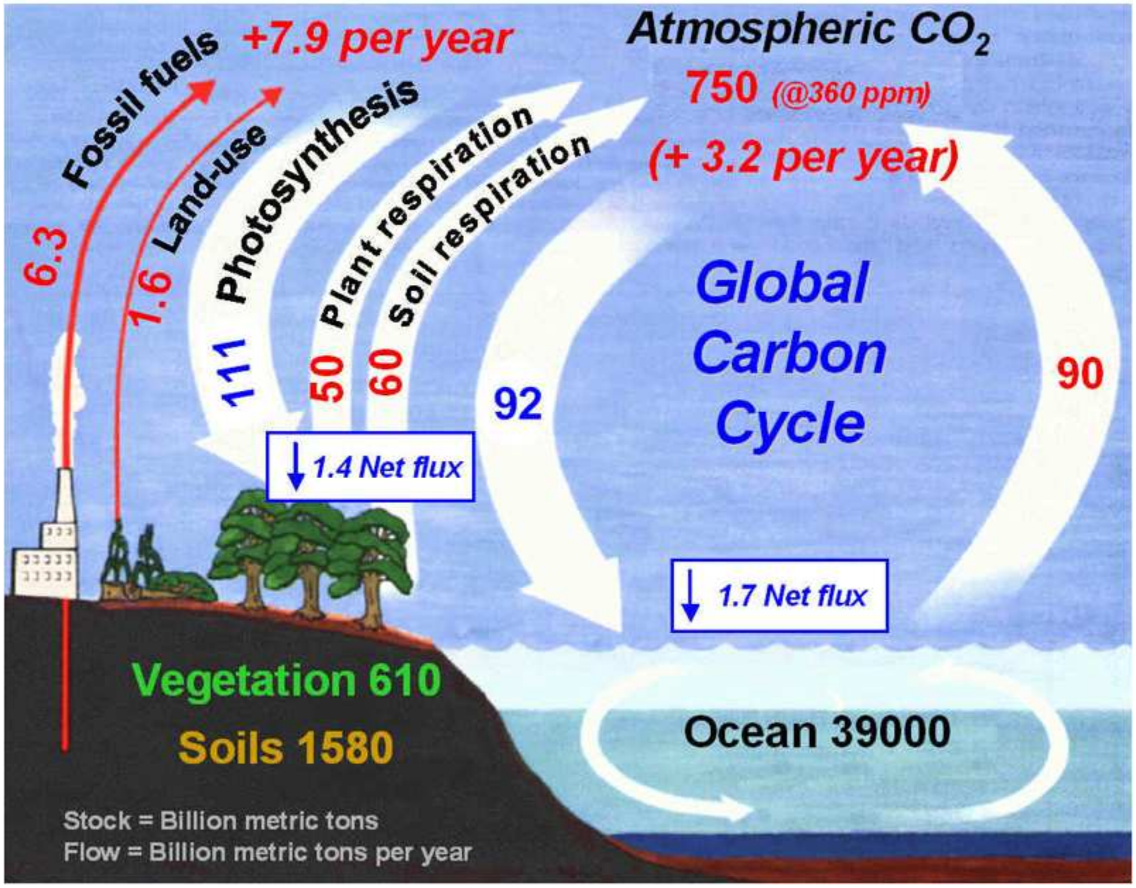

Figure 1. The global carbon cycle. The amount of carbon in the various reservoirs or components of the Earth are shown in this figure. Of direct concern to land observations of climate change are the 610 billion metric tons of carbon stored in vegetation (~85% in forests) and ~1580 billion metric tons stored in soils (~70% of that in forest soils). For these reasons, the study of land vegetation and their soils is extremely important to understand atmospheric carbon dioxide concentrations (Houghton 2005). Satellite observations provide critically important data needed for this understanding. The total yearly flux of carbon dioxide to the atmosphere is 7.9 billion metric tons. Of that, 3.2 billion metric tons accumulate in the atmosphere, 1.4 billion metric tons are absorbed by plants on land, 1.7 billion metric tons are absorbed by the oceans, and 1.3 billion metric tons is unaccounted for or missing.

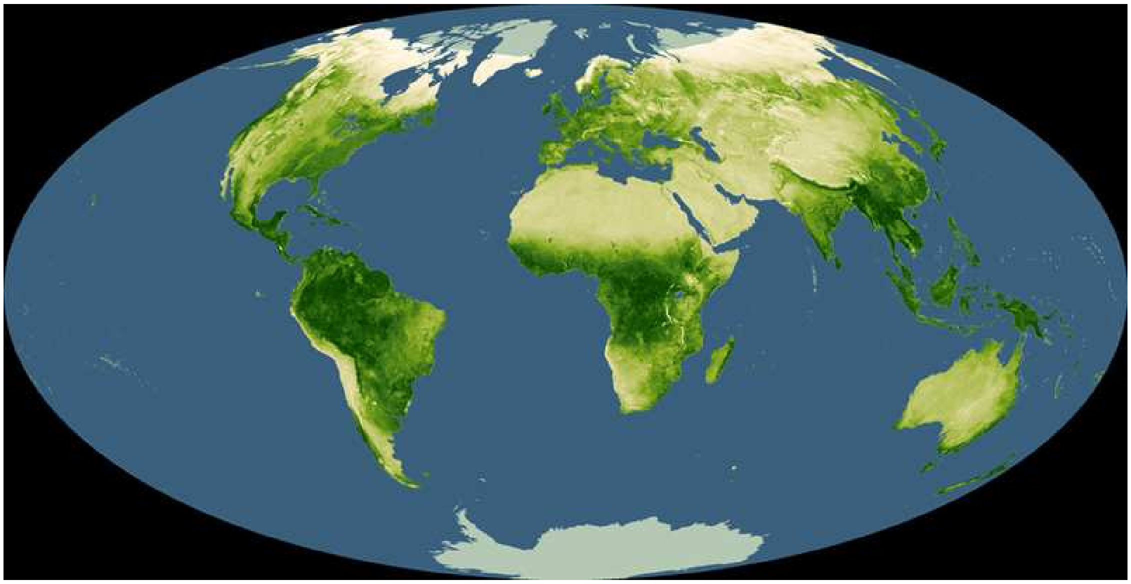

Figure 2. One method of mapping vegetation photosynthesis on land around the world is a measurement known as the Normalized Difference Vegetation Index or NDVI. This image shows NDVI from November 1, 2007, to December 1, 2007, during autumn in the Northern Hemisphere. This monthly average is based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. The darker green colors show land areas with high levels of photosynthesis, such as the Amazon Rainforest. The beige to white colors show areas with little or no photosynthesis, including deserts and areas with snow at this time. Areas with moderate amounts of photosynthesis are pale green. Land areas with no data appear gray and water appears blue.