Executive Summary—Baseline and Projected Future Carbon Storage and Carbon Fluxes in Ecosystems of Hawai‘i

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Hawai‘i is unique among the United States because of its tropical climate, geographic isolation, high rates of species endemism, and discontinuous landmass. The year-round warm, wet climate on the windward sides of islands and the high fertility of relatively young volcanically derived soils are ideal conditions for carbon input, storage, and sequestration in ecosystems of the main Hawaiian Islands. Over the last three decades, several plot- and stand-level studies, conducted at the scale of tens to hundreds of square meters, have demonstrated the high carbon sequestration capacity of Hawaiian terrestrial ecosystems with a focus on soils, live biomass, and plant productivity. However, there have been relatively few studies conducted at landscape (hundreds to thousands of square meters) to islandwide scales examining the biotic and environmental controls on aboveground carbon density and no islandwide to statewide estimates of carbon fluxes and net carbon balance for ecosystems of the Hawaiian Islands. The goal of this report is to provide robust baseline estimates of carbon storage and flux across the Hawaiian Islands based on the best available data and to then use this baseline data as input to predict how carbon cycling and storage may respond to projected future changes in climate, land use, land cover, and disturbance.

Major components of the assessment include a new high-resolution land-cover map for the State of Hawai‘i; projected future shifts in climatic zones owing to global warming; baseline estimates of carbon emissions from wildfire; comprehensive statewide estimates of current ecosystem carbon stocks in soils, live biomass, and detritus; comprehensive statewide estimates of current carbon fluxes from gross primary production (GPP) and ecosystem respiration (R_e); current and projected future stream- and groundwater carbon fluxes to nearshore waters; and statewide estimates of current and projected future net ecosystem carbon balance (NECB) based on projected changes in climate, wildfire, land use, and land cover. Major findings from the assessment are as follows:

Total carbon stored in terrestrial ecosystems across the seven main Hawaiian Islands (excluding Ni‘ihau) was estimated to be 258 TgC, of which 71 percent was soil organic carbon (SOC) to 1 m depth, 24 percent was live biomass (above and below ground), and 5 percent was dead biomass (a combination of litter and downed woody debris). Hawai‘i Island, the largest island in the Hawaiian archipelago, stored 136 TgC, which accounted for 58 percent of the total carbon storage in the State of Hawai‘i, whereas the island of Kaua‘i had the highest carbon density (carbon storage per unit area), estimated as 23.5 kgC/m^2.

Live-biomass carbon storage in native forests was estimated as 32 TgC, which was 51 percent of all carbon stored as live biomass (63 TgC), followed by invaded forests (21 TgC) and alien tree plantations (6 TgC).

Between 2003 and 2014, GPP across the seven islands averaged 20.2 TgC/yr, with Hawai‘i Island accounting for 55 percent of this flux (11.2 TgC/yr). The island of Kaua‘i had the highest mean annual GPP carbon flux density (GPP per unit land area) estimated at 1.85 kgC/m^2.

Carbon lost to the atmosphere from wildfire emissions was estimated as 0.03 TgC/yr, and carbon lost to nearshore waters from stream- and groundwater fluxes was estimated as 0.3 TgC/yr for the current baseline period, which was approximately 4 percent of statewide annual net primary production (NPP) of terrestrial ecosystems.

Terrestrial ecosystems of the seven main Hawaiian Islands sequestered an average of 0.34 TgC/yr during the baseline period, which was approximately 4 percent of statewide terrestrial NPP. Hawai‘i Island represented the largest carbon sink, sequestering 0.24 TgC/yr or 70 percent of total statewide carbon sequestration.

During the projected future period (2012–2061), carbon sequestration of terrestrial ecosystems of the State of Hawai‘i would decrease by more than 30 percent (from 0.34 to 0.22 TgC/yr) primarily because of a decrease in NPP and increased carbon losses from land-use and land-cover change, as well as increased aquatic carbon-leaching losses to nearshore waters.

The State of Hawai‘i was projected to remain a net carbon sink in 2061, primarily because of carbon sequestration in terrestrial ecosystems on Hawai‘i Island. However, predicted land-use changes on the islands of Kaua‘i and O‘ahu were projected to convert these islands from net carbon sinks to net carbon sources to the atmosphere by 2061.

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Limitations of the Assessment Report

There are several known limitations of the assessment report. First, only a single climate projection scenario was used to project moisture-zone shifts in Fortini and others (this volume, chap. 3). Future analyses would benefit from multiple climate projection scenarios. Second, estimates of ecosystem respiration in Selmants and others (this volume, chap. 6) were based on the relationship between estimates of GPP and R_e from eddy flux towers, none of which were located in the Hawaiian Islands, and these estimates agreed poorly with model output from Sleeter and others (this volume, chap. 8), yielding high uncertainty for this large and important pathway of ecosystem carbon loss to the atmosphere and also affecting estimates of net ecosystem production (NEP) and NECB.

With regard to future assessments, the technical needs for reduction of uncertainties present in this assessment will require enhancements in observation systems and modeling research. Key enhancements in observation systems include inventory measurements of shrubland and grassland aboveground biomass and root-to-shoot ratios, direct measurements of streamflow and carbon concentration of ephemeral streams on the leeward sides of the seven main Hawaiian Islands, and the incorporation of currently unpublished data from eddy flux towers in the State of Hawaiʻi (Thomas Giambelluca, University of Hawaiʻi at Mānoa) as well as the establishment of new eddy flux towers to directly assess the balance of CO_2 flux between terrestrial ecosystems and the atmosphere. Key enhancements in modeling research include the development of an ensemble approach to ecosystem modeling and the development and incorporation of multiple climate-change and land-management scenarios that include different intensities of agricultural activities, conservation, ecological restoration, invasive species management, and wildfire suppression and prevention efforts. Although there are substantial uncertainties in our analyses, the analyses themselves represent state-of-the-art science, and this assessment provides information for priorities in reducing uncertainties that should improve future assessments.