Ecosystem carbon balance in the Hawaiian Islands under different scenarios of future climate and land use change

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Running title: Hawaii carbon balance

Keywords: land use, climate change, carbon balance, Hawaii, scenarios, disturbance, ecosystem model

Date: July 24, 2020

Abstract

The State of Hawai‘i recently passed legislation setting a goal to be carbon neutral by 2045. Meeting this goal will partly depend on carbon sequestration by terrestrial ecosystems, yet the future direction and magnitude of the land carbon sink in the Hawaiian Islands is highly uncertain. We used simulation modeling to assess how projected future changes in climate and land use will influence ecosystem carbon balance in the Hawaiian Islands under four unique scenarios over a 90-year timespan. Net ecosystem carbon balance declined under all four scenarios. Moving from a high to a low radiative forcing scenario reduced net ecosystem carbon loss by ~21%, and net carbon losses were reduced by a total of ~55% under the combined scenario of low radiative forcing and low rates of land-use change. A sensitivity test of the CO_2 fertilization effect on plant productivity revealed it to be a major source of uncertainty in projections of ecosystem carbon balance. Reconciling this uncertainty in how net photosynthesis will respond to rising atmospheric CO_2 will be essential to better constrainment of models used to evaluate the effectiveness of ecosystem-based climate mitigation strategies.

Introduction

Methods

We used the Land Use and Carbon Scenario Simulator (LUCAS), an integrated landscape change and carbon gain-loss model, to project changes in ecosystem carbon balance for the seven main Hawaiian Islands under four scenarios of climate and land-use change. The landscape change portion of LUCAS is a state-and-transition model that applies a Monte Carlo approach to track the state type and age of each simulation cell in response to a pre-determined set of transitions (Daniel *et al* 2016). The carbon gain-loss portion tracks carbon stocks within each simulation cell over time as continuous state variables, along with a pre-defined set of continuous flows specifying stock level rates of change over time (Daniel *et al* 2018, Sleeter *et al* 2019). We parameterized the Hawai'i LUCAS model to estimate annual changes in carbon stocks and fluxes in response to land use, land use change, wildland fire, and long-term climate variability.

Study area

We simulated land-use change and ecosystem carbon balance for the terrestrial portion of the seven main Hawaiian Islands (Figure 1), a total land area of 16,554 km^2. We subdivided the study area into a grid of 250 x 250 m simulation cells (n = 264,870). Each simulation cell was assigned to one of 210 possible state types based on the unique combination of three moisture zones (dry, mesic, and wet; Figure S1), seven islands, and ten discrete land cover classes (Figure 1).

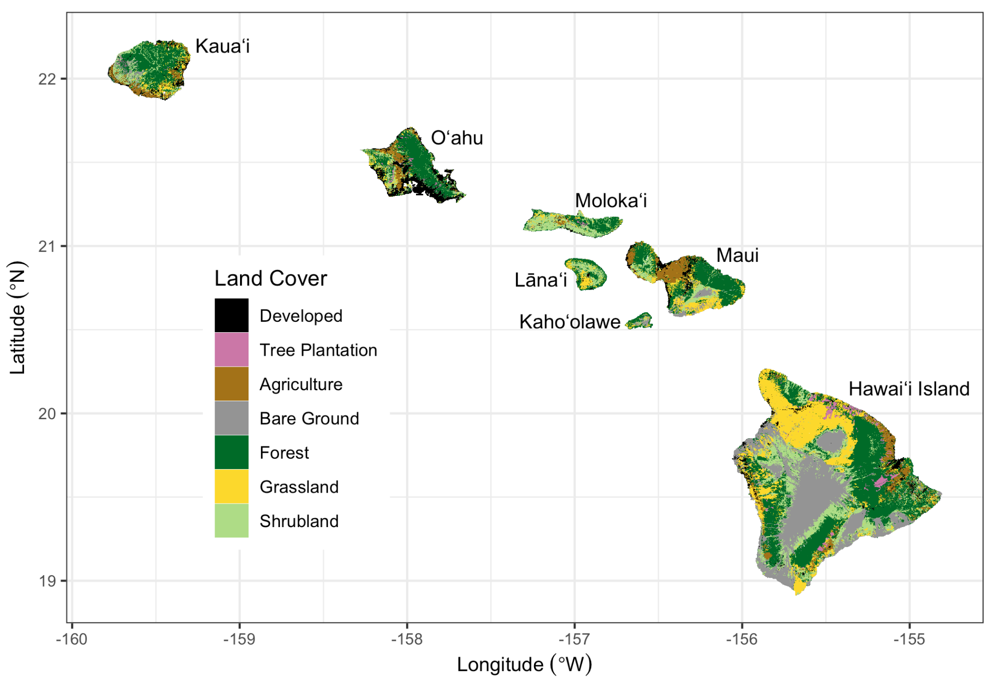

Figure 1: Land cover classification of the seven main Hawaiian Islands, adapted from Jacobi et al (2017). Agriculture in this map combines herbaceous and woody crops, but these two crop types are treated as separate land cover classes in the simulation model. Water and Wetland land cover classes are not shown.

States and transitions

Carbon stocks and flows

Initial conditions

Scenario simulations

Results

Discussion

Conclusion

Acknowledgements

This study was funded by the Biological Sequestration Program of the U.S. Geological Survey. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Data Availability

Tabular model output data are available from the USGS ScienceBase data repository at: https://doi.org/10.5066/P9AWLFKZ. Model input data and R code used to generate input data, summarize output data, and compile this manuscript are available from the HI_Model GitHub repository at: https://github.com/selmants/HI_Model.

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