

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

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16 tem model

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## 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<sub>2</sub> 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<sub>2</sub> will be essential to better constraint 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 of LUCAS tracks carbon stocks within each simulation cell over time as continuous state variables, as

well as a pre-defined set of continuous flows specifying stock level rates of change over time (Daniel *et al* 2018). The Hawai‘i LUCAS model estimated the annual change in carbon stocks and fluxes in response to land use changes associated with urbanization, agricultural expansion and contraction, forest and agricultural harvesting, and wildland fire. We also estimated the impact of short- and long-term climate variability on net primary productivity and the turnover of dead organic matter (Sleeter *et al* 2019).

### *Study area*

The study area encompassed the terrestrial portion of the seven main Hawaiian Islands, a total land area of 16,464 km<sup>2</sup> (Figure 1). This land area was subdivided into a grid of 250 x 250 m simulation cells. 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).

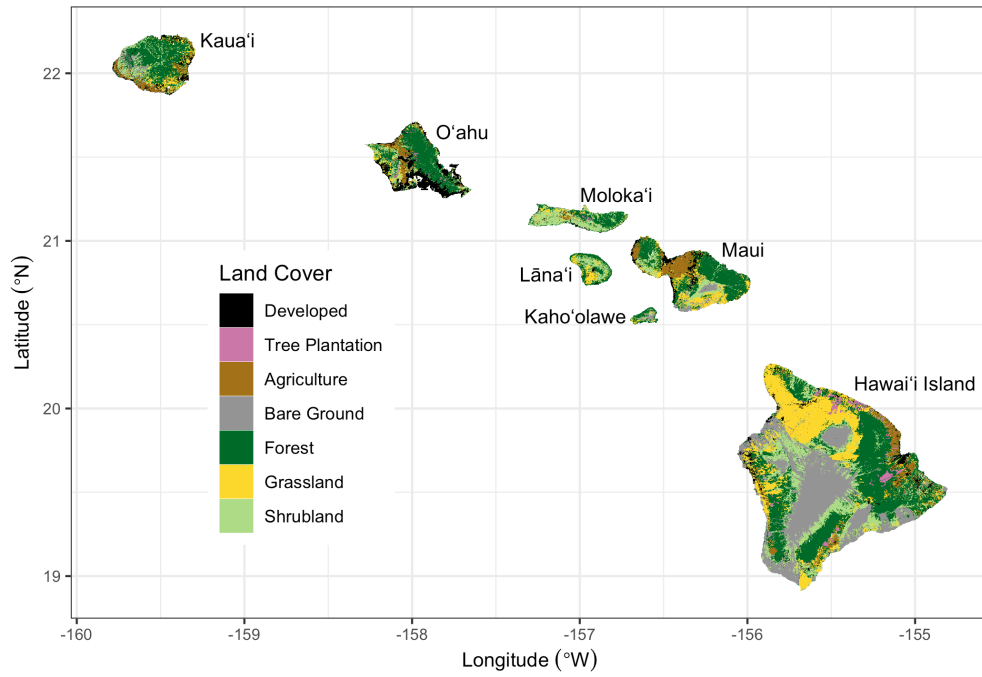


Figure 1: Land cover classification of the seven main Hawaiian Islands, adapted from Jacobi et al (2017). Agriculture in this map combines herbaceous and woody crops, but these two crop types are treated as separate land cover classes in the simulation model. Water and Wetland land cover classes are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

54 *States and transitions*

55 *Carbon stocks and flows*

56 *Initial conditions*

57 *Scenario simulations*

58 **Results**

59 **Discussion**

60 **Conclusion**

61 **Acknowledgements**

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63 Any use of trade, firm, or product names is for descriptive purposes only and does not imply  
64 endorsement by the U.S. Government.

65 **Data Availability**

66 Tabular model output data are available from the USGS ScienceBase data repository at:  
67 <https://doi.org/10.5066/P9AWLFKZ>. Model input data and R code used to generate input  
68 data, summarize output data, and compile this manuscript are available from the HI\_Model  
69 GitHub repository at: [https://github.com/selmants/HI\\_Model](https://github.com/selmants/HI_Model).

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