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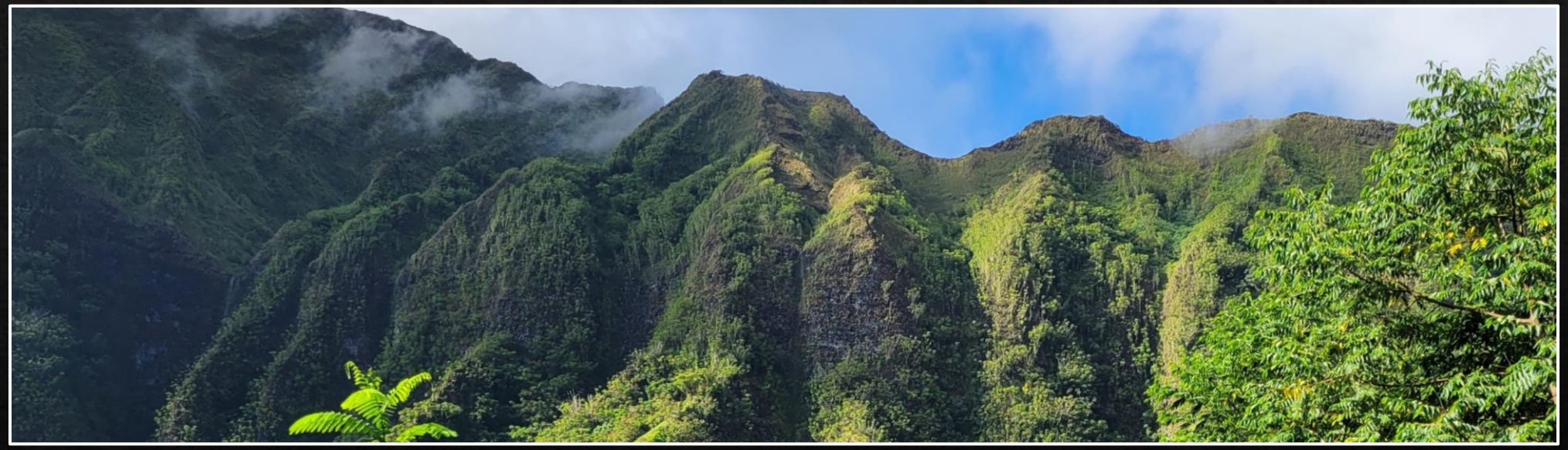
Pacific Islands Water Science Center

The Hawai‘i Groundwater Recharge Tool

An Interactive Website to Explore Recharge in Hawai‘i



Ha‘ikū Valley, O‘ahu

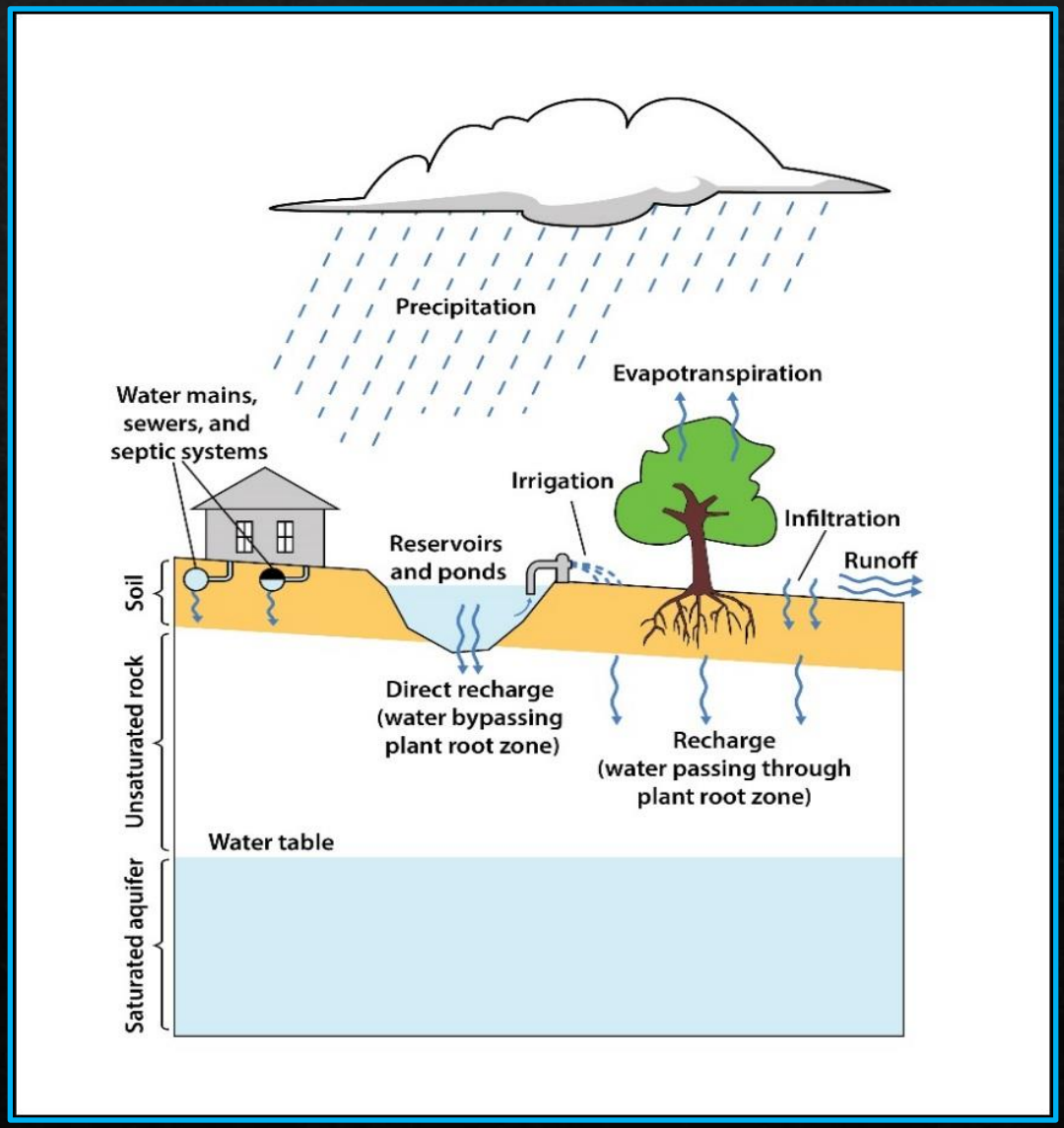
Scot Izuka, U.S. Geological Survey

EARTH 2023 Workshop

July 11, 2023

U.S. Department of the Interior
U.S. Geological Survey

Groundwater Recharge



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Hawai‘i Groundwater Recharge Tool

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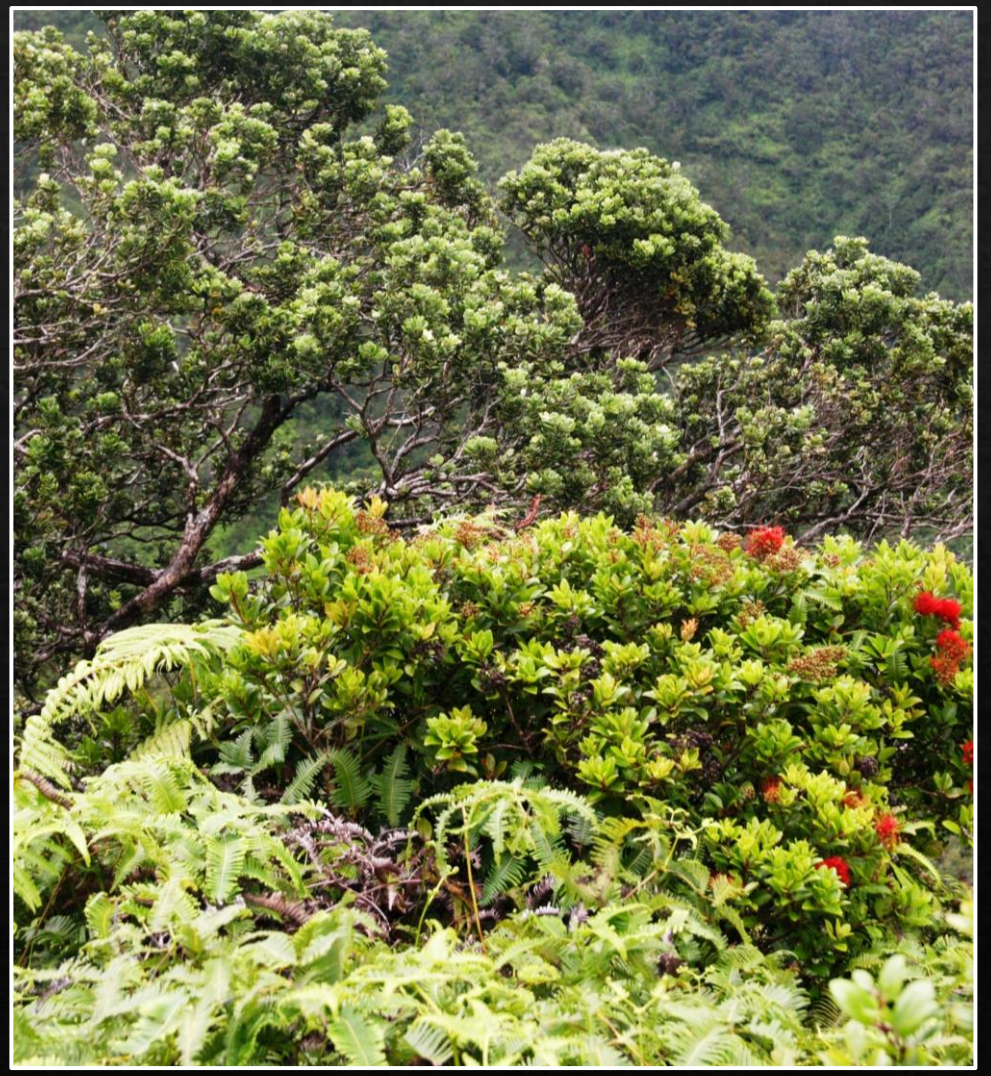
University of Hawai‘i



Upland forest, Ko‘olau Range, O‘ahu

The Hawai‘i Groundwater Recharge Tool

http://recharge.ikewai.org/

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Hawai‘i Groundwater Recharge Tool

An interactive website created by the University of Hawai‘i and U.S. Geological Survey

The primary source of freshwater to Hawai‘i’s groundwater systems is recharge. Accurate estimates of recharge are critical for groundwater-resource management and planning. The **Hawai‘i Groundwater Recharge Tool** allows users to evaluate the potential effects of land-cover and climate changes on groundwater recharge. This is a pilot website that is currently limited to the island of O‘ahu, but the website has been designed to be expandable so that other islands and conditions can be added in the future.

Recharge primarily originates as precipitation. In Hawai‘i, most precipitation is in the form of rain, with some contribution from fog. Only a fraction of the water from precipitation contributes to recharge; the remainder runs off to the ocean by way of streams, or returns to the atmosphere through evapotranspiration (evaporation and transpiration by plants).

Changes in precipitation caused by climate changes can affect recharge rates. Changes in land cover can also affect recharge because different types of vegetation and land uses have different rates of evapotranspiration (different land cover types also have different runoff rates, but these differences are not considered in the Hawai‘i Groundwater Recharge Tool). Irrigation of crops, parks, and golf courses can affect recharge. In urban areas, leaking water mains and seepage from septic systems can also affect recharge.

This website provides a baseline estimate of recharge representing recent conditions of precipitation (1978–2008 average) and land cover (2010). Users can change land cover and rainfall conditions to evaluate the effects on groundwater recharge. Results will be displayed as on-screen maps, and users will be given options to generate interpretive graphics or export results in various formats.

Results from this website are based on soil water-balance models. The user is responsible for understanding the method and its limitations. The user is also responsible for the appropriate use of the web interface.

Go to the Workspace to begin.

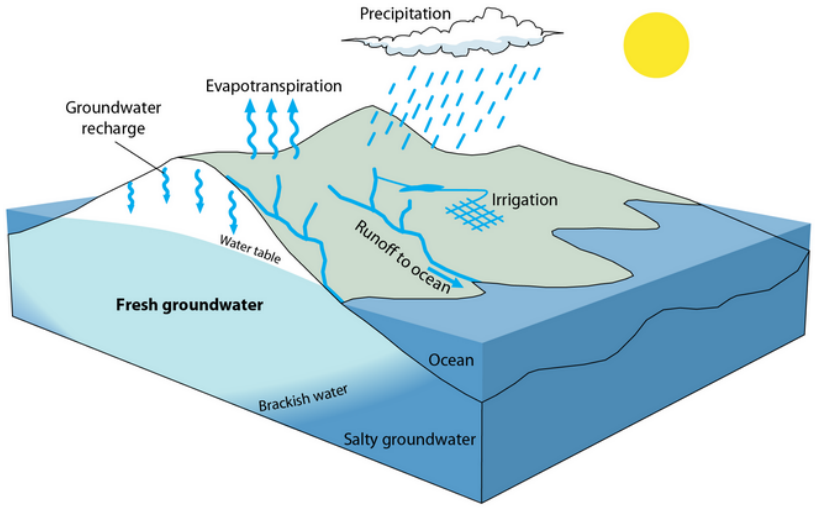

Figure 1. Conceptualization of the factors that affect groundwater recharge in oceanic islands. Groundwater recharge is water that infiltrates the ground surface from rainfall and other sources. Accurate estimates of groundwater recharge are critical for management and planning. Groundwater provides more than 90 percent of drinking water in Hawai‘i, and natural groundwater discharge to streams, springs, and the coast supports aquatic ecosystems.

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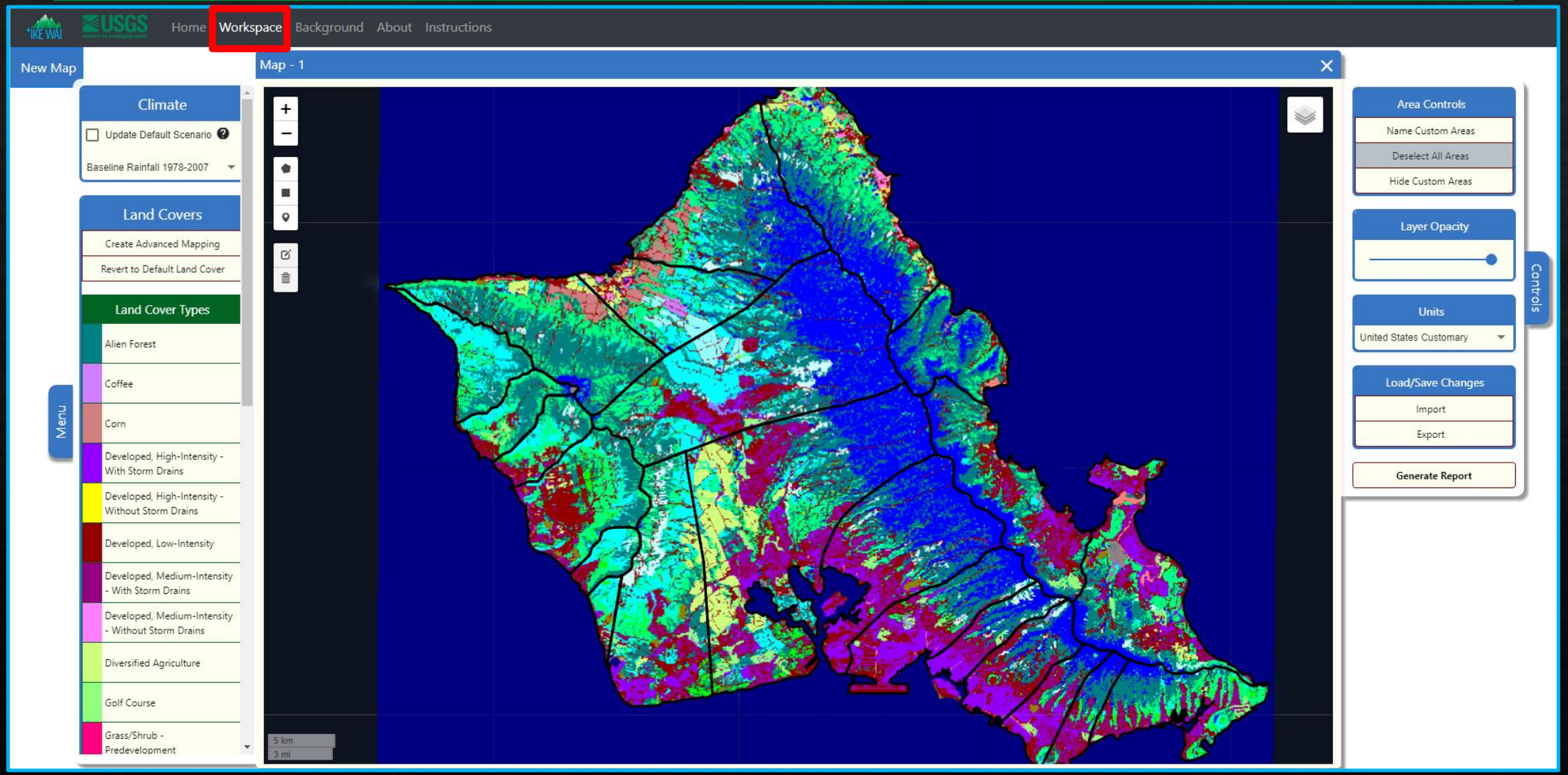
Workspace



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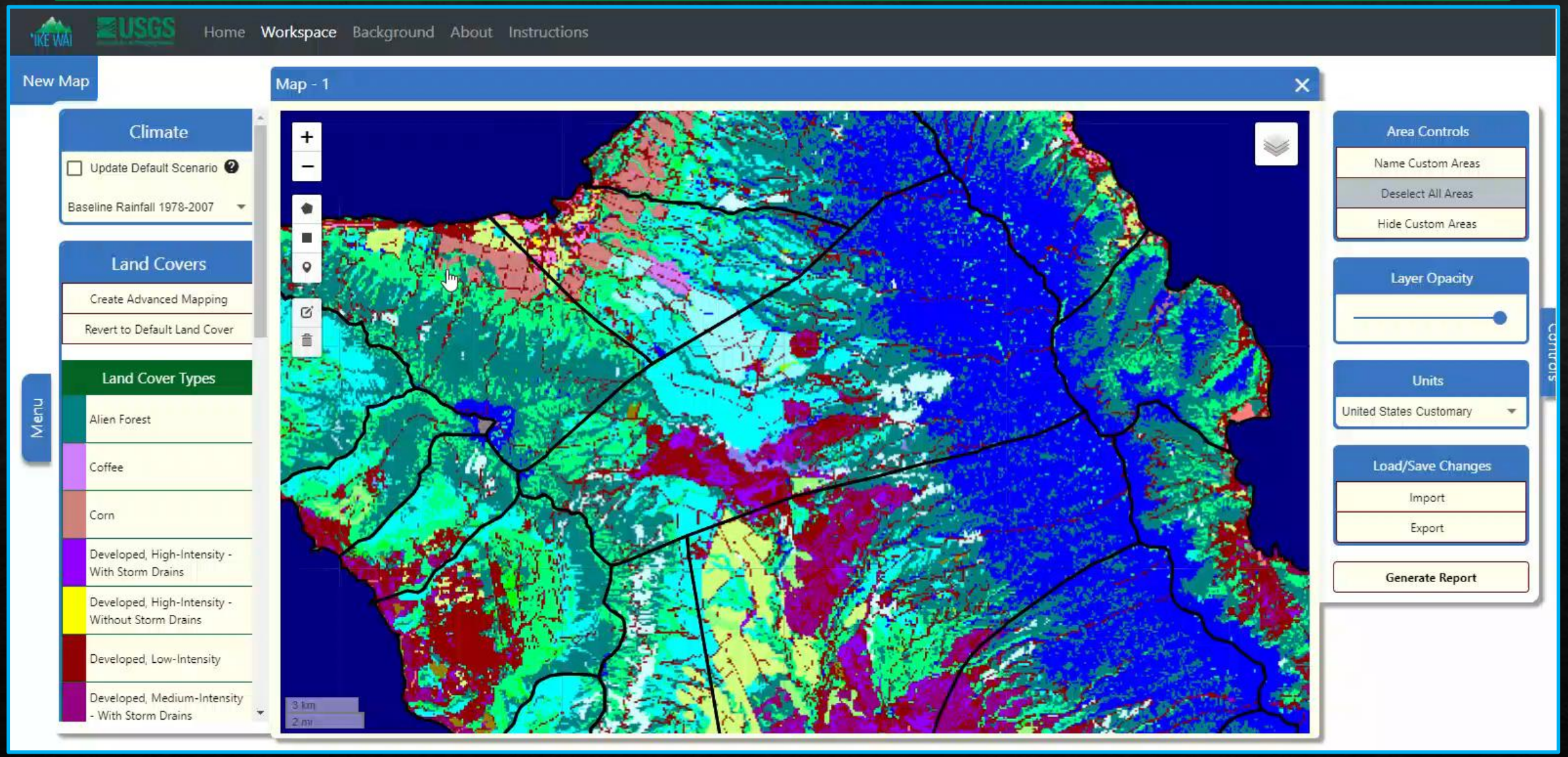
Changing Land Cover



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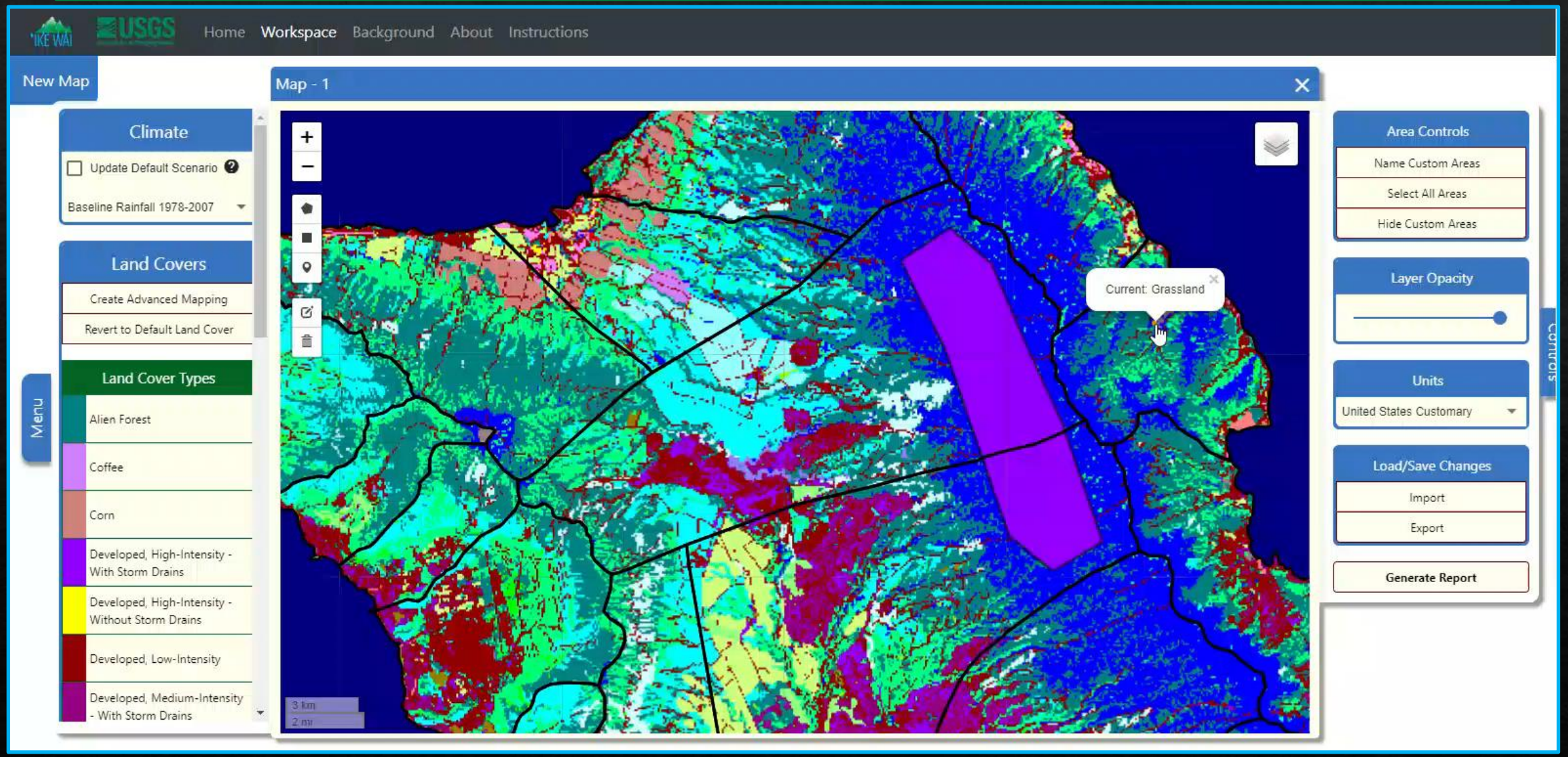
Changing Land Cover



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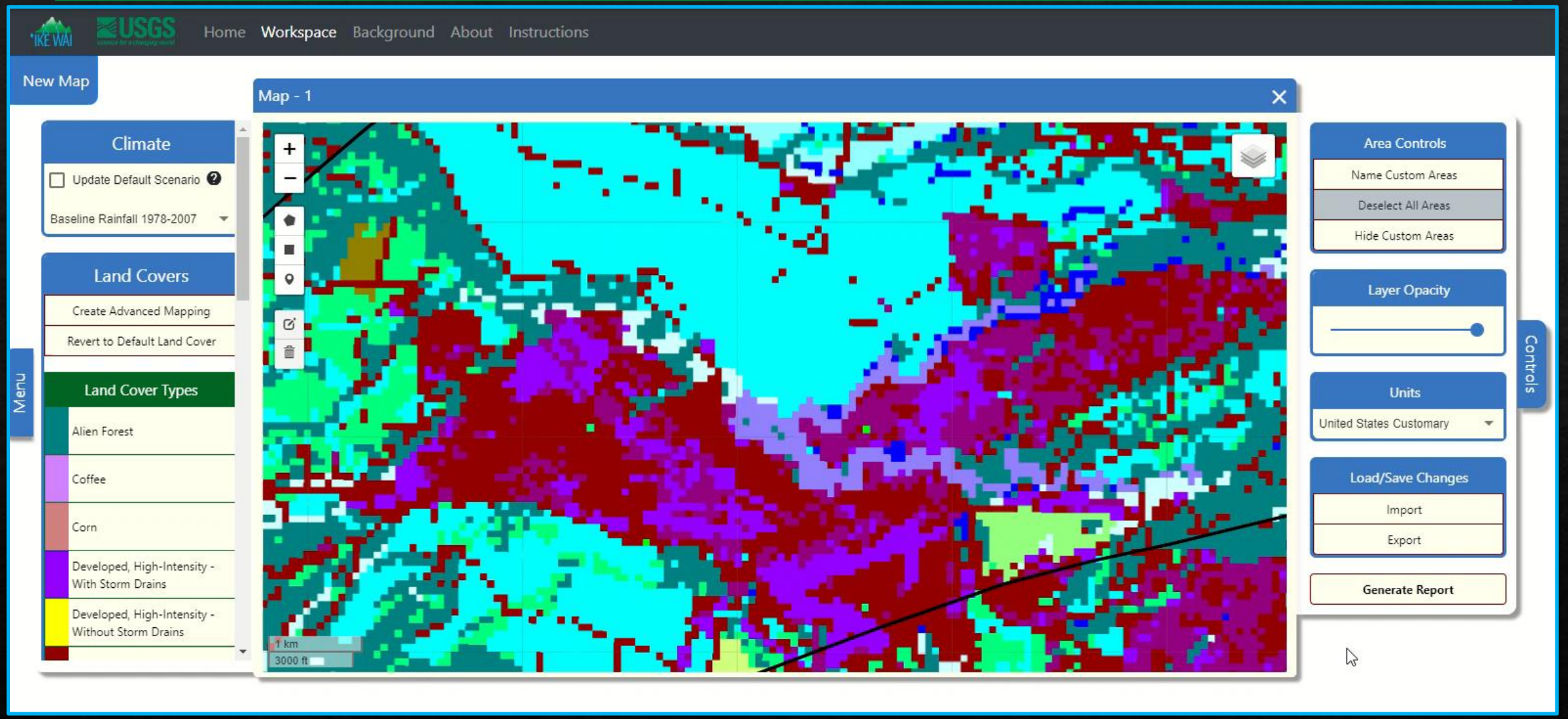
Changing Land Cover



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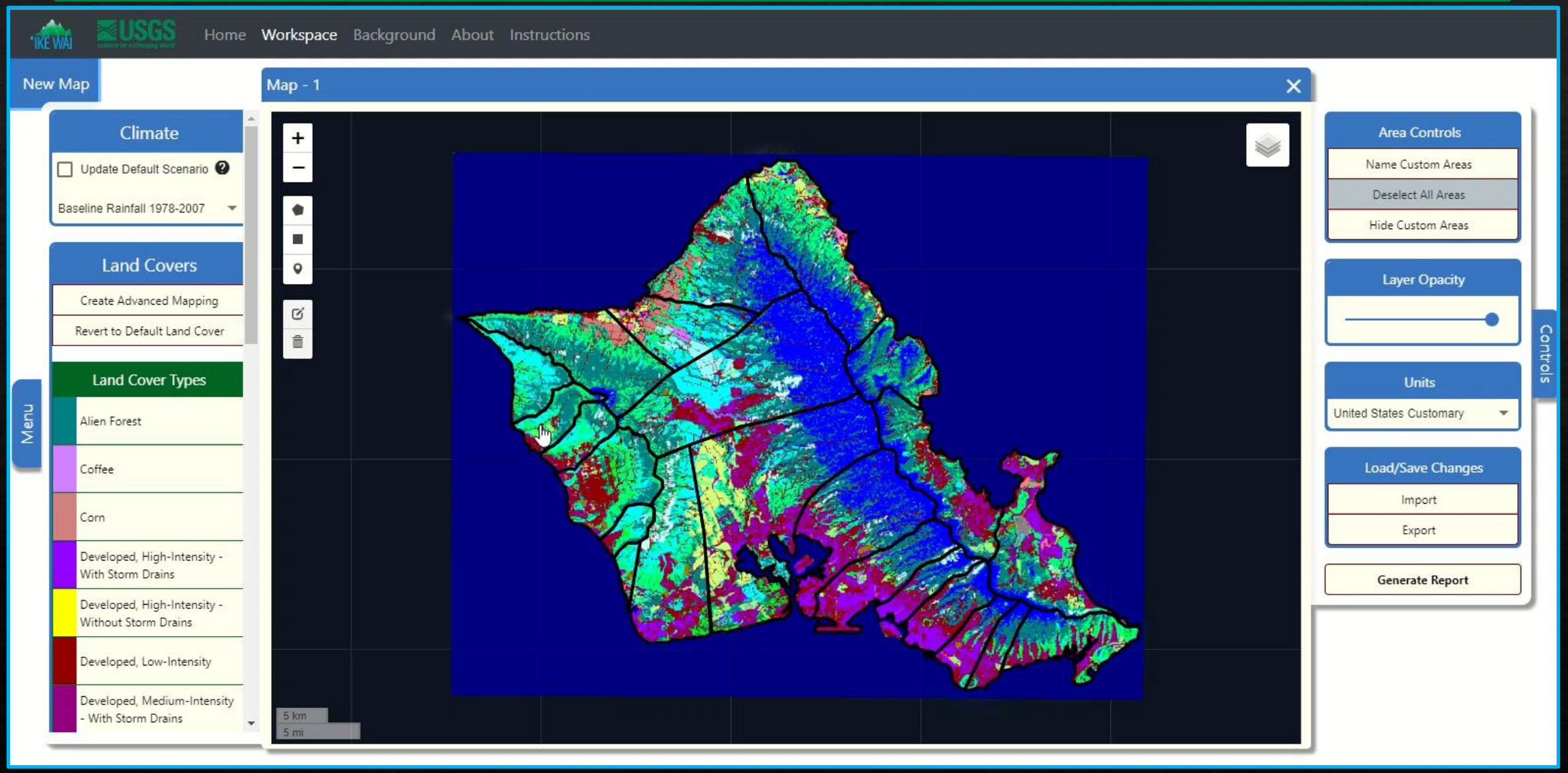
Changing Climate



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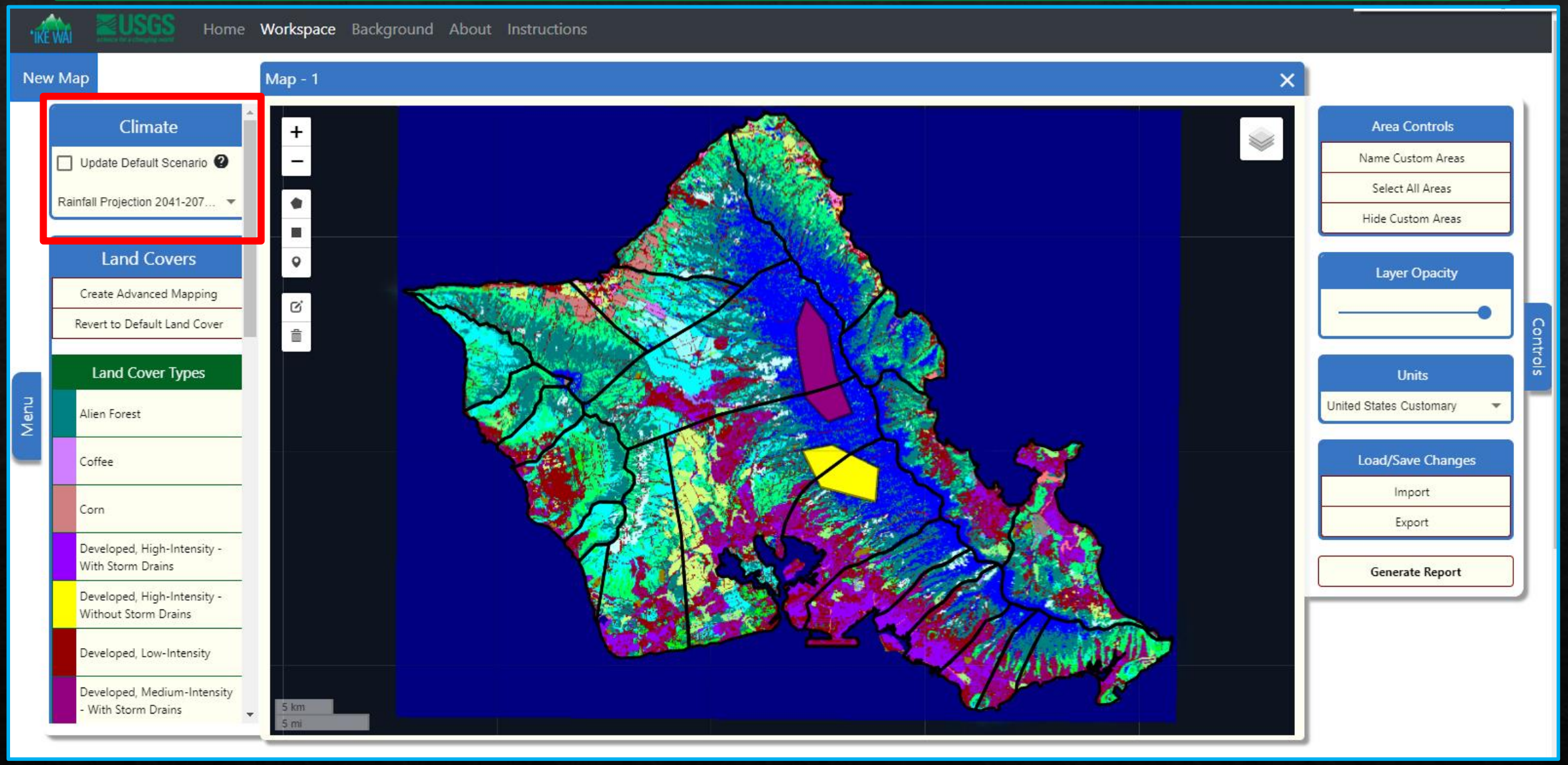
Changing Climate and Land Cover



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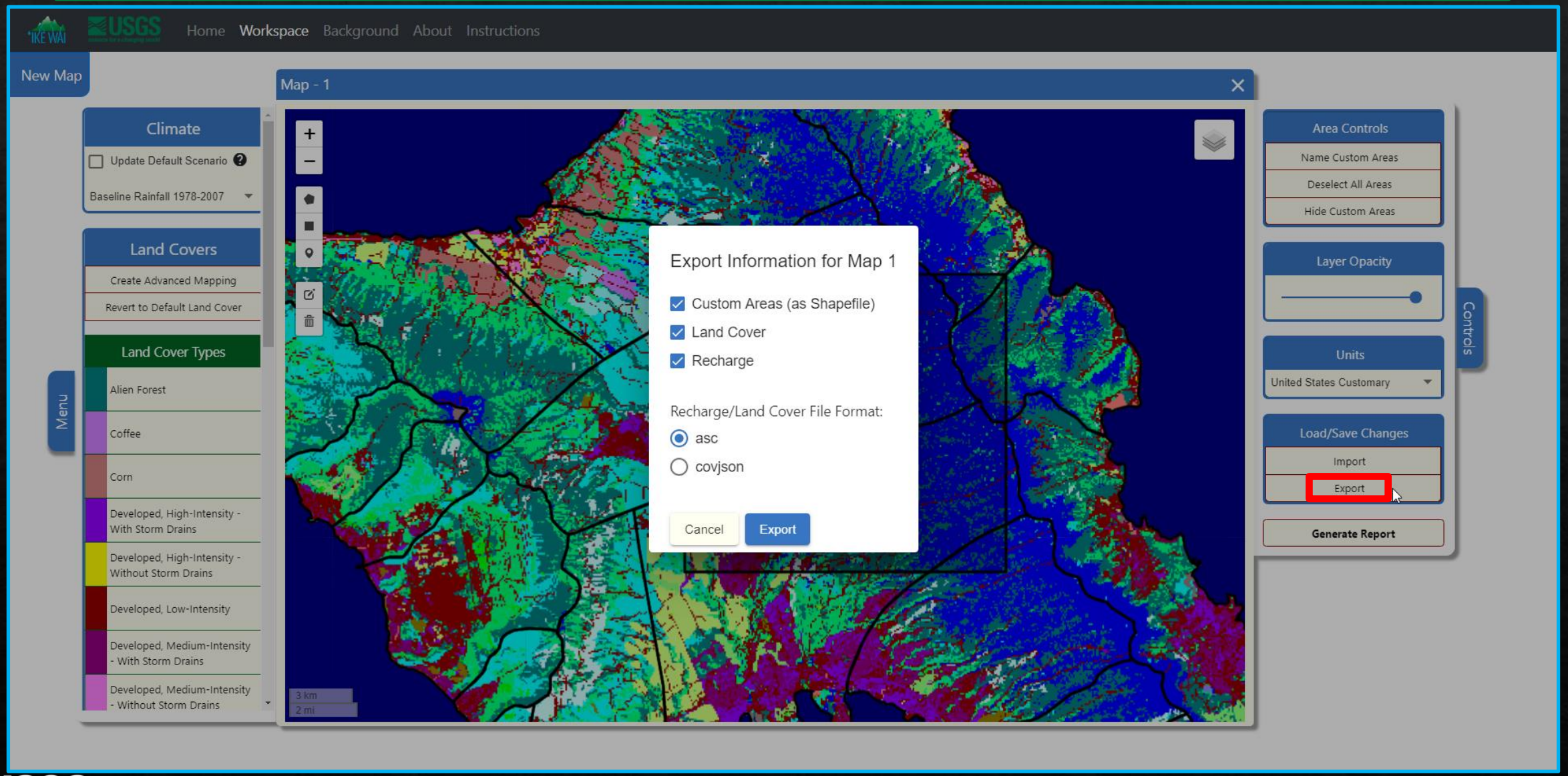
Exporting/Saving Work



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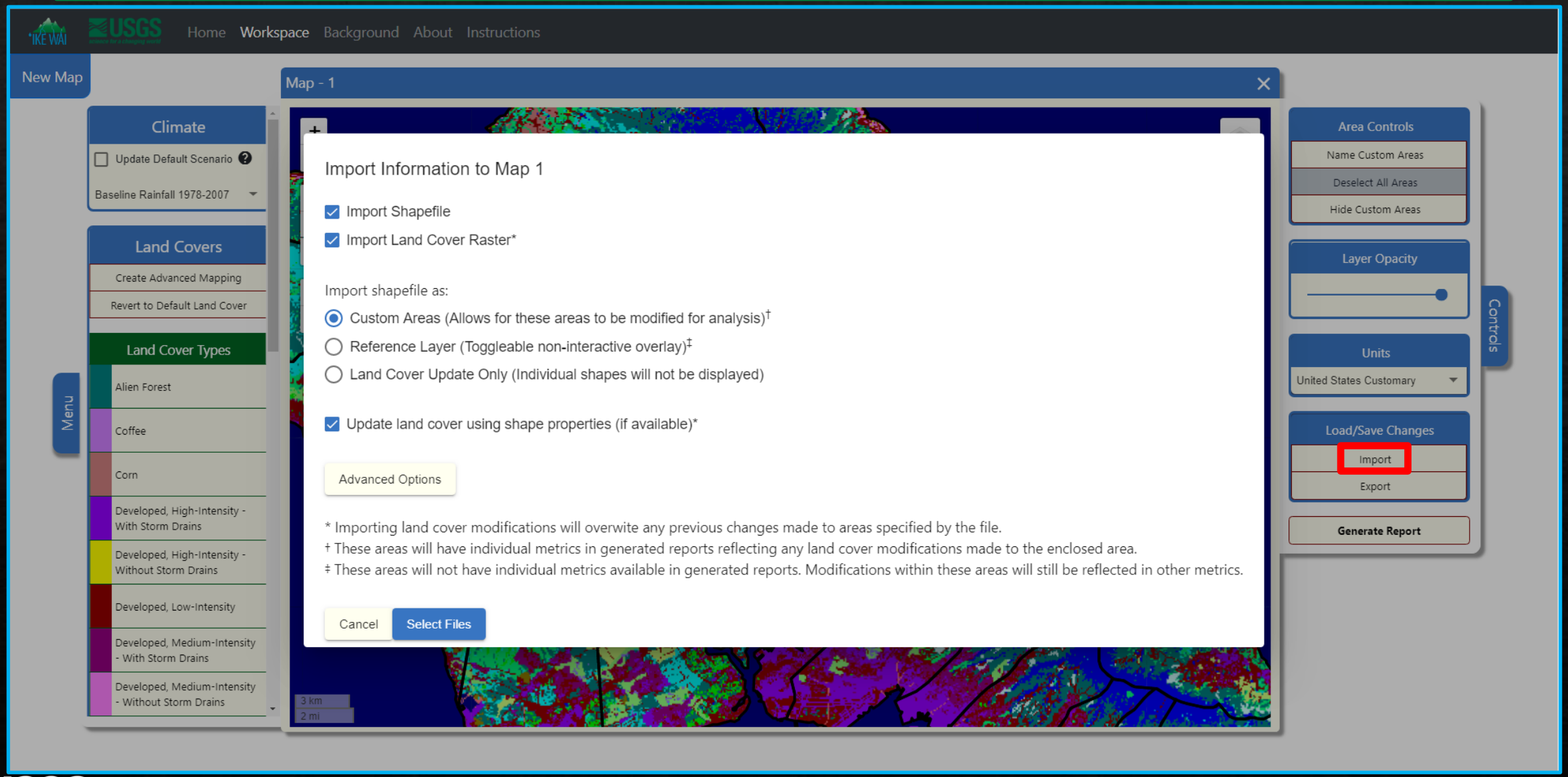
Importing Data Sets



Other Website Pages

Cultivated taro, Waipahu, O‘ahu

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Background

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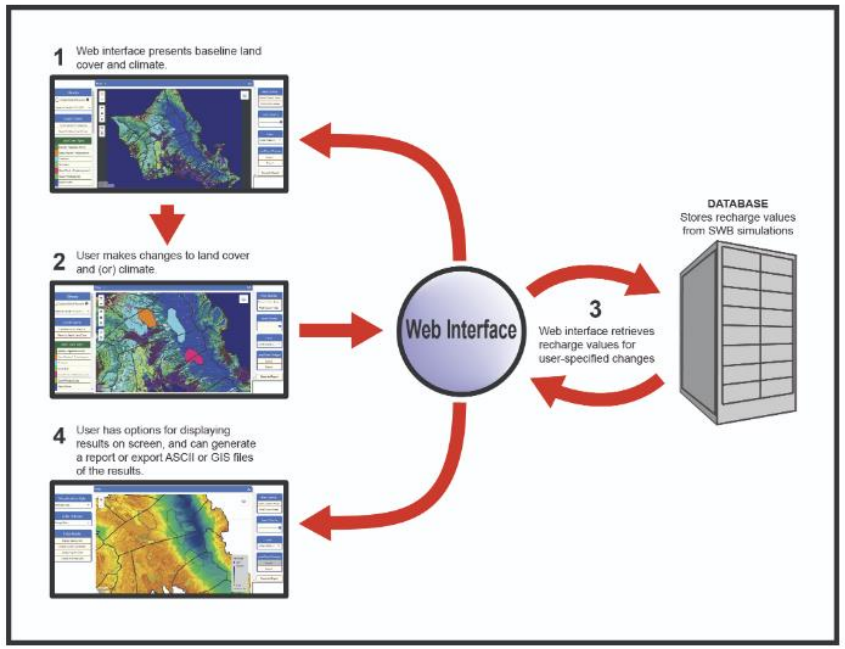
How the Hawai'i Groundwater Recharge Tool Determines Recharge

The Hawai'i Groundwater Recharge Tool allows users to evaluate how changes in land cover and climate can affect groundwater recharge. The web interface initially presents a baseline condition representing 1978–2007 average rainfall and 2010 land cover. Users can change land cover over areas of their choice using tools provided in the website, or by importing spatial datasets, such as shapefiles or raster files, specifying land-cover distribution. Users can also select a future climate condition (statistically downscaled projections of rainfall for 2041–2071 under representative concentration pathway (RCP) 8.5 [Elison Timm and others, 2015]). The web interface accesses a database of recharge simulations representing various possible combinations of land-cover and climate conditions, and returns the recharge corresponding to the user's input.



Database of Recharge Simulations

The database consists of 58 recharge simulations for O'ahu. Each simulation represents recharge that would result if the entire island was covered in one of the 29 land-cover

Table 1. Land cover types and codes used in the Hawai'i Groundwater Recharge Tool

Land Cover	Code	Land Cover	Code
Alien Forest	3	Native Forest	1

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Background (continued)

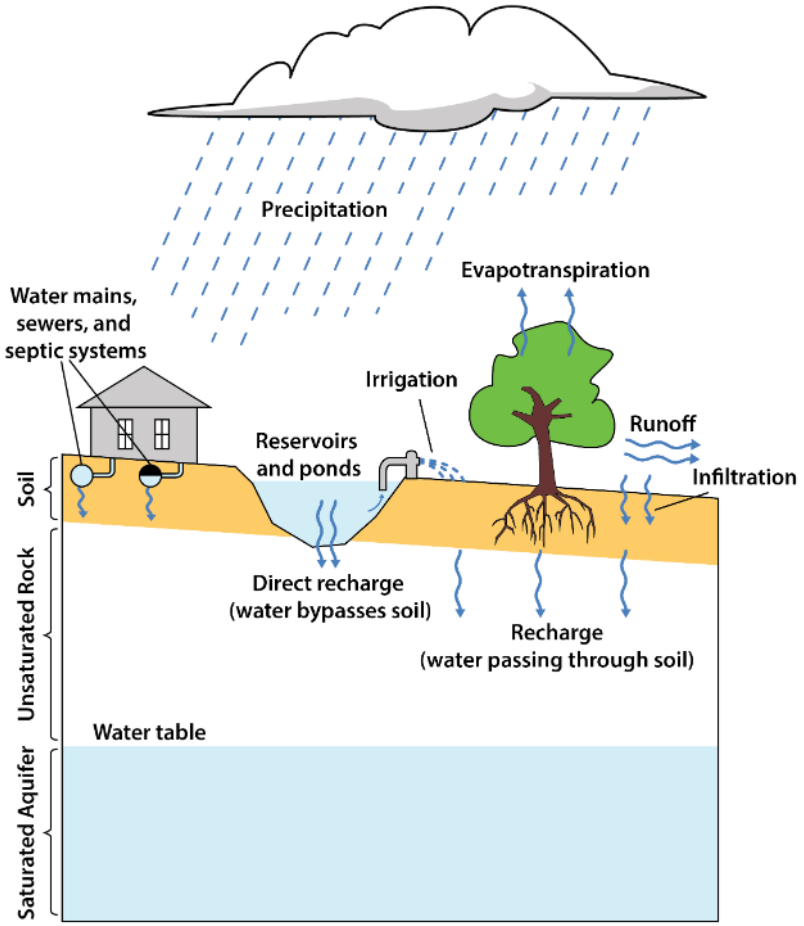
Source of the Values in the Database

The recharge values in the database were computed using the soil water-balance computer program (SWB) version 2.0 (Westenbroek and others, 2018). SWB estimates groundwater recharge from precipitation, soil, land-cover, and other data.

SWB accounts for water entering, leaving, and being stored within the soil on a daily basis. Most groundwater recharge originates as precipitation. Irrigation contributes additional water in some areas (the net effect on groundwater resources may be positive or negative, depending on whether the irrigation water comes from groundwater or surface water). Some of the water runs off the land surface or evaporates from wet surfaces. The remainder infiltrates the soil, where it is subject to uptake by plants through transpiration (the combined effect of evaporation and transpiration is referred to as "evapotranspiration"). In the soil water-balance computations of SWB, groundwater recharge occurs when more water infiltrates the soil than can be held in the soil given its water-storing capacity, antecedent water content, and losses through evapotranspiration. In some areas, additional water is contributed by leaks from ponds, reservoirs, water mains, sewer lines, and cesspools; in the SWB simulations, these contributions are considered "direct recharge" that bypasses the evapotranspiration processes in the plant root zone.

Parameter input values used to generate the SWB simulations were derived from spatial datasets compiled by Engott and others (2017) and Izuka and others (2018). However, SWB uses a rectangular-grid environment which differs from the mostly irregular (non-rectangular) polygon spatial datasets used by Engott and others (2017) and Izuka and others (2018). In most cases, the gridded input for SWB was created using the following procedure:

- The island of O'ahu was discretized (divided) into a grid consisting of 75-meter square cells
- The SWB grid was overlaid onto the irregular-polygon datasets used by Engott and others (2017) and Izuka and others (2018).
- Using the "rasterize" and "translate" functions of GDAL/OGR contributors (2018), each cell



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Background (continued)

Limitations

Accuracy of the results generated by the Hawai'i Groundwater Recharge Tool and their applicability for certain studies is limited by the assumptions of the soil-water budget approach and the quality of the various input datasets available for O'ahu. A review of the limitations appears below, but more complete descriptions of limitations are given by Engott and others (2017) and Westenbroek and others (2018).

- The Hawai'i Groundwater Recharge Tool does not distinguish between user-defined scenarios that are plausible and those that are unrealistic. Some land-cover types (and their parameter values) may not be applicable in all areas of the island (for example, evapotranspiration coefficients for native forests, which typically are in high-rainfall areas, may not be applicable in dry areas). Users are responsible for assessing the plausibility of scenarios they test.
- When designating an area as developed, high-intensity or developed, medium-intensity, users have the option of including storms drains (codes 9 and 10) or not including storm drains (codes 31 and 32). Users are responsible for understanding the implications of these options for their application; selection of the inappropriate option can have unintended results. In the 2010 baseline landcover, storm drains are applied to medium- and high-intensity developed land covers only in selected aquifer systems (State of Hawai'i, 2008), which is consistent with the procedure described by Engott and others (2017). For most of O'ahu, medium- and high-intensity developed land covers have storm drains (codes 9 and 10). In more rural northern O'ahu (aquifer systems 30401, 30402, 30403, 30601, and 30602), medium- and high-intensity developed land covers have no storm drains (codes 31 and 32). See Engott and others (2017) for more information.
- Changing land cover to taro (code 26), water body (code 13), or reservoir (code 14) in areas that don't already have them in the baseline land cover can lead to gross errors. Recharge rates for these land covers are fixed values that were not computed by the soil water-budget analysis, but were based on simplifying assumptions (Engott and others (2017)) that may not be transferrable to other locations.
- The Hawai'i Groundwater Recharge Tool results are long-term average recharge rates, and may not accurately simulate recharge over a short period.
- Land-cover types may exist that are not among the ones included in the Hawai'i Groundwater Recharge Tool.
- Estimates of runoff used in the SWB simulations have high uncertainty. Runoff is computed on the basis of runoff-to-rainfall ratios which are based on basin-integrated stream-gage data. Runoff-to-rainfall ratios are not computed for specific land-cover types and do not change when a user changes land cover. As a result, the Hawai'i Groundwater Recharge Tool is not able to assess changes in recharge related to differences in runoff for different land-cover types.
- Differences in the evapotranspiration rates of native and non-native forests are not well known.
- Projections of future precipitation are uncertain, particularly for the Hawaiian Islands (Keener and others, 2012); alternative projections exist besides the one offered by the Hawai'i Groundwater Recharge Tool. In addition, the only climate-change parameter that can be changed with the web interface is rainfall; changes to other climate parameters, such as temperature, reference evapotranspiration, and the spatial extent of fog contribution, cannot be simulated with the current Hawai'i Groundwater

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Instructions

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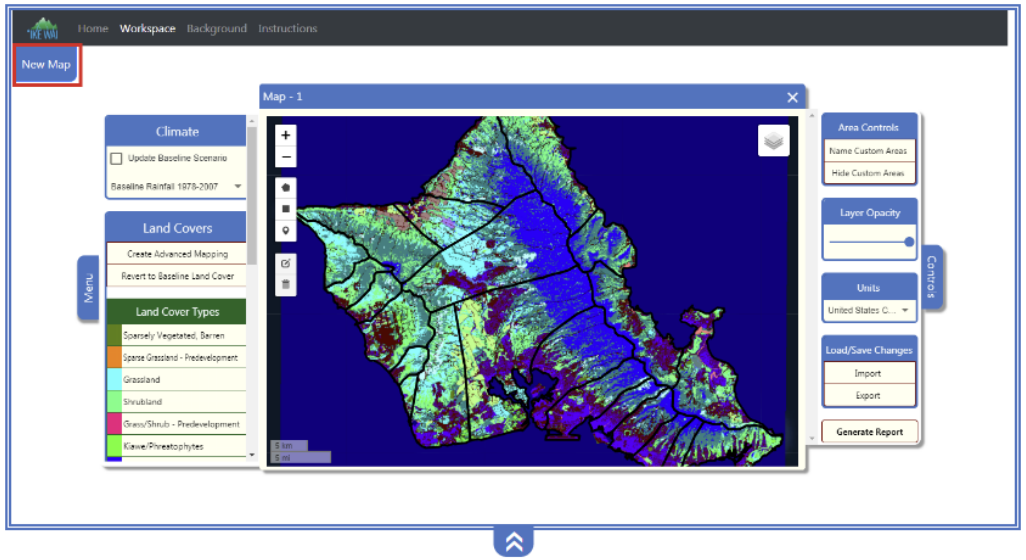
Workspace Usage

The Workspace should start with a map open. To add additional maps for analysis, click the "New Map" button in the top left corner of the screen. The maps provided in this application provide interactive visualizations – visual representations of a set of data. The two main visualizations presented are a land cover visualization, the default map view representing the land usage for the island of O'ahu, and the recharge visualization, representing the approximate groundwater recharge rates for the island based on the set land usage. A satellite representation of the island is also available.



Land Cover Visualization

Draw Tools

The initial map view represents the current land cover usage for the island of O'ahu. To create an area to update, the leaflet draw tools on the left side of the map can be used.

- The hexagon button allows drawing freeform polygons by clicking the map at the desired vertex positions.
- The rectangle button allows rectangles to be drawn by clicking at a desired starting point and dragging the mouse to adjust the width and height of the rectangle.
- The map point button allows for a single map cell ($75m^2$ area) to be selected.

When finished drawing, click the "Cancel" button to exit draw mode.

The two buttons below the draw controls allow polygons to be modified or deleted.

Menu Panel

The menu panel on the left edge of the map window provides controls for modifying land covers and climate scenarios.

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About

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About This Website

Website Authors

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Kolja Rotzoll, United States Geological Survey, Pacific Islands Water Science Center — Groundwater recharge computation and web application design

Sean B. Cleveland, University of Hawai'i at Mānoa, Information Technology Services — Agave platform database integration

Scot K. Izuka, United States Geological Survey, Pacific Islands Water Science Center — Web application design, documentation, and project oversight

Citation Information

All content and results are in the public domain and may be used freely, with appropriate credit given to this website. Suggested citation:

McLean, Jared H., Rotzoll, Kolja, Cleveland, Sean B., and Izuka, Scot K., 2019, The Hawai'i Groundwater Recharge Tool: website at https://recharge.ikewai.org.

Related Publications

Cleveland, S.B., McLean, J.H., Rotzoll, K., Izuka, S.K., and Jacobs, G.A., 2019, Enabling real-time user interaction for decision support: experiences extending a local Agave platform metadata service: in Practice and Experience in Advanced Research Computing (PEARC '19), July 28-August 1, 2019, Chicago, IL, USA. ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3332186.3332252

J. McLean., S.B. Cleveland, K. Rotzoll, S.K. Izuka, J. Leigh, G.J. Jacobs, R. Theriot, "The 'Ike Wai Hawai'i Groundwater Recharge Tool," In Proc. Gateways 2019, San Diego, CA, USA, September 2019. https://doi.org/10.17605/OSF.IO/TH9W2.

Rotzoll, K., S.K. Izuka, L. Bremer, J. McLean, S.B. Cleveland, L. Brewington, 2020, Exploring recharge changes with the web-based Hawai'i Groundwater Recharge Tool: presented at 2020 Pacific Water Conference, American Water Works Association, Honolulu, HI, February 5–6, 2020

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The Hawai‘i Groundwater Recharge Tool

- Online tool (http://recharge.ikewai.org/)
- Quickly explore potential effects of land-cover and climate changes on groundwater recharge…with some limitations
- Pilot website currently limited to O‘ahu and two climate scenarios, but it is expandable

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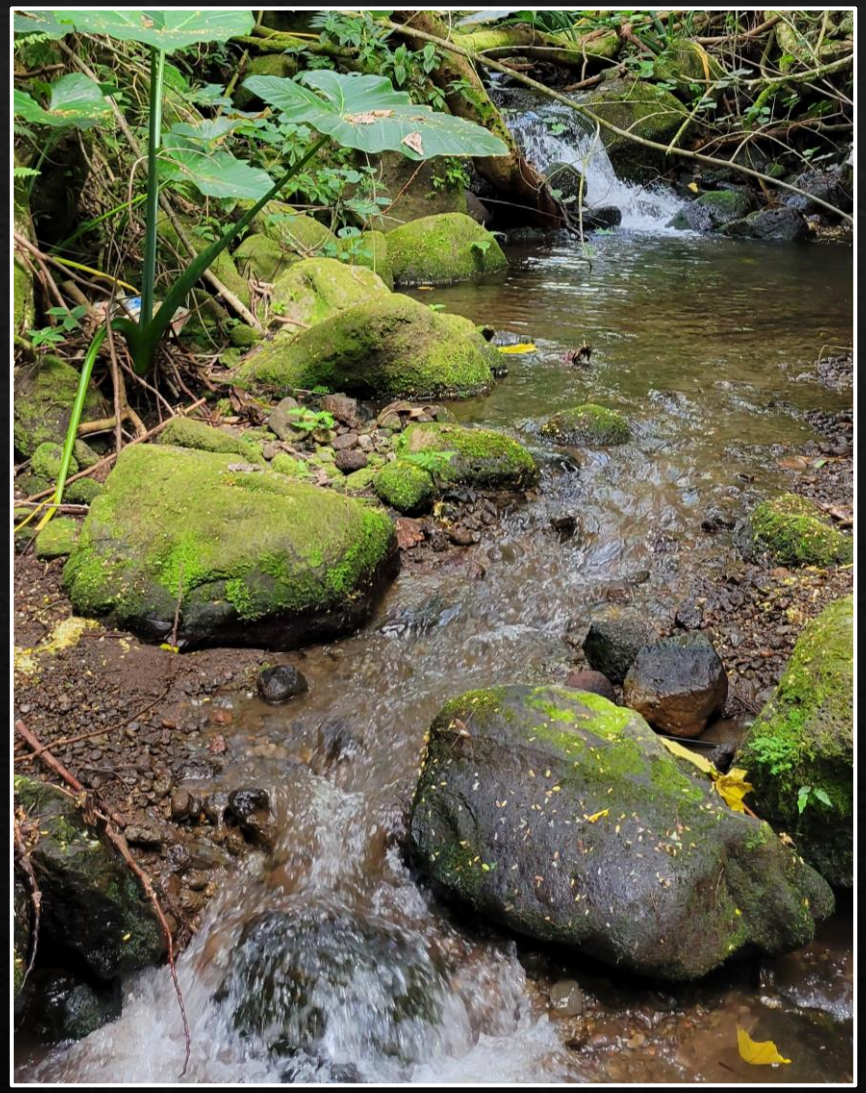
Speaker Contact Information



He‘eia Stream, O‘ahu

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