Carbon flux and Storage - State and Island level

The impact on climate change for each human use and land is expressed in comparable units through the CO_2 equivalents.

STATE & ISLAND LEVEL million metric tons of CO_2 equivalent ($mmtCO_2eq$)							
	State	**Oahu**	**Hawaii**	**Kauai**	**Maui**	**Molokai**	**Lanai**
Population[1]	1,361,790	953,207	186,738	66,921	144,444	7,345	3,135
Land area (acres)[1]	4,034,560	382,080	2,577,920	353,280	465,280	166,400	89,600
FLUX - Annual emissions minus annual sequestration							
Electric power[2]	10.18	6.77	0.77	0.35	0.78	0.05	0.02
Transport[2]	9.79	9.25	1.28	0.54	1.38	0.09	0.04
Food[3]*	3.49	2.44	0.48	0.17	0.37	0.02	0.01
Stuff[3]*	4.02	2.90	0.47	0.18	0.41	0.02	0.01
Waste[2]	0.78	0.72	0.14	0.07	0.13	0.01	0
Land use							
Livestock, ag, forest fires[2]	1.05	0.09	0.48	0.1	0.13	0.01	0.1
Grassland[4]	0.81	0.02	0.66	0.03	0.06	0.01	0.02
Urban trees[2]	-0.4	-0.4	no data	no data	no data	no data	no data
Shrubland[4]	-0.96	-0.07	-0.57	-0.08	-0.08	-0.11	-0.04
Forest[4]	-1.96	-0.23	-1.11	-0.23	-0.25	-0.08	-0.05
TOTAL NET EMISSIONS / YR	**26.8**	**21.49**	**2.59**	**1.13**	**2.93**	**0.02**	**0.11**
Long term carbon storage							
Forest[4]	143.79	19.03	92.63	0.03	21.25	6.77	4.09
Shrubland[4]	22.31	1.84	14.67	0.01	2.05	2.78	0.97
Grassland[4]	51.97	1.48	44.16	0.01	4.31	0.78	1.22
Soil / other land[4]	5.70	0.02	5.34	0.00	0.29	0.03	0.01
TOTAL STORED	**223.77**	**22.36**	**156.80**	**0.05**	**27.91**	**10.35**	**6.30**

*Mostly imported.

Sources

1 - https://energy.hawaii.gov/wp-content/uploads/2011/10/ghg-inventory-20081.pdf
2 - ICF International for DBEDt December 31 2008 (2007 for all island level data)
https://health.hawaii.gov/cab/files/2019/02/2015-Inventory_Final-Report_January-2019-004-1.pdf (2015 for State level data only)
3 - coolclimate calculator, UC Berkeley
4 - CAH USGS study 2017

Land Use: Part of the Problem → Part of the Solution?

Before human contact, Hawaii was covered with forests which stored carbon in their biomass and deposited organic matter in the soil. The capacity of the land to sequester and store carbon has been reduced due urbanization, agriculture and harvesting wood. Still yet, nine times the carbon emitted each year is stored in the top meter of Hawaii's soil (71%), in dead biomass on the ground (5%) and in the live biomass (24%).[1] Wetlands especially store carbon in the soil as the organic matter does not rot and builds up over time. Also, every year, 11% of the carbon emitted in Hawaii is sequestered by living plants. This sequestration is the amount of carbon taken in through photosynthesis, minus the amount released through respiration.

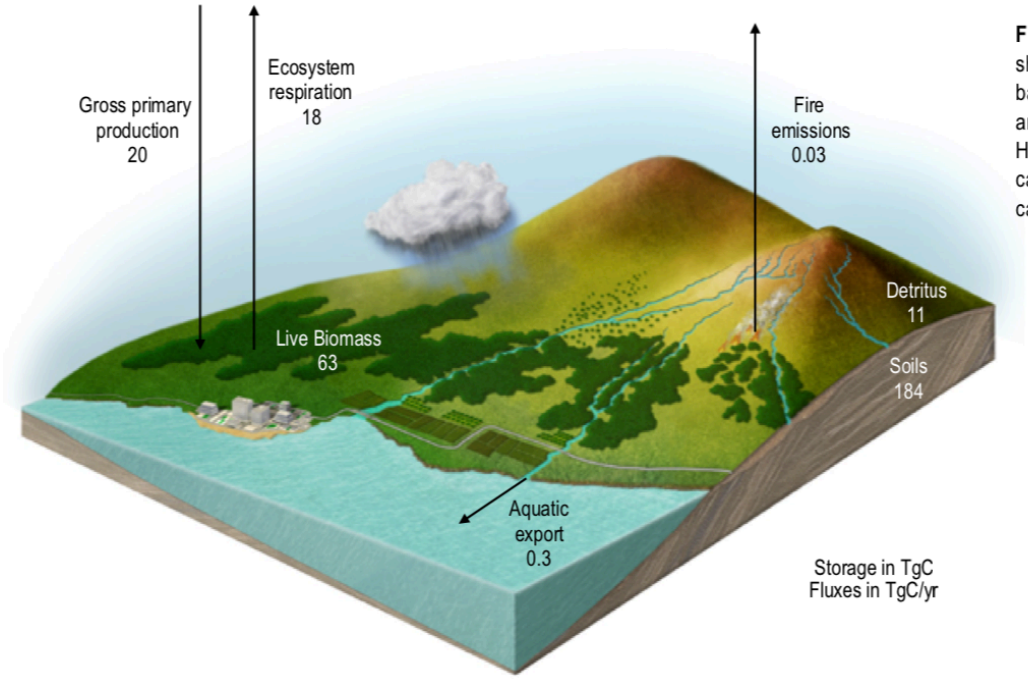

Figure 9.1. Diagram showing summary of current baseline carbon stocks and fluxes for the State of Hawai'i. TgC, teragrams of carbon; TgC/yr, teragrams o carbon per year.

Can Hawaii's natural carbon sink be protected? Can it be increased?

Carbon flux and storage State and island level

STATE & ISLAND LEVEL million metric tons of CO2 equivalent (mmtCO2eq)							
	State	**Oahu**	**Hawaii**	**Kauai**	**Maui**	**Molokai**	**Lanai**
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FLUX - Annual emissions minus annual sequestration							
Livestock, ag, forest fires[2]	1.05	0.09	0.48	0.1	0.13	0.01	0.1

[1] https://pubs.usgs.gov/pp/1834/a/pp1834.pdf

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Urban trees[2]	-0.4	-0.4	no data	no data	no data	no data	no data
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1 - https://energy.hawaii.gov/wp-content/uploads/2011/10/ghg-inventory-20081.pdf

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https://health.hawaii.gov/cab/files/2019/02/2015-Inventory_Final-Report_January-2019-004-1.pdf (2015 for State level data only)

4 - CAH USGS study 2017

Public and Private Forests

All Hawaii soil stores some carbon and all plants store carbon. Grasslands release more through respiration than they take in through photosynthesis. Forests store and sequester the most. Forests in wetter places store and sequester more carbon. Shrubland is forests with vegetation less than 20 feet tall.

Metric tons of carbon stored / sequestered by one square kilometer of land in Hawaii[2]:

mtCO2eq per km^2		
	store	Sequester/yr
alien tree farm	46,914	453
invaded mesic-wet	32,374	327
native mesic-wet	30,591	372
grasslands	13,439	-201
shrublands	9,011	353
invaded dry	8,819	173
native dry	7,616	298
bare	1,896	0

[2] https://pubs.usgs.gov/pp/1834/a/pp1834.pdf

Costs of restoring native forests would be variable for each site and work plan. The State is focused on first protecting existing native forests which is much less costly than restoring areas that no longer have native forests.

The following estimated costs are based on a study for restoring a native forest to a State managed watershed on Hawaii island that is predominantly invasive grassland. In many places, a crucial part of the restoration process is to first fence in the entire area and remove ungulates (pigs and goats). [3]

Protect existing native forest	cost per km^2
Install fence and remove ungulates and invasive plants	$46,259
Annual maintenance	$16,103
Replant native forests – no fence	cost per km^2
Restore landscape	$410,400
Annual maintenance	$15,900
Replant native forests – with fence	cost per km^2
Restore landscape	$456,660
Annual maintenance	$16,103

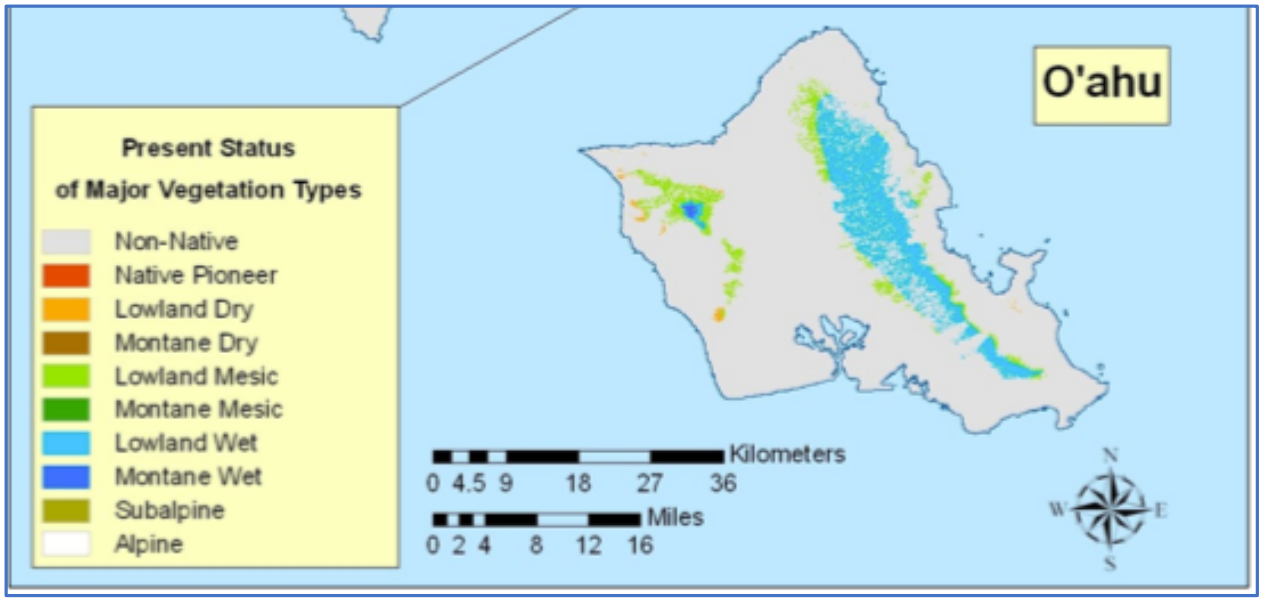
The value of forests. All forests provide benefits beyond carbon storage in terms of sediment control, water filtration and nutrient cycling, but native Hawaiian forests provide additional biodiversity benefits.

Hawaii's native forests are among the Earth's biological treasures, sheltering more than 10,000 unique species. These forests supply our state with fresh water, protect our world-class beaches from destructive run-off and sediment, and are a vital link to the survival of Hawaiian cultural practices. The forests of one watershed in Hawaii create $7.4 to $14 billion in benefits from water quality and retention, species habitat and biodiversity, subsistence, hunting and commercial harvests, aesthetic value and ecotourism, and climate control.[4]

Hawaii landscapes are dominated by invasive species on Oʻahu, Lānaʻi, and Molokaʻi (81–86 percent), and Hawaii (42 percent). Grasslands cover about one quarter of all land and are dominated by non-native species of grass. Efforts to increase the carbon capacity of the land can address these biodiversity issues at the same time.

[3] https://bioone.org/journals/pacific-science/volume-71/issue-4/71.4.2/Estimating-Cost-Effectiveness-of-Hawaiian-Dry-Forest-Restoration-Using-Spatial/10.2984/71.4.2.full

[4] https://www.nature.org/media/hawaii/the-last-stand-hawaiian-forest.pdf



https://dlnr.hawaii.gov/forestry/files/2013/09/Hawaii-Forest-Action-Plan-2016-FINAL.pdf
See pg. 202 for maps of all islands.

What the State is doing now.[5]

Protect existing forests. Hawaii has 43,194 km^2 of forest land. 34% is on public land and the rest is privately owned or managed.[6] The State tries to prevent environmentally important private forestlands from being converted to non-forest uses by purchasing it. They also work with private landowners to assist them with plans to restore and manage forests on their lands.

The State's top priority for forestry is to protect the supply of fresh water. To this end, the State is focused on watersheds and has established watershed partnerships between the State and other land owners on the various watersheds. The work includes fencing watershed forests, removing ungulates, removing non-native plants and planting native trees.

They also work to maintain the health of existing forests by controlling invasive plants, insects and plant diseases.

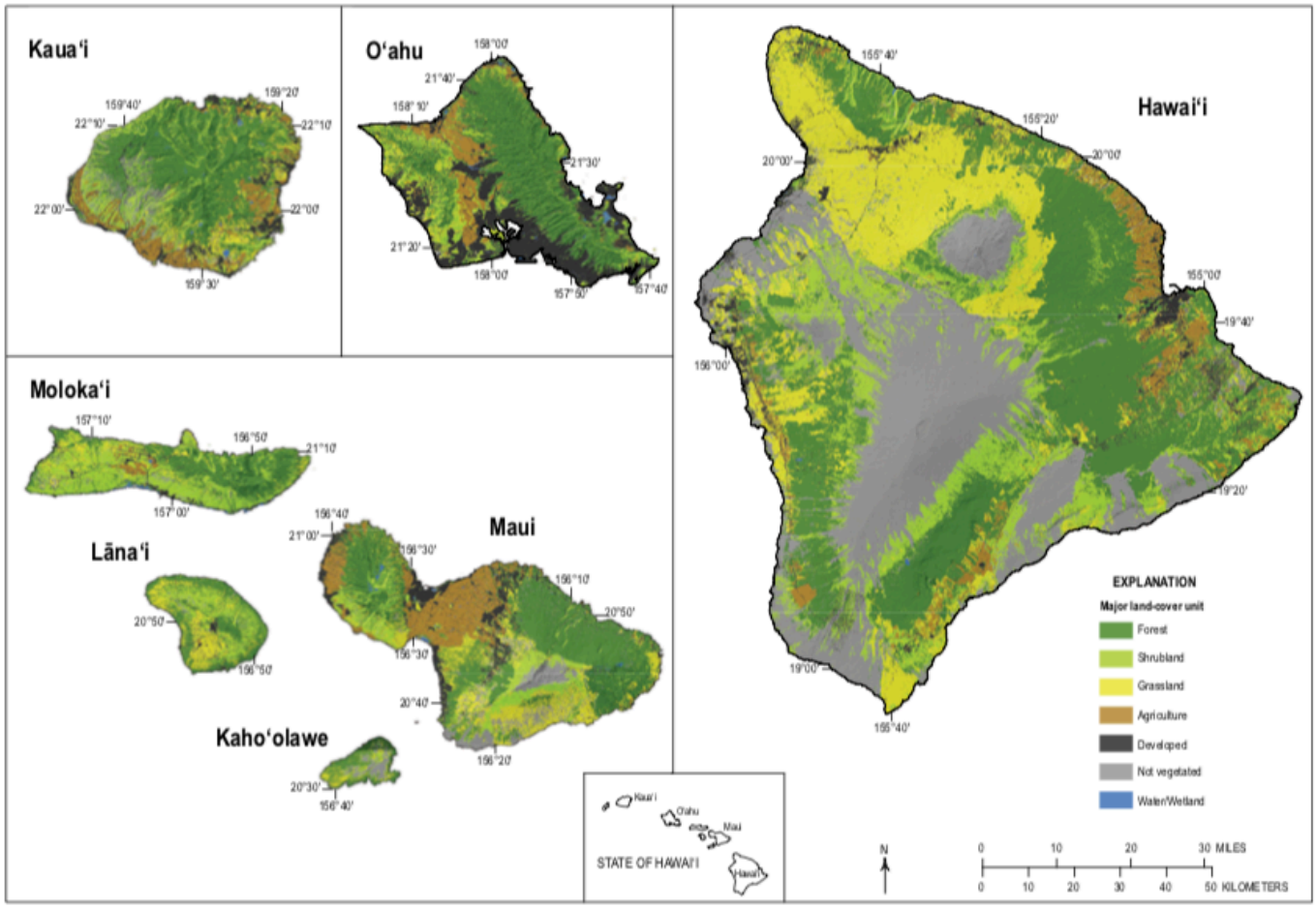
They also work to control and reduce wildfires.

Establish reforestation projects. These can target habitat restoration, protection of coastal communities from flooding, prevention of erosion, or commercial uses such as biomass and biofuel production, forest products or carbon offsets.

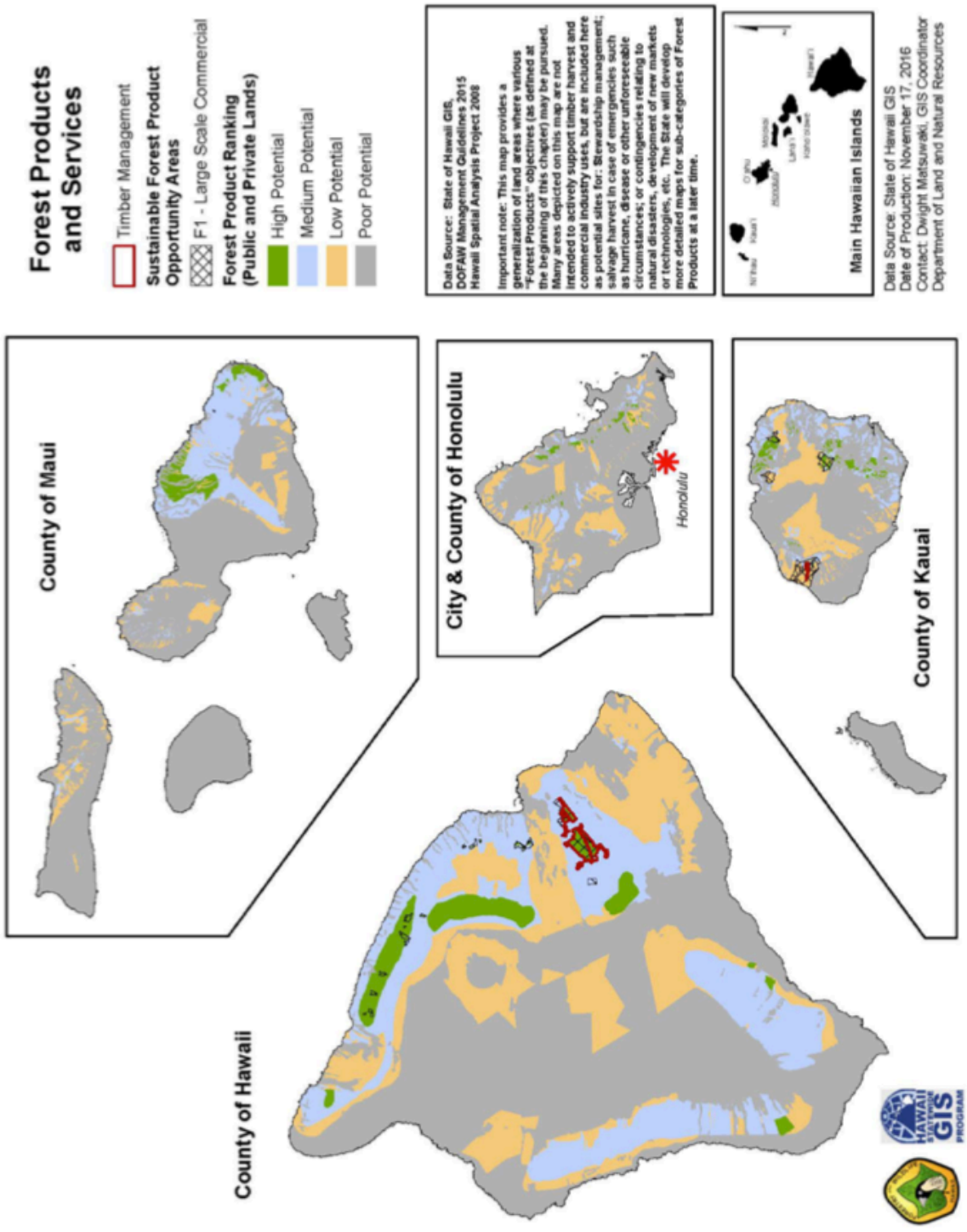
[5] https://dlnr.hawaii.gov/forestry/files/2013/09/Hawaii-Forest-Action-Plan-2016-FINAL.pdf
[6] https://www.stateforesters.org/wp-content/uploads/2018/07/Hawaii-2018.pdf

Look at maps of your project area. Are there opportunities to convert existing public lands from a grassland or shrubland to a forest? For the size parcel you identify, what would be the expected additional carbon benefits? If the forest was composed of native trees what would the biodiversity benefits be? What would be the expected costs?

This map shows existing land cover. You can see any area up close on a GIS map.
http://www.arcgis.com/home/webmap/viewer.html?webmap=ca79e1c44a884a93b9202399787a63d0&extent=-161.3148,18.4099,-153.8936,22.9312



The next map shows the areas DOFAW has designated as promising for providing forest products and services based on distribution and forest type, or potential to support forest vegetation, and by analyzing environmental factors such as rainfall, elevation, and soils. These forest areas are mapped for the entire state, including private and public lands, and are further categorized as having high, medium, low, or poor potential for forest.



Map 8.6. Priority area for forest products and services in the State of Hawai'i.

Urban Trees in Public and Private Land

Cost and Carbon sequestered / stored for Honolulu's urban trees
A 2007 study of 235,800 trees cared for by the Division of Urban Forestry, about 60% on streets and 40% in parks, found benefits of $2.98 for every $1 spent on trees. While benefits and costs of care varied for the 213 species and stages of maturity. The larger the trees, the more benefits they provided. On average they spent $30/tree/yr on maintenance. The trees stored an estimated 25,529 tons CO_2 (0.11 tons CO_2 per tree on average).[7]

Losing our urban forest. While we do not have good data over a long period of time, data from one recent 4-year period showed tree canopy loss in developed areas on Oahu of about 5% or approximately 76,600 trees.[8] Some larger subdivisions were built during this time, but most of the loss was from many small tree removals. The Division of Urban Forestry plants and maintains trees on Oahu along roads in neighborhoods and commercial areas. They have many more requests to remove trees in front of people's homes because the tree drop "rubbish" or blocks a view, then they have requests to plant new trees. People are also continually shifting yard space to built space on their residential properties. Trees do not live forever and it may have to be removed because it is old or diseased. The tree may not be replaced, but even if it is, the new tree will not provide the same environmental benefits until it matures.

Other Benefits. Urban trees have many benefits in addition to sequestering and storing carbon. They reduce the "heat island" effect that happens when our cities absorb and re-radiate the heat from the sun, making local temperatures much higher than surrounding areas. Trees reduce temperatures through their shade and through transpiration. When they shade homes and businesses, they reduce the need for air conditioning, saving money. They absorb harmful pollutants that cause respiratory problems and block sun which causes skin cancer. Trees increase the amount of rainwater that infiltrates the soil, recharging our groundwater. At the same time, trees decrease surface runoff which carries sediment and harmful pollutants to streams and the ocean and deposits on our coral reefs. They provide beauty and a sense of emotional well-being which translates to economic benefits for property owners and businesses. They provide habitat and food for birds and insects, and food for people as well.[9]

Plans for urban trees. The mayor has committed to planting 100,000 trees and expanding the urban canopy to reach 35% by 2035. Trees cost money to plant and maintain. There have been

[7] https://static1.squarespace.com/static/59af5d3cd7bdce7aa5c3e11f/t/5bd9f1a01ae6cfe0184dca4b/1541009827717/Hnl+Municipal+Forest+Resource+Analysis-2007.pdf
[8] https://smarttreespacific.org/wp-content/uploads/Tree-Canopy-Report-Honolulu-2016_revised091117.pdf
[9] https://www.treesforhonolulu.org

no staff increases or budget increases that would allow this planned expansion of the urban forest to be implemented.

Some non-profits plant trees and protect them from being cut down. A group of residents formed The Outdoor Circle 100 years ago and planted many of the mature trees in our parks and along our streets today.

Can Agriculture be Part of the Solution?

Agriculture is a major source of carbon emissions. Forests are cleared for agriculture, releasing the carbon. After that, they continue to emit more than they take in due to inputs like fertilizer, pesticide and herbicide, due to operating fossil fuel powered farm equipment, and due to tilling the soil which exposes more organic matter to bacteria that decompose it and release the stored carbon to the atmosphere. For farm animals, especially cows and sheep, they emit methane gas as a byproduct of their digestion. Manure, when it ferments, also emits methane.

Hawaii 2015 Ranching, Dairies and Farm emissions[10]	 MMT CO_2 Eq.
Enteric fermentation (gas from digestion)	0.24
Manure Management	0.04
Agriculture Soil Management	0.14
Field Burning of Agricultural Residues	0.01
Urea Application (fertilizer)	?
Agricultural Soil Carbon	0.56

Carbon farming - Ranchers and crop farmers engaging in practices that increase and store carbon in their soil call it "carbon farming." Their techniques include not tilling, composting, planting cover crops with deep roots, reducing tillage, leaving crop residues on the land, and managing grazing. [11] These practices also make the land more productive for the farmers by improving soil structure and its ability to hold on to water and nutrients.

Another strategy is to grow longer lasting crops that stay in the soil and are harvested each year. Scientists are working to develop crops with larger root systems so more carbon is stored in the soil, and more stays in the soil after harvesting. Changing agricultural practices can not only store more carbon in the soil than is lost, but it also increases biodiversity.

Agro-forestry - Tree plantations for lumber actually store and sequester more carbon than native or invasive forests in Hawaii.[1] Trees grown for lumber sequester and store carbon until

[10] https://health.hawaii.gov/cab/files/2019/02/2015-Inventory_Final-Report_January-2019-004-1.pdf
[11] https://www.nrdc.org/stories/could-our-farms-become-worlds-great-untapped-carbon-sink

they are harvested. When they are harvested, if some part of the wood does not rot because it is used for construction or furniture, the carbon will remain stored. Fruit trees can sequester and store carbon while providing food and other benefits.

What is the best way to use nature to sequester and store carbon in Hawaii?

What are the trade-offs between costs and benefits?

Cost of Using Fossil Fuels

Hawaii sends almost $4 billion annually out of the State to purchase fossil fuels. Funds spent on fossil fuels do not contribute to the economy in Hawaii. Also, dependence on oil makes the State vulnerable to oil price fluctuations. 2017 purchases[1]**:**
$3,757,000,000 - oil
$46,000,000 - coal
$91,000,000 - natural gas

There are many current and expected financial costs to Hawaii associated with climate change. These include damage to coastal infrastructure from sea level rise and storm surges. Damage to property due to increase storms and flooding. Increased temperatures and decreases in trade winds result in the need to install and use more air conditioning. Lost agricultural productivity. Decline in Hawaii's fisheries as a result of coral reef damage. Declines in tourism due to more frequent extreme weather and damage to our shoreline and reefs.

Dependence on fossil fuels makes Hawaii vulnerable to port closures due to natural disasters or military conflict. Ports closed briefly during Tropical Cyclone Olivia in 2018.

There is a risk of accidents and oil spills that could negatively impact wildlife in the ocean as well as seabirds on the surface of the ocean. Over 1,000 oil spills have been documented since 1960.[2]

Burning fossil fuels results in smog, acid rain, soot and particulates increase, greenhouse gas emissions, and dispersal of some heavy metal contaminants. These are harmful to human health, especially for people with respiratory ailments such as asthma.[3] You can calculate caused or avoided pollution here. http://www.cleanerandgreener.org/resources/pollutioncalculator.html

How does your solution compare to continuing to use fossil fuels?

[1] (www.eia.gov)
[2] https://www.livescience.com/9885-faq-science-history-oil-spills.html
[3] https://www.epa.gov/nutrientpollution/sources-and-solutions-fossil-fuels