

Hawaiian Islands Rates of Change

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Introduction

The following report evaluates rates of change for Habitats identified for Habitat Status Assessments (HSAs) by the Pacific Islands Fish and Wildlife Office for the Hawaiian Islands. These rates are intended to serve as baseline for a status quo future scenario under the HSA for all habitats except Streams. It utilizes available landcover/vegetation maps for the main eight islands (Hawai'i, Maui, Kaho'olawe, Lāna'i, Moloka'i, Oahu, Kaua'i, and Ni'ihau) from multiple time periods to identify how each Habitat changes over time. The following Habitats were evaluated in this project: Developed, Coastal, Wetlands, Dry Forest, Dry Grasslands and Shrublands, Mesic Forest, Mesic Grasslands and Shrublands, Wet Forest, and Wet Grasslands and Shrublands.

Methods

Rates of change for the Hawaiian Islands were estimated using regional change data layers from the Coastal Change Analysis Program (CCAP; NOAA 2008_{a-f}, 2009_{a-d}, 2010, 2013, 2014, 2015_{a,b}, 2017, 2018_{a,b}). Change rate time periods associated with each island are identified in Table 1. Each change data layer identifies areas where landcover types changed and stayed the same over several time periods. Unfortunately, the landcover types used in the CCAP analysis do not match up directly with all of the Habitats used in the Hawaiian Island HSAs. Specifically, the CCAP layer does not identify forest or grassland and shrubland areas that occur in dry, mesic, or wet moisture zones. Therefore, the CCAP categories had to be re-classified into wet, mesic, and dry forest and grassland and shrubland using the moisture layer map from Price and Jacobi (2012). The sections below outline the CCAP categories used for each specific HSA Habitat.

Developed – The Developed habitat was identified as all areas classified under CCAP as Developed Open Space, Impervious Surface, and Cultivated.

Coastal – CCAP identifies sand beaches as Unconsolidated Shoreline but does not have a separate Coastal class. Therefore, only beach areas were identified as Coastal habitat for this change assessment.

Grasslands and Shrublands (Dry, Mesic, Wet) – Grasslands and Shrublands are included in the Scrub/Shrub, Grassland, and Pasture CCAP categories. All areas within these categories that fell within the Dry, Mesic, and Wet moisture zones were assigned to those HSAs, respectively.

Forest (Dry, Mesic, Wet) – All forests in the Hawaiian Islands are included in the Evergreen, Deciduous, and Mixed Forest CCAP categories. All areas within these categories that fell within the Dry, Mesic, and Wet moisture zones were assigned to those HSAs, respectively.

Wetlands – The Wetland habitat was identified as all areas classified as Palustrine Forested Wetland, Palustrine Scrub/Shrub Wetland, Palustrine Emergent Wetland, Palustrine Aquatic Bed, Estuarine Aquatic Bed, Estuarine Emergent Wetland, and Water (excluding marine areas).

Once the CCAP change layer was classified into the appropriate HSA habitats, acreages for each transition between habitats was calculated. These acreages were then used to calculate the total increases and decreases in each habitat type over the time period of the CCAP layer. These total increases and decreases were divided by the number of years covered by the change layer (e.g., 1992 to 2001, 2001 to 2005, 2005 to 2010/11) to obtain annual rates of increase and decrease by

Table 1. Dates of Coastal Change Analysis Program change layer data for each island or island group used for estimating change rates for Habitat Status Assessments.

Island	1992-2001	2001-2005	2005-2010	2005-2011
Hawai'i	X	X	X	
Maui	X	X	X	
Kaho'olawe	X	X		
Lāna'i	X	X		X
Moloka'i	X	X	X	
Oahu	X	X		X
Kaua'i	X	X	X	
Ni'ihau	X	X	X	

habitat and year range. For this assessment, the average of the yearly rates for the 2001-2005 and 2005-2010/11 time ranges for each habitat and island was then used as the overall rate. The 2001-2005 and 2005-2010/11 time ranges used because they were expected to more accurately represent recent trends. Once calculated, the overall rates were then projected to 2035, using the carbon assessment map (which was based on 2012 imagery) as the baseline, to calculate changes in each habitat over the foreseeable future. Percent changes in a Habitat $\geq 10\%$ were generally considered significant for this assessment.

Results and Conclusion

Tables 2-4 and 6-8 summarize the change in acres and percent of island for each Habitat on Hawai'i, Maui, Kaho'olawe, Lāna'i, Moloka'i, Oahu, Kaua'i, and Ni'ihau from 2012 to 2035. These estimates represent the status quo of habitat change on each island. A brief discussion on the results for each habitat is provided below along with some information on whether change is likely or associated with mapping error or misclassification. The Conclusion section summarizes the expected changes by Habitat and provides recommendations for future assessments.

Coastal

Table 2 summarizes the changes in acres and percent of island for the Coastal habitat in the Hawaiian Islands from 2016 to 2035. With the exception of Kaho'olawe and Moloka'i, the spatial data used to calculate acreages of available coastal habitat indicates that it does not occur on most of the islands. The CCAP layer used to evaluate change also only identifies limited areas as coastal habitat. This is likely due to the scale of coastal habitat or the inability to differentiate it from surrounding habitats. Surveys by Jacobi and Warshauer (2017) clearly show that Coastal habitat is more extensive than reported here. Due to the limited data available and the small acreages identified as Coastal habitat, the changes noted are more likely to be associated with mapping and georectification error than actual change. Therefore, the change rates identified for Coastal habitat should be considered inconclusive.

Table 2. *Estimated acreages and percent of island in Coastal habitat currently (2012) and in the foreseeable future (2035) for the Hawaiian Islands (excluding the Northwestern Hawaiian Islands). Percent (%) change is the difference between the % of land in 2035 and 2012. No data is currently available for projecting habitat change in the foreseeable future for the remaining islands in the archipelago.*

Island	Current (2012)		Future (2035)		% Change 2012 to 2035
	Acres	% of Land	Acres	% of Land	
Hawai'i	0	0%	0	0%	0%
Maui	0	0%	0	0%	0%
Kaho'olawe	13	0%	13	0%	0%
Lāna'i	0	0%	0	0%	0%
Moloka'i	28	0%	85	0%	203%
Oahu	0	0%	0	0%	0%
Kaua'i	0	0%	0	0%	0%
Ni'ihau	0	0%	0	0%	0%

Developed

Tables 3 and 4 summarize the changes in acres and percent of island for the Developed habitat, with and without the cultivated CCAP landcover category, on the Hawaiian Islands. When cultivated is included in the Developed habitat, little to no change is projected for Hawaii, Kaho'olawe, Lāna'i, Moloka'i, Oahu, and Ni'ihau (Table 3). However, sizeable decreases in developed are projected for Maui and Kaua'i (Table 3). These decreases are related to the conversion of cultivated lands into other habitats, such as grasslands and shrublands. This is supported by the data in Table 4 which shows strong decreasing trends in the cultivated portion of the Developed habitat on Maui, Oahu, and Kaua'i. Figure 1 shows that the majority of the cultivated land is converted to Dry and Mesic Grassland and Shrubland, indicating the cultivated areas were likely abandoned and converted to Grassland and Shrubland naturally.

Developed habitat, with the cultivated portion removed, shows slight increases projected on Hawai'i, Maui, and Kaua'i (Table 4). This indicates that these islands will continued to be urbanized in the foreseeable future. Oahu also shows an increase in development but this is small in relation to the current level of urbanization on the island. The increases on Hawai'i, Maui, Oahu and Kaua'i are consistent with census projections of increased populations in Hawai'i, Maui, Honolulu, and Kaua'i Counties in 2035 (Table 5). The remaining islands show little to no change in the Developed habitat with the cultivated portion removed. Development may increase on these islands but the changes would be small in relation to the size of the currently developed area on the island.

Table 3. Estimated acreages and percent of island in Developed habitat currently (2012) and in the foreseeable future (2035) for the Hawaiian Islands (excluding the Northwestern Hawaiian Islands). Percent (%) change is the difference between the % of land in 2035 and 2012. No data is currently available for projecting habitat change in the foreseeable future for the remaining islands in the archipelago.

Island	Current (2012)		Future (2035)		% Change 2012 to 2035
	Acre	% of Land	Acre	% of Land	
Hawai'i	172,922	7%	183,465	7%	6%
Maui	99,478	22%	71,857	16%	-28%
Kaho'olawe	149	1%	149	1%	0%
Lāna'i	3,339	4%	3,481	4%	4%
Moloka'i	10,418	6%	10,247	6%	-2%
Oahu	122,313	33%	117,084	32%	-4%
Kaua'i	63,726	18%	23,487	7%	-63%
Ni'ihau	332	1%	332	1%	0%

Table 4. Estimated acreages and percent of island in cultivated and developed (excluding cultivated) habitat currently (2012) and in the foreseeable future (2035) for the Hawaiian Islands (excluding the Northwestern Hawaiian Islands). Percent (%) change is the difference between the % of land in 2035 and 2012. No data is currently available for projecting habitat change in the foreseeable future for the remaining islands in the archipelago.

Habitat	Island	Current (2012)		Future (2035)		% Change 2012 to 2035
		Acre	% of Land	Acre	% of Land	
Developed (minus cultivated)	Hawai'i	76,064	3%	87,090	3%	14%
	Maui	34,550	8%	38,528	8%	12%
	Kaho'olawe	149	1%	149	1%	0%
	Lāna'i	3,227	4%	3,369	4%	4%
	Moloka'i	6,658	4%	6,743	4%	1%
	Oahu	90,052	24%	95,053	26%	6%
	Kaua'i	28,402	8%	32,949	9%	16%
	Ni'ihau	332	1%	332	1%	0%
Cultivated	Hawai'i	96,858	4%	96,403	4%	0%
	Maui	64,928	14%	33,328	7%	-49%
	Kaho'olawe	0	0%	0	0%	0%
	Lāna'i	112	0%	112	0%	0%
	Moloka'i	3,760	2%	3,533	2%	-6%
	Oahu	32,261	9%	22,031	6%	-32%
	Kaua'i	35,324	10%	0	0%	-100%
	Ni'ihau	0	0%	0	0%	0%

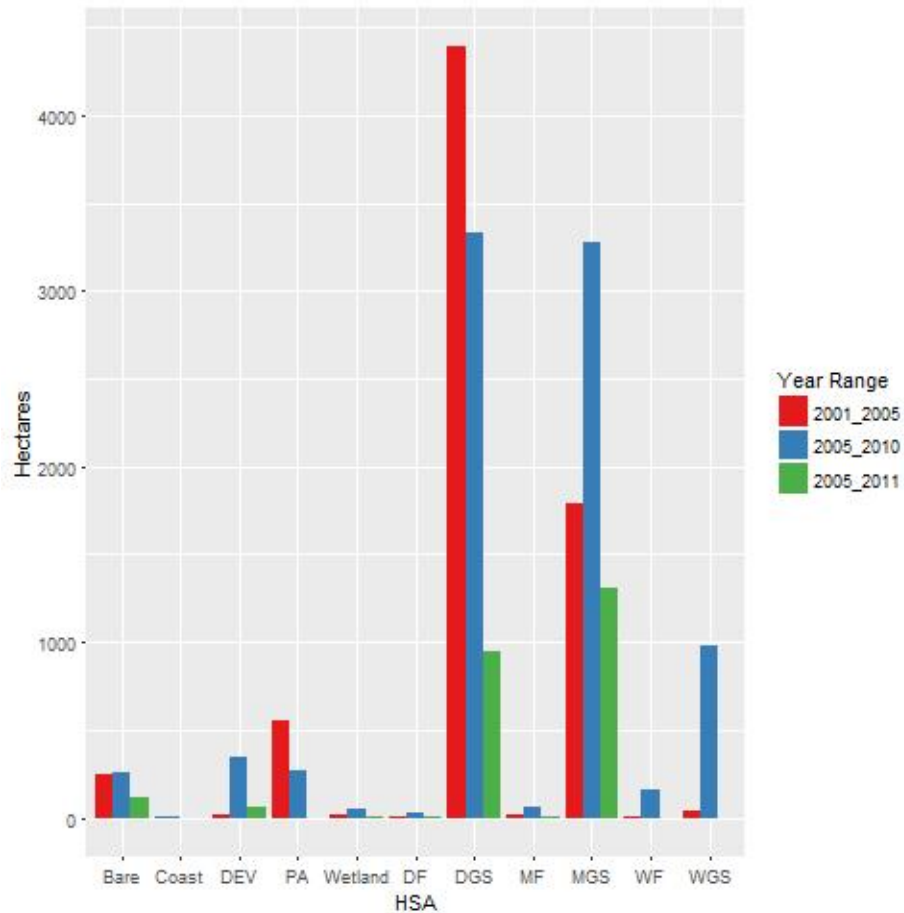


Figure 1. Hectares of cultivated converted to other Habitats between 2001 and 2011. Habitats include Bare, Coast, Developed (without cultivated, DEV), Wetland, Dry Forest (DF), Dry Grassland and Shrubland (DGS), Mesic Forest (MF), Mesic Grassland and Shrubland (MGS), Wet Forest (WF), and Wet Grassland Shrubland (WGS). See Table 1 for islands associated with year ranges.

Table 5. Census estimates of the human population in Hawai'i, Honolulu, Kaua'i, and Maui Counties from 1980 to 2010 and projected population sizes from 2015 to 2035. Data derived from Table 1-1 of DBEDT (2012).

Year	Hawai'i County	Maui County	Honolulu County	Kaua'i County	State Total
1980	92,900	71,600	764,600	39,400	968,500
1985	105,900	85,147	804,294	44,357	1,039,698
1990	121,572	101,709	838,534	51,676	1,113,491
1995	140,492	117,895	881,399	57,068	1,196,854
2000	149,244	129,078	876,629	58,568	1,213,519
2005	168,237	143,448	918,181	62,863	1,292,729
2010	185,406	155,214	955,775	67,226	1,363,621
2015	202,700	168,000	976,200	71,400	1,418,300
2020	220,900	181,000	1,003,700	75,600	1,481,200
2025	239,600	194,200	1,029,400	80,000	1,543,200
2030	258,500	207,300	1,052,100	84,400	1,602,300
2035	277,300	220,200	1,071,200	88,700	1,657,500

Forests

Tables 6 summarizes the projected changes in acres and percent of island for the different forest habitats in Hawaii from 2012 to 2035. In general there is expected to be little to no change in dry, mesic, and wet forests across the islands. The only exceptions are increases in dry forest on Kaua'i and mesic forest on Hawai'i. The increases in Dry Forest on Kauai are related primarily to conversion of Dry Grassland and Shrubland as well as some conversion of cultivated and pasture areas to forest (Figure 2). The increase in Mesic Forest on Hawai'i is associated with conversion of Mesic Grassland and Shrublands, Pasture (a subset of Mesic Grassland and Shrubland), and Bare areas to forest (see figure 3).

Table 6. Estimated acreages and percent of island in dry, mesic, and wet forest habitats currently (2012) and in the foreseeable future (2035) for the Hawaiian Islands (excluding the Northwestern Hawaiian Islands). Percent (%) change is the difference between the % of land in 2035 and 2012. No data is currently available for projecting habitat change in the foreseeable future for the remaining islands in the archipelago.

Habitat	Island	Current (2012)		Future (2035)		% Change 2012 to 2035
		Acres	% of Land	Acres	% of Land	
Dry Forest	Hawai'i	92,516	4%	93,511	4%	1%
	Maui	35,087	8%	34,803	8%	-1%
	Kaho'olawe	13,657	48%	13,657	48%	0%
	Lāna'i	31,610	35%	32,804	36%	4%
	Moloka'i	21,281	13%	21,281	13%	0%
	Oahu	25,161	7%	25,104	7%	0%
	Kaua'i	11,734	3%	18,980	5%	62%
	Ni'ihau	32,624	71%	32,226	70%	-1%
Mesic Forest	Hawai'i	203,305	8%	268,664	10%	32%
	Maui	56,363	12%	58,949	13%	5%
	Kaho'olawe	0	0%	0	0%	0%
	Lāna'i	952	1%	952	1%	0%
	Moloka'i	20,052	12%	20,052	12%	0%
	Oahu	80,344	22%	84,948	23%	6%
	Kaua'i	74,124	21%	80,376	23%	8%
	Ni'ihau	0	0%	0	0%	0%
Wet Forest	Hawai'i	516,109	20%	539,695	21%	5%
	Maui	94,246	20%	93,962	20%	0%
	Kaho'olawe	0	0%	0	0%	0%
	Lāna'i	3,190	4%	3,417	4%	7%
	Moloka'i	17,434	11%	17,434	11%	0%
	Oahu	60,916	16%	60,916	16%	0%
	Kaua'i	85,022	24%	84,908	24%	0%
	Ni'ihau	0	0%	0	0%	0%

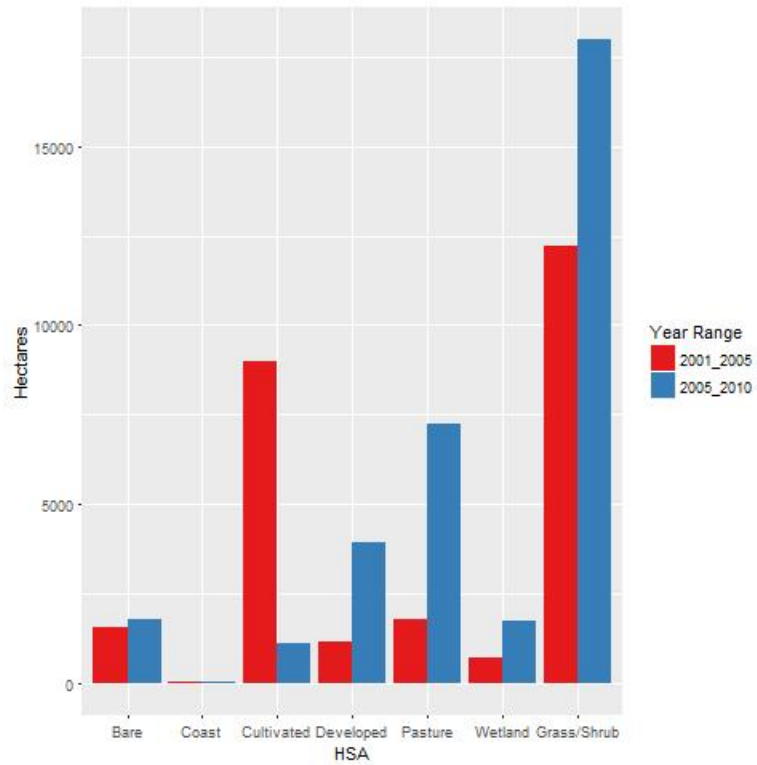


Figure 2. Hectares of Habitat converted to Dry Forest between 2001 and 2011 on Kauai.

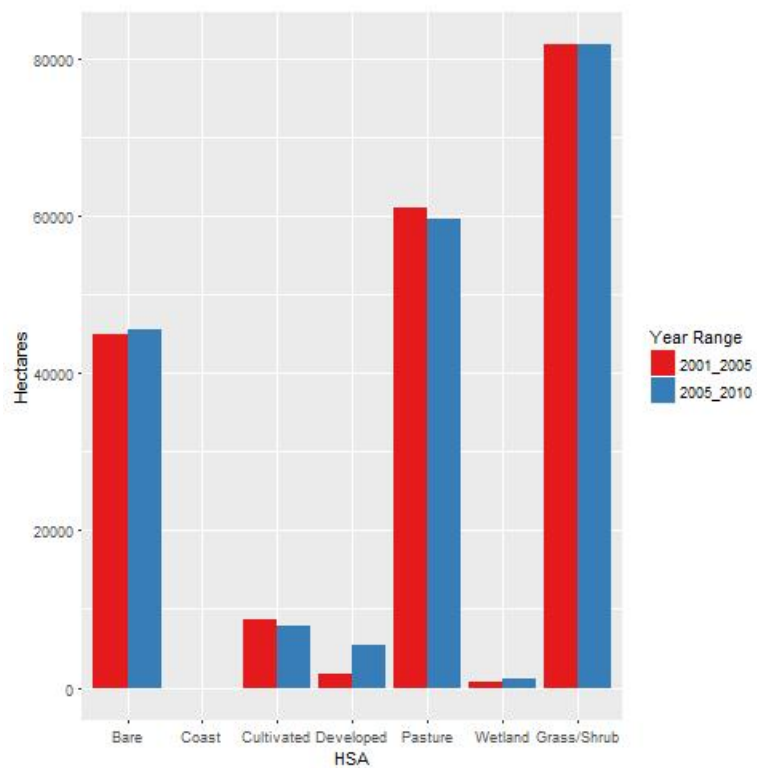


Figure 3. Hectares of Habitat converted to Mesic Forest between 2001 and 2011 on Hawaii.

Grasslands and Shrublands

Based on this assessment, Grasslands and Shrublands are projected to remain stable or increase across the islands (Table 7). Large increases in dry grassland and shrubland are expected on Maui, Lānaʻi, Oahu, and Kauaʻi. Slight increases in mesic grassland and shrubland are expected on Hawaiʻi and Maui while larger increases are expected on Oahu and Kauaʻi. Wet grassland and shrubland is generally stable except for an increase on Hawaiʻi and the potential loss of the limited wet grassland and shrubland on Lānaʻi. Figure 4-6 outline the sources of the increase in dry, mesic, and wet grassland and shrublands across the islands over the last decade. Over all islands, bare areas were primarily converted to Dry Grassland and Shrublands (Figure 4) while Mesic and Wet Forests were primarily converted to Mesic and Wet Grassland and Shrubland (Figure 5 and 6).

Table 7. Estimated acreages and percent of island in scrub/grass habitat currently (2012) and in the foreseeable future (2035) for the Hawaiian Islands (excluding the Northwestern Hawaiian Islands). Percent (%) change is the difference between the % of land in 2035 and 2012. No data is currently available for projecting habitat change in the foreseeable future for the remaining islands in the archipelago.

Habitat	Island	Current (2012)		Future (2035)		% Change 2012 to 2035
		Acres	% of Land	Acres	% of Land	
Dry Grasslands and Shrublands	Hawaiʻi	462,042	18%	442,008	17%	-4%
	Maui	66,058	14%	116,072	25%	76%
	Kahoʻolawe	8,611	30%	8,611	30%	0%
	Lānaʻi	46,839	52%	77,103	86%	65%
	Molokaʻi	74,744	46%	80,996	49%	8%
	Oahu	51,029	14%	78,991	21%	55%
	Kauaʻi	33,951	10%	74,786	21%	120%
	Niʻihau	6,948	15%	7,317	16%	5%
Mesic Grasslands and Shrublands	Hawaiʻi	325,322	13%	370,306	14%	14%
	Maui	54,244	12%	66,179	14%	22%
	Kahoʻolawe	0	0%	0	0%	0%
	Lānaʻi	2,198	2%	2,198	2%	0%
	Molokaʻi	9,022	5%	8,965	5%	-1%
	Oahu	21,043	6%	47,187	13%	124%
	Kauaʻi	45,416	13%	120,721	34%	166%
	Niʻihau	689	2%	689	2%	0%
Wet Grasslands and Shrublands	Hawaiʻi	114,971	4%	199,228	8%	73%
	Maui	14,643	3%	14,529	3%	-1%
	Kahoʻolawe	0	0%	0	0%	0%
	Lānaʻi	64	0%	0	0%	-100%
	Molokaʻi	5,627	3%	5,627	3%	0%
	Oahu	5,074	1%	5,074	1%	0%
	Kauaʻi	17,923	5%	18,150	5%	1%
	Niʻihau	0	0%	0	0%	0%

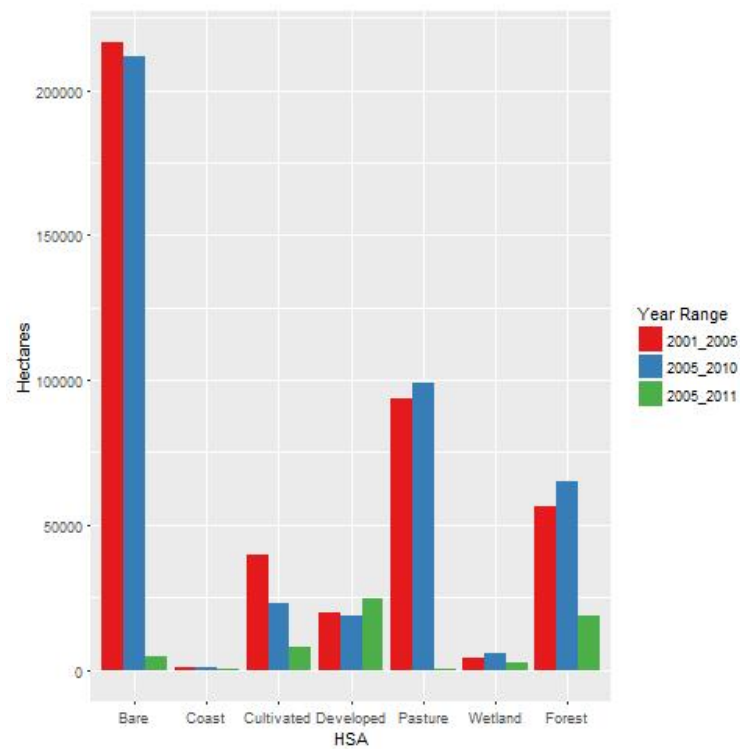


Figure 4. Hectares of Habitat converted to Dry Grassland and Shrubland between 2001 and 2011.

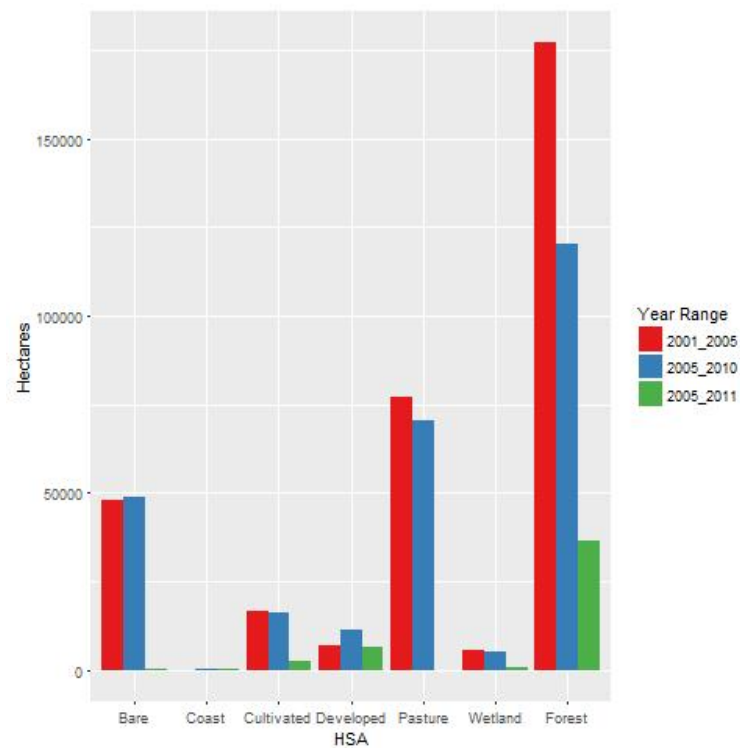


Figure 5. Hectares of Habitat converted to Mesic Grassland and Shrubland between 2001 and 2011.

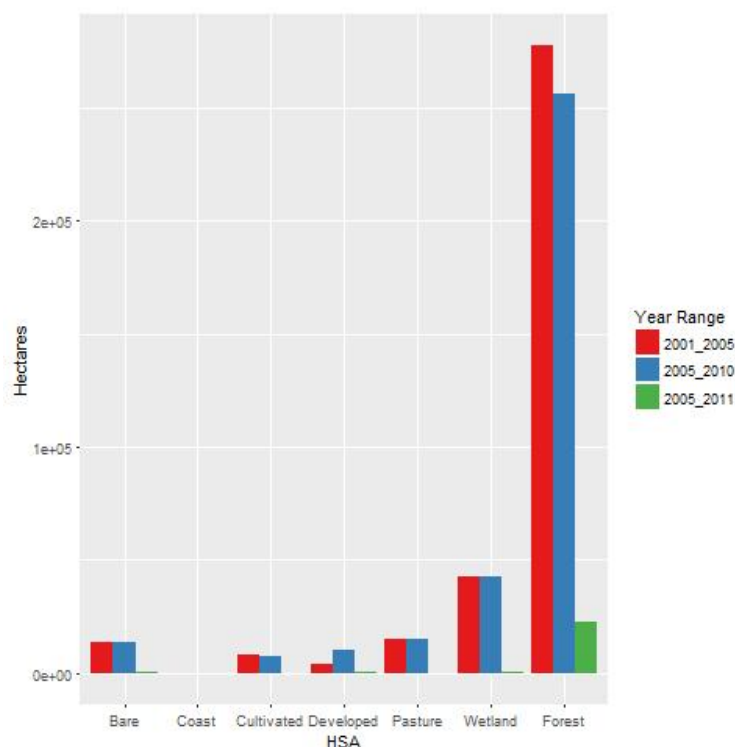


Figure 6. Hectares of Habitat converted to Wet Grassland and Shrubland between 2001 and 2011.

Wetland

This assessment projected little or no changes in the Wetland habitat in 2035 across the islands (Table 8). A slight increase is shown for Hawai'i and Ni'i'hau while a slight decrease is expected for Maui. The sources of the increase are uncertain and may be related to ponds created for grazing. The loss on Maui and increase on Ni'i'hau both are associated with reclassification to or from Coast (Figure 7 and 8). These are likely mapping errors and not actual changes. Therefore, Wetlands are expected to show little or no change in the foreseeable future.

Table 8. Estimated acreages and percent of island in wetland habitat currently (2012) and in the foreseeable future (2035) for the Hawaiian Islands (excluding the Northwestern Hawaiian Islands). Percent (%) change is the difference between the % of land in 2035 and 2012. No data is currently available for projecting habitat change in the foreseeable future for the remaining islands in the archipelago.

Island	Current (2012)		Future (2035)		% Change 2012 to 2035
	Acres	% of Land	Acres	% of Land	
Hawai'i	1,182	<1%	1,296	0%	10%
Maui	1,818	<1%	1,363	0%	-25%
Kaho'olawe	0	0%	0	0%	0%
Lāna'i	45	0%	45	0%	0%
Moloka'i	1,156	1%	1,128	1%	-2%
Oahu	3,136	1%	3,250	1%	4%
Kaua'i	1,948	1%	1,834	1%	-6%
Ni'i'hau	1,549	3%	2,004	4%	29%

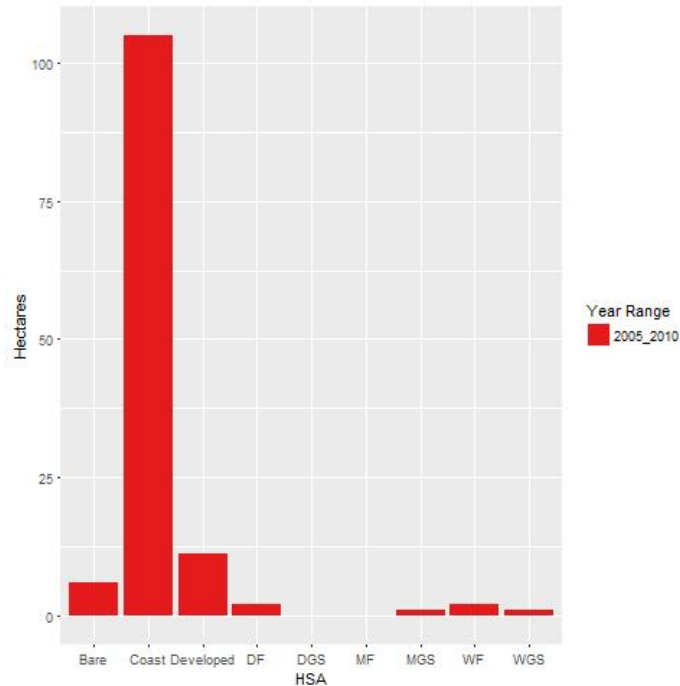


Figure 7. Hectares of Wetland converted to other Habitats between 2005 and 2010 on Maui. No change was observed from 2001 to 2005. Habitats include Bare, Coast, Developed, Dry Forest (DF), Dry Grassland and Shrubland (DGS), Mesic Forest (MF), Mesic Grassland and Shrubland (MGS), Wet Forest (WF), and Wet Grassland and Shrubland (WGS).

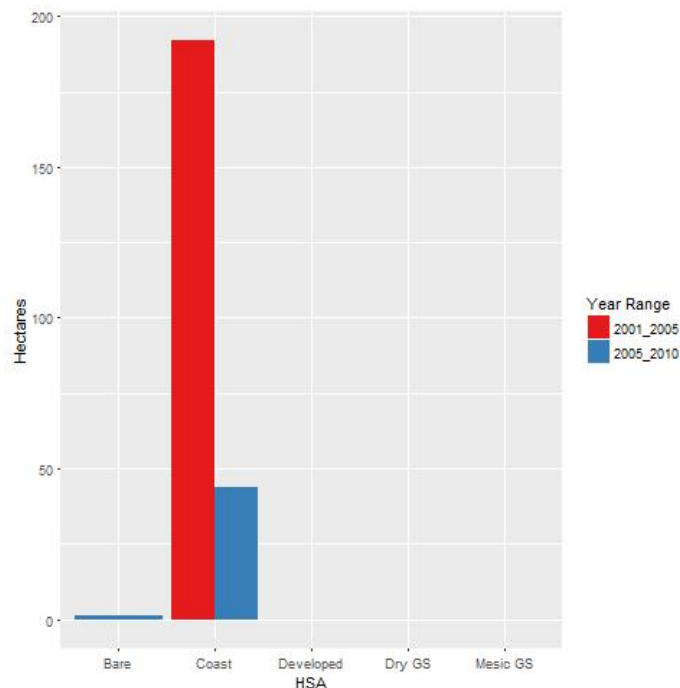


Figure 8. Hectares of Habitat converted to Wetland between 2001 and 2010 on Niihau. Habitats include Bare, Coast, Developed, Dry Grassland and Shrubland (Dry GS), and Mesic Grassland and Shrubland (Mesic GS).

Conclusion

Projected Habitat changes vary by island with some islands showing greater changes than others. However, the main changes expected include:

- Coastal Habitat – Indeterminable change in the foreseeable future due to limited data.
- Developed – Slight increase in urban areas on Hawai'i, Maui, and Kaua'i and decreases in cultivated areas on Maui, Oahu, and Kaua'i.
- Forest – Increase in Dry Forest on Kaua'i and increase in Mesic Forest on Hawai'i. No change in Wet Forest.
- Grassland and Shrubland – Increases in Dry are expected on Maui, Lāna'i, Oahu, and Kaua'i and increases in Mesic are expected on Hawai'i, Maui, Oahu and Kaua'i. Wet is generally stable except for an increase on Hawai'i and the potential loss of the limited areas on Lāna'i.
- Wetland – No changes in the foreseeable future.

Utilizing the CCAP data layers to evaluate Habitat rates of change for the HSAs was generally successful for all categories except Coastal. Currently, CCAP layers and other landcover datasets provide limited mapping of Coastal habitats. The coastal habitat mapping by Jacobi and Warshauer (2017) is the only detailed information on coastal habitat for Hawaii. Unfortunately, the data is only presented as lines and not as two dimensional maps. Therefore, acreages cannot be calculated from that data. We recommend that the work by Jacobi and Warshauer be used as the basis for detailed mapping of coastal habitat using high resolution satellite imagery prior to the next iteration of the Coastal HSA. This mapping effort could in turn be used as the baseline for evaluating changes to the coastal habitat for future HSAs.

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