Estimating the maximum extent of prehistoric taro production in Hawaii: a pilot study of Oahu

by: Brynna Bolger

About the project

Wetland conservation is a major focus around the world because of their benefits to humans and biodiversity. The many services provided by wetlands, such as water purification, flood control, fish nurseries, and bird feeding grounds, have made their conservation a significant concern. However, the land and freshwater resources required for wetlands are in high demand. This is true in Hawaii where freshwater is already limited and is being further stressed by increased development and population as well as wetland agriculture.

Wetland taro production, or lo'I, is and was very important culturally on the Hawaiian Islands as well as historically and ecologically. When the Polynesians arrived on Hawaii they were limited in what they could cultivate because of the topography and soil characteristics of the islands. Due to these limitations they took advantage of the natural flood planes to use natural and artificial wetlands for taro cultivation. Although today taro production has been replaced by other crops and now only accounts for less than 100 ha, at one time almost all of the potential taro-growing land was being cultivated for the crop (Müller *et al.* 2010).

Currently many researchers cite out of date literature regarding the extent of taro production when discussing wetland and other birds on Hawaii. Estimates of taro production have been based on the caloric needs of the estimated population size of Hawaii in pre-European times (Walker *et al.* 1977). However, as pointed out by Müller *et al.* (2010) this does not take into account consumption or use of taro beyond what was necessary. Müller *et al.* (2010) sought to use GIS to better estimate the potential areas for taro production given both natural and anthropogenic factors. This project attempts to improve those estimates by bringing in more advanced tools and more specific qualifiers for prehistoric wetlands. I focused this project on the island of Oahu in order to keep the size of data layers at a minimum. However the methodology described can be utilized for the other Hawaiian islands as well, apart from small alterations to environmental requirements.

Wetland taro production can occur in both natural and manmade wetlands, therefore, I first attempted to determine the historical extent of wetlands, using records of hydric soils, compound topographic index, and undisturbed wetlands. In determining wetland extent I needed to take into account the possibility of recent manmade wetland-like areas that can create hydric soils. In addition to wetland habitat, there are several other factors, which may determine suitability for taro growth, including precipitation, slope, elevation, distance to freshwater, and absence of wetland forests. Distance to freshwater and occurrence of wetland forests are variables that would have discouraged ancient Hawaiians from cultivating taro because of the high amount of effort required compared to reward.

The artificial wetlands created for taro give some idea of the extent of taro production in prehistoric times, which in turn gives us an idea of the social importance of taro that extended beyond caloric needs. Additionally, it provides further knowledge of the ways Hawaiians influenced their natural environment.

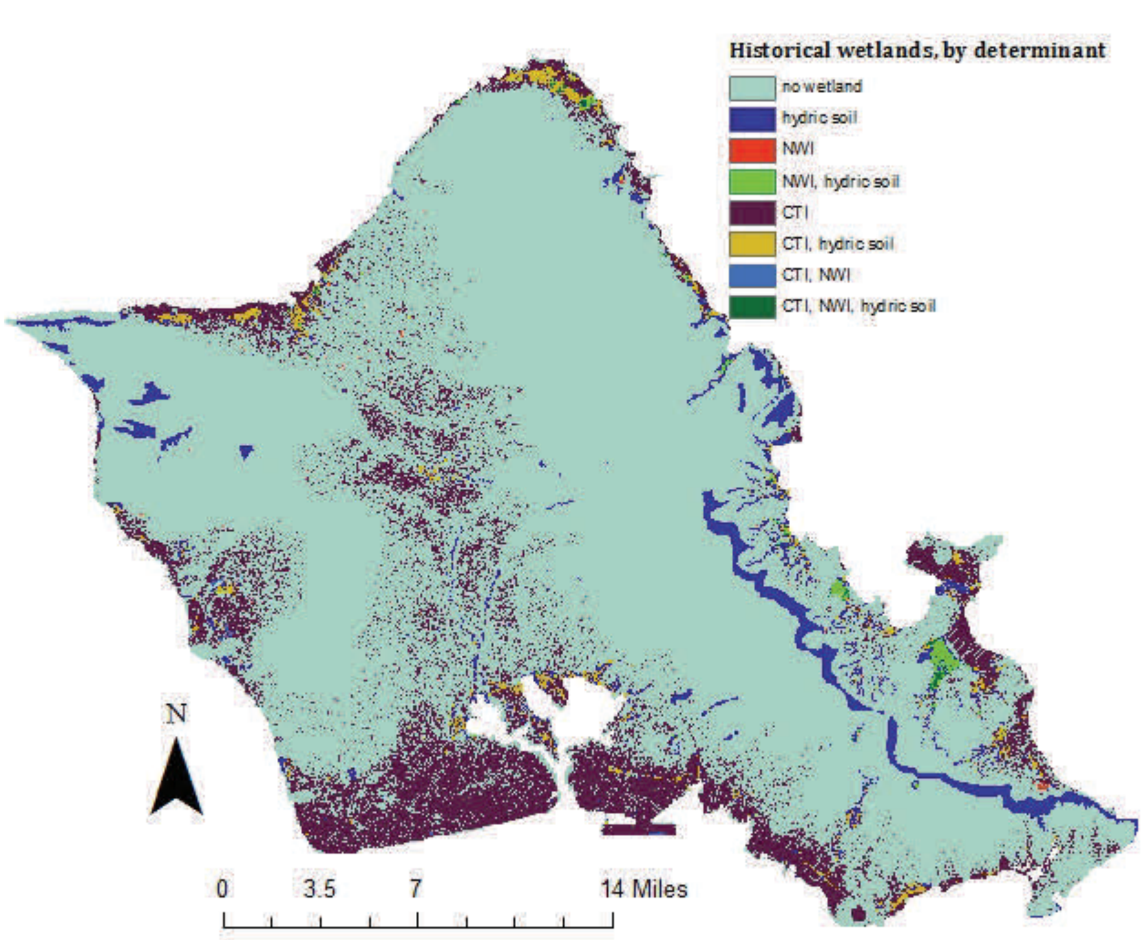

Figure 2. Extent of ancient wetlands determined by natural extant wetlands, presence of hydric soils and CTI analysis.

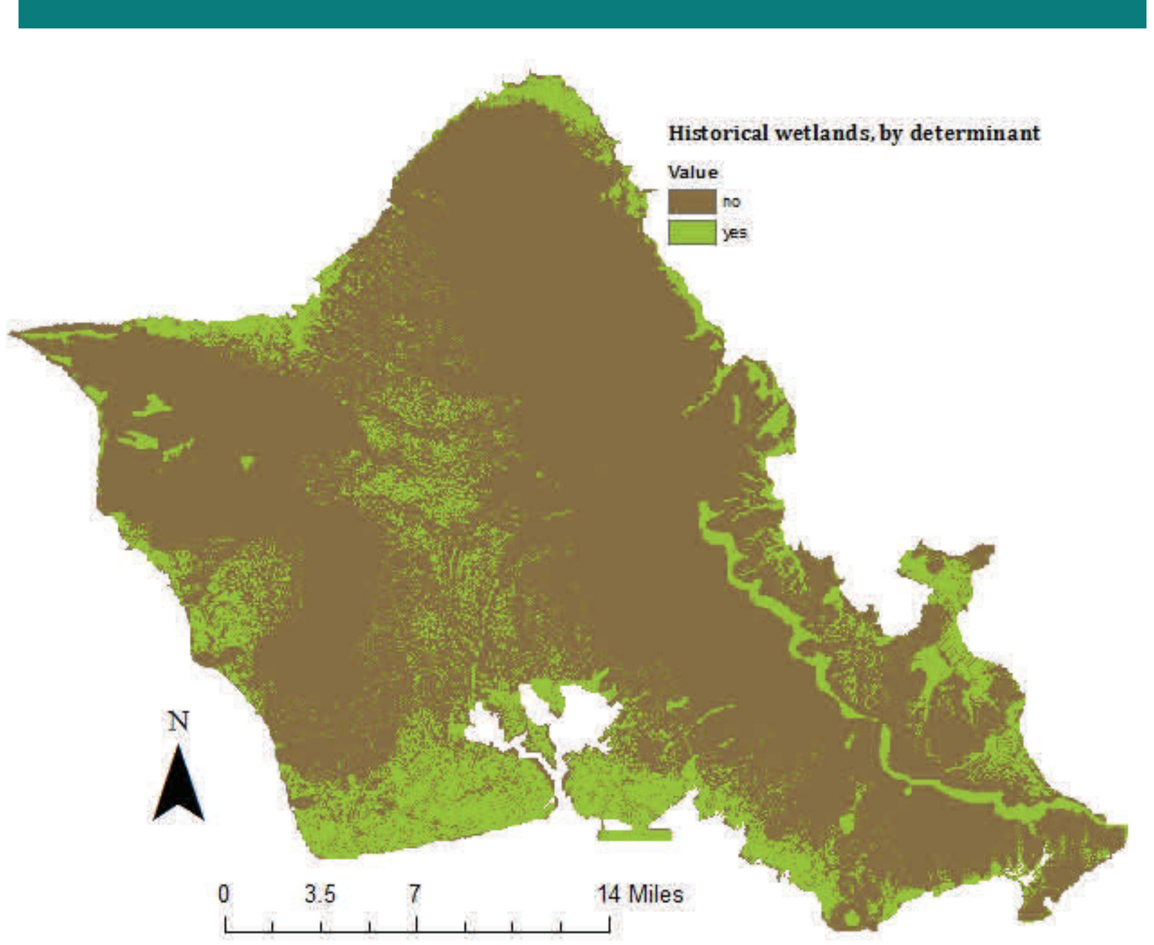

Figure 3. Extent of total ancient wetlands.

Figure	Total Area (km^2)
Environmental criteria met (Fig. 1)	244,832.80
Extent ancient wetlands (Fig. 3)	308,783.02
Maximum extent of ancient taro production (Fig. 5)	530,608.72

Table 1. Areas in kilometers squared.

Methods

In order to get an estimate of maximum historical taro production I created two raster files, which I then used to create a final visual and quantification of area. The first raster I built was an assessment of which lands on Oahu have the abiotic characteristics necessary for wetland taro to grow and would support wetland taro fields. The second was the maximum extent of ancient wetlands, which would provide natural areas for cultivation of the type of taro grown in Hawaii by ancient Polynesians.

The abiotic environmental factors I used to determine suitability include: elevation, rainfall, slope, and distance to freshwater. I used a Digital Elevation Model (DEM) of Oahu to select for two classes of elevation that would support taro growth – 1-200m and 201-330m. I then used average annual precipitation data to select for areas meeting the rainfall requirements for the two classes of elevation - >650mm at 1-200m and >800mm at 201-330m. Using the DEM and the slope tool I created a slope raster and selected for areas with a slope of 2-35%, assuming that terracing could occur. Lastly, using hydrology data, I created a buffer of 1 km around perennial streams, as irrigation would have required freshwater within roughly this distance (Müller *et al* 2010). In the end I created a raster of the areas meeting all four of these criteria using raster calculator.

To determine the extent of ancient wetlands I used three methods – looking at extant natural wetlands and assuming they also existed in the past, at hydric soils, and at a Compound Topographic Index (CTI). I set the threshold for the CTI using the average CTI for areas where wetlands are naturally occurring – 10.85. However, wetlands that are flooded due to coastal inundation were excluded when determining the average CTI value. I only used the CTI in developed areas because it is less reliable than the other two methods and thus was used only when the others were not possible. When looking at the naturally occurring extant wetlands I removed the marine wetlands and forested wetlands, based on research suggesting that wetlands were rarely deforested for agricultural (Athens and Ward 1993). The raster I created was the combination of all possible wetlands associated with these analyses.

To determine the maximum possible extent of ancient taro production combined the two rasters to show where taro fields in natural and manmade wetlands could have occurred.

Results

Based on this initial analysis, it appears that there is land on Oahu, 530608.72 km^2 that meets the requirements set for wetland taro production (Table 1; Fig. 4). It appears that on the southwest side of Oahu taro production was primarily located in natural wetlands while artificial wetlands made a significant contribution to taro growth in the northeast (Fig. 1; Fig. 3). A large percentage of ancient wetland area was determined by the CTI analysis, which may be due to the increased development on Oahu (Fig. 2).

Limitations

A major limitation of this pilot study is that the data is from present century Hawaii while the conclusions I draw are regarding pre-European times. I have assumed that the patterns of rainfall and stream flow have not altered significantly. Furthermore, I have assumed that terracing would occur if possible and deforestation of forested wetlands did not occur. I was also limited by specificity of where wetlands occurred. I used three methods of ancient wetland identification that each involved their own limitations and biases. However, this study was not meant to be a precise calculation of ancient taro production but rather a more accurate estimate of the maximum possible area of wetland taro.

Conclusions

The maximum extent of taro production I found in this study are greater than that of Müller *et al.* which is due to the inclusion of natural wetlands that were not accounted for. However, it is likely that ancient Polynesians would have taken advantage of these areas as the costs (i.e. irrigation and terracing) were reduced. While this is not a precise estimate of the actual area of land used for taro production, it does give us an idea of how much taro ancient Polynesians could have grown. This in turn reveals the potential environmental impact of ancient peoples as well as hinting at the importance of taro in daily life and how social stratification was manifested.

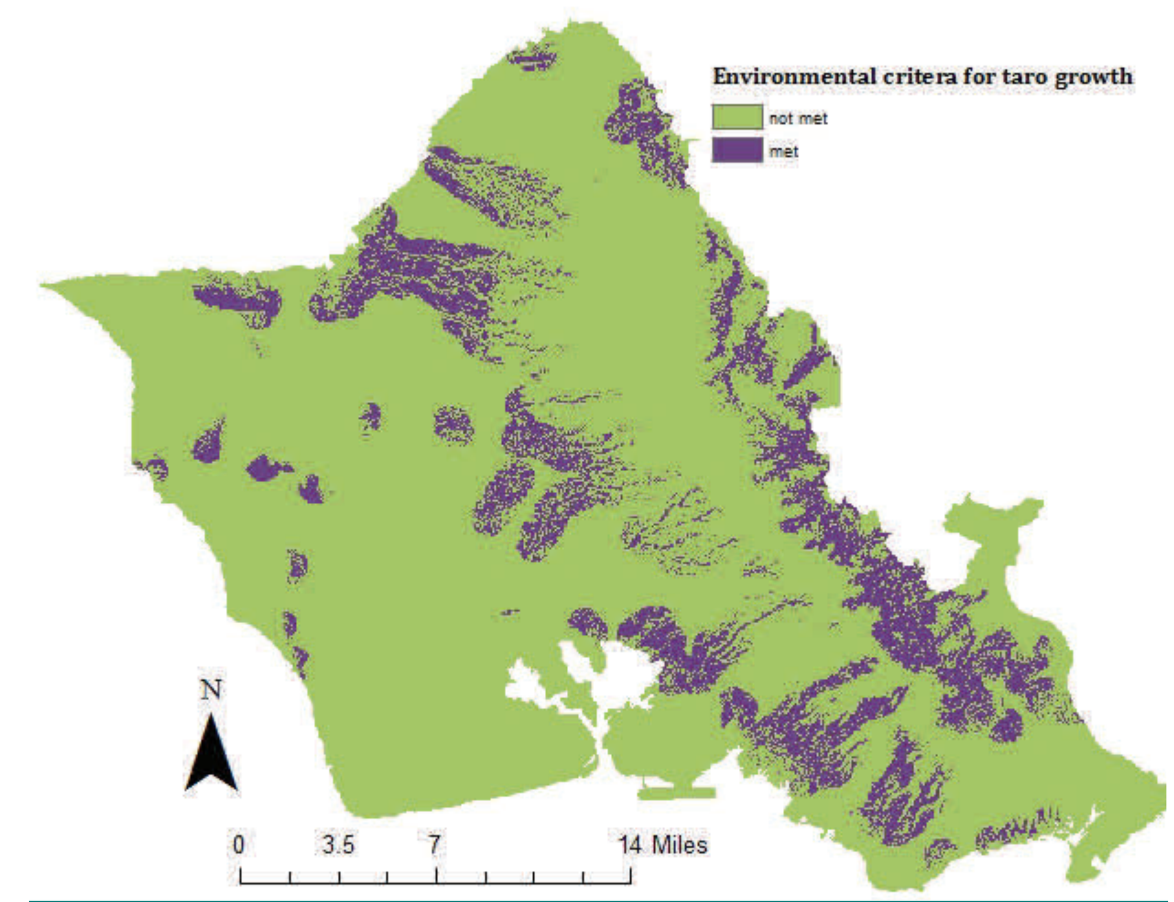

Figure 1. Areas suitable for taro growth according to rainfall, elevation, slope, and distance from freshwater requirements.

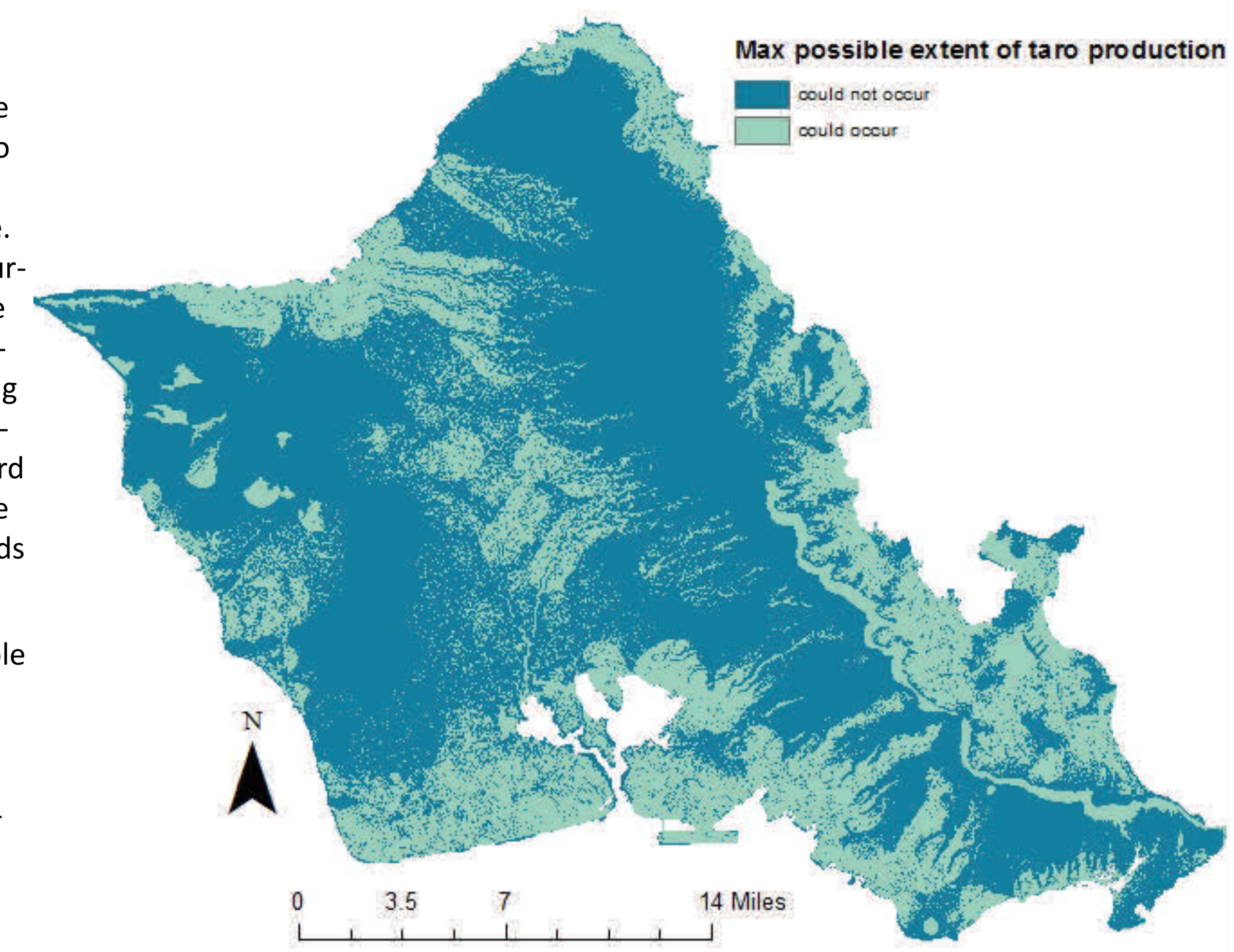

Figure 5. Maximum extent of taro production.

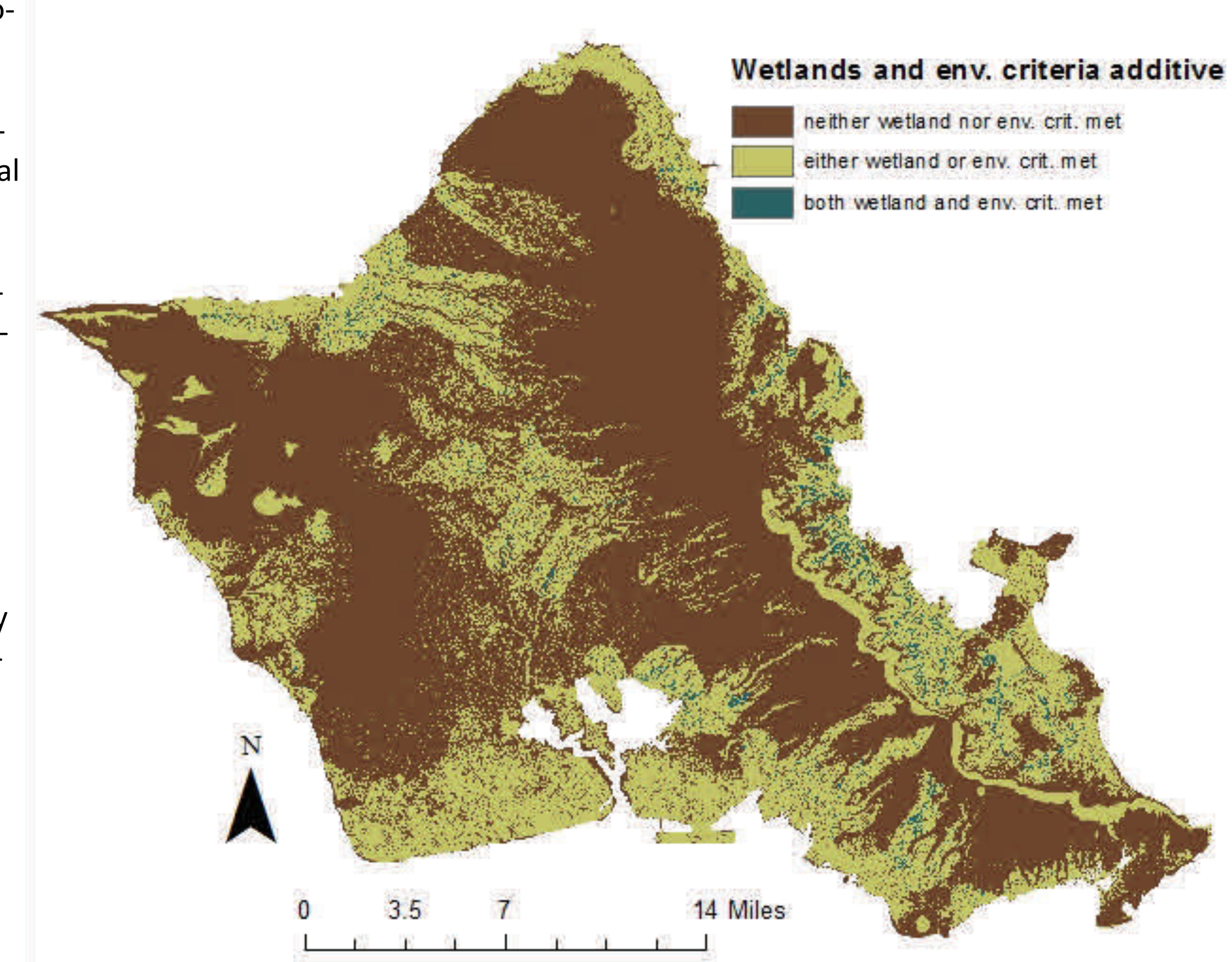

Figure 4. Extent of taro production with wetland area and land meeting environmental criteria as additive. Maximum extent of taro production based on the environmental criteria being met and the extent of wetlands.

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Cartographer: Brynna Bolger

Class: Advanced GIS, Spring 2012

Map Projection: NAD 1983 UTM Zone 4N, Meters

Data: Web Soil Survey, NOAA 2000, USGS 2002, Department of Geography at University of Hawaii at Manoa, U.S. Fish and Wildlife National Wetland Inventory, Hawaii State GIS Pro-