Remote Detection of Wetlands in the Hawaiian Archipelago

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Remote Sensing
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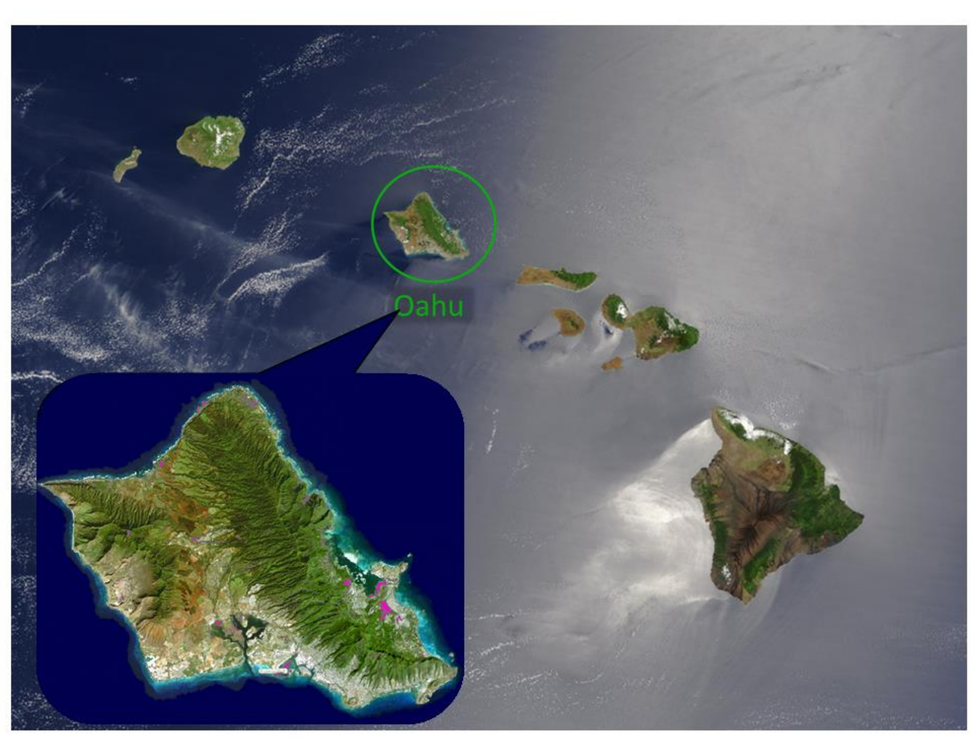
Background

Wetlands are some of the most valuable and threatened terrestrial ecosystems on the planet, providing ecosystem services worth over $5.8 trillion annually and being threatened by development and climate change (Costanza et al, 1997; Millenium Ecosystem Assessment 2002).

Wetlands on Hawai`i support over 25 endangered and threatened species, many of which are found nowhere else on earth. Out of 27 species of endemic waterbirds originally found in Hawai`i, 21 are now extinct, and the remaining 6 are endangered.

Wetland inventories are essential for monitoring human impacts on these valuable ecosystems. The National Wetlands Inventory, a project of the U.S. Fish and Wildlife Service, surveys wetland cover throughout the United States every few years using aerial photography and field surveys.

Ground truthing and aerial surveys can be immensely expensive and time consuming methods, and as a result NWI surveys can not be done frequently for all areas. Remotely-sensed images are acquired with high temporal frequency and at minimal cost to the user, and may enable easy and effective wetland monitoring.



Purpose:

We investigated the ability of remotely sensed images to identify wetland features on the island of Oahu, Hawai`i.

Method of study

We used a multispectral Landsat 7 ETM+ image taken in September 2003. We performed all pre-processing steps (radiometric and atmospheric correction, cropping) prior to analysis.

We transformed this image using four separate transforms, Normalized Difference Vegetation Index (NDVI), Normalized Difference Wetness Index (NDWI), Tasseled-Cap transform, and Principal Components Analysis (PCA). These transformed layers were divided into three "band groups", shown below.

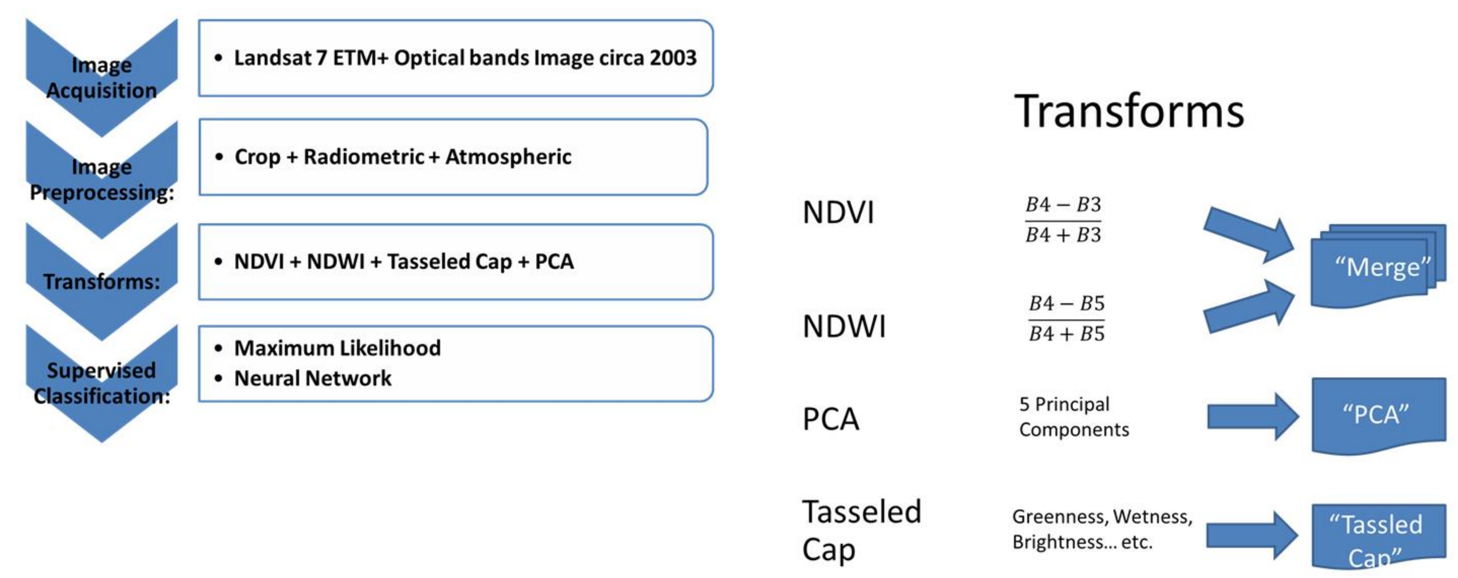


Image Classification

We classified transformed images using two supervised classification methods, Maximum Likelihood and Neural Network. Maximum likelihood is the most prevalent and widely used classification method for detecting wetlands (Ozesmi and Bauer, 2002), while the Neural Network classification has recently been suggested as a new alternative (Bao and Ren, 2011).

We guided supervised classification using Regions of Interest (ROIs) for 8 classes, including urban landcover, forest, agricultural land, bare land, and wetland. Wetland ROIs were taken from a modified NWI shapefile from 2010. In order to provide a "test group" of wetland areas, 20% of wetland features were excluded prior to use as a ROI.


Major Wetland on Oahu—True Composite Image

Maximum Likelihood classification was performed using default settings and probability threshold at .05. This low probability threshold was chosen to bias errors away from false negatives (when a pixel representing a wetland is classified as something else), because these were considered less acceptable than false positives (classifying a non-wetland pixel as wetland).

Neural Network classification was run with all default settings and 1,000 iterations.

Results and Analysis

Table 1 (Above right) shows producer accuracy (correctly identified rate of actual wetlands), user accuracy (the fraction of "wetland" pixels that are actual wetlands) and misclassification rate of 6 method pairs. The Neural Network classification of PCA had an extremely high tendency to overestimate wetlands, but correctly classified existing wetlands at the highest rate. The Maximum likelihood classification of the "Merge" transformation group had the lowest rate of false positives, but had high false positives.

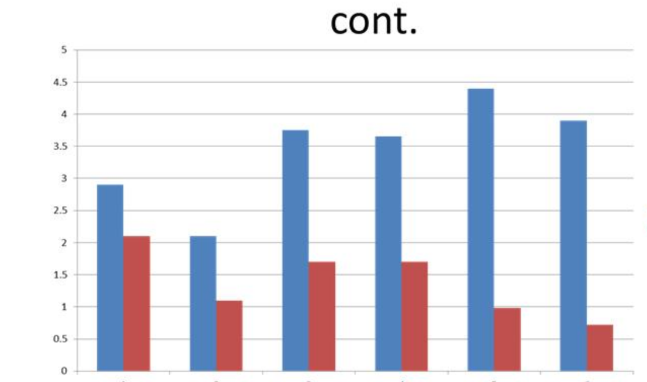
van Rees and Reed, in prep.

- 65% reduce of wetlands
- 25 Endangered Species Endangered and 75% of Native Water birds extinct due to habitat

Transformation	Classification	Producer Accuracy	User Accuracy	Misclassification Rate (95% conf. int.)
Merge	Max. Like.	0.583	0.021	0.04386, .04390
Merge	Neural Net.	0.419	0.011	0.06023, .06027
PCA	Max. Like.	0.754	0.017	0.06904, .06909
PCA	Neural Net.	0.883	0.009	0.14338, .14344
Tasseled Cap	Max. Like.	0.738	0.017	0.06831, .06836
Tasseled Cap	Neural Net.	0.787	0.007	0.17425, .17431

Among our 6 groups of observations, producer accuracy and User Accuracy exhibit an inverse relationship. As the probability threshold in Maximum Likelihood classification increases, producer accuracy drops steadily and user accuracy increases. The figure on the right displays this trend.

Producer Accuracy vs. User Accuracy cont.



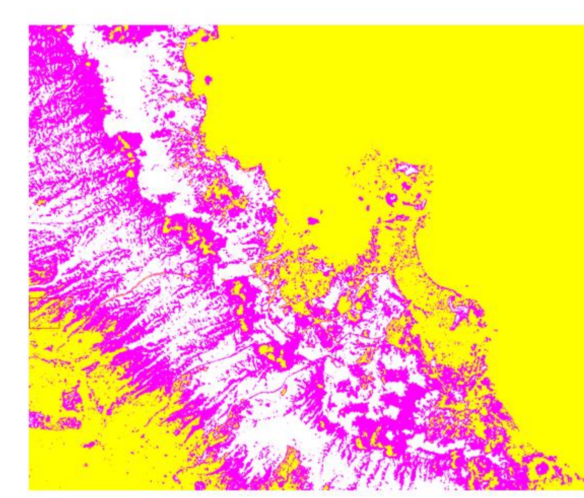
Series 1 = 5 times producer accuracy
Series 2 = 10 times user accuracy
Note: given the small percentage of wetlands, the two numbers are magnified In different times to show their relative trends.

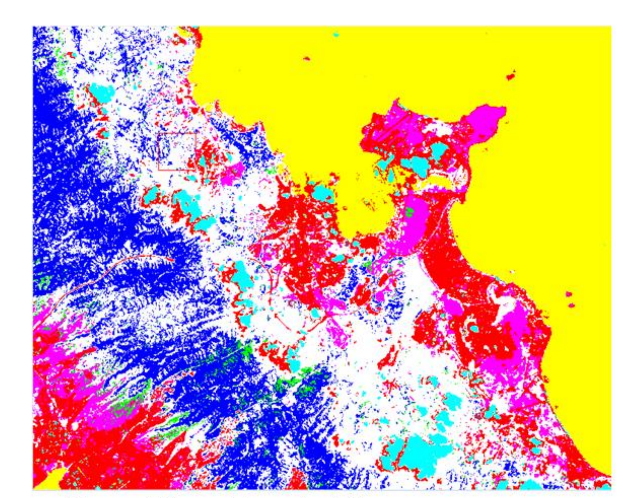
Summary & Implications:

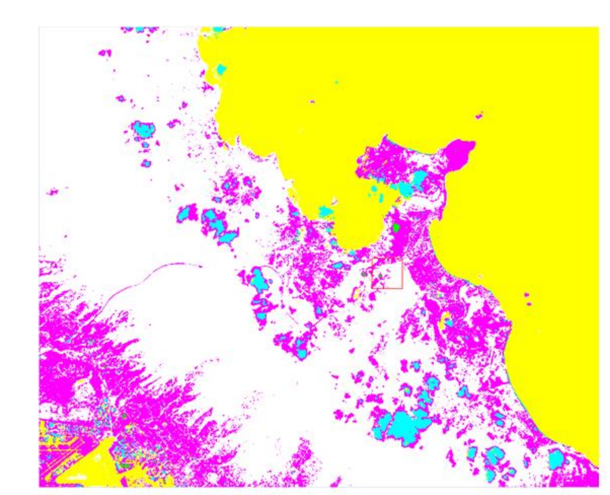
We found that remotely-sensed images can accurately detect wetlands in the Hawaiian Islands, but with a reasonably high tendency for error. Biasing this error toward positives yields relatively high rates of false positives, but these are considered more acceptable than false negatives.

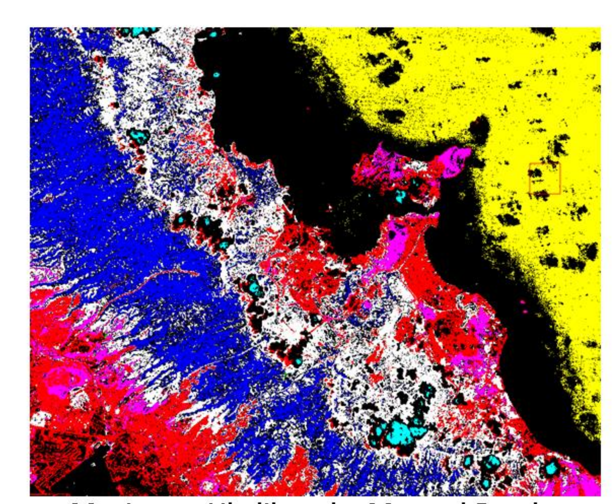
The distinct hydrology of the Hawaiian islands (high orographic rainfall) leads to many areas that hydrologically resemble wetlands, but are not ecological wetlands, leading to apparent overestimations of wetland cover by remotely sensed images. Remotely sensed images detect the moisture in these areas and could help redefine current definitions of wetlands for wetland delineation.

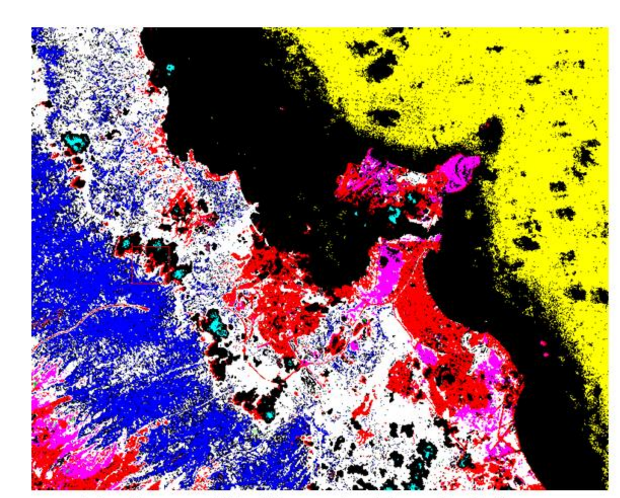
Remotely sensed images are a valuable tool for wetland inventorying and delineation, but cannot be a stand-alone approach; they are best used in combination with ancillary data sets like soil surveys and digital elevation models.

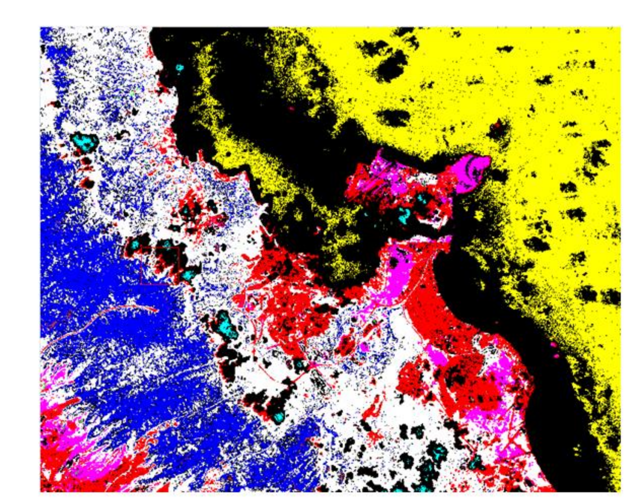

Neural Net—Merged Bands


Neural Net—Tasseled Cap


Neural Network—PCA


Maximum Likelihood—Merged Bands


Maximum Likelihood—Tasseled Cap


Maximum Likelihood—PCA

References:

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Costanza, R., R. d'Arge, R. de Groot, S. Farber. M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-60.

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Ozesmi, S.L. and M.E. Bauer. 2002. Satellite remote sensing of Wetlands. Wetlands Ecology and Management, 10(5) 381-402 (22).