Title: Mapping mangrove forest cover using Landsat-8 imagery, Sentinel-2, Very High Resolution Images and Google Earth Engine algorithm for entire Cambodia

Author:

Ms. Thida Tieng, Regional Resource Center for Asia and Pacific, Asian Institute of Technology;

Dr. Sahadev Sharma, University of Malaya; Dr. Richard A. Mackenzie, USDA Forest Service; Manjunatha Venkatappa, Asian Institute of Technology;

Dr. Nophea Sasaki, Asian Institute of Technology; Dr. Antoine Collin, 4Ecole Pratique des Hautes Etudes – PSL Research University

Mangrove restoration activities by local communities in Koh Kong province in 2016

Abstract: Currently there is limited information to estimate accurate and reliable mangrove forest area in Cambodia. Previous estimates did not explicitly illustrate the spatial distribution of mangrove for the entire country however , according to Global Forest Resource Assessment 2010, Cambodia's mangrove area cover in 1990 and 2010 was calculated at 79,638 ha and 55,704 ha, respectively using extrapolation of 1992-1996 (original data from Remote Sensing of forest cover 1992/93 and 1996/97) for 1990 and extrapolation of 1996-2002 (original data from Remote Sensing of forest cover 1996/97 and 2002) for 2010. This study mapped the spatial distribution of Cambodia's mangrove forest derived from 30 m x 30 m spatial resolution and polygon spatial extent from Landsat 8 (L8) image. Publicly available Landsat data was acquired from Google Earth Engine (GEE) Explorer including the Landsat Surface Reflectance-Landsat 8 (L8) OLI/TIRS; Top-Of-Atmosphere (TOA) L8 32-Day Reflectance Composite; Landsat Archive Pre-Collection from US Geological Survey (USGS, 2015); VHR Google-derived images (Collin et al. 2014) and field data collection from 63 plots representing the entire Cambodia of Surface Water Ambient Monitoring Program (SWAMP) to create a Google Fusion Table aiming at mapping the spatial resolution and extent. Random Forest (RF) Classifier, a supervised classification technique, was applied to three L8 images Archive Pre-Collection Level-1 (L8 OLI/TIRS) collected in December 2014, February 2015 and April 2015. Statistical analysis indicates the total area of mangrove forest cover reached 73,240ha with overall classification accuracy of 98.2%, 97.9% and 99.5% for three periods and the validation overall accuracy were 91.5%, 89.1% and 97.6%, respectively. Our findings suggest that L8 imagery and Google Earth Engine algorithm can be used to estimate area changes of mangrove forests in Cambodia with higher accuracy. The results of this study may be useful to assist decision making in planning for mangrove ecosystem restoration activities, evaluation of ecological services and in better estimation of carbon stock in mangrove forest. (Tier 1- default emission or Tier 3- plot data are more related to emission factor).

Introduction:

Given that mangroves have been characterized as having a high C density coupled with a high rate of deforestation, there is an increased interest in including mangroves as part of climate-change mitigation strategies that would reduce the anthropogenic emissions of greenhouse gasses (Kauffman et al. 2011). Despite their importance and significance, our understanding of the present status and distributions of mangrove forests of the world remain inadequate (Giri et al. 2010). This study aims to better achieve estimation of the mangrove areal extent and map the spatial distribution of mangrove using newly available platform (GEE) and publicly available Landsat data from Global Land Survey with higher accuracy assessment.

Methodology:

In Cambodia, mangroves are located in South-Western part of the country between 10º43'-11º85' N and 102º88'-104º44' E covering four province: Koh Kong, Preah Sihanouk, Kompot and Kep. 63 permanent sample plots from mangroves, salt pans and aquaculture ponds were collected and used as ground truthing data in combination with the plots collected from Google Earth Engine using remote sensing technique. The code editor platform were used as tool to collect the reference data, classify the images, training as well as produce the accuracy as indicated in **Fig. 1**. Field data collection was collected during the Sustainable Wetland Adaptation Mitigation Program (SWAMP) training to estimate Ecosystem Carbon Stock for Cambodia mangrove forest. The discrimination of mangrove, salt pan and aquaculture classes were assessed using combination of field work data with L8 32-Day Top of Atmospheres (TOA) Reflectance Composite images at bands 5-6-4 (Near Infrared, SWIR 1, Red) ; VHR images and S2 of color combination of band 8, 4 and 3 (Near Infra-Red Green Blue). Three L8 images were trained using supervised classification (Random Forest Classifier) and produced the training accuracy.

Result and Conclusion:

Fig. 2 indicates the average value each band and wavelength property for 40 geometry points of mangrove, 10 points of territorial forest, 10 points of aquaculture pond and 10 points of salt pan. The result of analysis on band spectra behavior of the sample used for L8 training indicate the discrimination of each land use type. The study found in average of collected sample, behavior of mangrove band is different from other vegetation of the terrestrial forest and those of salt pan and aquaculture ponds. Higher overall accuracy was achieved using google fusion table to train L8 image with random forest model indicated in **Table 1**. For all images used for entire country classification, the overall accuracy assessment and error validation from RF was found to be higher than 90%. In overall, the result of accuracy assessment indicated high accuracy for redistribution matrix which mean the number of sample that were collected for training the data were well represented. This study suggested that the clipping method assisted the training result in minimizing the errors and the confusion of among the land uses categories

This study found 73,240 ha of mangrove, 8,019 of salt pan and 6,211 ha of aquaculture pond for entire Cambodia in 2015. As shown in **Fig. 3**, The dense mangrove and aquaculture pond activities mostly locate in Koh Kong province following by Preah Sihanouk, Kompot and Kep. Salt pan activities mostly happened in Kompot and Kep. However, the test of our algorithm has not yet been applied to the previous landsat data (less than L8) therefore there might be limitation for us to assess the mangrove area change using the same script. This study presents the possibility of using freely available data combing with remote sensing technique and Artificial Intelligence (GEE) to assess and validate the maps as well as valuate the recent condition of mangrove forest based on free data at large scale such as country assessment.

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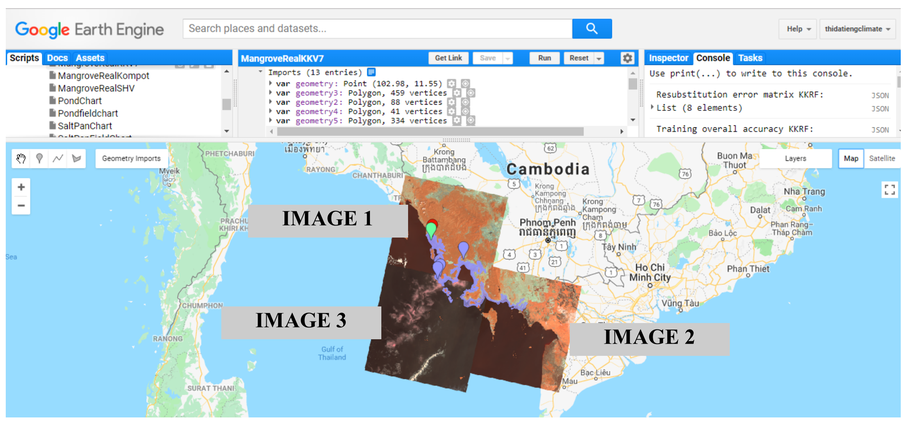
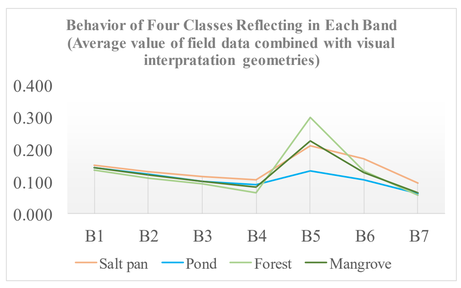


Fig. 1: Google Earth Engine Code Editor Platform indicating three L8 images



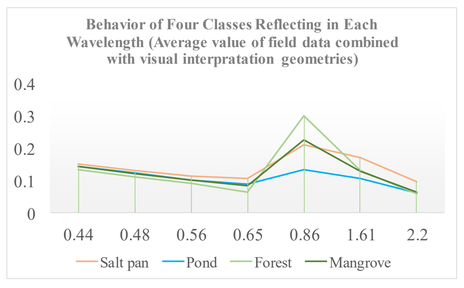


Fig. 2: Discrimination of each classes according to band and wavelength analysis.

Table 1: Summary of Accuracy (%) and Kappa statistics of RF

Land Use Category	Image1 Accuracy		Image2 Accuracy		Image3 Accuracy	
	Producer's	User's	Producer's	User's	Producer's	User's
Redistribution Matrix (overall accuracy)						
Mangrove	94	90	94	90	100	86
Aqu. Pond	100	87	92	98	NA	NA
Build-up	93	96	99	88	89	86
Agriculture	93	96	97	99	90	100
Mudflat	100	77	100	72	91	90
Water	100	100	100	100	100	100
Forest	98	99	96	94	95	96
Salt pan	100	65	96	89	100	100
Overall Accuracy	98.23%		97.94%		99.53%	
Kappa Statistics	0.9822		0.9791		0.9952	
Validation (error matrix)						
Mangrove	72	55	47	32	37	26
Aqu. Pond	17	6	69	77	NA	NA
Build-up	46	26	52	34	44	23
Agriculture	74	79	83	92	37	35
Mudflat	45	23	22	7	52	63
Water	99	98	100	99	99	100
Forest	92	96	84	74	74	78
Salt pan	25	6	51	46	37	26
Overall Accuracy	91.51%		89.14%		97.65%	
Kappa Statistics	0.9151		0.8914		0.9702	

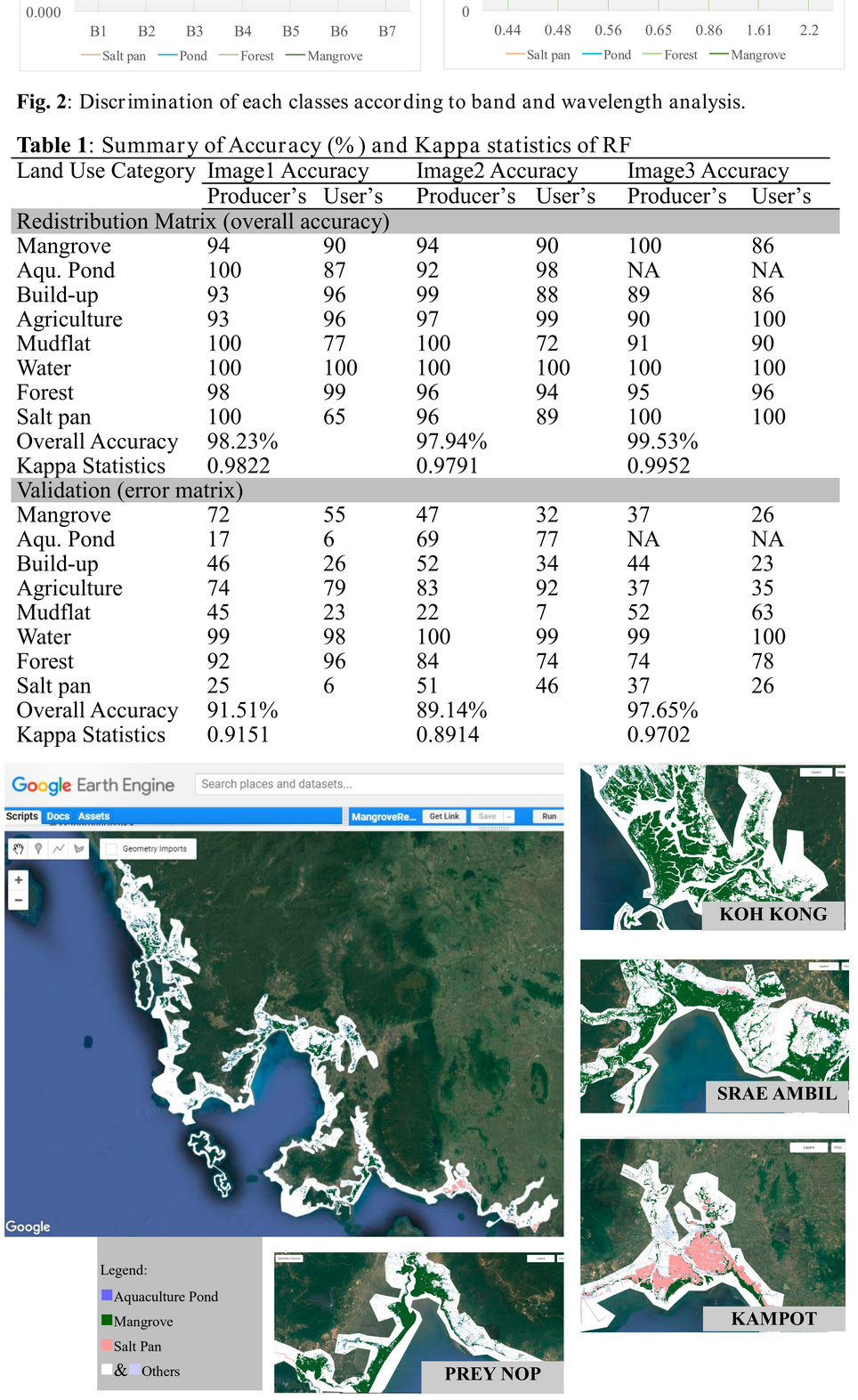


Fig. 3: Result of classification by each location and land use categories.