

# Detecting Forest Cover Change and Transition

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## Introduction

In the tropics, forest cover is changing rapidly, and scholars are interested in assessing those changes with a high degree of precision. Accurate measures of forest cover change have become increasingly important as quantification of carbon storage is critical in climate change scenario modeling and planning. Scholars have progressively turned to remotely sensed data analysis with the objective of quantifying and describing surface patterns. Much of this research has been directed towards deforestation in the tropics. However, recent evidence suggests that secondary forest recovery in the tropics is significant. Regional patterns of reforestation, derived via remote sensing analysis, in rural El Salvador and case studies of increasing forest cover are evidence that El Salvador may be shifting from net deforestation to net reforestation. This study of forest cover change in Ahuachapán, El Salvador utilized time-series Landsat imagery, socio-economic household surveys, and landscape level analysis to make assessments about a forest transition in El Salvador. Methods consider limitations on data.

## Background

Per the United Nations Framework Convention on Climate Change (UNFCCC), regular monitoring of changes in forest versus non-forest vegetative cover is required to accurately quantify the forest biomass. UNFCCC has suggested sampling using a hierarchical and nested approach by examining medium to coarse resolution imagery (DeFries et al. 2002) to identify areas of rapid land cover change and then interpret higher resolution imagery in the identified areas. The technique presents challenges where secondary forests are just now emerging or where there exists a high rate of fragmentation.

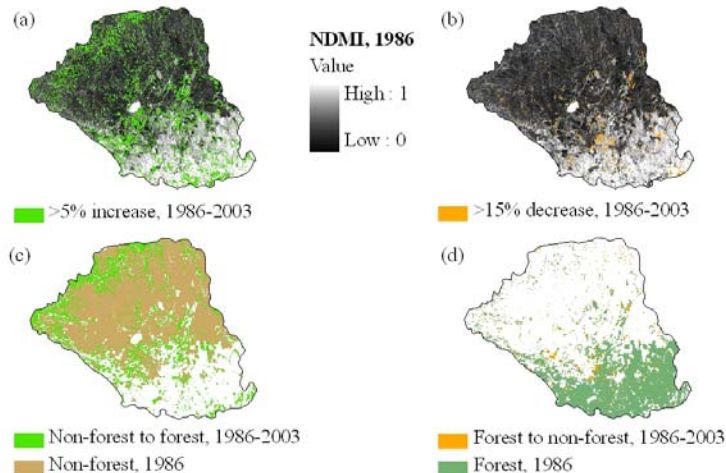
Moreover, remote sensing analysis does not rank a forest's importance or predict its continued existence since land use is not addressed. Some forests are more important than others as it relates to carbon storage. Still some forests may be inadvertently or intentionally unaccounted for in climate storage assessments. Yet, these forest types are important in their contributions. Since secondary growth and agro-forests in the tropical setting are difficult to detect using remote sensing alone, methods should be improved upon to ensure that these forest covers are counted.

In the rural areas of the municipality of Ahuachapán, El Salvador, population pressures are still high. Subsistence agriculture and some cash cropping prevail. Out-migration levels are low and remittances are at best minimal and unreliable for the few families who receive them.

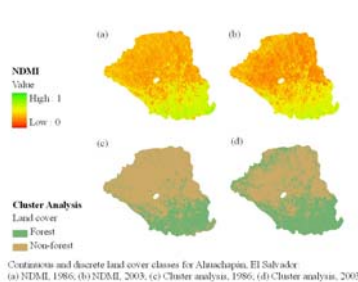
Given these conditions, theorists of forest transition theory would suggest that forest recovery is not at all likely here. The analysis evaluates whether forest is indeed returning here..



## Results



Land cover transitions, 1986-2003. (a) Greater than 5% increase in NDMI value, 1986-2003; (b) Greater than 15% decrease in NDMI value, 1986-2003; (c) Change from non-forest (1986) to forest (2003), derived from cluster analysis; (d) Change from forest (1986) to non-forest (2003), derived from cluster analysis.



Forest cover change by method for Ahuachapán municipality, El Salvador									
	NDMI		Cluster analysis		1986		2003		Net forest cover change 1986-2003
	Increase	Decrease	Increase	Decrease	Forest	Non-forest	Forest	Non-forest	
Greater than 5% increase 1986-2003	44.93	8.06	36.87	119.38	143.87	80.61	182.64	38.77	
Greater than 15% decrease 1986-2003									
Net forest cover change 1986-2003									
Total Area (km <sup>2</sup> )									

Accuracy totals of cluster analysis vs. NDMI for Ahuachapán municipality, 2003															
Class Name	Cluster analysis, 2003					NDMI, 2003									
	Net Total	Class Forest	Class Non-forest	Class Forest	Class Non-forest	Net Total	Class Forest	Class Non-forest	Class Forest	Class Non-forest					
Forest	133	129	99	Forest	63	50	41	Forest	88	39	17				
Non-forest	117	121	87	Non-forest	65	68%	Forest	44	74%	Non-forest	82				
Producer Accuracy	74.44% Forest					65.08% Forest					44.74% Non-forest				
User Accuracy	76.74% Forest					82.00% Forest					56.67% Non-forest				

## Discussion and Conclusion

The result of recoding the clusters is a thematic map of forest and non-forest classes. Typically, ancillary data are used to develop training sites to be input into a supervised classification where training sites correspond to land cover signatures. Since a relatively low number (~100) of training sites from GPS and sketch-mapping alone were available, the unsupervised approach was preferred.

NDMI is a valuable approach in determining new forest; however, the benefit of ancillary data or ground truth data supports the claim that remote sensing analysis is improved when tied to local knowledge. Future studies might incorporate NDMI and cluster analysis with ancillary data together to improve the estimates of forest cover and forest cover change.

The spatial distributions of forest in cluster analysis correlate with higher values of NDMI. Overall, NDMI and cluster analysis are appropriate methods for detecting forest cover and forest cover change in El Salvador.

NDMI results in net forest increase of 36.38 sq. km.. Cluster analysis results in net forest increase of 38.77 sq. km. The difference between the two estimates is .8% of the total land area of the municipality. Both suggest that forest cover is increasing in the municipality of Ahuachapán, El Salvador.; however, the definition of forest will impact the result.

## Methods

Two methods, NDMI and cluster analysis, are explored for their potential value in discriminating forest from non-forest, where forest is defined to include secondary forests, orchards, and living fences.

### Normalized Difference Moisture Index

An index image, of continuous data, was created by first calculating NDMI values for each date (j) of imagery by the following equation:

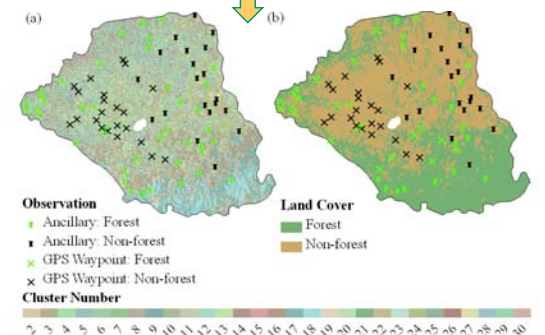
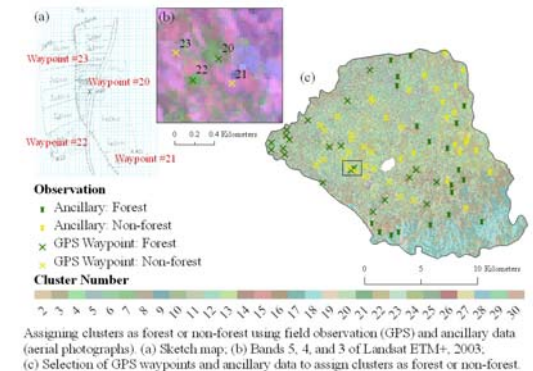
$$\text{NDMI}[j] = (\text{TM4} - \text{TM5}) / (\text{TM4} + \text{TM5}).$$

A difference image was created by:

$$\text{DIF}(1986 \text{ to } 2003) = \text{NDMI}[2003] - \text{NDMI}[1986]$$

### Cluster Analysis

The two images were classified to improve separation between forest and non-forest land cover types, with particular emphasis on separating agro-forest, orchards, living fences and secondary growth from other non-forest types. An unsupervised classification was carried out and 30 discrete classes were each assigned forest or non-forest in the signature editor using training sites developed from the ancillary data. Change detection was carried out on the classified images to produce images highlighting conversions of forest to non-forest and non-forest to forest.



Classification of forest and non-forest uses for 2003, using cluster analysis.

(a) Selection of GPS waypoints and ancillary data with clusters, 2003

(b) Forest and non-forest classification, 2003

**Data Sources:** One orthorectified Landsat Thematic Mapper (TM) image for April 7, 1986, one Landsat Enhanced Thematic Mapper Plus (ETM+) image for April 14, 2003, and aerial photographs for the study area in 2005 were acquired for the analysis. Longtime residents of the study area served as informants on past and present land cover and land use. Data collection from field based visits was carried out from February to April, 2007. Ground control points were collected in conjunction with household interviews. Sketch maps were utilized to distinguish orchards, living fences, and secondary forests from other land uses. Imagery was pre-processed to eliminate water, clouds, and cloud shadows and normalized to reflectance values.