**NASA DEVELOP National Program**



NASA Langley Research Center

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El Salvador Ecological Forecasting

Utilizing NASA Earth Observations to Develop a Historically Based Trajectory of Deforestation and Degradation in El Salvador

 **Technical Report**

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# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

El Salvador, Deforestation, Degradation, Remote Sensing, Forest Inventory, Land Use/Land Cover, Classification, Earth Observing Systems, Landsat, REDD+

# II. Introduction

Forests of Mesoamerica are critical to global ecological stability; supporting some of the most bio diverse ecosystems on Earth, removing carbon dioxide (CO2) from the atmosphere, acting as a carbon sink in the form of biomass accumulation (Houghton et al. 1991), and providing potable water through small streams and rivers which in turn support isolated rural communities who rely on these as their only source of water (Rosa et al. 2003).

However, these important forest ecosystems face many threats (Herold, et. al 2011). They are frequently exploited for timber by several industries, contributing to global deforestation and forest degradation. Subsistence farmers in this region commonly practice “slash-and-burn” agriculture, in regions with a low population density this method can be a sustainable practice, but large populations make slash-and-burn methods unsustainable and contributes to regional deforestation and forest degradation (Garcia and Gonzalez, 2004).

Of the seven countries in Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) El Salvador has the least forest cover (121,000 ha, of which only 25,000 ha are primary forest) and the highest population density (Billings et al. 2004/2). Forest biodiversity in La Mancomunidad La Montañona, a mountainous region in Northern El Salvador, is threatened by traditional slash and burn agricultural practices. Deforestation releases stored carbon into the atmosphere in the form of CO2 simultaneously decreasing the amount being removed through forest growth (Houghton et al. 1991). Removal of forest also impacts water quality by increasing runoff upstream of major rivers within the watershed (Paula et al. 2015).

The primary objectives of this project are to create a Land Use/Land Cover (LULC) model that determines regionally specific classes such as forest and tree species, agricultural and pastoral plots, and urban development, to create a Regional Forest Inventory (RFI) highlighting forest extent, including a distinction between primary and secondary forest, percent forest cover, and distribution of biomass and to create a model forecasting the extent of forest change using the RFI and LULC model. The project period was based on the longest time series available, 1986-2015. Landsat imagery from the dry season (November to April) was selected to coincide with ancillary data sets provided by project collaborators and end-users.

In collaboration with the NASA DEVELOP El Salvador Ecological Forecasting team, the ABES Project through the Earth Institute (EI) at Columbia University provided field surveys and additional satellite imagery to use as ground truth and satellite calibration data. End-users of the project include La Mancomunidad La Montañona, Chalatenango, El Salvador and the Ministerio de Medio Ambiente y Recursos Naturales (MARN). The ABES Project is working as an intermediary to incorporate the end products of the DEVELOP project into accessible tools and methodologies for the El Salvadoran partners. MARN is developing strategic policies specifically focused on reducing deforestation and degradation on the national scale.

The NASA National Science Application area being addressed in this project was Ecological Forecasting. The project uses time series images from the study area to examine historic forest change on a yearly basis. This information will be used to determine which regional forest dynamics, including which areas face the greatest risk of deforestation and forest degradation.

# III. Methodology

During the Fall 2015 NASA DEVELOP term, the El Salvador Ecological Forecasting team examined the Pine-Oak forests of Chalatenango. The end users and collaborators requested three end-results: a LULC classification, a RFI, and a forecast model predicting vulnerable areas and forest change. First, a LULC map was created identifying forest, pasture, crops, and urban land classes in order to gain a better understanding of regional forest dynamics. The RFI was then created based on the land use land cover classifications and checked for accuracy using the data available from the ABES project and MARN. It includes an assessment of forested and non-forested areas, percentage of tree cover, primary and secondary forest areas, and the distribution of biomass. The final step used the available data and combined it with the forest inventory and land cover land use analyses in order to create the forecast model. The methodology is designed in order to be easily replicable both on a larger scale and for future analysis of the same region.

**Data Acquisition**

Landsat 4, 5, 7, and 8 imagery for path 19, row 50 were downloaded from United States Geological Survey (USGS) for the years of 1986-2015 during the dry season, which runs from November to April. An image was downloaded for each season as close to the month of December as possible based on availability while maintaining minimal cloud cover. This was determined by manually choosing each scene from GLOVIS for the yearly season between the months of November and February.

The ABES Project and MARN provided survey data and additional satellite imagery. The end products and accuracy assessments used the ABES Field Surveys from the 2012, ground observations that were performed on forest sites ranging from 0.01 hectares to 1 hectare. This data were shared by ABES, who also provided both RapidEye imagery from 2012, 2014, and 2015 of the La Mancomunidad region, a 2010/2011 RapidEye of the whole country, and QuickBird imagery of the area from December 2012.

Additional data were acquired from various open sources. The terrain and elevation layers used for the forecasting model were acquired from SRTM-1 available on the USGS website. The municipalities and country outlines were downloaded from the Global Administrative Areas Database.

**Data Processing**

With three different end products being formed, each required a different methodology for processing the data. For all products the Landsat images were correct for atmospheric reflectance in ArcGIS and those above the 15% threshold were adjusted for cloud cover. The data from ABES was georeferenced so the field survey areas could be easily processed in ArcGIS and LandTrendr.

As of now, no additional data processing has yet been required.

**Data Analysis**

The most accurate LULC was based on the available data by testing several classification methods. The 2012 Landsat imagery for the region was classified by using several supervised and unsupervised methods. The accuracy of the different methods was assessed using the ABES field surveys from that year and the classification method was refined to be as accurate as possible within the Landsat 7? 8? 30 m resolution constraints. The reflectance values were then applied to previous years in order to create a time series of LULC. The accuracy of this method was also assessed; however, high resolution imagery from MARN was used, because ABES only conducted a 2012 survey.

The forest inventory was then created based on the LULC classification and the ideal parameters identified by ABES. First, all classifications were identified as either forest or non-forest to create the simplest inventory and time series. The percent tree cover was then assessed in forested regions using a NDVI composite and checked against the existing field surveys. A final parameter for the forest inventory identified primary and secondary forest cover based on the time series data. All non-forested sites in the base year were classified and cross-referenced with the following year to assess where the forest had regrown, the result being a forest classification of primary or secondary and secondary forest age.

The forecast model was chosen based on creating a method that would be easily replicable for MARN using their current software capabilities. The Landsat image time series was uploaded to LandTrendr, software capable of forecasting forest cover change at the pixel to pixel level.

# IV. Results & Discussion

# V. Conclusions

# VI. Acknowledgments

# VII. References

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# VIII. Content Innovation

# IV. Appendices

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