**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, Remote Sensing, Forest Inventory, Land Use/Land Cover, Earth Observing Systems

# II. Introduction

Forests of Mesoamerica are critical to global ecological stability; supporting some of the most bio diverse ecosystems on Earth (Hecht et al. 2006). Contributing to the removal of 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 (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 hectares) and the highest population density (295 people/km2) (World Bank, 2014; 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.

In collaboration with the NASA DEVELOP El Salvador Ecological Forecasting team, the Agroforestry for Biodiversity and Ecosystem Services Project (ABES) 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 is Ecological Forecasting. The project uses time series images from the study area to examine historic forest change on a yearly basis. This information was used to analyze forest dynamics at the regional scale and develop a forecasting methodology applicable to other regions of El Salvador.

# III. Methodology

During the Fall 2015 NASA DEVELOP term, the El Salvador Ecological Forecasting team examined the Pine-Oak forests of La Mancomunidad La Montañona, Chalatenango. The end users and collaborators requested three end-results: a LULC classification, a RFI, and a forecast model predicting forest change. First, a LULC map was created identifying forest, pasture, crops, and urban land classes in order to gain a better understanding of the regional forest dynamics. The LULC classification was used to develop the RFI, which was then checked for accuracy using field surveys and high resolution imagery (QuickBird 2.4m and RapidEye 5m) from the ABES Project and MARN. The RFI 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 RFI and LULC in order to create the forecast model. The methodology was designed to be easily replicable on a larger scale and for future analysis of the same region.

**Data Acquisition**

Landsat 4, 5, and 8 climate data record (CDR) imagery for path 19, row 50 were downloaded from United States Geological Survey (USGS) for the years 1986-2015 during the dry season, which runs from November to April. An image was downloaded for the available seasons as close to December as possible. Scenes were chosen manually, on the basis of image clarity, from the USGS Earth Explorer.

The ABES Project and MARN provided survey data and additional satellite imagery. The end products and accuracy assessments used the by the ABES Field Surveys from the 2012 ground observations that were performed on forest sites ranging from 0.01 hectares to 1 hectare. The data shared by ABES, provided RapidEye 5 meter orthorectified imagery from 2012 of the La Mancomunidad La Montañona region, 2012 RapidEye of the study region, and QuickBird 2.4 meter multispectral resolution imagery of a 100 km2 area from December 2012.

Additional data were acquired from various open sources. Hansen et. al research on global forest cover change was used as a reference that supports the replicability of LULC, RFI, and other forecasting methods. The terrain and elevation layers used in 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.

**Satellite Data Summary**

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| --- | --- | --- | --- |
| **Satellite** | **Resolution** | **Source** | **Use** |
| Landsat 4,5 TM | 30 meter | USGS Earth Explorer | LULC, RFI, Forecast |
| Landsat 8 OLI | 30 meter | USGS Earth Explorer | LULC, RFI, Forecast |
| RapidEye | 5 meters | ABES/MARN | Accuracy Assessment |
| QuickBird | 2.4 meter | ABES/MARN | Validation |

Table 1. Resolution, source, and research use of satellites summarized.

**Data Processing**

With three different end products being formed, each required a unique methodology, some initial processing was required for all end products. Landsat scenes are already atmospherically corrected in the CDR format. Imagery was clipped to the available RapidEye imagery outlining the study area, using a python script. The Hansen global forest cover dataset was clipped manually to the QuickBird extent using ArcGIS. Finally, the high resolution satellite imagery was resampled using ArcGIS to match the 30 meter pixels resolution of the Landsat scenes. This processed data were used in several different steps for creating the end products.

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

**Data Analysis**

The LULC was created from the 2014 Landsat imagery using several supervised and unsupervised methods. The accuracy of the different methods was assessed using the ABES field surveys and high resolution imagery from 2012. The classification method was refined to be as accurate as possible within the Landsat 8, 30 m resolution constraints. The results were used to create LULC for 2010, 1995, and 1986, building the most accurate time series possible.

A forest inventory was then created from the LULC classification and the ideal parameters identified by ABES. All classifications were identified as either forest or non-forest to create the simplest inventory and time series. The forest area was then separated by species and forest type using supervised and unsupervised classification methods. 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 classification of primary or secondary forest and secondary forest age. The parameters were combined to create the RFI.

The forecast model was chosen based on a method that would be easily replicable for MARN using their current software capabilities. The Landsat image time series was uploaded to LandTrendr software, which is 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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