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Indonesia Agriculture

Identifying Current Areas of Palm Oil Production and Modeling a Risk Map for Future Expansion in Central Kalimantan, Indonesia

 **Technical Report**

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Kyle T. Peterson (Project Lead)

Michael Riedman

Abigail Childs

Dr. Naikoa Aguilar-Amuchastegui , WWF (Science Advisor)

Aakash Ahamed, USRA/GSFC (Science Advisor)

# 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**

Agriculture, Indonesia, Maxent, Deforestation, Palm Oil, Remote Sensing

# II. Introduction

*Background*

Palm oil is the primary agricultural export of Indonesia, with Indonesia and Malaysia supplying 90% of the palm oil to the world market (Thomas, et al., 2015). In the past decade, worldwide demand for palm oil has grown exponentially as it has become an essential ingredient in most processed foods and household items such as make-up, soap, and toothpaste. In response to the growth of palm oil demand, the government of Indonesia formulated an agricultural policy in 2014 with the expressed goal of doubling palm oil production by 2020 (Thomas, et al., 2015). A central pillar of this plan is to convert unused land into palm oil plantations. The most readily available land to convert into palm oil plantations is uninhabited forest, particularly forested land in remote areas such as Central Kalimantan, where governance of protected areas is not stringent and opportunities for large plantations exist.

Coupled with the issue of natural forest loss are the negative environmental impacts of increased greenhouse gas (GHG) emissions. Within the past several years massive forest fires have also strict the region, many stemming from the clearing of land for palm oil plantations. Forest fire along with deforestation releases greenhouse gases, especially CO2, into the atmosphere. This negative externality is further heightened by the fact that most conserved rainforest in Central Kalimantan are located on top of peatlands, which are CO2 sinks. Deforestation accounts for 94% of GHG emissions in Indonesia (Fairhurst & McLaughlin, 2009), making Indonesia one of the top GHG emitters in the world (Ramdani & Hino, 2013). Government and local policymakers have thus far been unable to stop large and small scale deforestation and prevent rainforest and peatland loss.

In 2011 the government of Indonesia put a two-year moratorium on new licenses for land in natural forests and peatlands in an attempt to reduce deforestation and carbon emissions. This moratorium was extended for two years in 2013, and again in 2015. The moratorium does not address government licenses on natural forests and peatlands prior to 2011, nor does it apply to secondary forests, and does nothing to prevent against encroachment (Austin, Sheppard & Stolle, 2012). Moreover, the moratorium has not been strictly enforced by the government, making it possible for developers to clear forests and peatlands without regulation.

Previous studies have analyzed the impact of deforestation and have modeled the areas most at risk for future deforestation. Some of these studies are out of date (Ramdhani & Taufik, 2006; Uryu et al, 2008) and do not accurately reflect current conditions. Other studies incorporate current modeling techniques such as Maximum Entropy Modeling (Maxent), but are not specific to Central Kalimantan (Aguilar-Amuchastegui et al, 2014). While others studies are specific to Kalimantan and Borneo, they have used land capability evaluation analysis (Bhermana et al, 2013) or land use change analysis (Wicke et al, 2011; Ramdani & Hino, 2013) to measure deforestation and do not model future land use change. The limitation with these analyses is current palm oil plantations are difficult to locate with remote sensing systems. Therefore a modeling approach based on Maxent is appropriate since it uses known locations to model suitability for future locations.

*Project Objectives*

The objectives of this project are creating a risk assessment map identifying current palm oil plantations in the Central Kalimantan region of Indonesia, and model potential future palm oil plantations based on existing plantations. Current areas of palm production can be determined by mapping validated and unvalidated plantations and using the environmental inputs for those plantations to extrapolate the data to where other plantations may be located. Inputs can include such factors as: slope, aspect, elevation, vegetation indices, distance to roads, distance to water sources, population, humidity, temperature, precipitation. By identifying current palm oil plantations and modeling a risk assessment map, World Wildlife Fund, Roundtable on Sustainable Palm Oil and other organizations, can better identify areas to concentrate their deforestation efforts and better support decision makers when reviewing palm oil policy.

*Study Area and Period*

Central Kalimantan, located on the island of Borneo in the Republic of Indonesia, is the province that has the seen the largest increase in palm oil plantations (Ramdani & Hino, 2013). Much of Central Kalimantan is natural rainforest and home to many diverse plant and animal species. Since international demand for palm oil has increased, developers have been clearing conserved rainforest at the expense of native flora and fauna to create palm oil plantations. Often, these plantations are created without any national or local government oversight and as a result are created in conserved forests.

Figure 1.1: Study Area Map for Central Kalimantan, Indonesia



The study period for mapping deforestation for palm oil plantations in Central Kalimantan is from January 2000 through January 2016.

*National Application Addressed*

The primary NASA national application area addressed by this project is agriculture. Mapping the risk of palm oil plantation growth and deforestation in Central Kalimantan, Indonesia can positively impact the long term sustainability of the palm oil supply chain and substantially reduce deforestation. A map that models current and future palm oil plantations based on known locations can better predict future palm oil plantation growth and lead to targeted interventions that address both deforestation and agricultural growth in a sustainable and coherent manner. A risk model can help policy makers and NGOs better define forests at risk for agricultural expansion and deforestation.

*Project Partners*

The partner for this project is the forests division in WWF. Projects related to deforestation and forest conservation in Indonesia is a major focus area for WWF since forests provide species habitat protection. Current WWF deforestation programs in the area include a program to raise local governance of conserved areas by providing data and support to local governments. WWF is interested in this project since this project will add data and specificity to their current work.

The project of mapping known palm oil plantations and present forests that are at risk of becoming palm plantations in the Central Kalimantan province can help target the work that WWF is doing on the ground, thereby increasing the impact of their work. WWF currently relies on unvalidated data of palm oil plantations, but this data only shows where suspected current locations are, it does not show possible future locations of plantations. WWF will benefit from the methodology of risk mapping by better targeting their interventions.

# III. Methodology

*Data Acquisition*

Using the Maxent algorithm, data were divided into two categories: observed/known occurrences used as training data and environmental data representing explanatory variables.

*Vector Data*

The training data used in this study were shapefiles that contained known palm oil plantation locations in Central Kalimantan. WWF Indonesia provided this dataset which was a result of ongoing in situ research and was last updated November 2015.

Palm oil mill locations were prepared and verified by World Resource Institute (WRI) from data provided by FoodReg. These data were combined with data prepared by Global Forest Watch showing the location of Roundtable for Sustainable Palm Oil (RSPO) certified palm oil mills.

Administrative boundaries shapefiles were acquired from the Global Administrative Areas Spatial Database (GADM). These data were clipped to show only the regencies that make up Central Kalimantan, Indonesia. This modified shapefile was used to clip all other raster and vector files.

The roads and inland water shapefiles were downloaded via DIVA GIS and were produced by Harvard University’s Digital Chart of the World. These shapefiles were clipped to only show data within Central Kalimantan, Indonesia.

Indonesian conservation areas and Indonesian oil palm concession shapefiles were acquired from Global Forest Watch. The Indonesian conservation areas shapefile was created in 2010 and was created by the Indonesian Ministry of Forestry. The oil palm concession dataset was produced by the Indonesian Ministry of Forestry.

*Raster Data*

NASA Earth Observations were used to acquire precipitation, temperature, and humidity data. Average monthly rainfall was derived from level 3 data at the 0.25 degree resolution using TRMM TMI satellite data, ranging from January 2000 - January 2016. Data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument onboard the Terra platform were gathered at the 0.05 degree spatial resolution to obtain the average land surface temperature from January 2000 - January 2016. Relative humidity level 3 data from the Atmospheric Infrared Sounder (AIRS) instrument on the Aqua platform were the final atmospheric data acquired and were downloaded at 1 degree spatial resolution from January 2002 - January 2016. All atmospheric data were downloaded using the NASA Giovanni data portal.

Elevation data from the Shuttle Radar Topography Mission (SRTM) utilizing Interferometric Synthetic Aperture Radar (IFSAR) were downloaded, using the USGS EarthExplorer data portal, in the form of a digital elevation model (DEM). In order to cover the area of Central Kalimantan, multiple DEM’s were acquired and mosaicked together using ArcGIS. These data were acquired from the United States Geological Survey (USGS) at 1 arc-second spatial resolution, or approximately 30m per pixel at the equator.

Landsat 8 Operational Land Imager (OLI) data were acquired through USGS GLOVIS at a 30m spatial resolution. Tiles were chosen from dates between 2013 and 2015 based upon <20% cloud cover. This data was used as a way to visually verify data and model results.

Within the Maxent model, two vegetation indices were used: Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI). NDVI is used as an index of plant greenness and photosynthetic activity and is calculated as:

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EVI is calculated similarly to NDVI:

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The difference between EVI and NDVI is that EVI corrects for distortions in the red light caused by air particles and ground cover below vegetation. Both of these products were acquired directly from NASA as Terra MODIS level 3 products. These datasets were gathered at a 1km spatial resolution for January 2000- January 2016 and downloaded using the Giovanni data portal.

Global Forest Change data were acquired from the University of Maryland, Department of Geographical Sciences, created by Dr. Matthew Hanson and his colleagues using a time series of Landsat images between 2000 and 2014. These datasets included forest loss, forest gain, and tree cover. These datasets have a spatial resolution of 1 arc second, or approximately 30 meters per pixel at the equator.

Population data for Central Kalimantan, Indonesia, were acquired from NASA’s Socioeconomic Data and Applications Center (SEDAC). These data, stored in ASCII raster format, have a spatial resolution of 2.5 arc minutes. Population data for Central Kalimantan, Indonesia, were acquired from DIVA-GIS and created by Center for International Earth Science Information Network (CIESIN) with a spatial resolution of 30 arc-seconds.

Indonesia and Malaysia peatlands and Indonesia primary forest raster datasets were both acquired from Global Forest Watch. The Indonesia and Malaysia peatlands raster dataset was prepared by the World Resource Institute and the data were provided by the Indonesian Ministry of Agriculture in 2011. The Indonesia primary forest dataset was prepared by Global Forest Watch from data provided by the Indonesian Ministry of Forestry in 2012.

The global soil types data were produced by the Food and Agricultural Organization of the United Nations (FAO). The data were published in 2006 with a spatial resolution of 1km. This data illustrated areas in Central Kalimantan with histosol soils. This was used to verify the accuracy of the peatlands raster data.

The settlements data were created by the Indonesia Agriculture DEVELOP team due to the lack of data in the region. Points were made within ArcGIS online based upon the settlements indicated by ArcGIS Online “Imagery with Labels” basemap. These points were exported and verified within ArcGIS Desktop.

A basemap of Central Kalimantan, Indonesia, was created with pan-sharpened images gathered by Landsat 8 OLI from 2012-2016. Landsat 8 images were downloaded from USGS GLOVIS interface and chosen based on date and percent <20% cloud cover. This layer was used for visualization. These images have a spatial resolution of 1 arc-second.

*Data Processing*

Landsat 8 OLI and MODIS data had to be mosaicked to seamlessly cover the area of Central Kalimantan.

A boundary of Central Kalimantan, Indonesia, was created by using the data acquired from the Global Administrative Boundaries Spatial Database. Any regency that was outside of Central Kalimantan was omitted from the dataset. This modified dataset was used as a shapefile in ArcGIS Desktop to clip all other raster and vector files to the boundaries of Central Kalimantan, Indonesia.

Slope and aspect products were derived from the mosaicked DEM using geoprocessing tools in ArcGIS Desktop.

The Indonesia inland water data contained both a line layer and a polygon layer. Both of these layers were clipped to Central Kalimantan, Indonesia, using geoprocessing tools within ArcGIS Desktop. The polygon layer was converted to a line layer so it could be merged with the other line layer and then used as an input in the Euclidean distance function.

By calculating the Euclidean distances to roads, palm oil mills, water bodies, settlements and combining with slope data an accessibility index was created using ArcGIS. The accessibility index uses factors such as surface type, condition, and distance to networks to calculate the average speed to move across a given landscape (Eade et al. 2000).

A condition of Maxent is that all raster data must have the same cell size and resolution for Maxent to process and effectively model the data. Raster data were processed using a python program to make the resampling of raster data more streamlined. The program pulled raster files from a folder, merged rasters into a single file, converted rasters to have the same cell size, clipped rasters according to a specified shapefile, and converted the outputsinto ASCII files that could be entered into the Maxent program.

*Data Analysis*

Several iterations of the Maxent model were run using the TerrSet (Clark Labs) Habitat and Biodiversity Modeler (HBM) user interface to create the final outputs. Maxent is a proven machine learning technique that is commonly used to identify species habitat within a specific geographic bound. This technique aids in assessing the relationship between palm oil plantations and their assumed explanatory variables while also producing a map of palm oil plantation location likelihood. Along with a visual representation of the results given by the map, Maxent also generates a Receiver Operating Characteristic (ROC) and Area Under the Curve (AUC) score. These outputs produce a value range between 0-1. If the resulting score is less than or equal to 0.5 the model being assessed is no greater than pure chance (Aguilar-Amuchastegui et al., 2014). Using the AUC score and standard deviation each individual variable was evaluated to gauge its overall accuracy and contribution to the model. After carefully interpreting the model results in R and ArcGIS, changes were made and more iterations of the model were run. Finally, the palm oil plantation likelihood map was visually compared to the high resolution Landsat 8 imagery, Google Earth, and the known locations of palm oil plantations to verify results.

The resulting palm oil plantation likelihood map was then used to further create a risk map that modeled potential future expansion of plantations throughout the Central Kalimantan region.

More to come as the project advances…..

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

We would like to thank Dr. Naikoa Aguilar-Amuchastegui, Mona Wang, and David McLaughlin at the WWF for their support and input, particularly with the design of the project and encouraging the use of Maxent to model palm plantations.

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# VII. References

Aguilar-Amuchastegui, N., J.C. Riveros, and J.L. Forrest. 2014. Identifying areas of deforestation risk for REDD+ using a species modeling tool. *Carbon Balance Management* 9(10).

Austin, K., S. Sheppard, and F. Stolle. 2012. Indonesia’s moratorium on new forest concessions: key findings and next steps. WRI: Washington, DC.

Bhermana, A., B.H. Sunarminto, S.N.H. Utami, and T. Gunawan. 2013. The combination of land resource evaluation approach and GIS application to determine prime commodities for agricultural land use planning at developed area (a case study of Central Kalimantan province, Indonesia). *ARPN Journal of Agricultural and Biological Science*. 8(2): 771-784.

Eade, J.F.A., R. Knapp, G. LeClerc., A. Nelson, and M. Winograd. 2000. Accessibility Analyst: A Simple and Flexible GIS Tool for Deriving Accessibility Models. Centro Internacional de Agricultura Tropical (CIAT):Cali, Colombia*.*

Fairhurst T. and D. McLaughlin. 2009. Sustainable Palm Oil Development on Degraded Land in Kalimantan. WWF: Washington, DC.

Ramdani, F. and M. Hino. 2013. Land use changes and GHG emissions from tropical forest conversion by palm oil plantations in Riau province, Indonesia. PLoS ONE 8(7): e70323.

Ramdhani, Y. and R.K. Taufik. 2006. Land Suitability Analysis for Sustainable Oil-palm Plantations in Kalimantan using Fuzzy Weighted Linear Combination on Multi Criteria Spatial Decision Support System. *SarVision Indonesia*.

Thomas, M., J. Buchanan, D. McLaughlin, D. Grubba. 2015. Sustainable Sourcing Guide for Palm Oil Users. WWF: Washington, DC.

Uryu, Y., C. Mott, N. Foead, K. Yulianto, A. Budiman, F. Takakai, Nursamsu, Sunarto, E. Purastuti, N. Fadhli, C.M.B. Hutajulu, J. Jaenicke, R. Hatano, F. Siegert, and M. Stüwe. 2008. Deforestation, forest degradation, biodiversity loss, and CO2 emissions in Riau, Sumatra, Indonesia: One Indonesian province’s forest and peat soil carbon loss over a quarter century and its plans for the future. *WWF Indonesia Technical Report*. WWF: Washington, DC.

Wicke, B., R. Sikkema, V. Dornburg, and A. Faajj. 2011. Exploring land use changes and the role of palm oil production in Indonesia and Malaysia. *Land Use Policy* 28: 193-206.

# VIII. Content Innovation

AudioSlides

Inline Supplementary Material (figures, tables, computer code)

Interactive Map Viewer

# IV. Appendices