

MODELING POTENTIAL CONFLICT BETWEEN AGRICULTURAL EXPANSION AND BIODIVERSITY IN THE GREATER MAHALE ECOSYSTEM, TANZANIA

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December, 2012



AFRICA BIODIVERSITY COLLABORATIVE GROUP

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This report was made possible by the generous support of the American people through the United States Agency for International Development (USAID) under the terms of Cooperative Agreement No. RLA-A-00-07-00043-00. The contents are the responsibility of the Africa Biodiversity Collaborative Group (ABCG). Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of USAID or the United States Government. This publication was produced by the Jane Goodall Institute on behalf of ABCG.

Table of contents

Background	1
Study Area	1
Methods	5
Results	8
Implications for Conservation:	11
References	13

List of Figures

Figure 1.	Masito-Ugalla Study Area and the larger Greater Mahale Ecosystem.	2
Figure 2.	Agro-economic zones defined by criteria from Kigoma Region Socio-Economic Profile.	4
Figure 3.	Screenshots of mahalanobis distance modeling workspace in Google Earth Engine.	7
Figure 4.	Areas predicted to be potentially suitable for cultivation with trees and other crops overlay.	8
Figure 5.	Areas predicted to be potentially suitable as chimpanzee nesting habitats using two years of Landsat satellite data along with distances from steeps slopes, riverine forests, settlements and elevation in Google Earth Engine.	9
Figure 6.	Potential chimpanzee and agriculture conflict map.	10
Figure 7.	Potential biodiversity and agriculture conflict map using a map of focal conservation targets from the Greater Mahale Conservation Action Plan.	11

Background

Incompatible conversion of forests and woodlands to agriculture is one of the major drivers of deforestation, loss of habitat, biodiversity, ecosystem services and increase in CO₂ emissions in Tanzania. The country's economy is primarily agricultural based with more than 80% of the nation's population engaged in agriculture. However, the agricultural sector is seen as the major opportunity for investment on the basis that arable land accounts for 44 million hectares out of which only 10.1 million hectares are currently under cultivation (Baha 2012). The National *Kilimo Kwanza* (Agriculture First) initiative launched in 2009 encourages the transformation of the agriculture sector in the country by taking advantage of the numerous opportunities to modernize and commercialize agriculture in Tanzania.

With increases in population size as well as increased interest by foreign and domestic companies in large-scale agricultural investments in Tanzania for export and related investments in bio-energy, the threat to biodiversity and ecosystem services drastically increase, as will CO₂ emissions from agriculture conversions. Therefore there is an urgent need to better understand the geography and the ecological, social, economic and political factors driving land acquisitions and the conversion of natural lands to both subsistence and commercial agriculture, to mitigate the impacts on critical biodiversity and ecosystem services and to design landscapes that better work for people, agriculture and biodiversity.

In 2012 JGI completed research on large-scale land acquisitions in Masito-Ugalla Ecosystem in western Tanzania with a focus on modeling and mapping potential conflict between agriculture and biodiversity with special emphasis on chimpanzees as a keystone species for the region. The modeling approach developed in the case study will be expanded as part of the 2013 workplan for the larger Greater Mahale Ecosystem (Figure 1). The final layers will be used as an input to spatial optimization tool Marxan for developing biodiversity safeguards for agricultural expansion in Tanzania.

Study Area

The Masito-Ugalla Ecosystem (MUE) in western Tanzania is an ecologically rich area which boasts a variety of distinct species—including African elephants, rare orchids, ornate frogs and savanna-woodland-dwelling chimpanzees—and serves as a refuge for several species identified by the International Union for Conservation of Nature and Natural Resources (IUCN) as subjects of conservation concern, such as mninga trees, leopards, serval cats and ground pangolins. Additionally, nearby Lake Tanganyika hosts an assortment of aquatic life, including almost three hundred endemic species of fish (Snoeks 2000). Masito-Ugalla Ecosystem

comprises the northern section of the Greater Mahale Ecosystem (GME) along the border between Mpanda and Kigoma Regions (Figure 1).

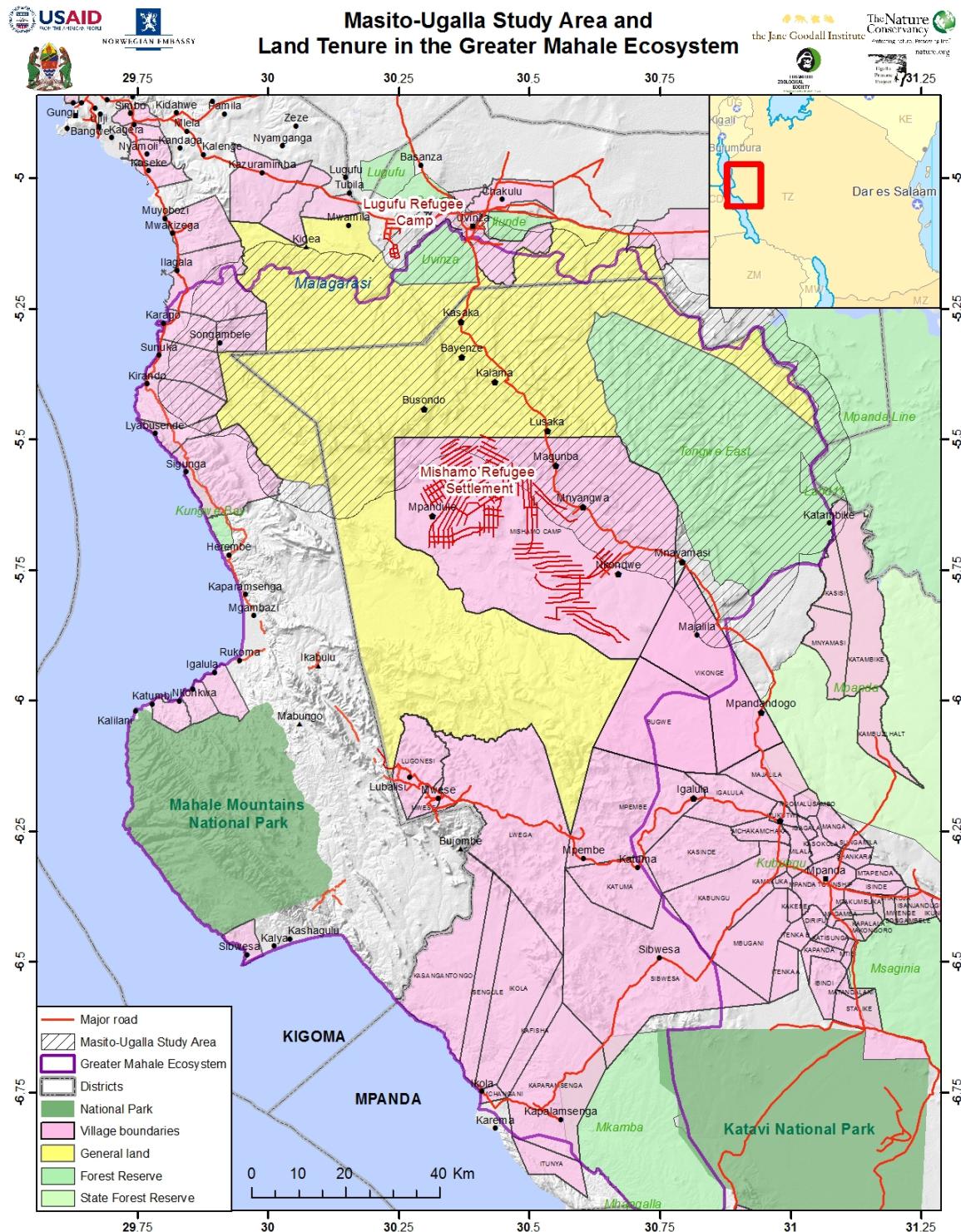


Figure 1. Masito-Ugalla Study Area and the larger Greater Mahale Ecosystem.

The area can be divided into four agro-economic zones on the basis of altitude and corresponding annual rainfall (Figure 2). This includes (directly cited from Kigoma Region Socio-Economic Profile):

The Lakeshore Zone: This zone lies within altitude of 800 -1000 meters with annual rainfall of 600–1000 mm. The Lakeshore Zone forms a narrow strip of land between Lake Tanganyika and the mountains dissected by numerous streams flowing into the lake creating in the process valleys in a few locations which support paddy farming. Cassava, maize, beans and oil palm are also grown. The main economic activity is fishing. Population is sparsely distributed with more concentration on the shores of the lake.

The Miombo Zone: The Miombo zone lies within altitude 1000 and 1200 meters with rainfall of 600–1000 mm. The area is generally covered with miombo woodland and is sparsely populated due to tsetse fly infestation. Economic activities include cattle rearing, hunting and honey/bees wax gathering with agriculture.

The Intermediate Zone: This zone lies between 1200–1500 meters above sea level with an annual rainfall of 850 mm to 1100 mm. The zone is characterized by swampy areas which provide great potential for irrigation. Population in this zone developed from both organized and spontaneous resettlement mainly from the Highland. Common food crops include cassava, maize, beans and sorghum/millet while oil palm, cotton and tobacco constitute the cash crops.

The Highland Zone: This zone lies within the altitude of 1500 meters to 1750 meters with annual rainfall of 1000–1600 mm. The zone is divided into two main parts. In the north the zone is located above the intermediate zone and has a high population. To the south there is a separate highland area as well as the Mahale mountains, reaching a maximum altitude of 2373 meters. This area is uninhabited and most of it has been designated a National Park.

Agro-Economic Zones in Masito-Ugalla and the Greater Mahale Ecosystem

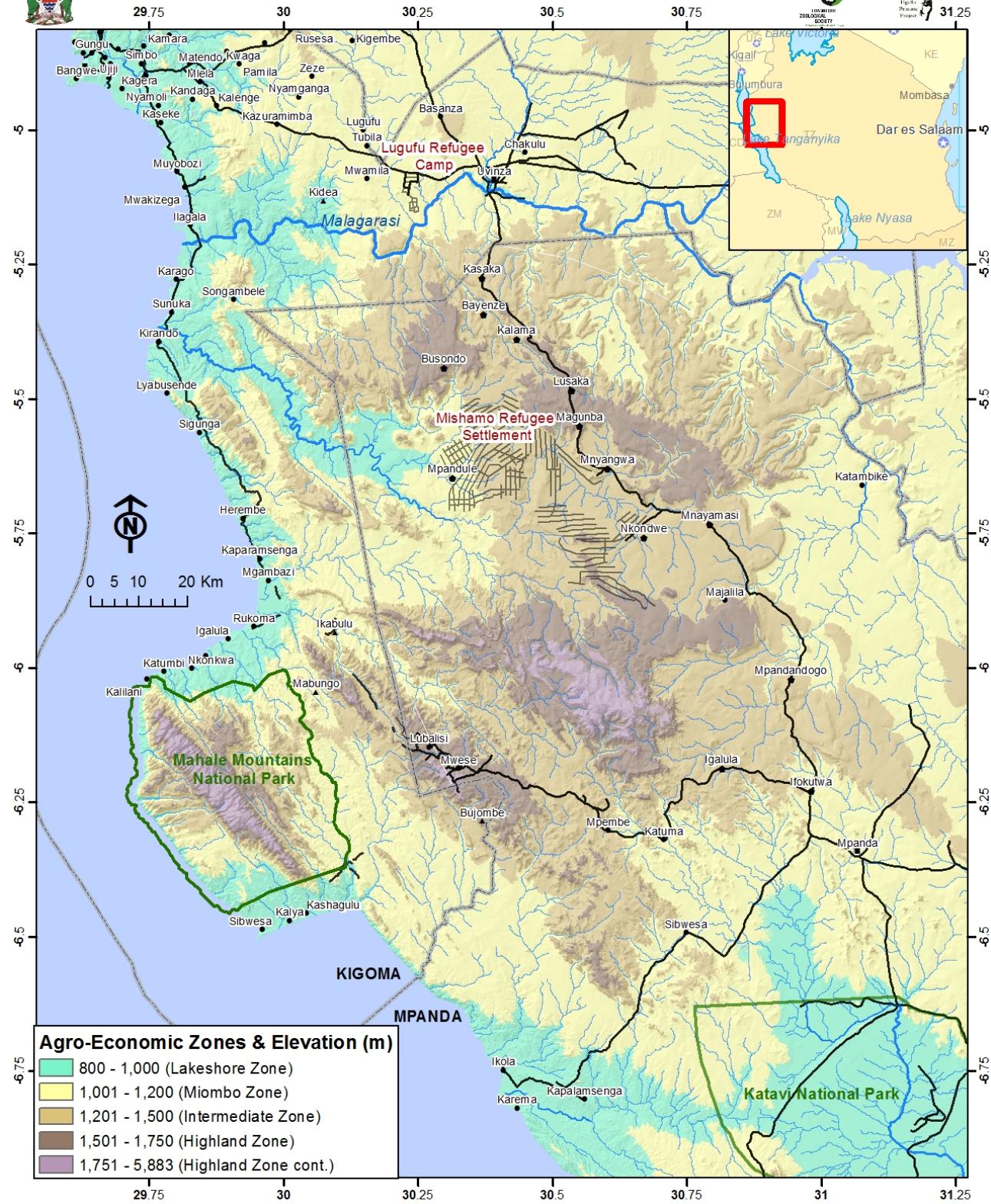


Figure 2. Agro-economic zones defined by criteria from Kigoma Region Socio-Economic Profile.

Methods

The geographic extent of the analysis covers a total of 794,434 ha and includes Masito-Ugalla core conservation area and 5 km buffer to capture a better representation of conditions in which agriculture activities occur in the region. A GIS database was developed combining all available baseline data for the region (e.g. administrative boundaries, protected areas, roads, streams, elevation, etc). The latest versions of the village boundaries and land use plans also have been digitized and added to the database (JGI and FZS, work in progress).

In order to develop a map showing potential conflict between agricultural expansion and biodiversity we first mapped potential cultivable lands and areas of biodiversity at the Masito-Ugalla ecosystem scale. There are numerous modeling approaches that can be used for this purpose. We applied Mahalanobis Distance algorithm using both ArcGIS, Esri software and Google Earth Engine in order to access thousands of terabytes of satellite data stored in Google cloud (<http://earthengine.google.org>).

We set the spatial resolution at 90-meter in order to capture important biodiversity habitats and landscape structures such as heterogeneous vegetation mosaic of riverine forests, wetlands, grasslands, savanna and miombo woodlands. This is also the scale at which most of the conversion of forests and woodland to agriculture happens in the region, driven by the expansion of small scattered farms along the roads, riverine areas and wetlands. Important variables such as precipitation were available only at 1 km and have not been used in this exercise. Instead, we attempted to predict potential agriculture suitability based on topography derived from SRTM DEM including elevation, slope, land forms and landscape roughness and biophysical variables directly extracted from 30-m Landsat TM and ETM+ remote sensing imagery, such as Normalized Difference Water Index (NDWI) sensitive to changes in liquid water content of vegetation canopies.

Potential areas suitable for agriculture have been mapped by modeling two general categories: farming with tree crops and farming with other crops. The farming with tree crops category includes mostly cash crops such as oil palm but also other food crops such as rice, banana and beans grown in wet valleys along the rivers. The farming with other crops category includes crops that can be grown away from the river valleys and on various slopes and land forms such as cassava, maize and coffee. The ground truthing or presence data for agriculture classes have been derived from field surveys collected between 2005-2012 (Moyer et al, 2006; JGI, 2007; Piel and Stewart unpublished data 2012) and village Forest Monitors using Open Data Kit (ODK) and Android smartphones and tablets (2012). However, those points did not capture the entire range of environmental conditions in which agriculture occurs in the region. Therefore, we complemented the field survey data with hundreds of random points (restricted to more than 100 meters from each other) generated within agricultures classes from 2007 vegetation maps

derived from Landsat TM and AWIFS satellite imagery. The points were validated using 1-meter resolution imagery in Google Earth and Earth Engine. 25% percent of the points have been randomly selected and set aside for validation and the remaining 75% were used for developing the model. The layers used for modeling the areas potentially suitable for agriculture included elevation, roughness of terrain, distance from streams, landforms, density of forests, woodlands and wetlands.

Potential distribution of biodiversity was modeled using chimpanzees as the main umbrella and keystone species for the region. Locations of chimpanzee nests, vocalizations and direct sightings recorded by field surveys from 2005-2012 were used as chimpanzee presence data (Moyer et al, 2006; JGI, 2007; Piel and Stewart unpublished data 2012). However, since the majority of chimpanzee presence data were nests it is important to underline that the predicted layer shows the potential distribution of chimpanzee nesting habitats only and not all the habitats potentially used by chimpanzees. Chimpanzee daily range can easily reach 5 km from the nests. If we buffer the potential nesting habitats by 5 km it covers all of the Masito-Ugalla ecosystem. Therefore we used potential chimpanzee nesting habitats as a general location of chimpanzee conservation hot-spots.

As part of this project JGI collaborated with Google Earth Outreach and Google Earth Engine and developed a cloud based platform that enabled for the first time to model species distribution in the cloud. This allowed us to predict potential chimpanzee distribution and agriculture suitability in Masito-Ugalla using thousands of terabytes of satellite imagery and other ancillary data stored and available in the Google Earth Engine platform (<http://earthengine.google.org>). It also allowed us to validate agriculture classes with high resolution satellite imagery (Figure 3).

We developed the final conflict map by overlaying the predicted potential land for agriculture and chimpanzee suitability layers with watershed, village boundaries, land tenure, protected areas, and distribution of other conservation targets in the region. In addition to chimpanzees, Greater Mahale Ecosystem Conservation Action Plan (2007) defined the following focal conservation targets: Rivers, streams and riparian habitats, Elephants, Montane ecosystems, Bamboo forest, Evergreen forest, and Miombo woodland/grassland mosaic. All these targets have been combined in one biodiversity index using normalized density and distance functions and overlaid with agriculture potential map.

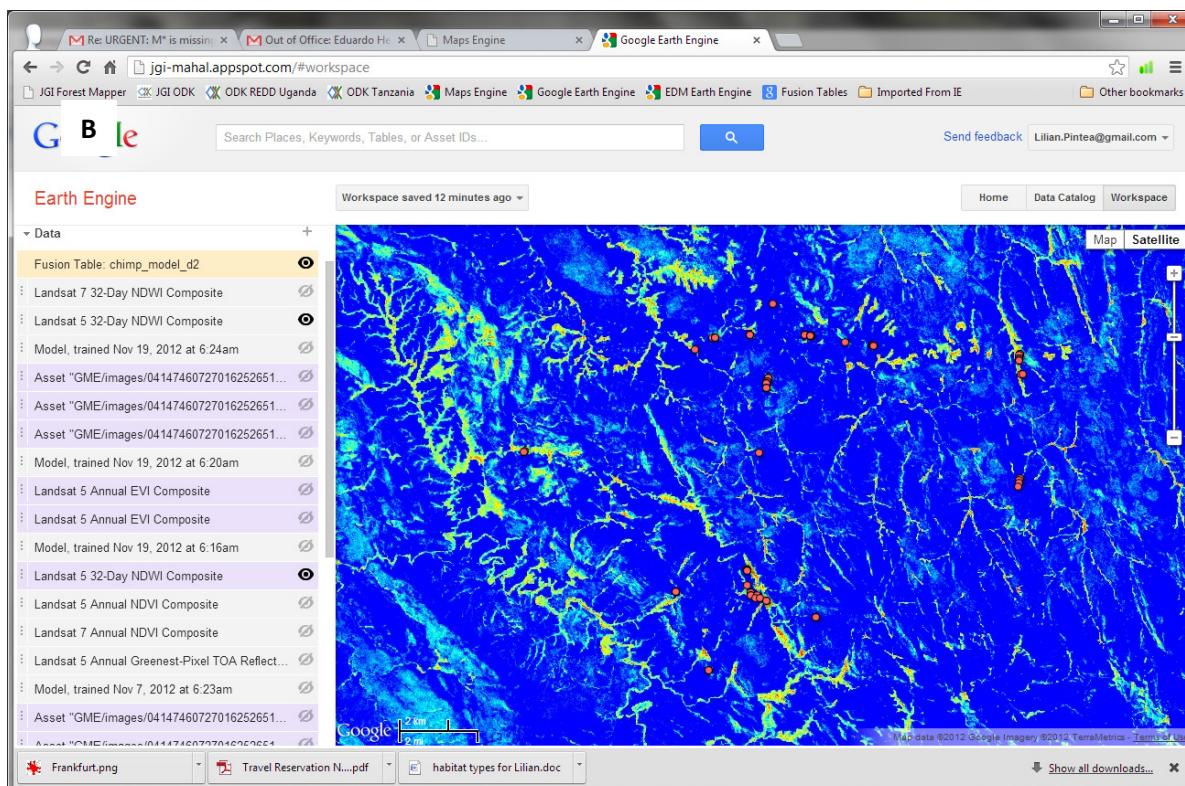
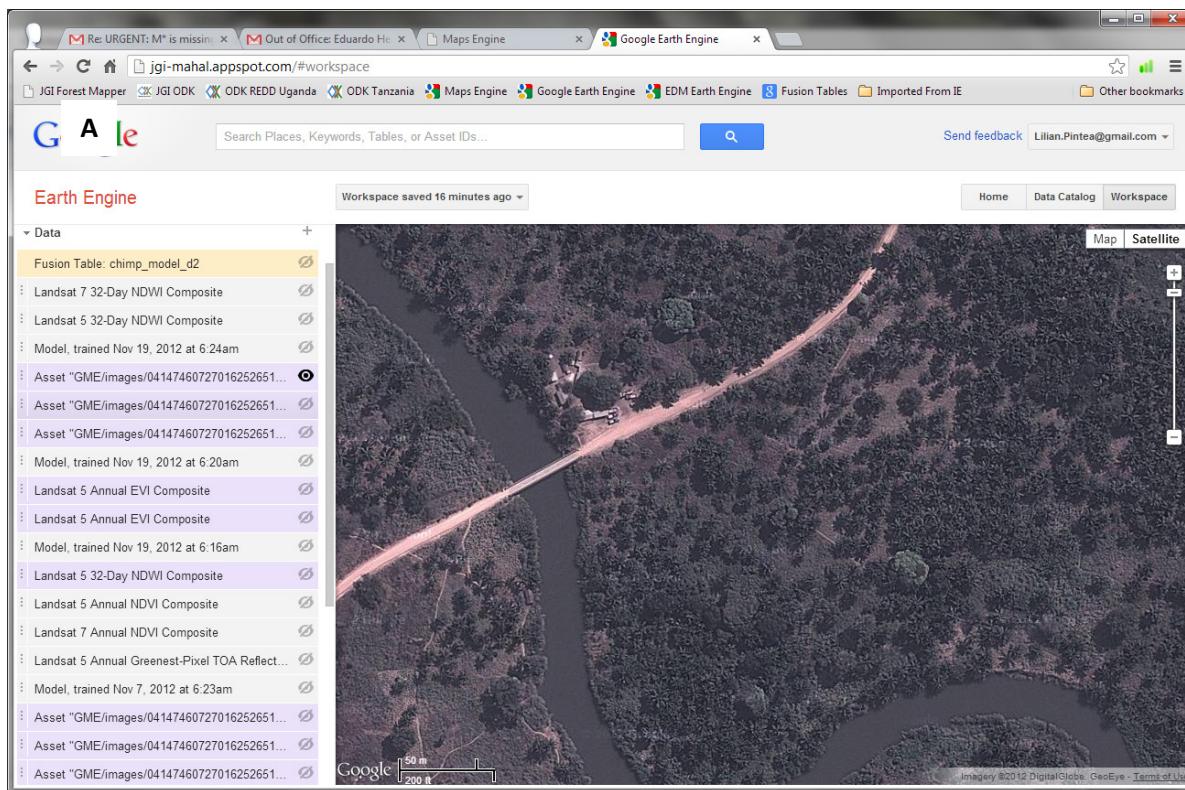


Figure 3. Screenshots of mahalanobis distance modeling workspace in Google Earth Engine. Note oil palms on the high resolution imagery (**A**) and chimpanzee nests overlay over NDWI satellite composites (**B**).

Results

Figure 4 shows the area predicted to be potentially suitable for cultivating crops with trees (e.g. oil palm and bananas) along with other important food crops such as rice, beans, maize and cassava. It also shows the maximum extent of areas potential suitable for cultivation if all the presence points (both cultivation with trees and other crops) are included in the model. Both models predict areas potentially suitable for agriculture along the valleys with large rivers and stream networks and along low to medium elevation gradients. **The model predicts approximately 302,760 ha or 38% of the Masito-Ugalla study area used in this exercise could be potentially cultivable. This number does not take into account access to roads, markets and other factors that would drive and limit the actual agriculture expansion. In 2007 only 14,428 ha or 2% of the study area was covered by farming.**

The agriculture model predicted correctly 90% of the randomly selected points set aside for validation. In general, the model also matches well with the expert knowledge of farming in the region. For example it correctly predicts areas that are heavily used for agriculture with rice and other crops south-east of Katambike village (Figure 4) (Kamenya & Lwehabura, 2012, personal communication).

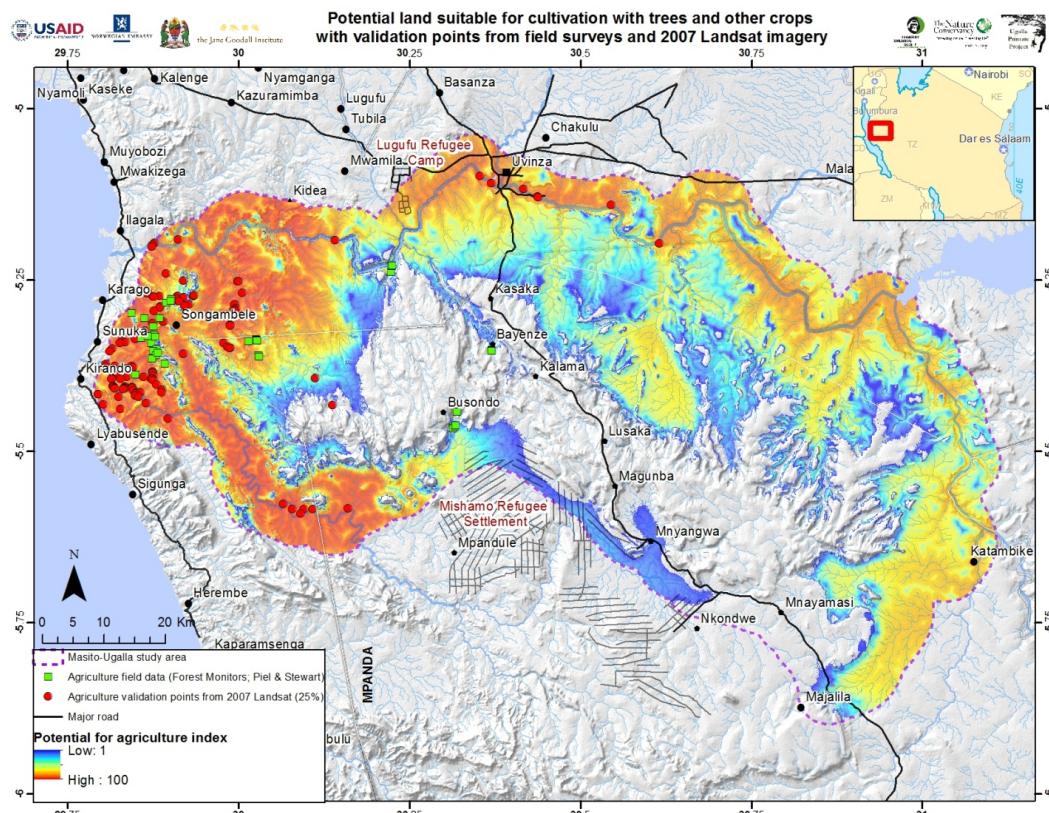


Figure 4. Areas predicted to be potentially suitable for cultivation with trees and other crops overlay with validation points from 2012 surveys (Piel & Stewart) and 2012 data collected by village Forest Monitors using Open Data Kit (ODK) and Android smartphones and tablets.

Figure 5 shows potential distribution of chimpanzee nesting habitats in the Mastio-Ugalla study area using a combination.

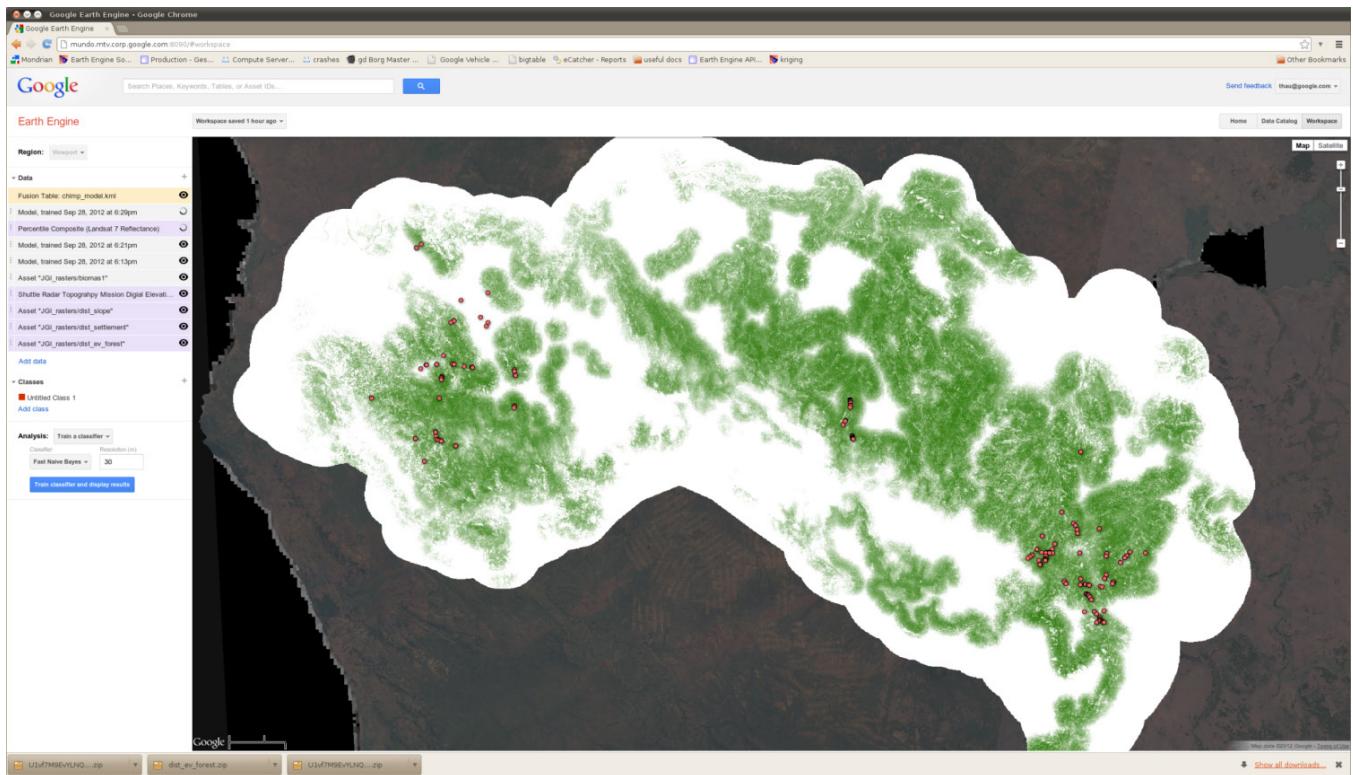


Figure 5. Areas predicted to be potentially suitable as chimpanzee nesting habitats using two years of Landsat satellite data along with distances from steep slopes, riverine forests, settlements and elevation in Google Earth Engine.

Note: Red dots indicate location of nesting sites recorded by village Forest Monitors (2012) using ODK and Android smartphones and tablets and biodiversity surveys (Moyer et al. 2006; JGI 2009, Piel & Stewart 2008; village Forest Monitors 2012).

The final conflict map between potential agriculture expansion and potential chimpanzee nesting habitats is shown in Figure 6. Potential chimpanzee nesting habitats cover 413,213 ha or 52% percent of the study area. Out of this 261,265 ha or 63% of the range is at some degree of potential risk—in direct geographic overlap with potential agriculture lands.

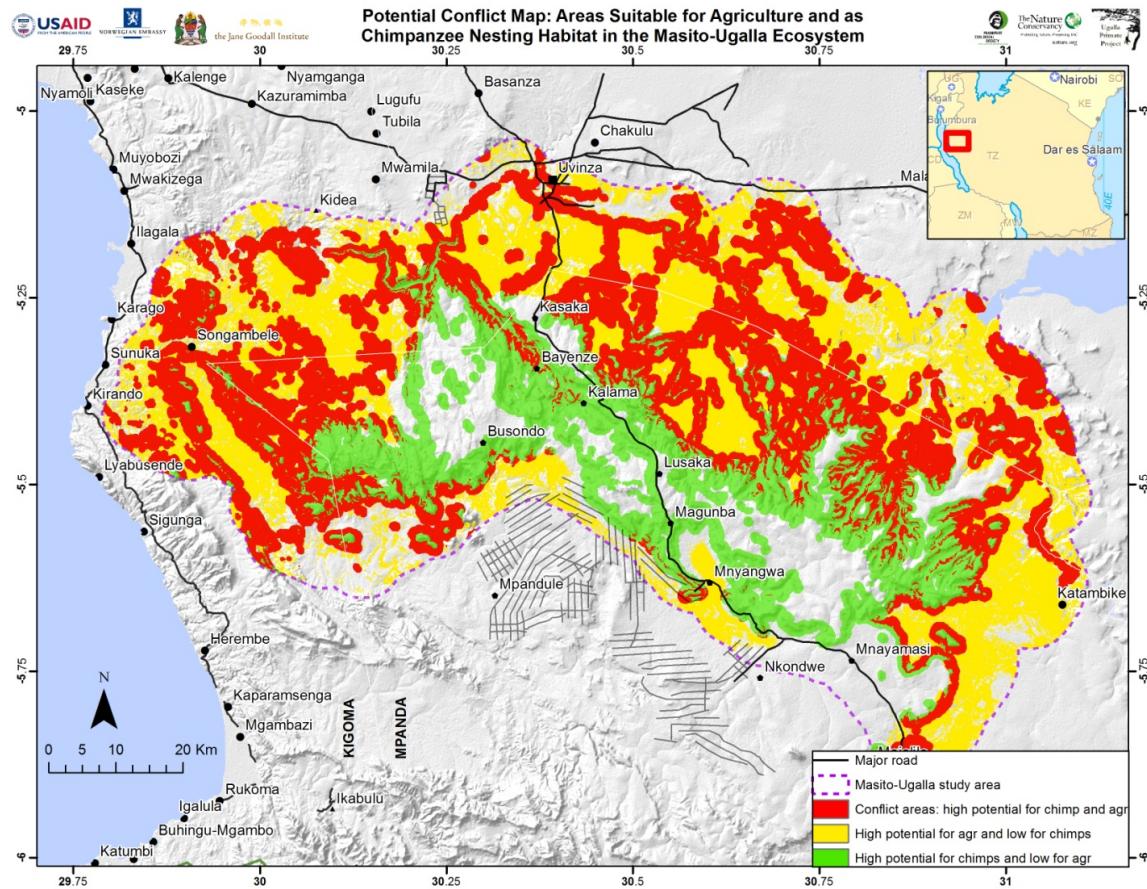


Figure 6. Potential chimpanzee and agriculture conflict map.

Figure 7 shows that when considering all the focal conservation targets Masito area has potentially relatively larger conflict with agriculture expansion than Ugalla. However, it is clear that in both regions critical for biodiversity areas, including important corridors will be significantly threatened by potential agriculture developments.

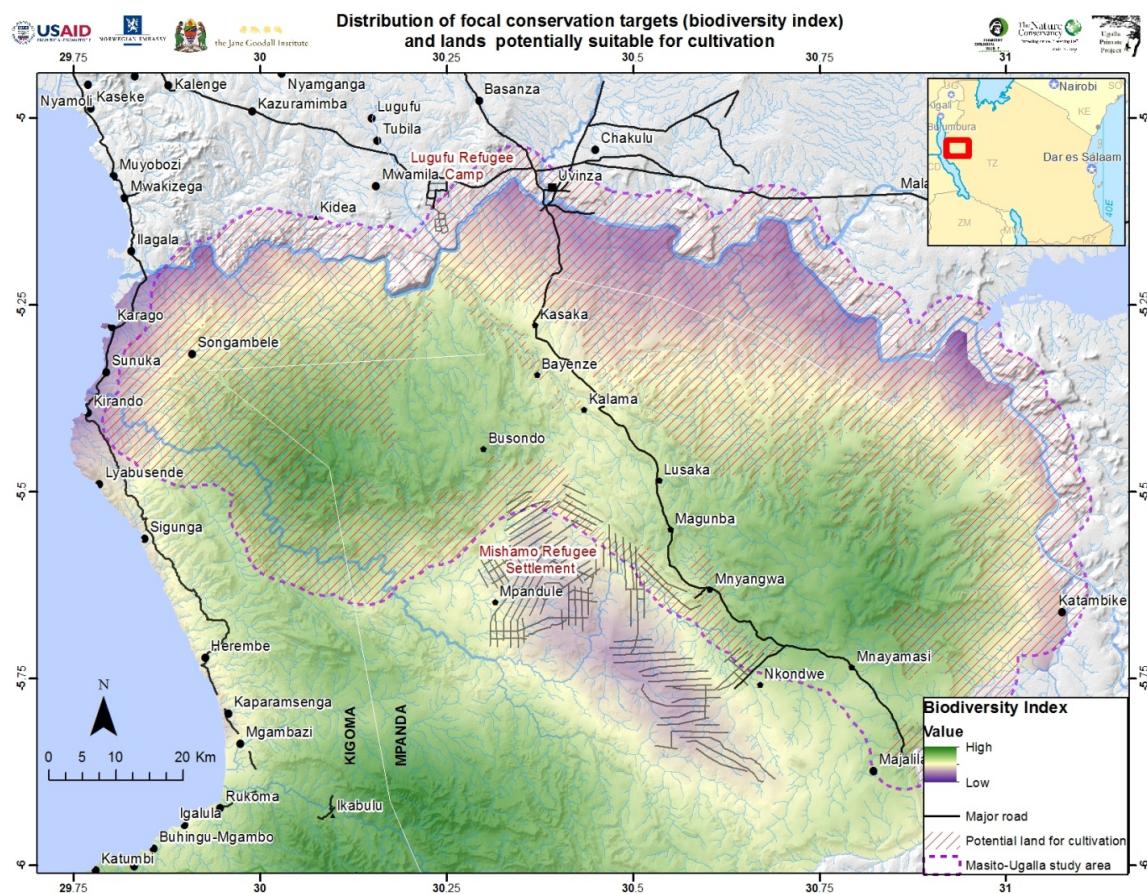


Figure 7. Potential biodiversity and agriculture conflict map using a map of focal conservation targets from the Greater Mahale Conservation Action Plan (FZS 2007) calculated as a biodiversity index overlay over lands potentially suitable for cultivation.

Note: Biodiversity index was not mapped for areas north of Malagarasi River.

Implications for Conservation:

This study is preliminary and focuses on developing and testing methodologies to model potential conflict between biodiversity and agriculture expansion at the regional scales using Masito-Ugalla Ecosystem as a case study. The methodology will be scaled up to the Greater Mahale Ecosystem in 2013. Only then Marxan optimization tools could be used to identify areas that best balance both agriculture and biodiversity objectives and identify potential safeguards (e.g. specific land use plans, spatial scenarios, or policies) for agriculture expansion.

It is clear that agriculture is one of the major threats to biodiversity in the region that could potentially lead to the loss of more than 60% of critical chimpanzee habitats in Masito-Ugalla alone. Agriculture is the predominant economic sector in the area and over 85% of the total population of the Kigoma and Mpanda region depends on agriculture for their livelihoods.

However, the bulk of agricultural production comes from smallholder farmers who employ very little capital.

Recently AgriSol Energy Tanzania and Serengeti Advisers Limited, a Tanzanian investment and consulting firm together with Iowa-based Summit Group and Global Agriculture Fund of the Pharos Financial Group, in partnership with AgriSol Energy LLC and the College of Agriculture and Life Sciences at Iowa State University have been planning to invest in agriculture in the land that is currently designated as refugee settlements in Katumba and Mishamo in Mpanda district and Lugufu in Kigoma rural district (Figure 2). In addition to soil fertility and suitability for agriculture, one of the main factors that led to the decision to invest capital in agriculture in former refugee areas was the lack of information on actual boundaries of the village and general lands (Baha 2012). This information was not available either at the national or local levels while former refugee settlements and camps were better demarcated.

Minimizing the tragedy of the commons by facilitating with the local communities and government Participatory Village Land Use Plans has been consistently identified as one of the main conservation strategies at several Conservation Actions Plans (Greater Gombe, Greater Mahale, Masito-Ugalla, and National Tanzania Chimpanzee Conservation Action Plans). While clarifying land tenure is still an important conservation strategy that needs to be continued, the availability of information on land use boundaries could accelerate and increase land allocations to foreign and local investments similar to AgriSol and make it easier for land grabbing.

Therefore there is an urgent need to prioritize areas that could balance both conservation of biodiversity and other ecosystem services supporting people livelihoods, including agriculture. Tanzania as a nation should take advantage of conserving its biodiversity and ecosystem services and make it an integral part of transforming its agriculture sector.

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