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DEVELOPMENT AND UTILIZATION OF GEODATABASE: PREDICTING BIODIVERSITY IN EQUATORIAL GUINEA, AFRICA

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DEVELOPMENT AND UTILIZATION OF GEODATABASE: PREDICTING
BIODIVERSITY IN EQUATORIAL GUINEA, AFRICA

By

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A REPORT

Submitted in partial fulfillment of the requirements for the degree of
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Chapter One

Abstract

Development and Utilization of Geodatabase: Predicting Biodiversity in Equatorial Guinea, Africa

After declaring independence in 1968 and discovering oil reserves in 1995, Equatorial Guinea has arisen as one of the wealthier countries in Africa but unfortunately has become one of the most volatile countries as well, with the numerous military coups and disproportionate distribution of wealth. This nation also houses some of the most diverse wildlife on earth, with several endangered species of mammals, as well as reptilian and bird species that are unique only to Equatorial Guinea. With increased bushmeat demand increasing in the last two decades, illegal hunting activities have increased as well, even in national parks. Because of the threats to the native flora and fauna species in the country, it becomes more important to determine what factors can motivate their movement and development. This way, we can predict the biodiversity in impacted areas and be able to coordinate better enforcement efforts to ensure the continued protection of these species and promote biodiversity throughout both Equatorial Guinea and the continent of Africa itself. The manufactured geodatabase will hopefully provide insight on how to predict biodiversity in the country's ecoregions and the factors that drive biodiversity. This document will provide formatting instructions on how the Equatorial Guinea geodatabase was created and how to manage and maintain the information stored within it.

Chapter Two

Body

Figure: Illustration of Equatorial Guinea and Bioko Island location within the continent of Africa.



Equatorial Guinea is a small coastal nation located in the central region of Africa. It was first established as a nation in 1968 after declaring independence from Spain (Campos 2008; Asongu 2009). Unfortunately, the country would be onset by a series of military coups, most notably in 1979 with the rise of Teodoro Obiang as the new president (Campos-Serrano 2013). Afterwards, in 1995 it was announced that oil and natural gas reserves were discovered within the country (Frynas 2004), boosting the country's wealth considerably to the point that Equatorial Guinea had become the wealthiest country per capita in all of Africa, and as high as

the top 45 countries in the world when adjusted for purchasing power parity (Campos 2008). However, the distribution of wealth has been completely skewed to the point where a larger portion of the population still live in poverty even in the 2020s. Within this often-unpredictable nation also lies some of the most diverse wildlife on the planet, with Equatorial Guinea having one of the highest species richness in Africa in terms of primates, with almost 30 different species between the mainland and Bioko Island (Cowlshaw 1999; Murai et al 2013; Zafra-Calvo et al 2010). The country's waters also contain four different species of marine turtles, all of whom are currently endangered (Abernethy et al 2013). Bioko Island in particular serves as important nesting and feeding sites for the turtles in the area. The country's mainland hosts endangered mammal species such as forest elephants, *Loxodonta cyclotis*; common chimpanzees, *Pan troglodytes*; and even the critically endangered western lowland gorilla, *Gorilla gorilla gorilla* (Cowlshaw 1999; Murai et al 2013).

Because of the sheer diversity in Equatorial Guinea, conservation efforts are especially important in promoting the biodiversity of not just the nation, but possibly the continent of Africa as well. Unfortunately, the resources necessary to maintain proper enforcement and protection of natural reserves is not always available, and as a result unauthorized hunting of animal species can occur (Abernethy et al 2013; Asongu 2009). While some of the incidents can be purely for sport, another possible cause could be the increased demand for bushmeat in the last two decades (Allebone-Webb et al 2011), which can lead to increased hunting rates and local extinction. Therefore, it becomes more essential to gather information on which species can be at the greatest risk of hunting practices and how enforcement practices can be improved to better ensure the animals' protection.

Development of a geodatabase will serve to model the distribution of native fauna in Equatorial Guinea and possibly determine factors that explain the movement patterns. Some of these factors that will be explored at later dates can include the development of transportation and infrastructure, different types of forest and their intended uses, levels of deforestation that currently exist in the country, climate-driven changes and the impacts they can have on local flora and fauna, and instances of hunting activities at or near existing reserves. The goal with this project is to be able to better predict what driving forces will influence species' activities or presence and to be able to use this information to coordinate better enforcement efforts to ensure that vulnerable and endangered species are better protected.

This document will provide information on developing and maintaining a geodatabase with the eventual purpose of being capable of predicting levels of animal and plant biodiversity throughout protected locations of Equatorial Guinea. Efforts to completing this task began in the summer of 2020 and is expected to be continued and expanded in the years (possibly decades) afterward. With this information, researchers can potentially use this information to determine how to improve proper enforcement efforts to protect vulnerable and endangered animal species in reserves and in doing so will promote biodiversity in the nation long after our present generations are done on this earth.

Chapter 3

Methods and Instructions

The Equatorial Guinea geodatabase will be a collection of shapefiles and raster layers of various biotic and abiotic factors that can hopefully be reliable indicators of biodiversity. It will also include collected GEDI data and metrics from the winter season of 2019-20 (project collection began December 2019 and biodiversity also tends to differ between wet and dry seasons). Every progressing year will have procured GEDI data from the affected time periods, as well as additional factors that have either not considered previously or data that does not exist for them at this time (deforestation and commercial/authorized logging, for example).

The geodatabase shall have the following feature class layers for consideration. **IMPORTANT NOTE:** all feature datasets and classes will use the same projection (WGS 1984 UTM Zone 32N) within the geodatabase.

#

1. Political Boundaries Feature Dataset. These are established political boundaries at various administrative levels, include a non-exhaustive list of city, state, providence, municipal, providence, district, regional, and national boundaries.
 - Central Africa: A polygon that includes the nations of Equatorial Guinea, Gabon, and Cameroon, later clipped to include only Equatorial Guinea's data. Includes measurements of hectare area and length in meters and area in square meters.

- Districts: Polygon that outlines all districts within the country. Provides similar information from administrative layer, but also provides units of hectares and square kilometers for each district.
 - Equatorial Guinea Border Administration Level 2: Polygon that outlines and provides names of districts and municipalities within Equatorial Guinea.
 - Municipalities: Polygon that outlines and lists each municipality in Equatorial Guinea. Units of measurement provides in square kilometers and hectares.
 - National limits: Polygon that outlines and indicates the different Equatorial Guinea boundaries, including the island and continental region boundaries. Includes boundary lengths in kilometers and hectares of each bordered area.
 - Provinces: Polygon that outlines and describes each province in the country. Hectares and square kilometers provided as units of measurement.
 - Regions: Polygon that outlines major regions (Administrative Level 1) for the nations of Equatorial Guinea, Gabon, and Cameroon. Later manually clipped to include only Equatorial Guinea's data. Provides names of regions and measurements in meters (length) and square meters (area). Also indicates source data locations.
2. Forests and Hydrography Feature Dataset. Hydrography includes rivers, streams, creeks, lakes, and other relevant bodies of water within Equatorial Guinea. Forest shapefiles provide information on types of forest and intended use (commercial, recreation, or other undefined functions) and their established boundaries within the country.

- Communal Forests: Polygon that outlines all communal forests within Equatorial Guinea. Forests developed to serve conservation purposes. Includes forest names, established locations, and coverage in units of hectares.
- Commercial Forests: Polygon that outlines all commercial forest within Equatorial Guinea. Forests developed for intention of harvesting for timber industry and possible removal for land development. Includes administrative sources, location, nations that intended to use timber, and units of measurement in hectares.
- Forest plots: Polygon that outlines all forest plots developed within Equatorial Guinea. Plots developed for numerous and specialized purposes. Includes names of the plots, locations, documentation certification, and units of measurement in hectares.
- Hydrography: Polylines that outline all rivers, streams, creeks, and other relevant bodies of water within the country. Includes water body type, names of the water bodies, and provides units of measurement in meters.
- National Forests: Polygons that outline all national forests with the intended use of education and recreational activities. Includes names of the parks, locations, level of importance (Ministro, Regional, Presidente, etc.), and units of measurement in hectares.

3. Infrastructure Feature Dataset. Shapefiles indicate areas of development, including established electrical grids, highway and roadway systems, railroad systems, and other relevant artificial structures.

- Electrical Grids: Polylines that outline existing or planning electrical grids throughout Equatorial Guinea. Includes data sources, development status, from-and-to locations, and units of measurement provided in meters.
- Global exposure: Point shapefile that indicates presence of exposed assets throughout Equatorial Guinea. Important in determining risk to exposed elements by variety of hazards, both natural and artificial, and how the nation's economy can be impacted by these actions. Includes information on each type of sector impacted (government, education, agriculture, etc.), although how the information is designated is unclear. Papers provided by developers of the shapefile (De Bono et al 2015, Tolis et al 2013, Pesaresi et al 2015) for more information.
- Highways: Polylines that highlight existing highway systems throughout the country. Intended for higher speeds and longer distance travel. Includes description and units of measurement in meters.
- Main Roads: Polylines that highlight all main road systems expanding through Equatorial Guinea. Intended for lower speeds and general use. Include type of road (primary, secondary, tertiary), names of the roads, types of road surface, and units of measurement in meters.
- Railroads: Polylines that highlight all railroad systems developed throughout the country. Describes railroad status (operational, in development), and length in meters.
- Road systems: Polylines that highlight all road systems in Equatorial Guinea. Include general use roads, but commercial roads are provided as well. Includes

information on description of the roads, road categories (municipal, providential, rural, etc.), its usage status (active or not active), and units of measurement in meters.

4. Settlements and Renovations Feature Dataset. Shapefiles indicate areas of permanent establishments for the purpose of habitation, including cities, towns, villages, and other relevant settlements. Also includes renovations in the form of national reserves, as these are permanent locations that are not for the purpose of transportation, commercial usage, or serving the role of other existing infrastructure.

- Lugares poblados: Translated as “populated places” in English. Points shapefile that highlights (almost) all permanent settlements throughout Equatorial Guinea. Includes description of settlement (City, Town, Village), location within providences, name of the settlements and their coordinates in longitude and latitude (decimal format).

- Populated Places: Points shapefile that highlights permanent settlements throughout the country, including some points that were missed from previous shapefile. Includes names of settlements, description of settlement, and populations of each settlement.

- Protected Areas: Polygon shapefile that outlines all reservation locations for the purpose of wildlife conservation. Includes names of reserves, types of reserves and categories (listed as I-IV), locations of each of the reserves, and units of measurement in both hectares and square meters.

- Settlements: Points shapefile that outlines all settlements that are not classified as higher population settlements. Includes names of settlements, locations of each of the settlements, and settlement description.

5. Raster layers from GEDI data, sourced from Oak Ridge National Laboratory (Dubayah et al 2021). Part of ongoing data collection efforts starting from December 2018 as means to measure biodiversity, water/carbon cycles, evaluate forest management and climate change, etc. Separated into multiple levels (Lv. 1, 2, 3, and 4), with Level 3 dealing with canopy height and ground elevations.

- GEDI Lv 3 Mean Canopy Height
- GEDI Lv 3 Canopy Height Standard Deviation
- GEDI Lv 3 Mean Ground Elevation
- GEDI Lv 3 Ground Elevation Standard Deviation
- GEDI Lv 3 Count of Footprints

6. Toolbox

- Calculate Geometry Attributes
- Calculate Field
- Clip
- Extract by Mask
- Create Feature Dataset
- Project

#

1. Gain access to the internet and obtain necessary layers from following websites.
 - diva-gis.org for Railroads shapefile.
 - data.globalforestwatch.org for Central Africa; Communal and Concessional Forests; Districts; Forest Plots; Hydrography; Lugares Poblados; Municipals; National Forests; National Limits; Populated Areas; Protected Areas; Providences; and Road Networks shapefiles.
 - data.humdata.org for Highways, Main Roads, Populated Locations, Regions, and Settlements shapefiles.
 - geodata.lib.berkeley.edu for Electrical Grids, Equatorial Guinea Border Administration Level 2, and Global Exposure shapefiles.
2. Download all file folders to designation of choice (documents, desktop, etc.), then locate folders and extract all folder contents.
3. Open ArcGIS Pro and click on Add Data > Data, then browse to folders and add all feature class layers to get started. Rename all layers as needed (Right-click on layer > Properties > General, then type under Name).
4. Go to Geoprocessing Tab (located at bottom), then type Clip. It should be the first option as Analysis Tools. Take other shapefiles and clip to the National Limits shapefile. This step ensures that all data is from Equatorial Guinea and not from surrounding nations.

- Input Features = layer you wish to add, Clip Feature = National Limits shapefile,
Output Feature Class = whatever you wish to name the layer and desired location,
XY tolerance = good practice to use 1 meter as tolerance limit for clipping.

5. Once all layers are clipped, right-click on layer and select Attribute Table. Update topology by right-clicking on any table field with units of measurement (ha, sq_kilo, etc.), then select Calculate Geometry. Input Features and Target Field should already be included; Property = whatever type of measurement you wish to include, usually length or area; Area Unit = the unit that is desired (square kilometers, hectares, etc.), coordinate system = what the coordinate system is currently for layer. Repeat steps for all fields with units of measurement where applicable and for all layers.

- IMPORTANT NOTE: Do this BEFORE proceeding to projecting coordinate systems for the layers, otherwise there will be inaccurate results!

6. Right-click on layer > Symbology, then change visual properties to ensure both ease of reading and that some map features are relevant in color (water = blue, vegetation = green, etc.).
7. After changes in symbology and topology are made and all changes are saved, go to Catalog and click on Databases to navigate to existing geodatabase. Right-click on geodatabase > New > Feature Dataset to begin developing and organizing datasets for the geodatabase.

- Output Geodatabase = the current one, Feature Dataset Name = what the desired name for the dataset is, Coordinate System = desired coordinate system for use (in this case, WGS 1984 UTM Zone 32N).

Use this information to complete the following datasets: Boundaries, Forests and Hydrography, Infrastructure, and Settlements and Renovations. Make sure the coordinate system is the same for all of them.

8. Go to Geoprocessing Tab, type in Project to begin inputting correct coordinate system for all shapefile layers. This is important, as the layers will not be imported into the feature datasets within the geodatabase unless the projections match.

- Input Dataset = the layer that needs to change, Output Dataset = whatever name is desired and intended folder location, Output Coordinate System = the same coordinate system that was used for the feature datasets in Step 7.

9. Save all changes at this point, then update topology for all layers by repeating the instructions outlined in Step 5.

10. Go to Catalog tab, then right-click on feature dataset > Import > Feature Class(es).

- Input features = the shapefiles that should be included in the feature dataset, output geodatabase = name of the feature class itself.

Input shapefiles into feature datasets in the following order.

- Boundaries: Central Africa, Districts, Equatorial Guinea Border Administration Level 2, Municipals, National Limits, Providences, and Regions.

- Forests and Hydrography: Communal Forests, Concessional Forests, Forest Plots, Hydrography, and National Forests.

- Infrastructure: Electrical Grids, Global Exposure, Highways, Main Roads, Railroads, and Road Systems.

- Settlements and Renovations: Lugares Poblados, Populated Areas, Protected Areas, and Settlements.

11. Gain access to daac.ornl.gov by using Google search engine for “Oak Ridge GEDI Data”. Obtained data was current as of date of publication, March 15, 2021. From there, navigate to Visualize and Subset Data portion of page, gives highlighted option for Spatial Data Access Tool. Click it, then sign in with an existing account to be able to procure data. If not, then the user will need to create an account with Earthdata before continuing.

- When signed in and with the Spatial Data Access Tool, zoom in to the area(s) of interest, then click on the third button on the left side to drag box of the area. Change the projection to WGS 1984 and the format as GeoTiff before downloading.

Repeat the above steps for the following layers: Mean Canopy Tree Height, Canopy Height Standard Deviation, Mean Ground Elevation, Ground Elevation Standard Deviation, and Counting Footprints.

12. After all layers are downloaded, add them to ArcGIS Pro using the instructions from Step 3.
13. Navigate to the Geoprocessing tab and type in Extract by Mask.

- Input raster = the layer that needs to be clipped, Output Extent = the extent that the layer needs to be clipped, in this case the extent of the National Limits shapefile. Output Raster Dataset = whichever name is desired for the new layer.

- Navigate to Environment tab of the tool, then ensure that the Extent is set to the National Limits shapefile. DO NOT change the projection of the raster layer or the layer itself will likely crash.

14. Repeat Step 13 for all five raster layers, then make sure that the non-clipped raster layers are removed from the Contents portion of ArcGIS. Those layers will not be needed at this point, and removing them also makes it easier to manage and organize both the Contents and the geodatabase itself.

Chapter Four

Appendix

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- (which is on land ceded from the Ojibway in the Treaty of 1824)

Chapter Five

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