**Africa Food Security & Agriculture**

*Predicting the Likelihood of Human-elephant Conflict and Assessing Elephant Habitat Conditions During Extreme Drought and Crop Deficit in the Kavango-Zambezi Area*

**Project Team**

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**Project Overview**

***Project Synopsis:***

This project employs Earth observations and elephant tracking data to examine human-elephant conflict (HEC) drivers in the Kavango-Zambezi area, focusing on Victoria Falls, Zimbabwe, and the Okavango Delta, Botswana. As drought conditions worsen, elephant presence in developed areas increases, threatening human safety and crop production. To support project partners at The Ecoexist Project and Connected Conservation in mitigating threats to agriculture, the team conducted a time series analysis of environmental factors that may influence elephant movements across the landscape. Project results highlight differences in elephant movement between wet and dry seasons that can inform enhanced elephant conservation practices.

***Abstract:***

Human-wildlife conflict is increasingly more common due to human population growth, habitat fragmentation, and changing climatic conditions. This conflict is particularly evident in the Kavango-Zambezi area, where over three million people share the landscape with an abundant megafauna population. As the changing climate continues to exacerbate drought severity and subsequent food availability, conflict between humans and wildlife has become more prevalent. In the Kavango-Zambezi area, conflict between elephants and humans has resulted in crop loss, property damage, and threats to public safety. In order to manage current and future conflict, The Ecoexist Project and Connected Conservation have been working to empower farmers and conserve the natural habitat. This DEVELOP project employed Earth observations to conduct a time series analysis of vegetation health change, elephant movement, and climate conditions, from 2017 to 2020. Data were aggregated into the wet (November through April) and dry (May through October) seasons. The resulting analysis demonstrated the potential to use Landsat 8 Operational Land Imager (OLI), Global Precipitation Measurement’s Integrated Multi-satellite Retrievals for GPM (GPM IMERG),and TerraClimate data to identify potential areas of conflict under increased seasonal variability. An improved understanding of conflict drivers will help support sustainable wildlife conservation and food security in the future.

***Key Terms:***

Human-elephant conflict (HEC), Kavango-Zambezi, NDVI, drought, crop raiding, kernel density, habitat conditions

***National Application Area Addressed:*** Food Security & Agriculture

***Study Location:*** Kavango-Zambezi Area of Botswana and Zimbabwe

***Study Period:*** 2017 – 2020

***Community Concerns:***

* Habitat fragmentation, human population growth, and shifts in the severity and length of the dry seasons increasingly bring free-ranging elephants from national parks to developed areas, causing a rise in the incidence of HECs.
* HECs could undermine conservation efforts and increase poaching rates as community perceptions of elephants are tainted when elephants threaten residents, damage property, eat refuse from landfills, and raid the crops of subsistence farmers.
* Local non-governmental organizations work directly with agricultural communities to identify how land use change, drought, and habitat condition changes relate to the movement and behavior of problem elephants. However, more targeted research is needed to improve their conflict mitigation and resolution efforts.

***Project Objectives:***

* Analyze the relationship between elephant movement, vegetation health, and climate conditions
* Develop reusable codes for partners to replicate the analysis as more elephant data become available
* Create elephant kernel density heatmaps to identify human-elephant conflict risk areas

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **The Ecoexist Project** | Dr. Anna Songhurst, Field and Program Director; Dr. Graham McCulloch, Policy Director | End User | Yes |
| **Connected Conservation, South Africa Office** | Dr. Ferrell Osborn, Director; Malvern Karidozo, Senior Researcher | Collaborator | Yes |

***Decision-Making Practices & Policies:***

The Ecoexist Project supports wildlife management through timely research and scientific communication tools. The mission of The Ecoexist Project is to reduce human-elephant conflict and find strategies for coexistence by collecting social, ecological, and economic data and collaborating with local community partners. It also collaborates with local, national, and international groups to develop policies and programs to mitigate the effects of human-wildlife conflict. The Ecoexist Project began transcribing HEC events in the Panhandle of the Okavango Delta in 2008, and has placed GPS collars on over 20 elephants since 2014 with the support of Botswana’s Ministry of Environment, Wildlife and Tourism, and the Department of Wildlife and National Parks. In its current capacity, The Ecoexist Project empowers farmers with affordable tools to attempt to reduce crop-raiding.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Surface reflectance | Operational Land Imager (OLI) surface reflectance (2017-2020) was used in Google Earth Engine to calculate the Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI), which provide information on vegetation health across areas with varying vegetative cover. Six-month seasonal composite images were evaluated from 2017 to 2020 to visualize and statistically quantify change in vegetation health around Victoria Falls and the Okavango Delta. |
| **GPM IMERG** | Monthly precipitation | Global Precipitation Measurement’s Integrated Multi-satellite Retrievals for GPM (IMERG) is an algorithm dataset that estimates the average monthly precipitation rate in millimeters per hour from NASA-owned GPM satellites. This dataset was leveraged in Google Earth Engine to quantify the six-month average seasonal precipitation rates in the study area from 2017 to 2020. The resultant outputs were incorporated into the bivariate analysis to examine the relationship between precipitation and elephant movement. |

***Ancillary Datasets:***

* Connected Conservation Elephant GPS data – Tracking data collected daily from 13 bull elephants fitted with GPS collars between 2017 and 2020, several of which cross the borders of Botswana, Zimbabwe, and Zambia and regularly raid the crops of tribal communal lands used for agriculture. The team used these data to identify the areas that elephants frequent and highlighted these in the kernel density heatmaps.
* TerraClimate: Monthly Climate and Climatic Water Balance for Global Terrestrial Surfaces, University of Idaho – This is a raster image dataset available in Google Earth Engine which was leveraged to create Temperature and Palmer Drought Series Index (PDSI) layers across the study area from 2017 to 2019. The data contains interpolated on-ground measurements from the WorldClim dataset, Climate Research Unit Time Series 4.0 (CRU Ts4.0), and the Japanese 55-year Reanalysis (JRA55).

***Software & Scripting:***

* Esri ArcGIS Pro 2.6.2 – Map creation
* Google Earth Engine API – Image processing: image enhancement, cloud masking, mosaicking; computation: NDVI and SAVI surface creation; data acquisition: PDSI, temperature, and precipitation
* R Studio 1.2.5033 – Elephant GPS collar data cleaning, processing, and animation creation
* QGIS 2.18 and 3.12 – Kernel density heatmap creation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **2017 to 2019 NDVI and SAVI Time Series** | Landsat 8 OLI | The partners will use the results of the time series (2017 to 2019) to evaluate trends in the health and condition of elephant habitat and agricultural crops relative to seasonal changes and climatic factors. | N/A |
| **2017 to 2019 Climate Data Time Series** | GPM IMERG | The partners will use this time series to assess seasonal fluctuations of PDSI, temperature, and precipitation over time and its resulting impact on elephant habitat condition and water availability. | N/A |
| **Kernel Density Heatmaps** | Landsat 8 OLI | The partners will use the kernel density heatmaps to identify areas highly frequented by elephants as well as reveal elephant movement and crop-raiding patterns across years and seasons. | N/A |
| **Bivariate Maps** | Landsat 8 OLI  GPMIMERG | The partners will use the bivariate maps to understand the correlation between the environmental factors and elephant “hot spots” identified by the kernel density heatmaps. | N/A |
| **Google Earth Engine Script for Time Series of Vegetation Health and Climate Data** | Landsat 8 OLI  GPM IMERG | The partners will use this code to recreate these time series in future studies as more elephant tracking data becomes available.  \*\*Code will be updated and re-released following Term II. | III |
| **R Script and R Markdown File** | N/A | The partners will use this code to iteratively clean, process, and visualize elephant data as more becomes available.  \*\*Code may be updated and re-released following Term II. | III |

***Product Benefit to End User:***

The goal of this project was to complement the research efforts of The Ecoexist Project by assessing how environmental variables, such as climatic factors, seasonality, and vegetation health, affect elephant movement. This research can be used to inform farmers of patterns in elephant crop raiding behavior and equip them with appropriate wildlife management tools. The resulting analysis, which covers six-month wet and dry seasons from 2017 to 2020 overlayed with elephant tracking data, will aid end users in understanding the relative significance of vegetation health, drought, temperature, and precipitation. Understanding these spatial and temporal patterns can support farmers in effectively implementing mitigation measures, such as using chili pepper to deter elephants from entering their farmland. A thorough analysis of elephant movement, vegetation health, and climate can be leveraged by policy makers through collaboration with The Ecoexist Project to support sustainable wildlife and food security.

***Project Continuation Plan:***

At the end of the first term, the end products were handed-off to the future team to strengthen the conclusions drawn during this project. We recommend that the next team utilize high-resolution Planet Labs imagery to create updated land use and land cover maps of the region to identify elephant corridors and determine high-risk areas for crop-raiding events. These products could be combined with seasonal vegetation health trends, climate predictions, and real-time elephant tracking data in a predictive model to identify areas that will be more susceptible to HECs under various climate scenarios.

**References**

Githiru, M., Mutwiwa, U., Kasaine, S., & Schulte, B. (2017). A spanner in the works: Human-elephant

conflict complicates the food-water-energy nexus in drylands of Africa. *Frontiers in Environmental Science, 5*:69. <https://doi.org/10.3389/fenvs.2017.00069>

Mumby, H. S., & Plotnik, J. M. (2018). Taking the elephants’ perspective: Remembering elephant behavior,

cognition and ecology in human-elephant conflict mitigation. *Frontiers in Ecology and*

*Evolution, 6*:122. <https://doi.org/10.3389/fevo.2018.00122>

Pozo, R. A., Coulson, T., McCulloch, G., Stronza, A. L., & Songhurst, A. C. (2017). Determining baselines

for human-elephant conflict: A matter of time. *PLoS ONE, 12*(6), e0178840.

<https://doi.org/10.1371/journal.pone.0178840>