**NASA DEVELOP National Program**

**2020 Fall Project Proposal**

**Georgia – Athens**

**Africa Food Security & Agriculture**

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

**Project Overview**

***Project Synopsis*:** This project studies human-elephant conflict along the Botswana-Zimbabwe and Zimbabwe-Zambia boundaries of the African Kavango-Zambezi Transfrontier Conservation Area (KAZA-TFCA) where drought increasingly brings free-ranging elephants from national parks to developed areas where they threaten people and destroy crops. The project will work with the NGOs, the Ecoexist Project and Connected Conservation, to document trends in land use, habitat condition, and agricultural practices. To do this, Earth observation data from Terra ASTER, Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, , and Sentinel-2 MSI along with movement data from GPS-collared bull elephants in portions of Botswana, Zambia, and Zimbabwe will be utilized. Products analyzing urban/agricultural expansion, habitat condition, and crop health during drought will assist the NGOs with protecting elephant corridors, making recommendations to local decision makers, and fostering coexistence between agricultural lands, land owners, and elephants.

***Community Concern:*** The KAZA-TFCA encompasses conservation lands in five African countries where 75% of the continent’s elephant population cohabits with over three million people. Although elephants are of vital ecological, societal, and economic importance, urban development and shifts in the severity and length of the dry seasons increasingly bring free-ranging elephants from national parks to developed areas; in these areas, elephants threaten residents, damage property, eat refuse from landfills and raid the crops of subsistence farmers. Local NGOs aim to reduce human-elephant conflict and promote coexistence through better understanding of linkages among drivers of land use change, drought, and habitat condition related to the movement and behavior of problem elephants.

***Source of Project Idea:*** Dr. Marguerite Madden, the DEVELOP GA science advisor, works with researchers from US universities, international NGOs, and African National Parks to deploy GPS collars on bull elephants in the KAZA-TFCA. This team studies broad-scale changes in elephant habitat condition, urban expansion, and agriculture in tribal lands related to drought, elephant movements, and conflict mitigation. Dr. Madden brought the idea of a NASA DEVELOP project that would use time-series of Earth observations, climate data, and elephant GPS tracks to better understand drivers of human-elephant conflict.

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

***Study Locations:*** Kavango-Zambezi Transfrontier Conservation Area of Botswana, Zimbabwe, Zambia

***Study Period:*** 1987 – 2020 (June – August)

***Advisors:*** Dr. Marguerite Madden (University of Georgia, Department of Geography), Dr. Sergio Bernardes (University of Georgia, Department of Geography), Dr. Andrea Presotto (Salisbury University, Geography and Geosciences Department), Dr. William Langbauer (Bridgewater State University, Biology Department)

**Partner Overview**

***Partner Organizations:***

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

***End User Overview***

***End User’s Current Decision-Making Process:***The Ecoexist Project currently works to reduce human-elephant conflict and find strategies for coexistence by collecting social, ecological, and economic data and collaborating with local partners. They empower farmers with affordable tools to attempt to reduce crop-raiding. For example, one of their donors, the Good Planet Foundation, developed an early warning alert system for farmer-to-farmer cell phone communication about elephant crop raiding activity. Ecoexist has already adapted Terra MODIS vegetation health products into their products that they disseminate. They collaborate with local, national, and international groups to develop policies and programs addressing the root causes of wildlife conflict.

***End User’s Capacity to Use NASA Earth Observations:***

*Ecoexist Project* – Drs. Songhurst and McCullough, Directors of The Ecoexist Project, lead programs coordinating with local farmers to reduce human-wildlife conflict. They are currently advising a Masters student who uses geospatial platforms to assess changes in the availability and distribution of water holes, which influence elephant movement during drought conditions. They have had difficulty obtaining a complete history of water presence/absence and drought metrics (NDVI, burn area, and drought indices). These difficulties in processing and manipulating NASA Earth observations data have motivated them to seek out capacity building opportunities to address these obstacles.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*Connected Conservation, South Africa Office* – Dr. Osborn and Mr. Karidozo develop mitigation measures to reduce human-wildlife conflict. They have deployed GPS collars on 13 free-ranging bull elephants and tracked their movements for up to two years within Botswana, Zimbabwe and Zambia. All archived and current elephant tracking data will be provided for this project. Connected Conservation will also assist in using the elephant tracking data within GIS software.

***Dissemination by Boundary Organizations*:**

*Ecoexist Project* – Drs. Songhurst and McCullough promote coexistence between elephants and people by empowering farmers with affordable and effective tools to deter crop-raiding and reduce conflicts with elephants. They also collaborate with local, national, and international groups to assist in the development of policies and programs that address the causes of human-wildlife conflict. These partners work directly with local farmers and decision makers in Botswana and working groups of the KAZA-TFCA. They will disseminate results of this project on their website and present results at local workshops and meetings.

*Connected Conservation, South Africa Office* – Dr. Osborn and Mr. Karidozo cooperate with resource managers of national parks within the study area who respond to human-elephant conflict reports and local farmers impacted by elephant crop raiding. Results of this project will be conveyed to resource managers through workshops held in Victoria Falls and Mr. Karidozo’s liaison with tribal leaders.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team and Science Advisors will have weekly Google Meet meetings with Dr. Anna Songhurst, Dr. Graham McCulloch, Dr. Ferrell Osborn and Mr. Malvern Karidozo. The team will also communicate with them weekly via email. The Project Lead will serve as the point of contact for the partners during the term.

***Transition Plan*:** During the final week of the term, the NASA DEVELOP team will host a Microsoft Team’s Meeting and will encourage all partner organizations, as well as their collaborators to attend. Map end products will be handed off to Drs. Songhurst, McCulloch and Osborn following the final presentation and handoff. All deliverables will be handed off to the partners following NASA Export Control and through NASA LFT, due to their international status. The partners currently plan to incorporate the products of Term 1 by February 2021.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Terra ASTER** | Spectral reflectance, Global Digital Elevation Model (DEM) | These data and the DEM will provide information on spectral reflectance and elevation in the KAZA-TFCA study area that will be used to identify habitat and terrain conditions that may influence bull elephant movements. |
| **Landsat 5 TM** | Surface reflectance | Using TM surface reflectance (1987-2013) to calculate the Normalized Difference Vegetation Index (NDVI) will provide information on the vegetation health in forests, woodlands, and agricultural cropland. The Soil-Adjusted Vegetation Index (SAVI) will provide information for sparsely vegetated shrub lands and grasslands. The spectral signatures from these images will assist with land cover classifications.  |
| **Landsat 8 OLI** | Surface reflectance | Using OLI surface reflectance (2013-2020) to calculate the NDVI will provide information on vegetation health in forests, woodlands and agricultural cropland. The SAVI will provide information for sparsely vegetated shrub lands and grasslands. The spectral signatures from these images will assist with land cover classifications. |
| **Sentinel-2 MSI** | Surface reflectance | Sentinel data will supplement the Landsat 8 data (5-day revisit increases the potential for gap filling cloud covered areas) and help in examining land use/land cover and vegetation condition since 2015. |

**Ancillary Datasets:**

* NOAA Global Historical Climatology Network (GHCN) – Yearly June-August daily *in situ* data will be used for an analysis of precipitation and temperature trends
* NOAA National Centers for Environmental Information (NCEI) Global Summary of the Month (GSOM) – Monthly summaries for mean maximum, mean minimum and mean temperatures; total precipitation; departure from normal of the mean temperature and total precipitation; number of days that temperatures and precipitation are above or below certain thresholds; and extreme daily temperature and precipitation amounts will be used as descriptor variables
* IGAD Climate Prediction & Applications Centre (ICPAC) Data Library and Maproom – Data accessed and downloaded via the data library and maproom will provide Standard Precipitation Index (SPI) values as well as information on the onset and cession of the growing season. This information
* Connected Conservation Elephant GPS data – Tracking data collected daily from 13 bull elephants fitted with GPS collars between 2016 and 2020. Several of the elephants cross the borders of Botswana, Zimbabwe and Zambia and regularly raid the crops of tribal communal lands used for agriculture. The team will use these data to know the areas that elephants frequent and highlight these in the land cover maps.
* Kavango Zambezi Tourism Without Boundaries Land Cover and Protection Shapefiles –These data will assist the team with known protected areas, roads, and rivers as of 2005.
* World Pop Population Counts – The Individual Countries 2000-2020 UN adjusted dataset for Zambia, Zimbabwe and Botswana will be used to highlight high density areas that overlap with the elephant GPS location data.

**Software & Scripting:**

* Esri ArcGIS 10.6 – Image classification, modeling, and map creation
* Esri ArcGIS Pro – Image classification, modeling, and map creation
* Google Earth Engine API – Image processing, including image enhancement, gap filling, mosaicking, and computing NDVI and SAVI
* LandTrendr – Provide spectral signatures from the Landsat imagery

**Decision Support Tool & End Product Overview**

***End Products:***

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| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **1987 to 2020 Land Use/Land Cover Time Series**  | The partners will use the results of the time series (1987 to 2020) to identify the remaining habitat suitable for free-ranging elephants and identify areas that have transitioned to urban or agriculture from classes more suitable. | Time series beginning in 1987 of land use/ land cover from Landsat 5 TM, Landsat 8 OLI, and Sentinel-2 MSI. For time periods with available elephant presence points, those data will also be included. | I |
| **1987 to 2020 NDVI and SAVI Time Series** | The partners will use the results of the time series (1987 to 2020) to evaluate trends in the health and condition of elephant habitat and agricultural crops related to drought and changes in dry season timing. | Time series beginning in 1987 of vegetation indices derived from Landsat 5 TM, Landsat 8 OLI, and Sentinel-2 MSI. For time periods with available elephant presence points, those data will also be included. | I |
| **1987 to 2020 Climate Data Time Series** | The partners will use this time series to assess seasonal fluctuations of temperature and precipitation over time and its resulting impact on elephant habitat condition and agricultural crops. | Time series of each climatic variable accessed through the ICPAC, GHCN, and the GSOM data will provide climatic trends to compare to trends in vegetation health. | I |
| **Vegetation and Climate Relationship Analysis** | The partners will use the results of the correlation analysis to assess climate drivers of elephant habitat condition and agricultural crop health. | The spatial-temporal trends of vegetation health and climate data will be statistically correlated to quantify significance. | N/A |

***End User Benefit*:** Drought stressed vegetation in conservation areas drives elephants to raid crops, increases human-elephant conflict and creates food shortages for local residents. This project will provide information on trends in the health and condition of elephant habitat that are influencing elephant movement and agricultural crop raiding during anomalous dry seasons and droughts. Improved understanding of elephant movement during periods of drought will help farmers prepare mitigation measures, such as deploying chili pepper oil, to deter elephants from entering their fields.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2020 Fall to 2021 Spring

***Multi-Term Objectives:***

* **Term 1 (Proposed Term):** 2020 Fall (GA) – Africa Food Security & Agriculture
	+ The first term’s goal is to provide the partners with information on the interaction of human-elephant conflict drivers. Using Earth observations and ancillary data, the project will assess urban development and agricultural encroachment into elephant habitat, as well as elephant impacts on agriculture in tribal communal lands. Trends in vegetation health using NDVI and SAVI document spatio-temporal patterns of elephant habitat condition and agricultural crop maturity related to elephant movements, crop raiding and human encounters. Analyses of ICPAC, NOAA GHCN and GSOM data can provide knowledge on climate drivers of human-elephant conflict. Vegetation health results will be related to temperature and precipitation variables for 4 time periods, 1987 to 2020.
* **Term 2:** 2021 Spring (GA) – Africa Food Security & Agriculture II
	+ End products from the first term will be extended to the broader KAZA-TFCA area covering portions of Botswana, Zimbabwe and Zambia. What was learned at the regional level with Landsat and Sentinel-2 data for the KAZA-TFCA will enhance conservation decision-making and mitigate drought-driven human-elephant conflict. The project also will also use the GPS locations of elephants and products from the first term to conduct a Maximum Entropy Model to create habitat percent cover, agricultural crop raiding probability and human-elephant proximity risk maps.

***Related DEVELOP Work:***

2020 Summer (GSFC) – Southern Bhutan Ecological Forecasting: Utilizing NASA Earth Observations to Assess Elephant Habitat Suitability in Southern Bhutan to Inform Decisions about Wildlife Corridor Placement

2014 Spring (GA) – South Africa Ecological Forecasting: Understanding Landscape Changes in Elephant Habitat within the Kruger National Park through NASA Earth Observing Systems

**References:**

National Oceanic and Atmospheric Administration. (2017). National Oceanic and Atmospheric Administration Climate Data Online. [https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:ZI000067843/detail](https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND%3AZI000067843/detail)

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