# Saving the Savannah For A Rainy Day:
# Studying the Impact of Precipitation On Elephant Migration and Savannah Health

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Other roles:
Slides - Conner
Report Formatting - Sho

**< Overview > (Prakash)**

The African elephant is the largest animal walking the Earth. Numbering three to five million in the last century, African elephant populations were severely reduced to their current levels because of hunting. In the 1980s, an estimated 100,000 elephants were killed each year and up to 80% of herds were lost in some regions. Elephants play an important role in the East-African eco-system both ecologically and as a vital source of revenue through tourism.

The conservation of the African elephants is an issue of global significance and understanding the movement of these movements including when they move, why they move, and where they move is key for successful conservation and management. Failure to understand the migration dynamics and their factors impact the successful protection of these animals and are likely to lead to increased animal-human conflicts. As habitats contract and human populations expand, people and elephants are increasingly coming into contact with each other. Where farms border elephant habitat or cross elephant migration corridors, damage to crops and villages can become commonplace. This often leads to conflicts that elephants invariably lose.

In the past availability of data on tracking the animal movement to the landscape, dynamics was not possible. However, now with the availability of GPS receivers on the elephants allows us to track daily/hourly movements and relate to the availability of satellite imagery that depicts landscape patterns over time. Changes in the landscape can be derived using the Normalized Difference Vegetation Index (NDVI) and are derived using satellite remote sensing data.

The purpose of this study is to utilize the predictive power of using NDVI data to determine the movement of elephants to develop strategic insights for elephant conservation, reduce animal-human conflicts and improve ecological balance.

**< Theory > (Prakash)**

## Migration

A study of the elephant migration patterns reveals the following insights [1]. The drivers of elephant migration are a complex interaction between individual traits, elephant population density, and the distribution and availability of resources. There are two types of migrations that these elephants demonstrate. (a) Migration can be obligate where the individuals migrate annually (b) Migration can be facultative, where the individuals do not migrate annually, but rather opportunistically due to local conditions. Elephants typically migrate during periods of plant growth to access high-quality forage and then return to avoid adverse weather conditions or limited resources when seasons change.

The African elephant is a water-dependent species and has a larger effect on the savanna ecosystem than any other single herbivore and is often referred to as as eco-system engineer [3]. High concentrations of elephants can modify vegetation structures, converting woodlands to shrubland [5] with modifications in plant and animal species composition.

Studies have shown that environmental heterogeneity and patch size, estimated using remote sensing are good predictors of elephant movement [4]. Environmental heterogeneity is used here as an umbrella concept representing the degree of non-uniformity in land cover, vegetation, and physical factors (topography, soil, climate) [5].

## Human-elephant conflict

African elephant conservation priorities have moved from concerns over habitat damage to alarm over ivory poaching to conflict with people. Elephants make forays into areas of human settlement and destroy crops, raid food stores, and damage water sources, and occasionally injuring or killing people in the process. People retaliate by injuring, killing, or using deliberate measures to displace the elephants. From current knowledge [2], it is improbable that human-elephant conflict can ever be eliminated. However, it can be mitigated, and the objective should be to reduce to a level that local people can tolerate. There is evidence habitat availability is more important in retaining elephants than is a protection status for wildlife. Hence understanding the migration patterns and influence of landscape changes on migration are key to unraveling a complex phenomenon.

## Economic benefits of elephant tourism

A study conducted [6] in 2016 has shown that the lost economic benefits that elephants could deliver to African countries via tourism are substantial and approximately $25M annually.

Satellite-derived NDVI

Studies [7] have shown that NDVI has been successfully applied to research on trends and variations in vegetation distribution and dynamics, to monitor habitat degradation. NDVI can become an extremely useful tool to understand how vegetation dynamics and changes affect movement patterns and population dynamics of animal populations.

**< Research Question > (Sho)**

- How do changes in precipitation in the savannah ecosystem affect elephant migration patterns?
- Does climate change induced lack of rainfall in the savannah change the migration push of elephants and other species out of old habitats to new ones?
- Can predicting the migration patterns of elephants help prevent animal-human conflict in the regions where humans and animals co-exist?

**< Data > (Sho)**

Elephant Data

We will attach GPS monitoring devices to up to 10 elephants in the protected area. This device is designed to record each elephant's location every hour, and usually lasts from 200~400 days depending once attached to the elephants in the form of collars. This GPS based location data will be stored in a longitude and latitude format which will be easy to plot on maps to visualize physical locations of elephants. These devices are designed not to hurt elephants in any way nor will it cause the animal’s behavior to change.

Precipitation Data

This will be publicly available precipitation data in the savannah region. Ideally this will contain historical data with a significant time range (up to 30 years) so that we can identify changes in precipitation patterns and link this information to how elephants move throughout the region. We can combine locally available data as well as international weather data to validate

Normalized Difference Vegetation Index (NDVI) Data

Available free of charge from NASA's moderate resolution imaging spectroradiometer website, this satellite sensing data set will allow us to analyze vegetation information in the savannah, which will allow us to correlate elephant migration patterns information with the historical availability of vegetation in the region.

**< Sample > (Conner)**

We will consult with wildlife and elephant specialists to identify a random sample of elephants from the African Savannah biome, using powers analysis in conjunction with domain expertise to identify the ideal sample size and range to be representative of the elephant population. Once the elephant sample has been selected, we will monitor their locations over a two year period and collect precipitation and vegetation data over the same period and covering the same geographic boundary the elephant population inhabits.

**< Variables and/or Intervention > (Conner)**

The variables we will measure are precipitation, vegetation growth, and elephant migration routes. The precipitation will be the key independent variable upon which the elephant migration and vegetation growth will be dependent. Elephant location data, measuring the elephants' migration patterns over time, will be the target variable upon which our hypothesis rests.

**< Study Design > (Conner)**

The study will address a key question related to climate change impact in the African Savanna ecosystem. Understanding the effect of precipitation and vegetation growth on elephant migration will transitively grant insight into the impact that decreased precipitation due to climate change will have on the savannah ecosystem as a whole.

Assumptions

We assume our randomly selected sample of elephants is representative of the entire population, that the migration of elephants has a strong direct impact on the health of the savannah ecosystem, and that precipitation is a measurable factor of climate change, and the understanding of precipitation effects on the ecosystem is transitive to understanding the effects of climate change indirectly on the ecosystem as a whole.

Ethics

We will cooperate with local and regional governments to contribute to awareness and mitigate impact toward justice, respect for persons, and beneficence with regard to international cooperation to study and to protect the savannah ecosystem. We will consult with elephant and wildlife specialists to inform ethical treatment of the GPS tagging and monitoring of elephants and respect for wildlife and the communities dependent on that wildlife. We will also include local representatives in the study process to ensure equal and just access to study results and processes, as well as any economic benefits that may result from our study.

Tasks:

1. Data Collection

Using domain expertise from wildlife specialists and statistical methods via powers analysis, we will identify a herd or group of elephants within the African Savannah biome using random sampling techniques. We will place commercially available GPS trackers on those elephants that will monitor their location and movement, with regular transmissions collected as observation data. This collection will continue for a period of 2 calendar years, and we will ensure continuous satellite imagery collection over the same geographic area inhabited by the elephants over the same duration of time. Similarly, we will ensure continuous collection of precipitation and vegetation data via satellite remote weather sensors.

2. Data Analysis

Once collected, we will validate the precipitation data and vegetation data using descriptive statistical analysis to compare our collected data with local and international data sources containing similar observations. This will identify potentially anomalous, erroneous, or inaccurate data. During the 2-year collection period, we will conduct a continuous analysis of the elephant location data, satellite sensing data pertaining to vegetation, and precipitation data, with the purpose of identifying descriptive statistics to identify outliers or potentially anomalous data. Euclidean-based cluster analysis will help identify outlying data observations that may be erroneous or anomalous, allowing us to monitor the ongoing fidelity of our data collection sources. Following the 2-year collection period, we will conduct time-series trend analysis on the data to identify key trends and patterns of seasonality. We will also analyse the data from a geospatial perspective, identifying key clusters and outliers. By cross-referencing trends and outliers across all of our datasets, we will be able to spot statistical correlations between the precipitation, vegetation, and elephant movement.

3. Modeling

We will use feature engineering to derive variables specifically related to precipitation and vegetation growth from the satellite data and weather data. Once the features are generated, we will use linear regression models with the elephant location data as target variables for prediction. We will use various statistical methods such as mean-square-error analysis to measure the performance of said regression model. Following that assessment, we will perform the same modeling process using randomly generated data in place of the ground-truth data. If our hypothesis is correct, that precipitation and vegetation growth are positively correlated with elephant migration, then the model using ground-truth data will consistently out-perform the model trained on randomly generated data.

**< Statistical Methods > (Sho)**

Using the sample data collected from the elephants as well as the satellite based imagery data, we will use conventional statistical methods like Linear Regression and t-test to understand the significance of the individual elephant movements as well as the statistical significance of sample data from satellite imagery (NDVI). These methods will allow us to extrapolate our findings from the sample data to a larger population of the savanna ecosystem.

**< Potential Risks > (Sho)**

Scientific Validity

We will ensure that data collection methods and statistical methods used in this study follows industry standards and best practices, in order to mitigate the errors in data that we plan to derive our conclusions from. That being said, the elephant movement data collected will be raw data based on actual movement of wild animals. This means that there could be unexpected and outlier behaviors by these animals that are hard to predict and difficult to find causation. Therefore, there is a possibility that, for example one year out of the 2 years we collected data, the elephants had an extraordinary movement, which could taint the data collected. As this part of the study is entirely out of our control (and should be), the audience of this study will be reminded of the uncertain nature and scientific validity of the study.

Elephant Movement Data

Perhaps one of the largest risk factors for this study is the collection of individual elephant movement data. GPS monitoring devices will be attached to the elephants' legs using secure straps; however, once the devices are attached there are numerous possibilities for the straps or the GPS to malfunction, causing a hurdle in the data collection process. Although the devices are specifically designed to withstand the external elements (direct impact, rain, continuous exposure to water etc), this still does not prepare the devices or the strap keeping the devices immune to unexpected circumstances. This is going to be attached to wild animals in the savanna, after all. If a device breaks or detaches from the elephant, there is virtually nothing our researchers can do at this point - therefore, we would lose a portion of the data collection. The number of devices used for individual elephants should include extra devices in anticipation of losing a few devices in the course of 2 years.

Law and Ethics

As mentioned in previous sections, experts will be consulted to ensure that attaching the devices to elephants does not interfere with the elephants life and in any way and does not hurt the elephants. However, introducing an electrical device to wild, untampered environments does involve a degree of ethical considerations regardless of the effect on the elephants. For this, local laws and regulations (especially those pertaining to the savannah, which are often National Parks of the local country) will be strictly adhered to, to ensure that all processes, including entering the savannah to attach the devices, complies with laws and regulations that protect the environment. In addition, independent experts will be consulted on multiple occasions to ensure that impact to the environment is as small as possible.

Other data, like the local and national weather data as well as NDVI data are publicly available data from accredited institutions (for example, NDVI is provided by NASA to the public for free), hence we do not expect major legal or ethical issues on this front.

**< Deliverables > (Sho)**

Phase 1: Data collection and monitoring

- Duration: 2 years
- In the 2 years that data is being collected from the devices attached to the elephants, GPA location data will be available for compiling and organizing. In

addition, NDVI data and weather data will also be collected during this time and researches should be organizing the data in a meaningful way.

Phase 2: Data checks and sorting

- Duration: 1 month
- Once data collection from the elephants are complete, researchers will have a months time to sort through the data and perform general checks (like statistical analysis) to ensure the data validity and clean the data for use in the next step.

Phase 3: Data analysis and modeling - finding conclusions

- Duration: 3 months
- At this stage researchers will have the opportunity to apply the modeling of the data described in the section above to start answering the research questions proposed. At the end of this phase, we should be arriving at our conclusions based on the data collected and compiling our findings into a report as well as a presentation.

Phase 4: Publication and presentation

- Duration: 1 week
- 1 final report that contains answers to our research question, other conclusions, and specific recommendations to local authorities and environmental research institutions should be published at this stage. In addition, researchers should have the opportunity to travel to key stakeholder institutions to present their findings in a 1-2 hour presentation in a scientific conference format.

**< Future Research > (Prakash)**

(1) Elephant migration is a complex phenomenon and while the core study explores the impact of environmental heterogeneity on elephant movement, studies have shown that the presence of artificial water supply also known as water holes influences elephant movement. There is an opportunity to study whether strategic construction of waterholes can contain the elephants in protected areas thereby reducing the risk of encroachment into adjacent farmlands.

(2) The local people play a key role in protecting and co-existing with the elephants. A study to understand motivations, behaviors, attitudes, and incentive structures for the local people will be key to understand the social and economic aspects of the people impacted and possibly offer creative solutions for a harmonious co-existence.

**< Sources > (Prakash)**

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