Kavango-Zambezi Vulnerability and Adaptation Project Report 2018

Field Work, Logistics and Permissions
Field work for the study took place from May-August, 2018, although initial communication and coordination with proper authorities in Zambia began in 2017. The KAZAVA team represents researchers from four American universities and one independent African researcher. The team includes the following personnel: Drs. Andrea Gaughan & Forrest Stevens (University of Louisville), Dr. Narcisa Pricope (University of North Carolina Wilmington), Dr. Joel Hartter and Mr. Michael Drake (University of Colorado), Dr. Jonathan Salerno (Colorado State University), and Dr. Lin Cassidy (Independent Consultant, based in Maun, Botswana). In addition, the following Zambians were part of our team: Mr. Moses Nyoni and Dr. Patricia Mupeta-Muyamwa.

While in the field, we collaborated and conducted research under the guidance of multiple members of the traditional authority within Western Zambia. Most importantly, we worked closely with Mr. Lawrence S. Sitoboha, personal secretary to the Nduna Anasambala - Mwandi Kuta (Traditional Court), who assisted us in translating our survey instruments into Silozi, conducted introductions of the project to local communities and the five surveyed villages, and facilitated meetings with the Area and Silalo Induna. Before we began our research, with the assistance of Mr. Moses Nyoni, we conducted introductions with the following Induna and received permission to work: Chief Imbwae (Lusu), Deputy Chief Imbwae (Kalobolelwa), Induna Solola (Makanda), Induna Kapau (Kapau), and 16 village headmen in Kaale.

Additionally, the KAZAVA project collaborated with area experts to make sure that we were asking the right questions, to connect us with local specialists and to build foundations for future research collaborations. These experts included Village Action Group members from Kaale, Silumbu, and Kalobolelwa. As per the stipulation in our research permit, we also worked closely with Mr. Henry Maseko from the Department of National Parks and Wildlife who facilitated meetings and contact with other DNPW officials throughout the GMA. Information and meetings were also held with Mr. Conrad Muyaule from the World Wildlife Fund, Sesheke Office.

The survey work was only possible through the help of six research assistants and one field cook who worked with us closely throughout the month of July (Figure 1). These research assistants were selected from an extremely competitive pool of 90 applicants that were interviewed on 2 July 2018 at the Sioma ZAWA camp. Our assistants, both male and female, were all highly qualified in their communication skills, interpersonal ability, spoke English well, and had survey experience. They represented a geographic area between Sesheke and Sioma. They included: Mr. Moses Kalondwe Kabilima (Sesheke), Mr. Lubasi Imbula (Sesheke), Mrs. Martha Maele (Sioma), Mr. Simasiku Simasiku (Sioma), Mr. Michael Mwangala Lifalalo (Kalobolelwa), Mr.

Lishomwa Musiwa (Silumbu), Ms. Precious Mushokabanji Muliokela (Field Cook, ZAWA camp).

Figure 1. KAZAVA enumerator and trainer survey team.

Data Collection - Methods

Fieldwork in Zambia had three distinct elements: household surveys, mapping of natural resource use areas, and vegetation reference sampling and measurement. In addition, we include in this report results from satellite analyses providing broad, general patterns of vegetation and rainfall conditions for the larger KAZA study region.

The study area extent is defined by the Lower West Zambezi Game Management Area (LWZ-GMA). The LWZ-GMA is located in western Zambia and covers a total area of 19,300 km^2. LWZ-GMA follows the Zambezi River and is home to an estimated human population of 70,157 (Department of National Parks and Wildlife & Ministry of Tourism and Arts, 2016). LWZ-GMA is bounded by Namibia to the south, Angola to the west, the Upper West Zambezi GMA to the north, and unprotected lands across the Zambezi river to the east. Our study was conducted in five communities within the Sesheke West Community Resource Board (CRB), one of the LWZ-GMA two administrative units (Figure 2), and chosen for comparability with ongoing research in two other community-based conservation (CBC) areas in Namibia and Botswana. These two community areas are the Chobe Enclave Conservation Trust (CECT) and Mashi Conservancy, in Botswana and Namibia, respectively. For the Zambia study area, three of the communities (Kaale, Lusu, Kalobolelwa) were located on the banks of the Zambezi river, among a mixture of floodplains and upland forests. The remaining two communities (Kapau and Makanda) border Sioma Ngwezi National Park and are surrounded by savanna woodland.

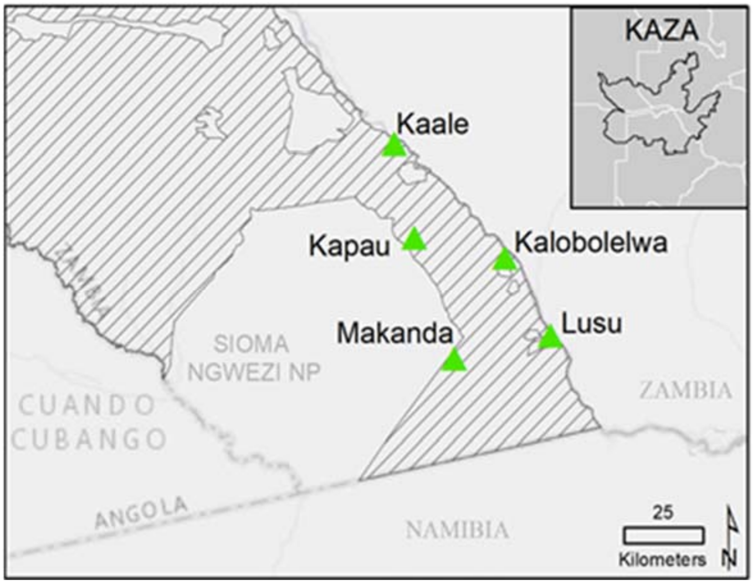

Figure 2. Study region in the Lower West Zambezi Game Management Area with five village areas highlighted.

<u>Household Surveys</u>

Household surveys were conducted in five communities in the LWZ-GMA, July 2018: Lusu, Kalobolewa, Kapau, Makanda, and Kaale. Surveys were designed to measure household livelihoods and vulnerability. Questions focused on farming, adaptation to drought and flooding, interactions with wildlife, sources of income, and resource collection. The approach incorporates the sustainable livelihoods perspective (Scoones, 1998), a framework used to conceptualize livelihoods based on distinct capital assets (economic, human, natural, physical, and social capital). The framework allows for identification of what combination of livelihood assets comprise strategies for a particular, desired outcome. While the framework can be applied at various scales (e.g. national versus individual), we focus on the household level. Our goal is to then integrate an understanding of livelihoods with environmental conditions to characterize household vulnerability. A total of 245 surveys were conducted in Zambia (481 additional surveys were completed in Botswana and Namibia in 2017). The Zambia sample design and survey protocols included the following:

- Selection of the five communities within the Sesheke West CRB jurisdiction
- Random sampling of approximately 50 households within each village area
- Implementation of surveys by six trained enumerators from the Sesheke West CRB

Surveys were conducted entirely in Silozi and the collected data are confidential and all responses are not identifiable to individual respondents.

Livelihood capitals for each household were estimated from the survey data, and are defined as follows:

Social capital is a measure of the extent to which households are integrated within broader local social networks (Bebbington, 1997, Scoones, 1998). Social capital supports livelihoods and provides access to other types of capital through relationships, which can be critical in times of stress. To assess social capital we asked if households participated in CBC activities, if they traded with or exchanged services with other community members, and if they were involved in any community organizations.

Natural capital is a measure of household access to, ownership of, and quality of natural resources (Costanza et al. 1997, Hunter et al. 2014). Natural capital is the foundation of rural livelihoods in this region and is susceptible to ongoing stress caused by drought, soil degradation, human-wildlife conflict, and other environmental processes. To assess natural capital we asked households to report the amount and type of natural resources they collect and typically have access to, the type of water source they use, income earned from collection and sale of natural resources, and the status of land tenure.

Physical capital refers to local infrastructure and physical assets to which a household has access (de Sherbinin et al. 2008, Vincent and Cull 2010). Physical capital often enables household adaptation and agricultural innovation and is important in responding to changing environmental conditions. To assess physical capital we asked households to report if they owned certain household goods, farming equipment, and vehicles. We also asked about the homestead itself, specifically the material that the walls and roofs are made from, the number of sleeping rooms in a household, and the type of toilet the household uses.

Financial capital is a measure of household wealth and access to financial resources (Abel et al. 2006). Financial capital enables households to be less risk averse and provides access to information and opportunities, increasing overall resilience. Because most livelihoods are natural resource reliant in this region, we measure financial capital largely through household farming and livestock ownership. We specifically ask about the number of livestock owned, the acres of land owned and planted with crops, and income earned (and lost) from the sale of livestock and crops (or loss). We additionally ask about income from tourism, off-farm employment, and other sources (e.g. loans, government pension)

Human capital refers to the skills, knowledge, experience, health, and education a household has among its members (Scoones 1998, Bebbington 1999). Human capital provides the capabilities necessary to maintain and adapt livelihoods. To assess human capital we asked households to report all individuals living within the household and their gender, age, highest education, employment status, and health status.

Measuring the five types of capital at the household level provides a broad assessment for the status of households in the region and, likely, their vulnerability to ongoing change.

<u>Resource Mapping</u>

Mapping natural resource use areas was intended to provide a more nuanced understanding of how people make use of their surrounding environment by mapping the places where people go to collect resources. As part of the household survey, respondents were asked about where they most often collected various natural resources, such as firewood, thatching grass, and building poles. Listed resources were firewood, thatching grass, building poles, fish, reeds, palm leaves, medicinal plants, and fruits and vegetables. We compiled all resource area names and associated resource types reported by each village area. Household survey questions included:

- "Did you collect any of the following natural resources during the wet/dry season in the past 3 years?" (listed above)
- "[What is the] Name of the main area where you usually collected [the resource] in the wet/dry season in the past 3 years?"
- "How do you usually travel there (walk, cart, canoe, etc.)?"
- "Time taken to get to the area"
- "Total quantity gathered during the wet/dry season since this time last year"

To account for possible error and bias in this process, we consulted with our survey enumerators to confirm resource areas names provided existed, and we cross-checked these area lists with the Area Induna or knowledgeable area resident to confirm that no important resource areas had been omitted. We counted the number of times each resource area was mentioned in the surveys to prioritize mapping of the most frequently used areas. Next, using key informants from each survey area (often VAG members), we traveled to each resource area and collected handheld Global Positioning System (GPS) coordinates of the area's boundaries. Further analysis and processing using a Geographic Information System (GIS) allowed us to use the collected GPS coordinates to map the boundaries of the resource collection area. Knowing the location of these resource collection areas will allow us to investigate how far individuals must travel to collect resources. Information will indicate focus areas to in attempting to quantify the impact that humans have on the environment through the use of remotely-sensed imagery. A detailed summary of the entire workflow is provided in Figure 3.

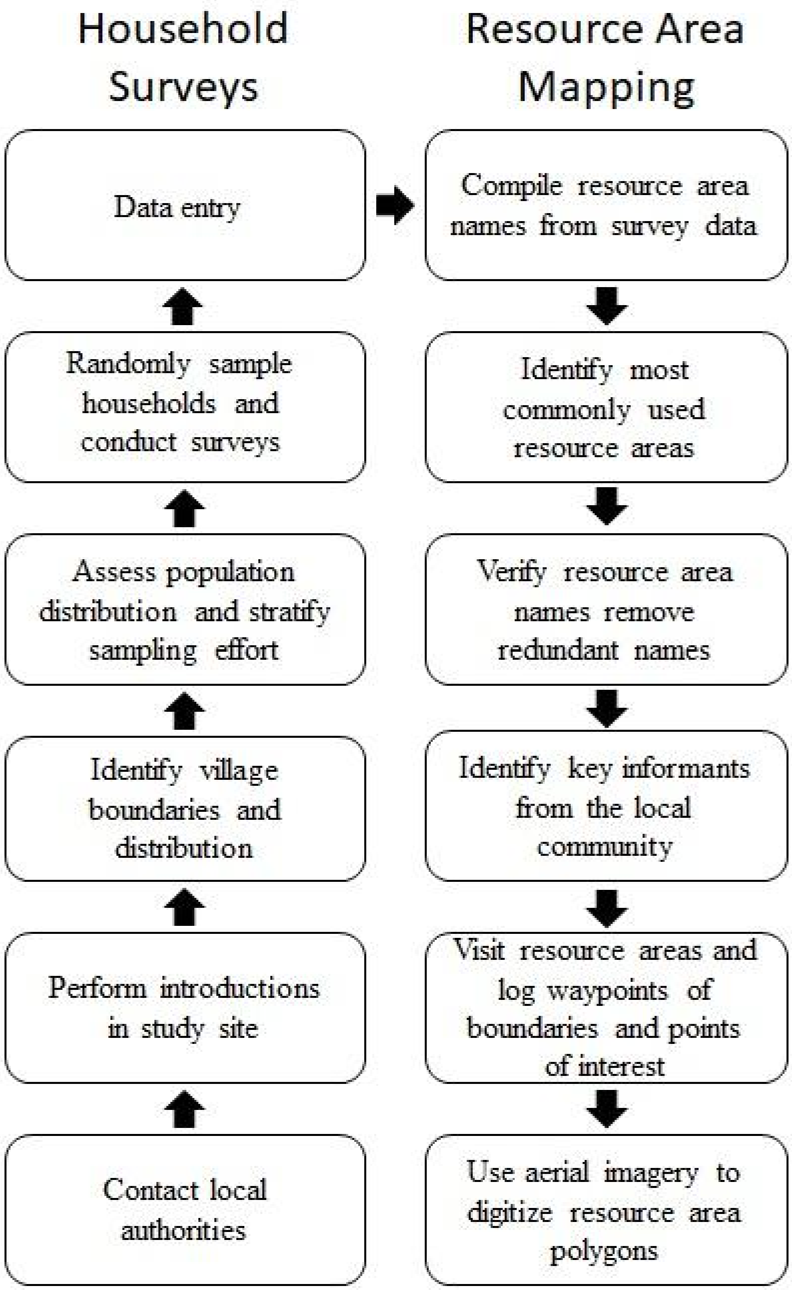

Figure 3. Flowchart of the main steps taken during data collection for household surveys and livelihood resource area mapping.

Following completion of the household surveys and resource area mapping, we recorded the number of individual households that reported visiting a resource area. We combined and summarized household survey data to create measures of use for each identified resource area including:

- Number of households utilizing each resource area
- Number of resource areas utilized by each household
- Type and amount (kg) of resource extracted in the wet and dry season
- Average reported time traveled to reach the resource area

Environmental Data

Field Reference Samples - LWZ-GMA landscape

Reference samples are used to validate conditions on the ground for satellite-based remote sensing data. The reference samples provide identification of ground cover, vegetation condition, and land use and land cover data to subsequently associate with remotely sensed data and analysis. We collected reference samples of various land cover types throughout the region in order to properly calibrate these remotely-sensed data sets, and to allow for accurate interpretation of aerial imagery used to understand shifting environmental conditions and change over the larger study area. We traveled to areas with a variety of vegetation types and levels of human impacts and, using a Trimble GPS, we logged details about the land cover in these locations.

We collected reference samples within 1, 2, 3, and 3+ kilometers from the village centers. We also buffered primary roads from OpenStreetMap (https://www.openstreetmap.org/). Within the intersection of these, we randomly placed 50 sampling points, of which we attempted to visit equal numbers as logistics and timing allowed by storing and loading GPS coordinates of each, following these coordinates and where safe access can be ascertained, and applied a field-based, reference sample survey including photos and vegetation, land cover, and land use description.

Remote Sensing Analysis - KAZA landscape

To quantify landscape variability and changing precipitation regimes for the larger study area we analyzed two remotely sensed data products. We derived a satellite-based greenness index, the Normalized Difference Vegetation Index (NDVI), from the Advanced Very High Resolution Radiometer (AVHRR) GIMMSg3 v1 8 km data product (Pinzon and Tucker, 2014). For each ~8 km pixel, a coefficient of variation (CV, measured as standard deviation / mean) was calculated from the maximum NDVI value measured between October-December (OND) for each year 1981-2015 (35 observations per pixel).

For a spatially explicit assessment of changes in rainy season length, we calculated the number of days in the wet season of each water year (October - June) between the first and last five-day period (pentad) receiving 10 or more millimeters of rainfall, as estimated from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS, version 2.0 final), 0.05 arc-degree data (Funk et al., 2015). For each ~6 km pixel a trend line was then fitted across the water years beginning in 1981-2016 (36 water years) from which a slope and its statistical significance was estimated (Fig. 10b). GIMMS data were aggregated and analyzed in R; CHIRPS data were analyzed using Google Earth Engine (Gorelick et al., 2017).

Data Results and Products

Household Surveys

General Household Trends

We surveyed 726 households total, including 245 in five Zambian communities. Within the 245 Zambian households surveyed, 70% of households were male-headed and households had an average of six members. Seventy-five percent of surveyed household members were under the age of 30. The majority of the population self-reported being “somewhat healthy”, with less than 10% of the population reporting being “unhealthy”, and 75% reporting being “very healthy.” Forty-four percent of the population had no formal education, 35% of the population had completed pre-school or primary school, 18% had completed some secondary school, and less than 1% had completed college or technical school. Eleven percent of households included a member that had an off-farm job and average household income was between 500 and 2000 Kwacha. Less than 10% of households reported receiving food aid, government pension, or formal or informal loans.

Table 1 highlights several key aspects of livelihood conditions in each village area. A food security index was calculated following procedures of the Household Food Insecurity and Access Scale (Coates et al., 2007). This scale is composed of questions that have been used in several countries to distinguish food insecure from food secure households (e.g. recently, did you worry that your household would not have enough food, or that any household member not able to eat the kinds of foods you preferred because of a lack of resources?). The index has a hypothetical range of 1 – 4, from least to most food secure. Observed household food security scores fell between 1.00 and 1.34 with the highest food security in Kalobolelwa. Food security in Zambia falls below the mean score of Botswana and Namibia (1.75). Farm size was more variable, with the largest farms located in Kapau (1.84) and Kaale (1.82). Compared within Zambian communities only, the two village areas farther away from the river, Kapau and Makanda, had the lowest mean income recorded. Notably, Kapau households had the lowest income and yet the highest recorded farm size. A gathered food index was created based on the total amount of food and types and types of food a household gathers locally (de Leeuw and Mair, 2009, Gifi, 1990). The village area closest to Sesheke, Lusu, had the lowest gathered food index, but the greatest cattle ownership. Chicken ownership was greatest in Kaale and Kalobolelwa and lowest in

Makanda. Institutional engagement (a scaled index created based on the number of institutions in which a household reported being involved, such as conservancy or VAG, divided by the maximum number of institutions any household was involved in) was greatest in Kaale. Finally, maize harvest (in kg) was largest, on average in Makanda and smallest in Kaale.

Table 1. Average household food security (index), farm size (hectares), income earned in the past twelve months (US dollars), and gathered food (index), cattle and chicken owned, institutional involvement (a measurement of the total number of institutions a household is involved in divided by the maximum number of institutions, six, any household reported involvement in), amount maize harvested last season (kg) across the five communities surveyed and averaged for Zambia and communities in Namibia and Botswana.

Area	Kaale	Kalobolelwa	Lusu	Kapau	Makanda	Zambia
Food security index	1.1	1.3	1.2	1.0	1.0	1.1
Cropland planted (ha)	1.8	1.7	2.5	1.8	0.8	1.6
Income ($USD)	128	82	170	39	54	84
Gathered food index	7.2	8.2	5.2	7.5	8.5	7.3
Cattle owned	5.6	5.0	6.9	3.6	5.4	5.6
Chickens owned	12.9	12.8	10.0	9.0	4.5	9.6
Institutional involvement	0.7	0.5	0.6	0.3	0.3	0.5
Maize produced previous harvest (kg)	410.6	675.5	586.7	471.8	727.7	573.6

Variation in capital across communities
To examine variations across villages in terms of a household's ability to adapt to changing livelihood conditions, we created indices for each type of capital based on household access and use of various resources. Figure 4 indicates very little difference for any capital asset indices for the five village areas. Human capital was the highest capital asset for any village area while all village areas had low financial capital, with Lusu, the closest village to Sesheke having a slightly higher value. Physical capital was slightly higher for those villages along the Zambezi River which may relate to accessibility of the tarmac road and distance needed to travel to larger towns. Social and natural capital were relatively low for all five village areas compared to other types of capital.

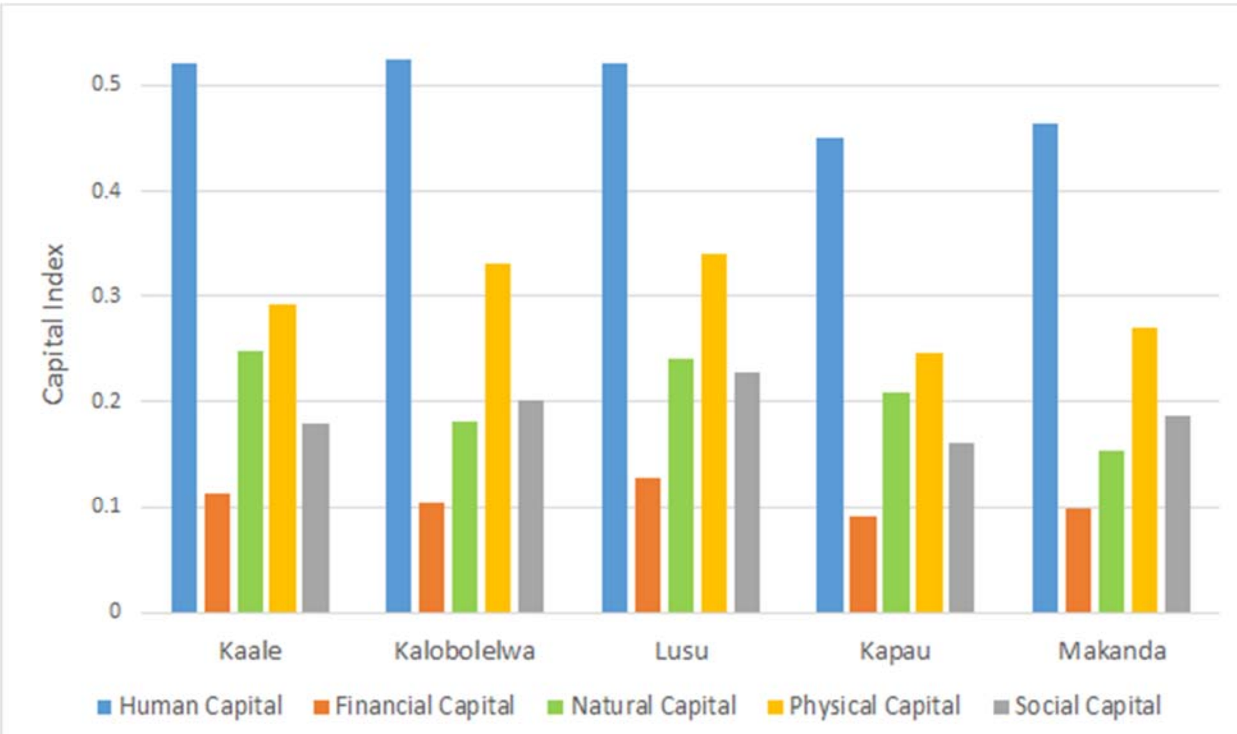

Figure 4. Variation in household capital across the five villages surveyed in Zambia.

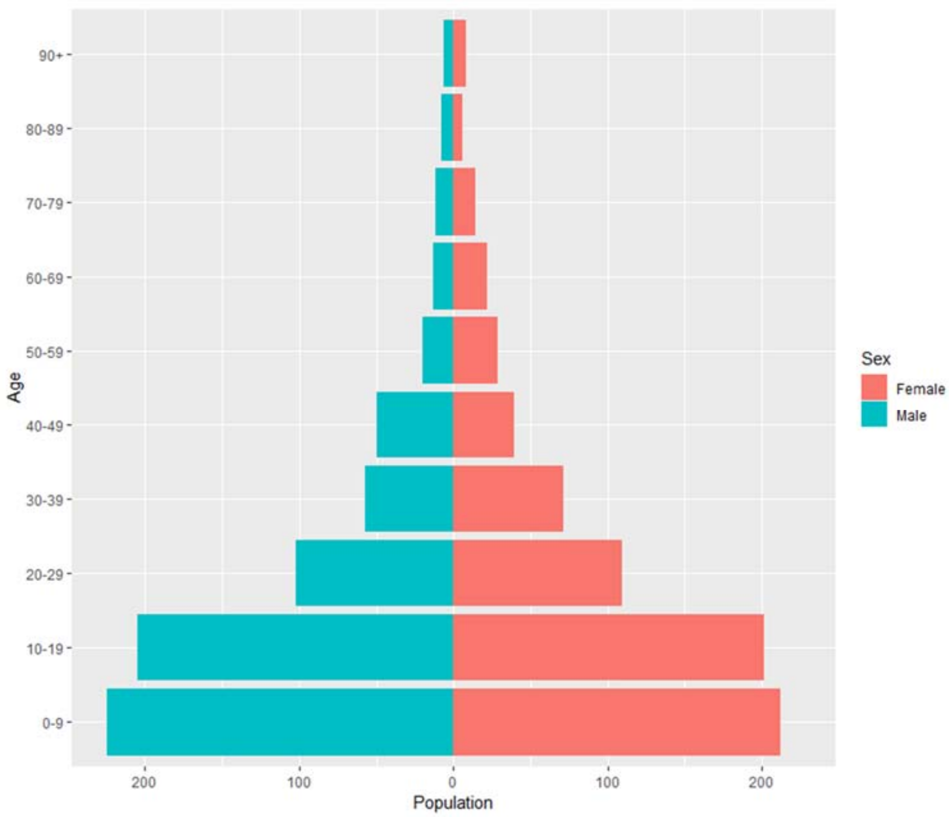

Figure 5. Population pyramid for households surveyed across the five Zambian communities included in our study.

Comparison with other KAZA countries

Mean values of many livelihood measures in Zambia were lower than those in Namibia and Botswana (Table 2). In terms of natural resources, Zambian households had smaller average farms than those in Botswana and fewer livestock (with the exception of chickens, Zambian households have more, on average, than Namibian households). However, mean reported maize yields were higher in Zambia than in Namibia, and comparable to yields in Botswana. Mean reported farm size and average area planted were smaller in Zambia than other sites. Zambian households reported lower food security, lower average household income, and lower income from natural resources than other sites.

In terms of human capital, in both Zambia and Namibia, most people had completed pre-school but not primary school, while in Botswana most had completed primary school. All three countries had similar average health status, with most household members reporting being somewhat healthy or very healthy. We created an index of employment based on whether or not household members had on-farm positions (e.g., herder), off-farm positions (e.g., safari guide, driver), or a position of power (e.g., government officer, headman). Higher values indicate that more household members have off-farm employment or positions of power. Zambian households had lower employment values than in other countries. Finally, in both Zambia and Namibia, fewer than 1% of households surveyed had electricity, compared with over 50% in Botswana.

Table 2. Household measures across three KAZA countries. This table provides values for average household area planted last season, the average amount of maize harvested last season, the average number of cows and chickens per household, the average value of the food security index, the average income generated during the last twelve months, the average income generated by sale of natural resources, average health status (a value of three indicates “very healthy”, a value of one indicates “unhealthy”), percent of households with electricity, and average household education (a value of three indicates primary school completed, a value of four indicates junior secondary school completed), and average household off-farm employment (values were divided by the maximum reported so they scaled between 0 and 1, higher values indicate more off-farm employment).

	Botswana	Namibia	Zambia
Farm size (ha)	10.0	3.1	2.7
Amount maize harvested (kg)	582.3	316.4	573.7
Cows	8.6	3.2	2.8
Chickens	7.6	2.9	4.7
Income (USD)	2250	640	221
Natural resources income	77.3	39.7	10.6
Health status	2.8	2.8	2.7
Average Education	4.1	3.4	3.5

Employment index	0.4	0.2	0.1
Electricity in household (% of households)	52%	<1%	<1%

We used the household surveys to assess financial, social, natural, human, and physical capital in our Bots, Nam and Zam study areas (Figure 6). In terms of overall household capital, Zambia, on average, had comparable natural, financial, and human capital as Botswana and Namibia, but lower social and physical capital. Zambian households tended to have lower access to physical resources (such as farming equipment and household goods like mobile phones, stoves, and radios) and smaller farms than households in Botswana. Each of the capital indices were scaled relative to the maximum reported values of the raw numbers within each country. So individual household indices and the average reported is also a reflection of potential inequality. In terms of overall household capital, Zambia, on average, had comparable natural, financial, and human capital as Botswana and Namibia, but lower social and physical capital (Figure 6). Zambian households tended to have lower access to physical resources (such as farming equipment and household goods like cell phones, stoves, and radios) and smaller farms than households in Botswana.

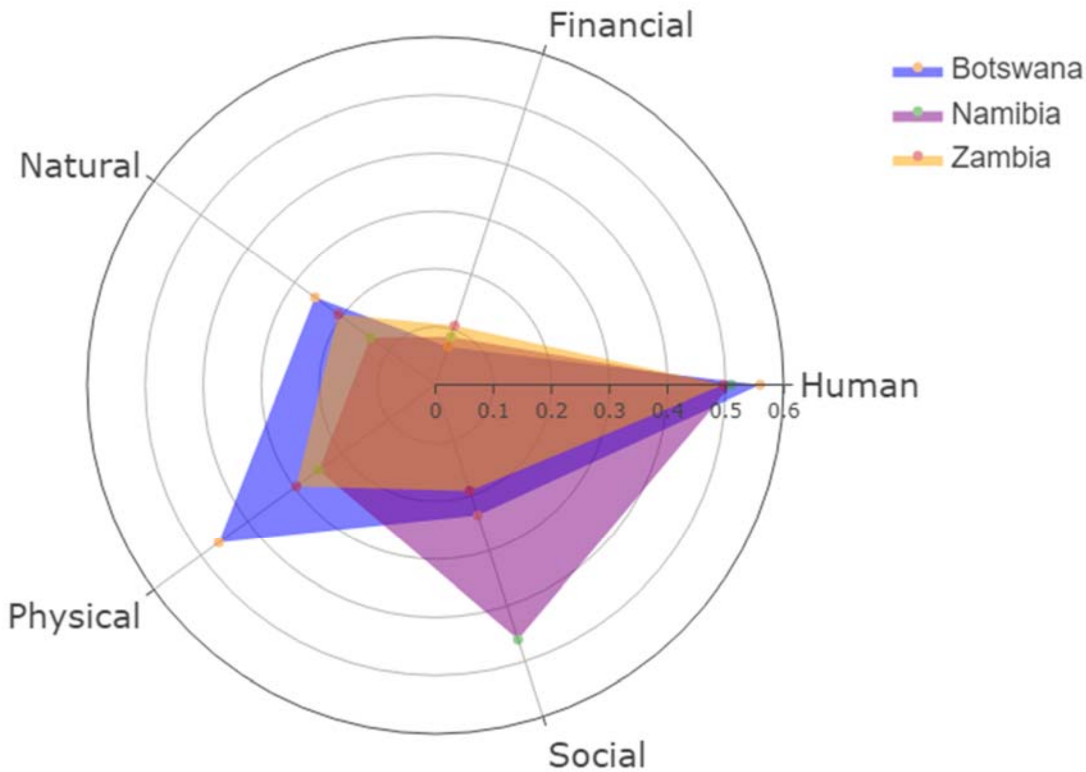

Figure 6. Variation in average household capital across Botswana (blue), Namibia (purple), and Zambia (orange). All values are averaged for all households for each country. The numbers represent a scale where we summed all household responses related to each type of capital (e.g. human capital: highest education, health status; financial capital: income, loans received). We scaled responses by dividing by the maximum value reported in each country (this ensured all values were between 0 and 1). Larger values indicate more capital on average.

Resource Mapping

We mapped a total of 77 resource collection areas in the LWZ-GMA (Figure 7). These resource areas had an average area of 10.2 km^2 and perimeter of 11.2 km^2. Each resource area was identified as the primary collection spot for a given resource by an average of 3.2 households. Similarly, each household named an average of 2.2 resource areas that were accessed for resource collection of any kind. Within our sample, an average of 723 kg were collected within each resource area for each resource, far exceeding the average yield in similar studies in Namibia (199 kg) and Botswana (89 kg). The highest concentration of resource use/collection areas occurred along the Zambezi river and the boundary of Sioma National Park.

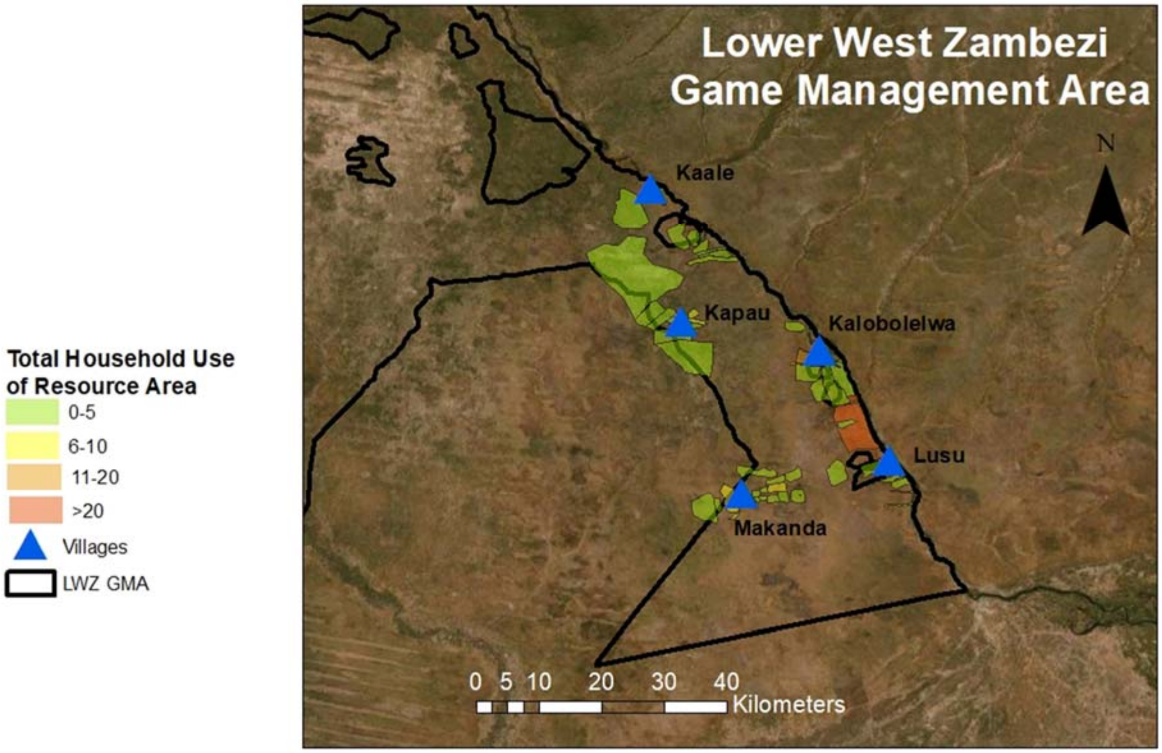

Figure 7. Mapped resource areas in the LWZ GMA. Each resource area is colored in accordance to the number of households that listed utilizing the resource during our household surveys.

Table 3 provides a summary of resource areas by country. While Botswana had the fewest total resource areas, a higher number of households accessed the same resource use area than in either the Namibian or Zambian context. However, Zambian resource areas were the most heavily utilized with an average of 723 kg of resource collected by resource area.

Table 3. Summary statistics for all resource areas by country. Average values (standard deviation) are displayed where applicable.

Region	Total Resource Areas	Perimeter (km)	Area (km^2)	Households/ Resource Area	Resource Areas/ Household	Amount Collected/ Resource Area (kg)

Botswana	53	7.3 (8.1)	4.4 (10.1)	5.8 (8.5)	2.6 (1.4)	89 (167)
Namibia	84	3.6 (4.5)	1.2 (3.0)	3.3 (5.2)	2.5 (1.2)	199 (698)
Zambia	77	11.2 (9.7)	10.2 (23.2)	3.2 (7.4)	2.2 (1.0)	723 (3875)
Total	214	7.3 (8.3)	5.22 (15.3)	3.8 (7)	2.4 (1.2)	401 (2625)

Across the individual resource types, there is significant variation in collection behavior in each country (Figure 8). On average, Zambian households collect less firewood, thatching grass, and reeds than the communities in the other three countries but more building poles and palm leaves than communities in Botswana. In contrast, households in Zambia (many of whom rely heavily on the resources of the Zambezi river) collect more than twice as many kilograms of fish than households in Namibia and Botswana. Some resources have significant local cultural and commercial value, and are more likely to be collected in certain communities as a result. Grapple, also known as devil's claw (*Harpagophytum* spp.), is a medicinal plant used locally and commercially for treatment of a wide range of common maladies. Households in Namibia collect more than ten times as much grapple than those in Zambia or Botswana, likely because it is a culturally important plant for medicinal purposes and has strong economic markets in place for sale and global export (Sunderland and Ndoye, 2004).

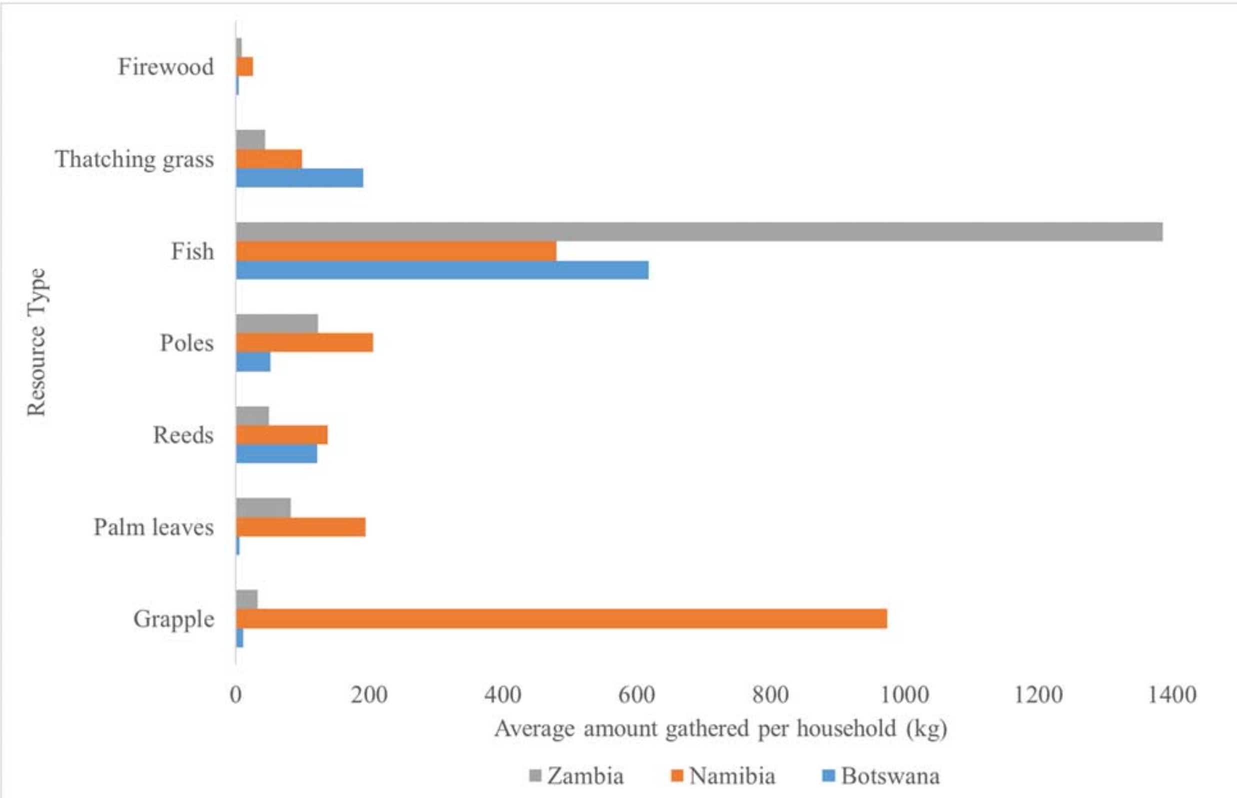

Figure 8. Average annual amount gathered by a household (kg) for each resource type across the three countries.

Environmental Conditions

LWZ-GMA land cover

A total of 53 reference samples were collected in 2018 and summarized in Table 4. Outside of areas designated for settlement (housing and farming), mixed woodland was the most common land cover type followed by scrub. All areas showed evidence of human disturbance, such as resource collection, foot travel, and livestock grazing. Evidence of fire was seen in a majority of reference sample locations, with observations being split nearly evenly between old and recent signs of fire. Variation in canopy closure across all reference sample plots was also quite large. The minimum, maximum, and mean canopy closure percentages were 1%, 60%, and 26% respectively.

Table 4. Summary of reference samples by land cover type and dominant disturbance type.

Land Cover	**Count**	**Disturbance Type**	**Count**
Grassland with scrub	3	Bush encroachment	7
Grassland with trees	3	Evidence human use	21
Mixed woodland	37	Evidence old fire	11
Mopane woodland	1	Evidence recent fire	10
Scrub	5	Logging	4
Scrub with grassland	4		

The distribution of the land cover reference samples provides useful information to the contemporary state of land cover around the sampled community areas (Figure 9). The distribution of reference points, highlighted in Figure 8, notes the variation in land cover type based on the visited areas.

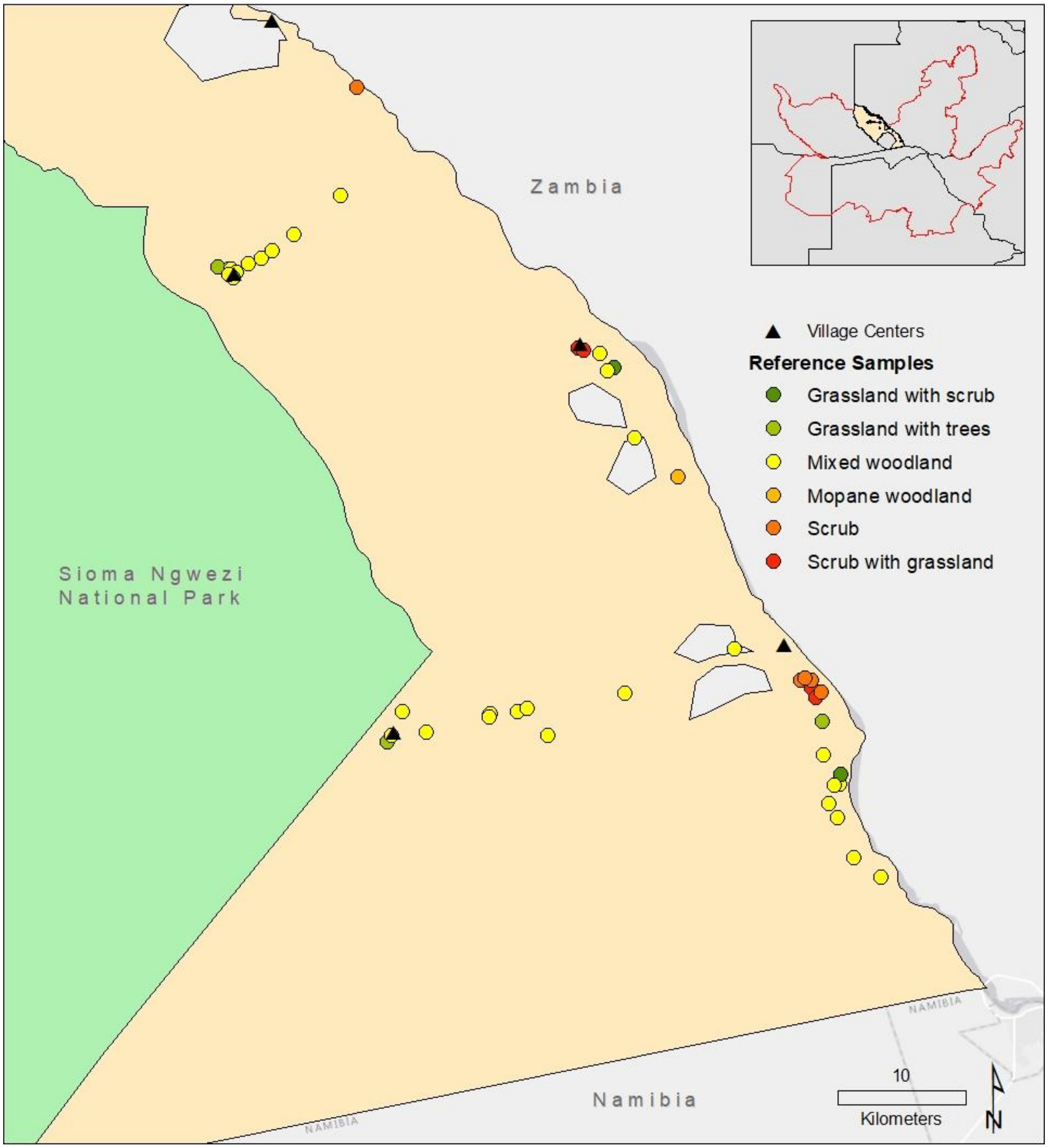

Figure 9. Spatial distribution of vegetation reference samples collected in the Lower West Zambezi GMA. Reference sample points are displayed by dominant land cover type.

Remote Sensing Analysis - KAZA landscape

Rural, household biophysical conditions are challenging for many areas across KAZA and will only worsen as the KAZA climate becomes warmer, drier, and more variable over the next decades (Nkemelang et al., 2018). Since 1981, we show increasing variability in interannual vegetation "greenness" during the rainy season onset (Figure 10a). This variability is greatest in Botswana although there is variability across all three country sites. Variability implies high environmental uncertainty regarding wet season onset. Accurate timing of maize planting is critical in short, low-rainfall growing seasons.

Exacerbating these existing conditions, rainy seasons are becoming shorter across much of KAZA. Significant declining trends in the number of rainy days per season are apparent in our study sites, 1981-2017 (Figure 10b), notably located in the southern portion of the LWZ-GMA. These trends can primarily be attributed to later onset of significant rainfall. Such changes contribute further to uncertainty in agricultural decision-making.

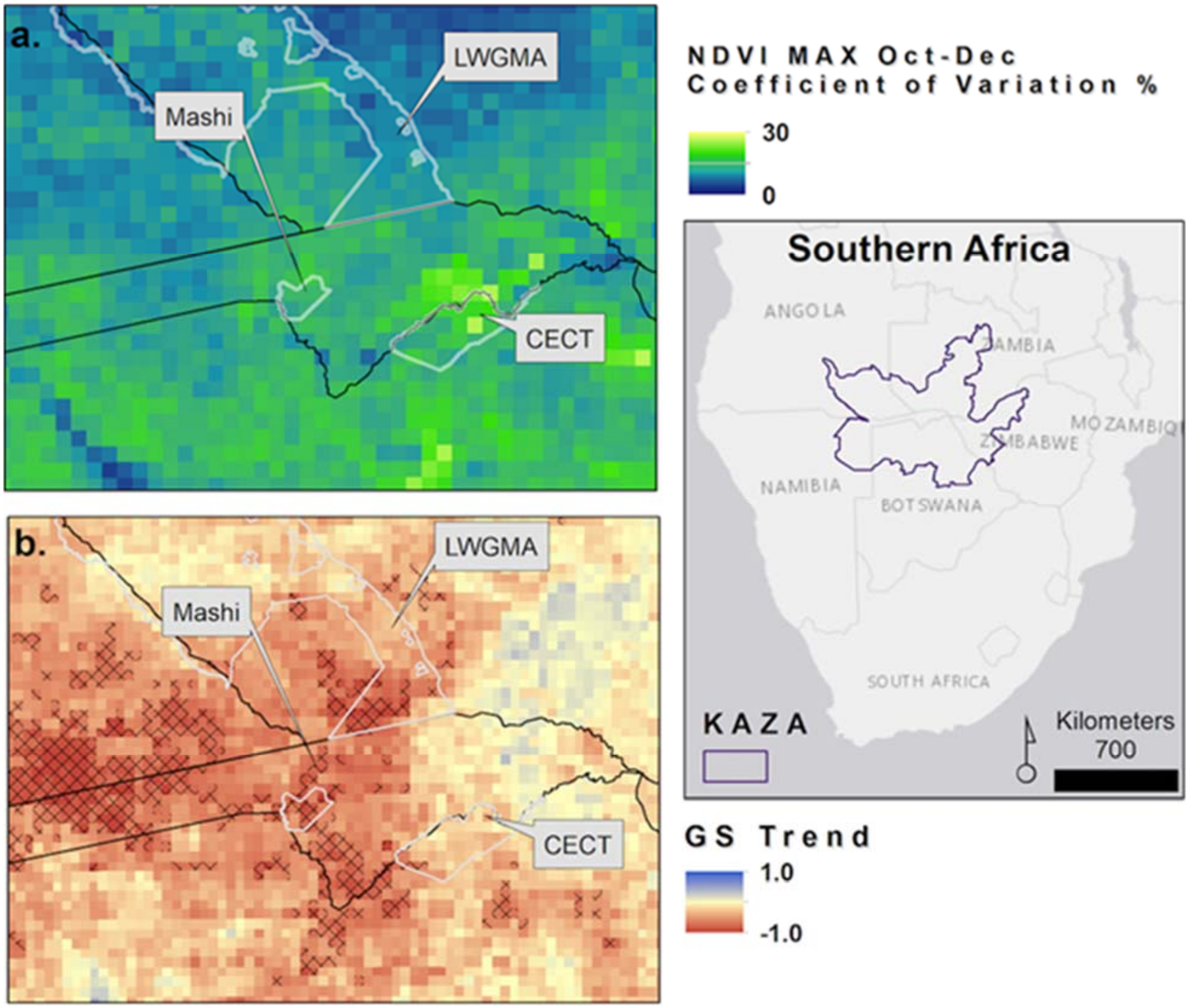

Figure 10. Landscape and climate patterns. a. Coefficients of variation (CV) of maximum October-December (OND) vegetation "greenness," 1981-2015. Pixels with higher CV values will experience the greatest range in timing for maximum greening to occur between October and December **b.** Trend in wet season duration, 1981-2017 (hashing indicates significant trends). Positive values suggests the wet season length has increased since the early 1980s. Negative values suggest the wet season has been getting shorter since the early 1980s.

Data Summary and Discussion

Livelihoods Assessment:

Communities in the Zambia exhibited similarities to those in Namibia and Botswana in certain aspects, such as food security, yet there were marked differences in others, such as livestock ownership and cash income. These features likely reflect wider geographic differences and households' abilities to access different forms of capital. For example, it is unsurprising that Makanda and Kapau households earn relatively lower cash income given their greater distance from the Tarmac road and larger population centers of Sesheke, Sioma Town, and Mongu. Yet, these two more isolated communities differ from each other in farm yields, as measured in maize, which suggests unique conditions that our household data do not measure.

The three study sites were indeed unique. Botswanan households received significant financial support from government and NGOs, including pensions, work programs, and other social services (mean: $1,304 per annum). Such support, in terms of cash inputs from those sources, was much lower for households in Namibia and Zambia (mean: $163 and $30 per annum, respectively). In all communities, social services and aid amounted to the majority of household income, highlighting both extremely marginal agricultural conditions and limited economic diversification.

Recognizing the disparity/lack of financial inputs to many households, what is provided to households from the surrounding landscape is important. The environmental conditions and variability from year to year can directly impact vulnerability at the household level. Early planting can result in crop failure, while late planting prolongs the hunger season. Moreover, because elephant mobility is largely unrestricted across KAZA, animals accessing dispersed, patchy areas of forage frequently transit through farms and settlements during the growing season (Purdon et al., 2018).

Resource Mapping:
Resource mapping is an important tool to characterize the human footprint in the LMZ-GMA. Capturing the land areas in which households are daily reliant upon highlights the expanded area that people need outside settlement and agricultural lands. Our findings indicate that natural resource use and access is spread throughout the different community and not known by any one person. By combining household surveys and on the ground mapping, we were able to refine community level knowledge into accurate spatial data. Zambians collected the most resources and their resource areas were clustered closet to village areas. This might suggest that the LWZ GMA is more productive than the other CBCs, or alternatively, that the community is more reliant on natural resources.

Accurately identifying the full spatial extent of human activities in a conservation landscape is vital for any land management initiatives trying to balance conservation and livelihood development, and is a major challenge when determining how changes in that environment will benefit or challenge households and their food security. It is the intersection of these land uses and socioeconomic conditions that represent the various ways in which households can adapt or respond to changes in the environment and ultimate the impacts on overall wellbeing, and therefore studies like the one we are undertaking are critical.

These challenging economic conditions exist within a dryland region projected to get warmer, drier, and more variable over the next decades. As noted in Figure 10b, changes in the growing season implies a high degree of environmental uncertainty for spatially constrained farming and resource use activities. For example, accurate timing of planting maize is critical for a short, low-rainfall growing season; early planting can result in crop failure, while late planting prolongs the hunger season just prior to harvest. Moreover, because wildlife mobility is largely unrestricted across KAZA, patchy, varying vegetation conditions in Figure 10a need to support both human and wildlife movement and activities.

Closing:
The data and summary provided above provides a baseline set of information and description of the data collected. Continued data analysis will include pooling all household data into a larger model that will attempt to untangle those intersections between land use, socioeconomic conditions, and household food security. Furthermore, continued remote sensing data analysis will hope to provide a context for understanding how land cover, vegetation, and climate may influence household conditions captured in this snapshot in time, and provide insight into how things may be changing. These will include an examination of the linkages between remotely sensed metrics of varying spatial scales to the known resource use areas and household reliance data from the surveys. As the research progresses, all data products and completed scholarly works will continue to be provided in accessible formats to collaborators and stakeholders in the countries represented in our research. Providing actionable feedback is an important aspect of our research and making sure that in-country decision-makers might benefit from these products is an ongoing effort by the research team.

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