J10.2 “NOW IT DOES NOT RAIN:” OBSERVATIONS, EXPERIENCES AND LOCAL MODELS OF CLIMATE CHANGE IN SOUTHERN MOZAMBIQUE

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1. INTRODUCTION

Southern Africa’s vulnerability to climate variability has promoted a strong research agenda investigating the effects of potential change, particularly on food security, the agricultural sector, and disaster management. While informative about large-scale changes, the coarse resolution of global and regional modeling efforts may be inappropriate for needed policy and intervention efforts at the village scale (Wilbanks and Kates 1999). This coarse resolution fails to capture how climate varies over complex terrain, and some interactions between climate, environment, and human communities are not readily observed in the data sets used for large-scale models (Magistro and Roncoli 2001). Finally, influential parameters affecting individual and community reactions to change may be ignored, misunderstood, or remain unknown (Rayner 2003).

We propose complimentary analysis of local climate change models. Such models incorporate human observations and experiences of past climate events and changes within a particular community (Salick and Byg 2007). As a result, they offer critical insight into locally important factors that trigger responses to new climate conditions. Local climate change models are not predictive; however, they highlight locally relevant climate and climate-associated environmental parameters of change and can be used to ground-truth regional predictive models. The insights into human-environment interactions provided by local models assist policy and intervention efforts.

In this paper, we explore the climate and climate-induced environmental changes residents of Matutúine District, Mozmbique have observed over the past 45 years (1963-2008). We then develop local climate change models based on these observations and experiences. We use climate data collected at a regional weather station to triangulate residents’ observations, and highlight the extent of regional change.

2. METHODS

2.1 *The Field Site*

Situated in the southernmost district of Mozambique, Matutúine District incorporates 5,400 km^2 of coastal forest-savanna mosaic (Figure 1). Freshwater and brackish lakes, the Maputo and Futí Rivers, and pans nestled between the vegetated sand dunes support the high biodiversity of this district. Climate, particularly rainfall, plays a key role in regulating production and distribution of both wild and domestic species. Rains falls heaviest along the Indian Ocean coast (1000 mm/yr) and on the slopes of the Lebombo Mountains (800 mm/yr), while the savanna plains remain relatively dry (600 mm/yr) (Tello 1972). Most of the rain falls during the hot, summer months of October to April when temperatures average 25^{o}C. The winter months of May to September bring cooler (20^{o}C), drier conditions. An 18-year oscillation overlays the district’s annual precipitation cycle and creates nine years of relatively dry conditions followed by nine years relatively wet conditions (Tyson et al. 2002). Matutúine District faces both drought and flooding risks.

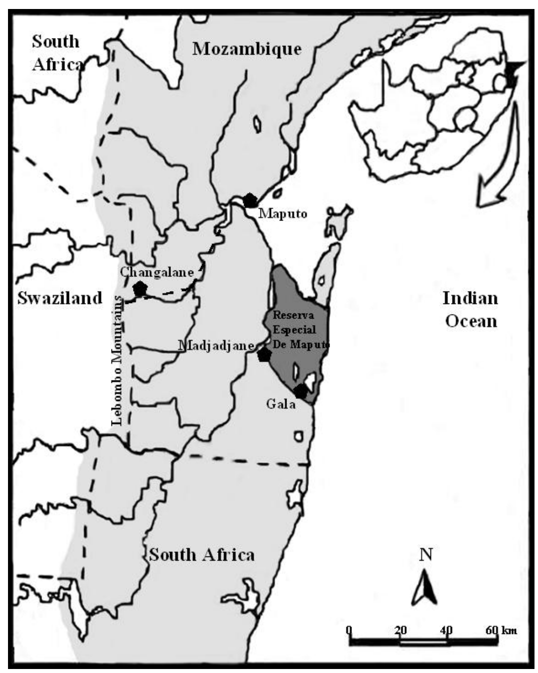

Figure 1. Map of Matutúine District, Mozambique.

Most residents of Matutúine District claim Mazingiri Ronga ethnicity – approximately 90% within the study communities. Ronga occupation of this area dates back at least 500 years base on evidence from oral histories, archived documents, and archaeological materials (Bruton et al. 1980). The

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local economy is based on a combination of swidden agriculture and foraging. Livelihood activities like fishing, goat and cattle herding, mat and charcoal production, beekeeping, reserve work, and tourism supplement household resources and generate income. Past researchers have speculated that residents maintain their dual economy and a large portfolio of other livelihood activities due to the area's high climate variability (Bruton et al. 1980, Felgate 1982). Intergenerational transmission of ecological and cultural knowledge remains strong, despite large population losses in these communities during the Civil War (1986-1992), because survival depends upon accessing a wide range of wild and domesticated resources through their mixed subsistence-based economy. This dependency suggests that residents of Matutúine District would therefore be keenly aware of any climate and climate-associated environmental changes.

2.2 *Data Collection and Analysis*

We conducted semi-structured interviews with 28 men and women, ages 30 to 100+, in the communities of Madjadjane and Gala from August to October 2007. Madjadjane stretches along the Futí River in a predominantly woodland landscape, while 19km away the homesteads comprising Gala are scattered across a predominantly grassland landscape between two lakes. During our interviews, we asked two questions: (1) What, if any, changes to climate have you noticed over the course of your life? (2) What, if any, changes have your noticed in the environment (the land, your community, your household, plants, animals) associated with these changes? The open-ended nature of these questions likely produced conservative results as more people may have observed a particular change than reported this change.

After coding interviews for text analysis of key phrases and concepts, we also converted answers into a quantitative form to build the local climate change models. We ran a two-step cluster analysis on all change related and demographic variables collected during the interviews, and calculated an Akaike Information Criterion (AIC), AIC change (ΔAIC) and Akaike weight (w_i) for each set of clusters. Each cluster produced by the two-step analysis represented a local climate change model. In non-hypothesis driven work, two-step cluster analysis is useful for finding optimal groupings of variables (Kaufman and Rousseeuw 2005). AIC a rigorous, statistically solid method that focuses on the strength of the evidence to assess which of the cluster sets contains the simplest and most likely groupings of variables (Wagenmakers and Farrell 2004).

We obtained monthly precipitation and average monthly temperature data at Changalane Weather Station (CWS) for 1963-2008 from the Instituto Nacional de Meterologia in Maputo, Mozambique. Weather forecasts for inland areas of Matutúine District use data from this station. The location of CWS in the Lebombo foothills means that the data do not represent exact conditions for Madjadjane or Gala. However, trends in this dataset can be used to triangulate informant observations of climate trends. We reorganized monthly data prior to analysis to reflect local conceptions of annual cycles so that comparisons could be made. The year for local farmers traditionally begins in October when the rains arrive and crops are planted, rather than January. In our analysis, year 1963/64 begins October 1963 and ends September 1964. We made temperature scatterplots to look at changes over time seasonally and in the early growing season months of October, November, and December. Following McKee et al. (1993), we calculated and plotted Standard Precipitation Indices (SPI) for annual, seasonal, and early growing season months.

3. RESULTS

3.1 *Climate Change Observations*

All interviewed residents stated that they were currently experiencing a short-term drought. Almost all residents stated that over the long term, temperatures have increased in both summer and winter, the summer rains begin later than expected, and the amount of rain falling is decreasing overall. The temperature increases are linked to drought and vegetation dieback. As one Gala farmer said, "Now it does not rain. It is all dry. In the past it rained a lot. The heat is not the same, now it gets very hot. A lot of heat causes drought." The eldest farmer interviewed believed the long term changes to rainfall were part of the regular long-term climate cycling based on her experiences over the course of her 100+ year lifetime and stories from her parents and grandparents. Only Gala residents mentioned that the timing of the seasons is changing.

SPI data show drier than average conditions for Matutúine District since 2003/04 (Figure 2). Mozambican climatological research indicates that the long-term precipitation cycle has become more erratic since 1983/84 (Coelho and Littlejohn 2000). The SPI data reflect some of these changes in greater oscillation extremes and longer dry periods.

Temperature data shows statistically significant increases both seasonally and for the early growing season months (Figure 3). In the past 45 years, winter temperatures have increased 1^{o}C and summer temperatures by 1.4^{o}C. The average temperature rose 1.7^{o}C, 2.1^{o}C, and 1.1^{o}C in the early growing season months of October, November, and December respectively.

3.2 *Climate-induced Environmental Changes*

Residents attributed a wide range of environmental changes to climate change. However, 41% of residents observed no climate-associated environmental change and instead attributed local

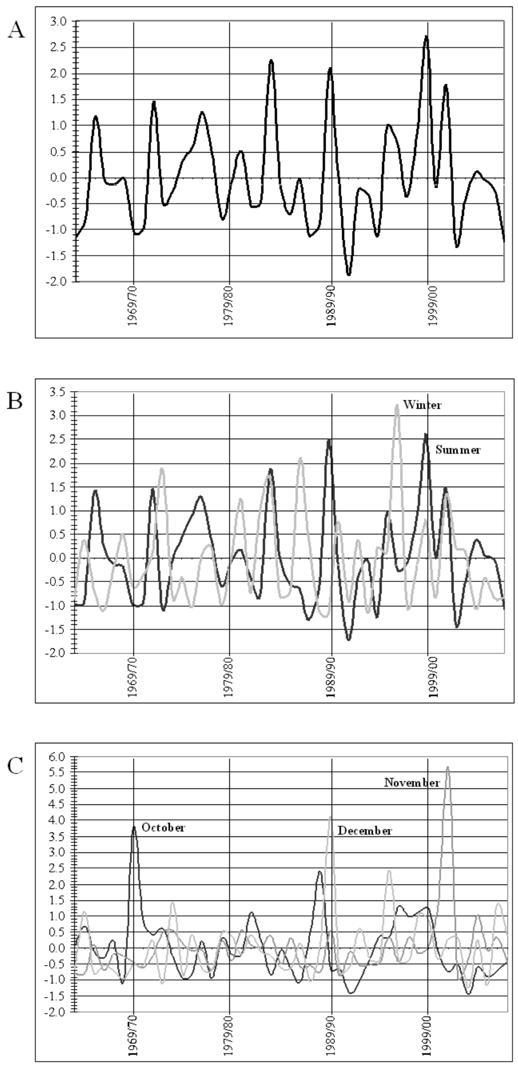

Figure 2. Standard Precipitation Index (SPI) data for Changalane Weather Station, 1963-2008. SPI values are on the y-axis and years on the x-axis. Values -1 to 1 are considered normal, above 1 indicate wet to flooded conditions, and below -1 indicate dry to drought conditions. (A) shows annual SPI values. (B) shows seasonal SPI where winter is a grey line and summer a black line. (C) depicts SPI values for the early growing season months of October (black), November (grey), and December (light grey).

environmental changes to the Civil War or its repercussions. All of the remaining residents in both communities discussed declining crop and wild fruit production, increased crop raiding by elephants, changes to forest area coverage, and that their total way of life has changed. Additional climate-induced changes were observed by only one or two individuals. These observations included less water in rivers and wells, increased health problems and

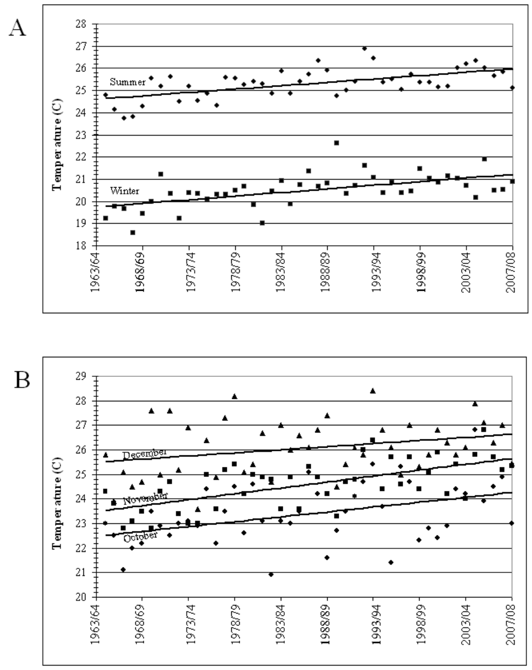

Figure 3. Average temperatures for Changalane Weather Station 1963-2008. (A) Mean seasonal temperatures show a 1.4^{o}C increase for summer ($p<0.000$) and 1^{o}C increase for winter ($p<0.000$). (B) Mean temperatures for the early growing season show a 1.7^{o}C increase for October ($p<0.004$), a 2.1^{o}C increase for November ($p<0.000$), and 1.1^{o}C increase for December ($p<0.051$).

disease, the appearance of new plants, the arrival of a new agricultural pest following the 2000 floods, fewer cattle, increased wildfires, fewer wild animals, and changes to the human population.

3.3 *Local Climate Change Models*

Our analysis optimally clustered informant change observations into three clusters (Table 1). Each cluster of observations represents a local climate change model. One model contained all of the observed changes. The other two models show change observations sorted along community lines (Figure 4).

Number of Clusters	AIC	ΔAIC	w_i
1	634.125	81.528	1.91×10^{18}
2	560.432	7.835	0.02
3	552.597	0	0.96
4	560.336	7.739	0.02
5	572.186	19.589	5.36×10^{18}

Table 1. Two-step clustering results with AIC values.

Model 1: Madjadjane

Climate Changes:
- Short-term drought
- Over the long-term, the timing of the rains is erratic and there is less rain overall
- Temperatures are increasing

Environmental Changes:
- Crop production has declined
- Total way of life has changed
- Increased elephant raiding of crops
- Forests are smaller
- Wild fruit production has declined
- Less water in nearby rivers and wells
- Health problems/disease has increased
- Forests are bigger
- Population has increased
- New plants have appeared
- Agricultural pest appeared after 2000 floods

Demographic Characteristics:
- Madjadjane resident
- Lived in community on average 52.2 years
- Average age is 62.9 years
- Predominantly female (70.6%)
- Born in Madjadjane (58.8%), Gala (17.6%), Matutúine District (100%)

Model 2: Gala

Climate Changes:
- Short-term drought
- Over the long-term, the timing of the rains is erratic and there is less rain overall
- Temperatures are increasing
- Seasonal timing has changed

Environmental Changes:
- Crop production has declined
- Total way of life has changed
- Increased elephant raiding of crops
- Forests are smaller
- Wild fruit production has declined
- Fewer cattle
- Wildfires more common
- Population has decreased
- Fewer wild animals present

Demographic Characteristics:
- Gala resident
- Lived in community on average 32.8 years
- Average age is 58.7 years
- Predominantly male (72.7%)
- Born in Gala (27.3%), Madjadjane (9.1%), Matutúine District (81.8%)

Figure 4. Local climate change models for Matutúine District, Mozambique.

4. DISCUSSION

Residents reported their observations in the context of livelihood activities where knowledge of expected climate patterns is used to make decisions about household production. Their focus on increasingly erratic rainfall reinforces the idea that climate change severely compromises the abilities of individuals and communities to sustain themselves as they have traditionally and historically. Residents often explained their observations through causal chains which provide insight into socio-ecological patterns and processes in Matutúine District.

Farmers delay clearing and planting fields when the rains are late, and crop production is further compromised by reduced rainfall later in the season. Late and reduced rainfall also delays wild fruit tree blooming, and reduces wild plant production, forage quality, and groundwater and river flow. Crops are frequently planted adjacent to rivers and lakes because the soils retain moisture longer. During droughts, elephants move closer to these permanent water sources and their hunger, driven by poor quality forage, may end with the animals raiding readily available crops. Lowered wild plant production negatively affects other income-earning livelihood activities. Lost labor capacity through out-migration, hunger, and disease can limit local production further. The range of ecological and social disruptions engendered by climate change supports the belief of local residents that their entire way of life has changed.

Given that Gala residents share family, history, and cultural ties with Madjadjane we propose an environmental explanation as possible source of the differences between models. These differences in the perception of altered season timing and climate-induced environmental changes may be the result of differences in residents' day-to-day experience with predominant surroundings. Madjadjane's riverine woodland habitats are very different from Gala's predominantly grassland environs. Tree cover, access to water, and the spatial distribution of resources likely affect perceptions of change. Changes in tree dominated vegetation along permanent waterways may be subtler and require large changes to become apparent. However, grass-cover dieback and drying up of scratch wells or water holes in drier grassland areas might reinforce faster recognition of environmental changes driven by climate. Madjadjane's model may represent a woodland climate change model, while Gala's model represents a grassland model for this district. Future research exploring the validity of this hypothesis would be worthwhile.

5. CONCLUSIONS

Analysis of local climate change models offers insight into changes and connections that global and regional models cannot capture. None of the climate changes residents observed between 1963 and 2008 may seem exceptionally large or significant when read as numbers in a report. Yet when the rains fail, the successful practice of local livelihood activities and the functioning of ecological processes in Matutúine District deteriorate quickly. As a Gala fisherman stated, “Nothing can be done without rain.” In this paper, we examined local climate change models improve understandings of how climate and environmental parameters interact to generate change at the local level. In the process of our analysis, we discovered locally important changes that would likely not have appeared in regional models.

Decision-making under uncertain environmental circumstances requires knowledge of past and present conditions to make the predictions of expected conditions needed for planning considerations. The predictions generated by regional climate change models provide useful information to start thinking about intervention and adaptation. However, the coarse resolution averages effects across the landscape regardless of existing physical, ecological, and cultural diversity. We propose complementary analysis of local climate change models as a way to access the more specific data required for the production of focused policy and decision-making. Site-specificity of the detailed observations used to generate a local model cancels the averaging effect seen in regional models and establishes what locally important changes will need to be addressed for successful intervention and adaptation.

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