Principal Components of Local Climate and their implications for Climate Change Adaptation: Case Study from the Savannah of Nigeria

Mayowa FASONA[1], Mark TADROSS[2], Ademola OMOJOLA[1] & Babatunde ABIODUN[2]

[1]Department of Geography, University of Lagos, Nigeria, e-mail: mfasona@unilag.edu.ng , [2] CSAG, Environmental & Geographical Science Department, UCT, Cape Town, South Africa

Abstract

Many climate impact applications are sensitive to local differentials in the climate system. This study investigates how eco-geographic factors influence the local climate and propagate eco-climatic complexes that vary spatio-temporally. Local geography data including elevation, slope, aspect, vegetation, population density, and soil potential for agriculture were integrated with present and statistically downscaled future rainfall and temperature and analyzed using geographic information system and principal component analysis. The result was profiled for local climate drivers and associated spatial structures in present and future climate (2046-2065) scenarios. The results suggest a local climate system driven by the coupling between terrain, rainfall and temperature in all seasons. In the present climate, this coupling creates eco-climatic complexes that extend from the southeast to northwest corridor in all seasons except June-July-August (JJA) when it is shifted to the northeast axis. This pattern is projected to continue in the future climate scenario, but its spatial influence and intensity would weaken around the northwest axis and rainfall will become less significant in the system in JJA. The clustering of rural settlements around these complexes suggests the climate-positives produced by the system significantly support rural livelihoods. Thus, these eco-climatic complexes represent climate sensitive natural resource systems that are important in planning place-based and context-specific adaptation in the Savannah .

1. Introduction

The blue and green water footprint together with ability to introduce innovative water management practices may become critical in defining the future pattern of agrarian land uses across time and space in the Nigerian Savannah. Long term rainfall signals have already become more erratic in space and time distribution [Nicholson 2000, Afiesimama *et al.* 2006, Abiodun *et al.* 2007], and the percent of irrigated agricultural land is negligible. The mesoscale convective process (MCS) which controls the climate of the Nigerian Savannah relies on the local forcing - especially the complexity in terrain and land cover - to propagate. It accounts for over 75% of total rainfall received [Omotosho and Abiodun 2007]. Understanding the nature, role and spatial pattern of associated structures of such regional to local scale forcing is important for climate change adaptation and local level mitigation planning. A degree of local forcing that varies by region and season complements synoptic-scale forcing to influence local climate [Hewitson and Crane 2006]. Local perturbations including terrain, land cover, and land-water boundary often exert strong influence on the local climate at relatively fine scale and create eco-climatic structures that support the natural resource capita on which rural livelihoods thrive. Many impact applications including adaptation strategies, ecosystems management, and local mitigation actions are very sensitive to fine scale climate variations that are poorly parameterized in coarse global climate models (GCMs) and regional climate models (RCMs). Their relatively coarse resolutions often mask large differentials in local forcing and local scale circulation and perturbation induced by landscape complexity.

Empirical downscaling is one way to generate point scale data that captures fine scale variations in local climate and explore regional and local scale responses to global climate change. [Hewitson and Crane 2006, Wilby et al. 2004]. It is important for generating regional and local scale scenarios of future climate to make information available for the impacts, adaptation and vulnerability community. Downscaled climate data integrated with local geographic data can be analysed to explore information on spatial pattern and extent of influence of the factors on the local climate system. This can be evaluated for the extent to which each local forcing will interface with the local climate system and the implication of the concomitant fine scale structures produced across space and time for natural resource management and place-based and context specific adaptation planning. This study presents evidence that local geographic factors interacting with climate have the potential to produce climate-sensitive eco-climatic structures across space and seasons which support the natural resource capital and is important for measuring resilience and planning rural adaptation to climate change across wooded savannah of western Nigeria.

2. Study Area

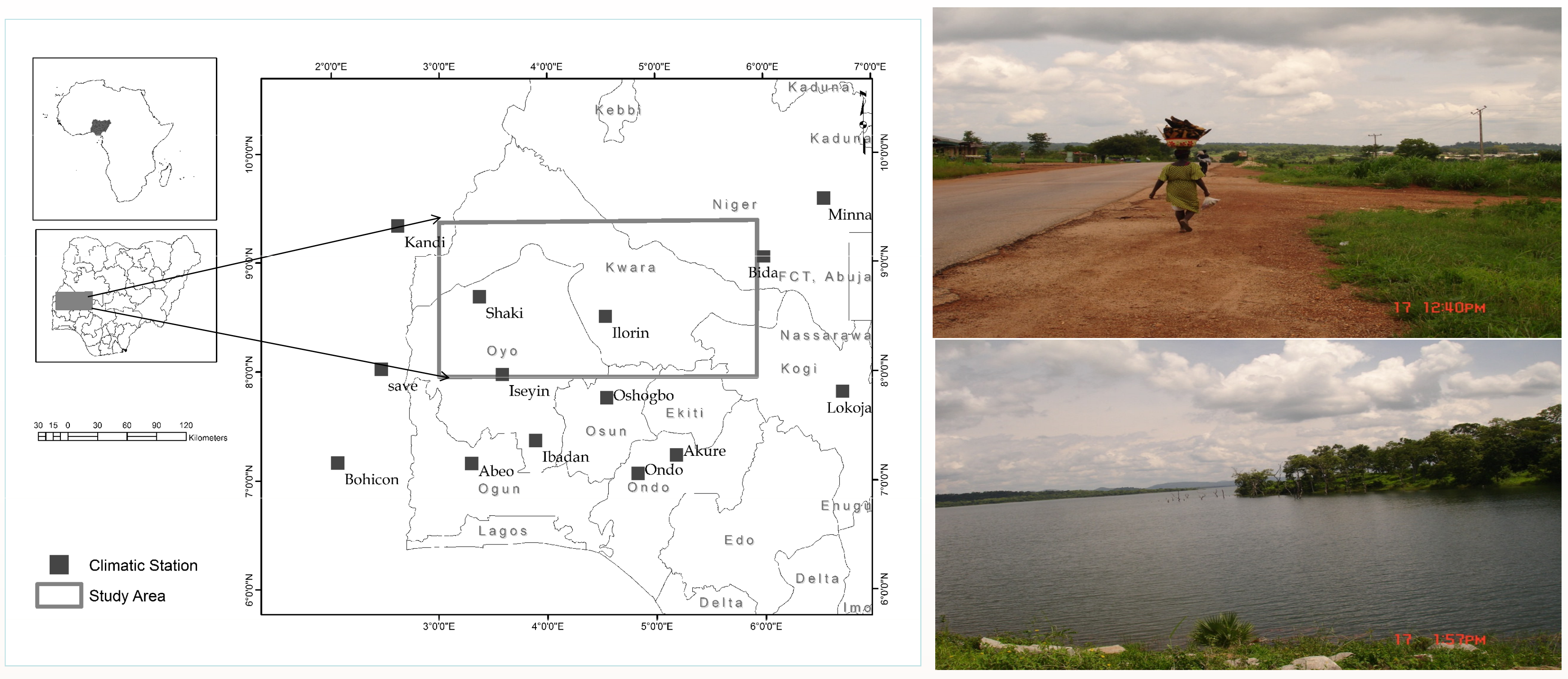
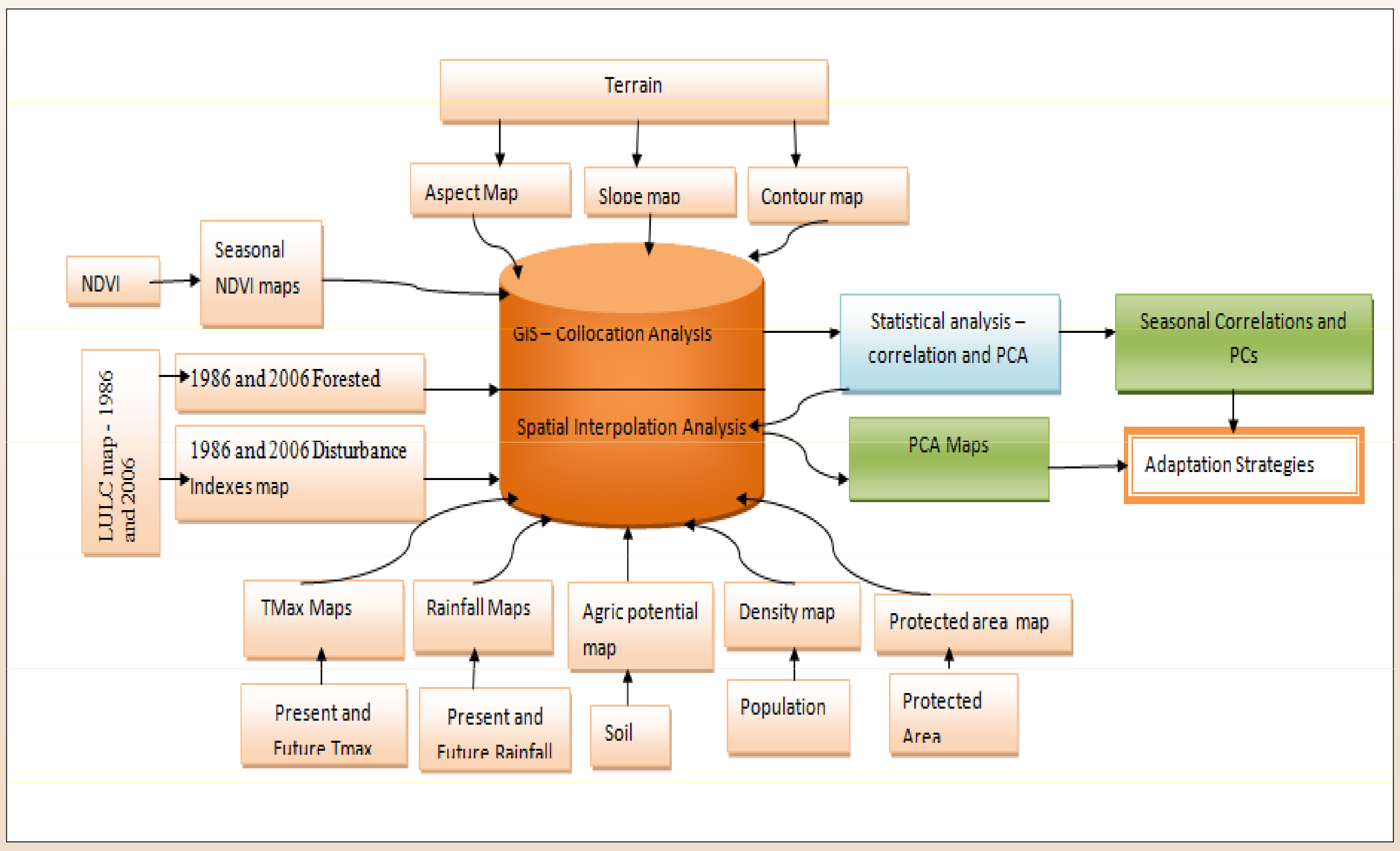


Fig 1: The Study area map (Left) and some characteristics of the area (Right)

Annual rainfall -900mm -1300mm – 75% from mesoscale processes, Population – High density agrarian landscape. Livelihood – tied to small-holder rain-fed agric , Irrigation – potential high, actual very low , Natural capital - significant to human well-being, Actual and Potential Natural Resource Conflicts – Very high

3. Methodology



Terrain

Aspect Map

Slope map

Contour map

NDVI

Seasonal NDVI maps

LULC map - 1986 and 2006

1986 and 2006 Forested

1986 and 2006 Disturbance Indexes map

GIS – Collocation Analysis

Spatial Interpolation Analysis

Statistical analysis – correlation and PCA

Seasonal Correlations and PCs

PCA Maps

Adaptation Strategies

TMax Maps

Rainfall Maps

Agric potential map

Density map

Protected area map

Present and Future Tmax

Present and Future Rainfall

Soil

Population

Protected Area

Fig 2 : The Research Framework

References

S. Nicholson, "Land surface processes and Sahel climate,". *Reviews of Geophysics*, Vol 38, No 1, 2000, pp. 117-339. E.A. Afiesimama, J.S Pal, B, J Abiodun, W.J Gutowski and A. Adedoyin, "Simulation of West African monsoon using the RegCM3.Part I: Model validation and interannual variability." *Theor. Appl. Climatol*. Vol 86, 2006, pp. 23–37. B.J Abiodun, J.S Pal, E.A Afiesimama, W.J Gutowski and A. Adedoyin, "Simulation of West African monsoon using RegCM3 Part II: impacts of deforestation and desertification, *Theor. Appl. Climatol*. Vol 93, 2008, pp. 245-261. J.B Omotosho and J. Abiodun, "A numerical study of moisture build-up and rainfall over West Africa". *Meteorol. Appl. Vol* 14, 2007, pp. 209–225. B.C. Hewitson and R.G Crane, "Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa". *Int. J. Climatol*. Vol 26, 2006, pp. 1315–1337. R.L Wilby, S.P Charles, E. Zorita, B. Timbal, P. Whetton and L.O Mearns, "Guidelines for use of climate scenarios developed from statistical downscaling methods". *TGICA. IPCC* Supporting Materials,2004

4. Results

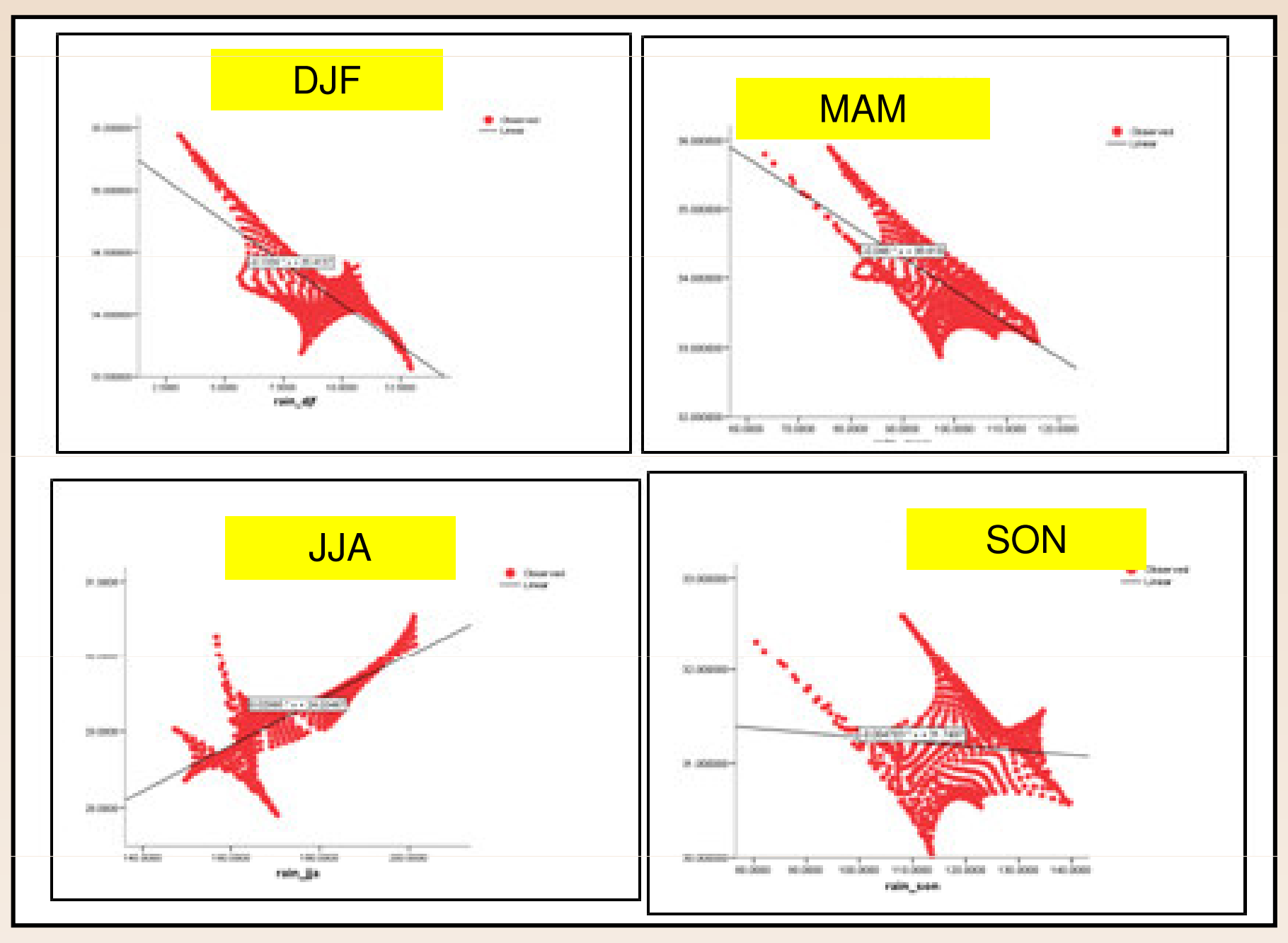


Fig 3a Correlations: Rainfall Vs Maximum Temperature

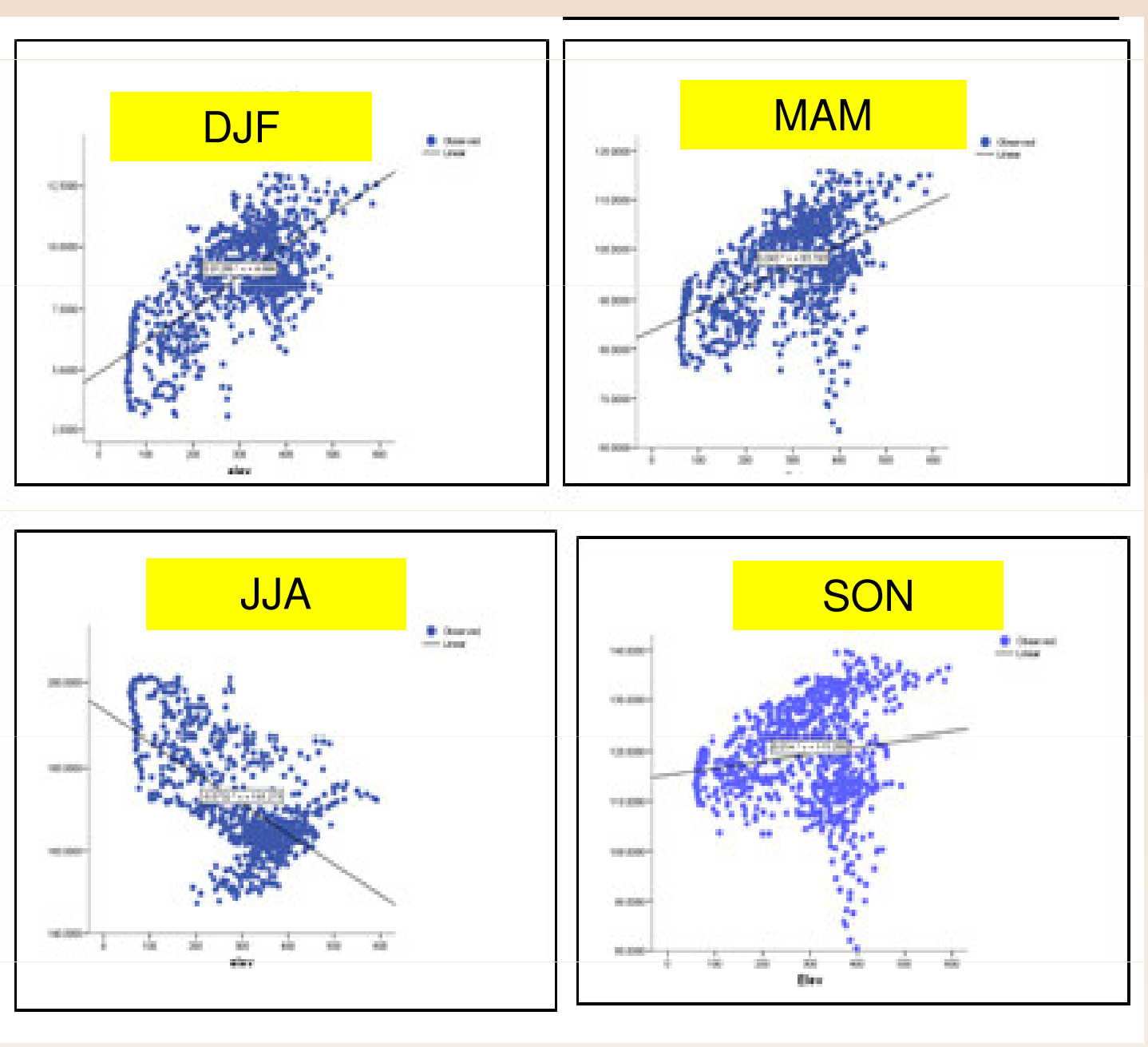


Fig 3b: Correlations: Rainfall Vs Elevation

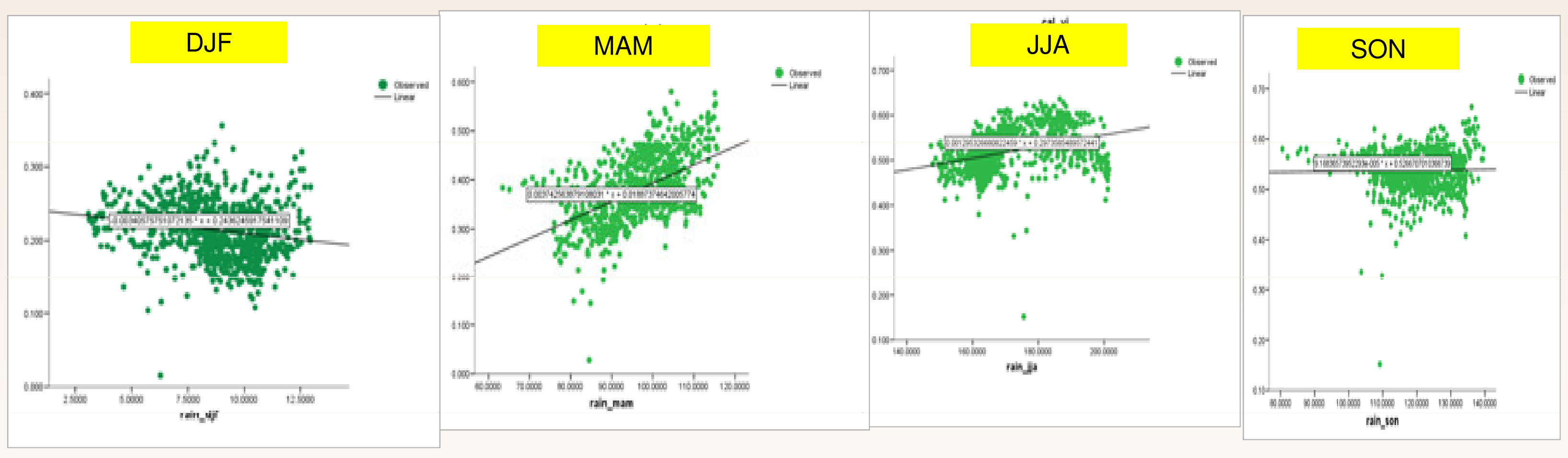


Fig 3c: Correlations: Rainfall Vs NDVI

Table 1: Extracted Principal Components for Present Climate (Left) and Future Climate (2046-2065) (Right)

Variables	Component 1	2	3	4	5	6
Aspect	.129	-.116	.220	-.138	.621	-.287
Slope	-.075	.156	.236	.274	.014	-.534
Elevation	-.818	-.018	.292	.063	.059	.060
Population density	-.168	.234	-.062	.289	-.062	.312
Soil potential for agric	.099	.081	.320	.130	.119	.663
Distance to water	-.076	-.023	.111	.534	-.017	.154
Protected areas	.175	.215	-.292	.503	-.135	-.001
NDVI for 1986	-.210	-.001	.770	.156	-.059	-.026
NDVI for 2006	-.096	.156	.756	-.195	.018	.041
Average Tmax for 1986	.958	.033	-.045	.050	.028	.057
Average Tmax for 2006	.961	-.037	-.049	.087	-.007	.054
Average rainfall for 1986	.125	.931	.008	-.005	-.024	-.019
Average rainfall for 2006	-.650	.690	.069	-.045	.056	-.013
Disturbance index for 1986	-.162	-.063	-.030	.097	.760	.292
Disturbance index for 2006	.055	-.200	.126	.642	.215	-.117
Forested areas in 1986	.001	-.090	.465	-.176	-.660	-.019
Forested areas in 2006	-.121	-.058	.393	-.681	-.070	.136
Long-term mean rainfall	-.048	.915	.097	.007	-.080	.035

Variables	Component 1	2	3	4	5	6
Aspect	-0.035	-0.094	0.431	0.383	0.052	0.387
Slope	0.133	-0.150	-0.199	-0.208	-0.031	0.756
Elevation	0.823	-0.157	0.192	-0.197	-0.120	0.007
Population Density	0.151	-0.285	-0.286	-0.049	-0.197	-0.446
Soil potential for agriculture	-0.005	-0.085	0.010	0.172	-0.848	0.022
Distance to water	-0.029	-0.387	-0.016	-0.376	-0.317	-0.008
Protected area	-0.241	-0.406	-0.504	-0.085	0.108	-0.039
Disturbance index for 1986	0.100	-0.535	0.438	0.421	-0.152	-0.077
Disturbance index for 2006	-0.182	-0.523	0.217	-0.372	-0.110	0.173
Forest area in 1986	0.112	0.640	-0.086	-0.482	-0.267	0.058
Forest area in 2006	0.295	0.654	0.288	0.157	-0.243	0.005
Long term average rainfall	0.746	-0.025	-0.518	0.294	-0.035	0.108
Monthly average rainfall	0.746	-0.026	-0.518	0.294	-0.034	0.107
Long term average Tmax	-0.867	0.114	-0.292	0.207	-0.169	0.093
Mean monthly Tmax	-0.867	0.104	-0.283	0.209	-0.172	0.096

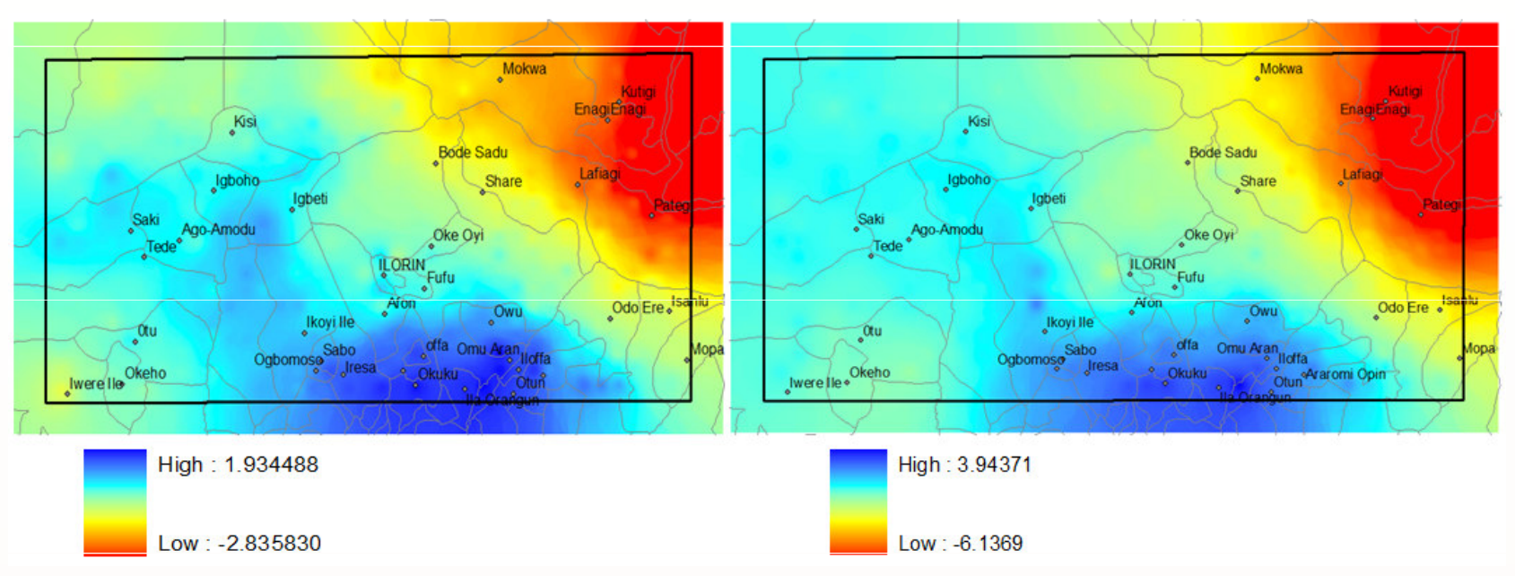


Fig 4a: DJF: Elevation varies directly with Rainfall and Inversely with Tmax in present (Left) and future (Right)

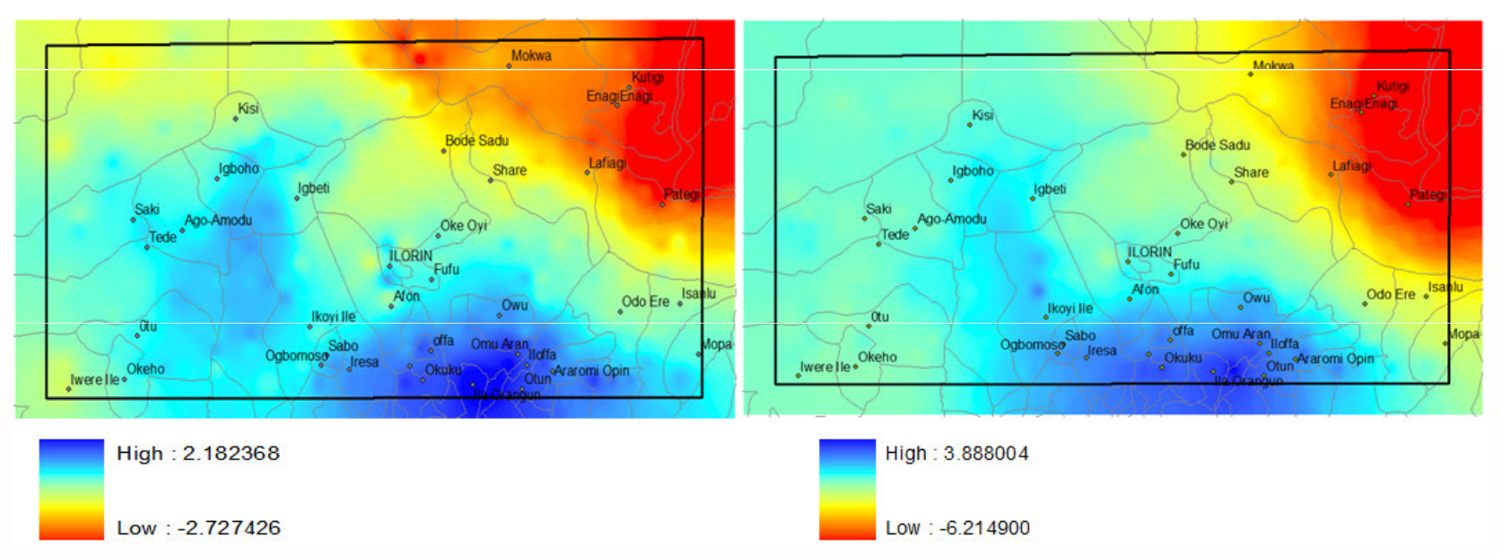


Fig 4b: : MAM: Rainfall and Tmax vary inversely with Elevation for present climate (including NDVI) (Left) and in future climate (Right)

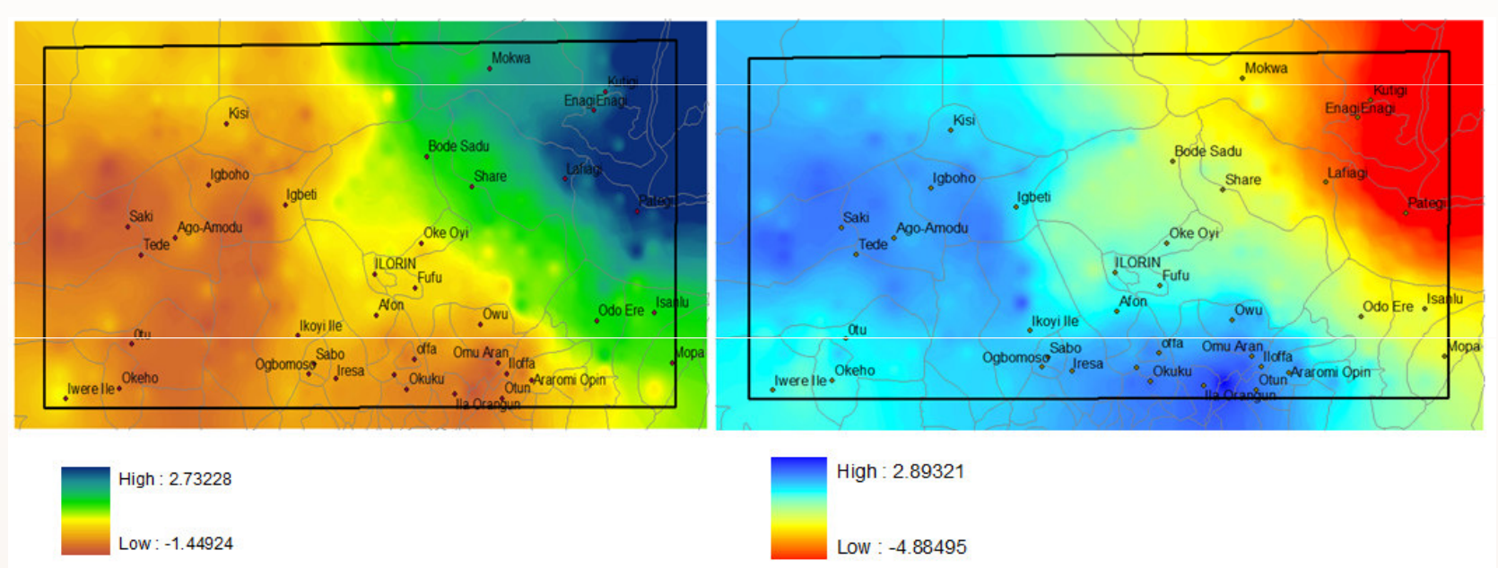


Fig 4c: : JJA: Rainfall and Tmax varies inversely with Elevation in present climate (Left), and future climate (Right) –when rainfall is no longer significant in the system

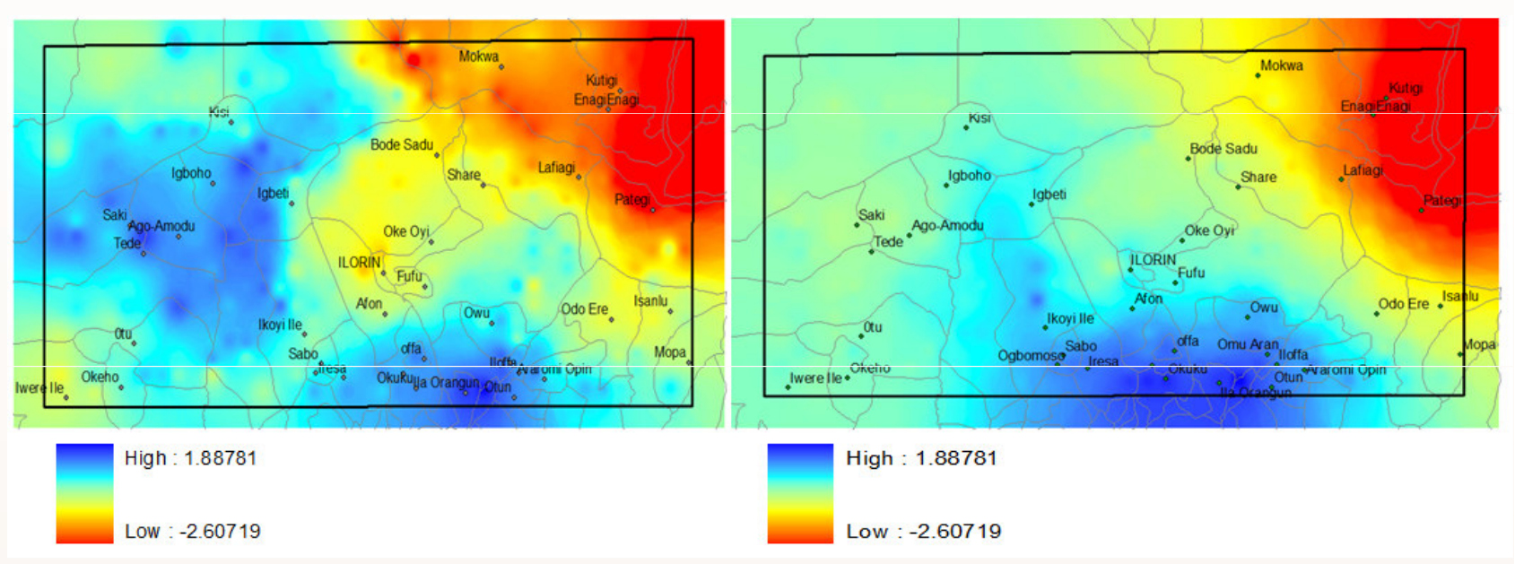


Fig 4d: : SON: Elevation Varies inversely with Tmax only in present climate (Left), and also directly with rain in future climate (Right)

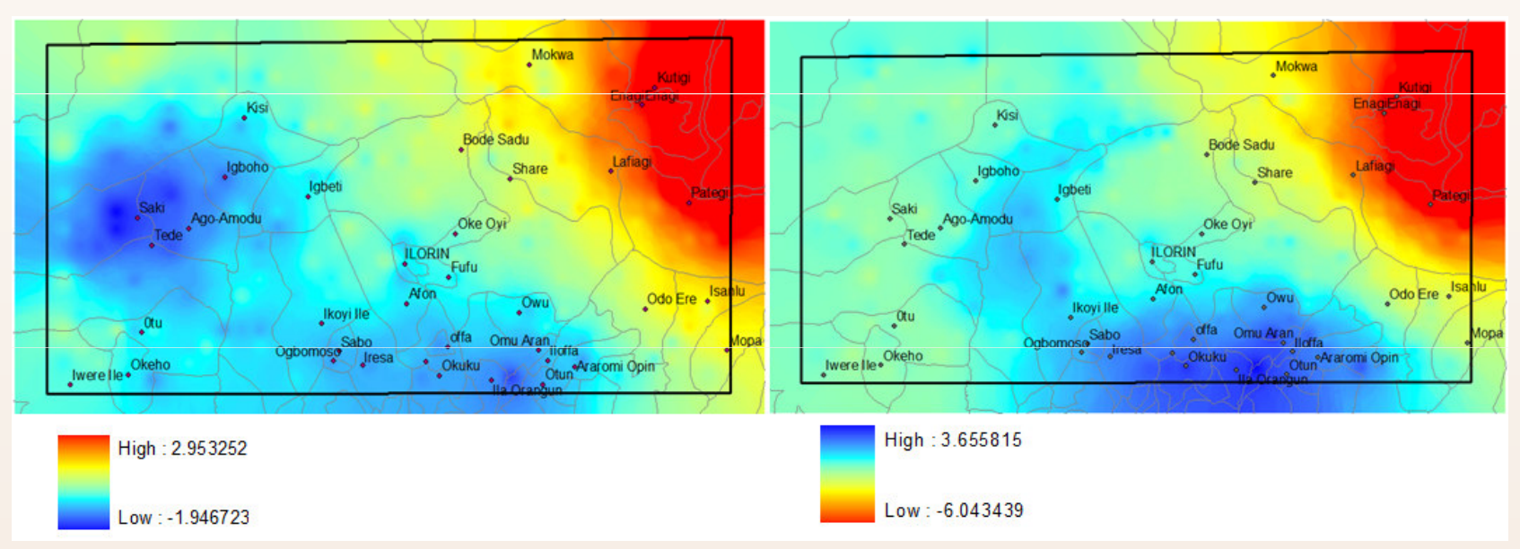


Fig 4e: : The annual average: Rain and Tmax sensitivity to terrain in Present climate (-Elevation, -rain, +Tmax) (Left), and future climate (+Elevation, +rain, -Tmax) (Right)

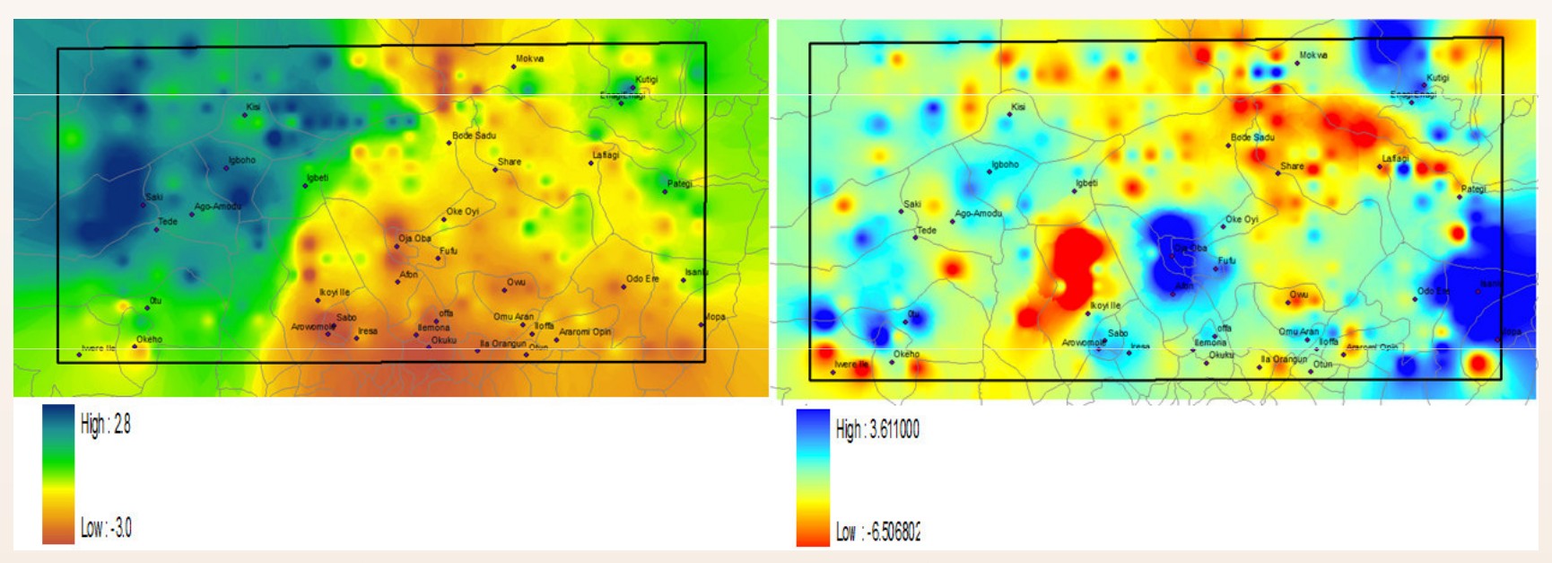


Fig 4f: : Av_future-PF3: Mean rainfall Varies directly with Protected area (Left), Average PF5: Soil Potential for agric inversely related to slope (Right)

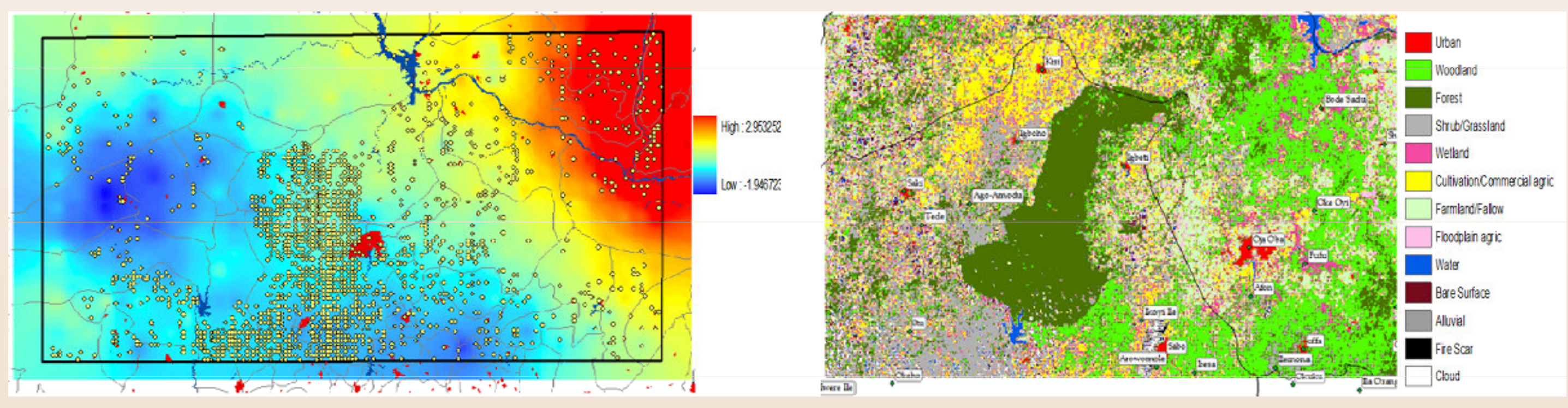


Fig 4g: : Rural Settlement clusters around the climate-positives (Right); Present Landcover Pattern of the study area (Right)

5. Conclusions

The principal factors suggest a strong coupling between the climate and the terrain in all seasons. The variation in the spatial pattern of influence is consistent with the locational pattern of communities and their livelihood systems which suggests dependence on the eco-climatic complexes produced by climate-terrain interaction. While the observed pattern is projected to continue in future, its spatial influence will severely diminish and some areas that presently support large agrarian population and viable rural livelihoods may be negatively impacted. The land surface conditions that enhance the propagation of the present pattern of climate-positives constitute a climate-significant factor that must be given serious consideration in local climate mitigation and adaptation planning in the savannah.

Acknowledgment:
This research was carried out under the African Climate Change Fellowship Programme (ACCFP). The ACCFP is supported by a grant from the Climate Change Adaptation in Africa (CCAA) funded jointly by Canada's International Development Research Centre (IDRC) and UK's Department for International Development (DFID). The International START Secretariat is the implementing agency in collaboration with the Institute of Resource Assessment (IRA) of the University of Dar es Salaam and the African Academic of Sciences (AAS). CSAG, UCT, Cape Town was the host Institution and UNILAG was the home institution.