MODELING CLIMATE FOR ECOLOGICAL STUDIES IN SOUTHERN KENYA

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Abstract
Ecological studies often use Geographic Information System (GIS) models to predict or explain biogeographical patterns and range distributions of various species. Climatic data are often interpolated into high resolution spatial GIS layers to be used in GIS models. The wildlife rich Southern Kenya, generally characterized by two dry seasons and two wet seasons, has a sparse and irregularly spaced network of weather stations, presenting a challenge for ecologists who intend to use climatic data in their models. The suitability of Regression Analysis (RA) to interpolate climatic surface models for this region at various temporal scales was examined using analysis of variance (ANOVA). It was found that for all but one wet season, precipitation could be accurately modeled using RA. ANOVA results also indicated that it was possible to accurately model temperature at various temporal scales.

Key words: GIS, regression analysis, analysis of variance

1.0 Introduction

Ecological studies often use Geographic Information System (GIS) models to predict or explain biogeographical patterns and range distributions of various species found within (Browning *et al*., 2005; Stepehnson *et al.,* 2006). Climatic data consisting of precipitation, maximum temperature and minimum temperature are often interpolated into high resolution spatial GIS layers to be used in GIS models (Shiklomanov and Nelson, 2003). Covering approximately 291,323 square kilometers, the area between central and the southern tip of Kenya, commonly referred to as Southern Kenya, is rich in wildlife that includes primates, big cats, elephants and buffalo. The world renowned Amboseli, Maasai Mara and Lake Nakuru National Parks are just three examples of wildlife sanctuaries found within this region. Southern Kenya has a sparse network of weather stations, most of which are located in irregularly spaced towns found along a highway that runs across the region, presenting a challenge for ecologists who intend to use climatic data in their models. Methods for interpolating climatic data include Thiessen Polygons, Inverse Distance Weighted Interpolation, Trend Surface Analysis, Local Polynomial Interpolation, Regression Analysis, Kriging, CoKriging and Radial Base Functions (Burrow and McDonnell 1998). While even more complex methods exist, in most cases simple regression equations adequately summarize much of the spatial variation in climate (Goodale *et al*., 1998). Here we explore the suitability of Regression Analysis (RA) to model climatic surface models for Southern Kenya, models which can then be used in ecological studies.

2.0 Methodology

Climatic data, from 1984 to 2011, consisting of average monthly precipitation, average monthly minimum temperature and average monthly maximum temperature, were collected from thirteen weather stations (Mombasa, Malindi, Voi, Amboseli, Makindu, Machakos, Wilson, Narok, Nakuru, Meru, Garissa, Laikipia and Kisumu). Twelve of these were monitored by the Meteorological Department of Kenya and one by the Amboseli Baboon Research Project. While precipitation data was obtained from all the 13 stations, temperature data were not available from one station (Wilson).

The average monthly minimum (Min-Temp) and maximum temperature (Max-Temp) for each month were calculated from the monthly data. The average minimum temperature (Average Min Temp) and average maximum temperature (Average Max Temp) for all years was calculated using the average monthly temperatures for all years. The average monthly precipitation (Precipitation) for each month was calculated from the monthly data for all stations. The average precipitation for all years (Average Precipitation) was then calculated using the average monthly precipitation for all year.

2.1 Regression Analysis

A line graph of Precipitation indicated that there are two wet seasons and two dry seasons. The first wet season (WS1) begun in March, and ending in May. The second wet season (WS2) begun in October, ending in December. The first dry season started in January and run to the end of February (DS1). The second dry season (DS2) started in June and ended in October. Regression analysis between Altitude and the temperature data was carried out for the monthly data (Min-Temp and Max-Temp), seasonal data (WS1, WS2, DS1, DS2), and annual data (Average Min-Temp and Average Max-Temp). Regression analysis between Precipitation and distance from the Indian Ocean was carried out for the seasonal data and Average Precipitation.

The distribution of weather stations in the study area with normalized bar graphs indicating the altitude, average precipitation (Precipitation), average minimum temperature (Min Temp) and average maximum temperature (Max Temp) for each station.

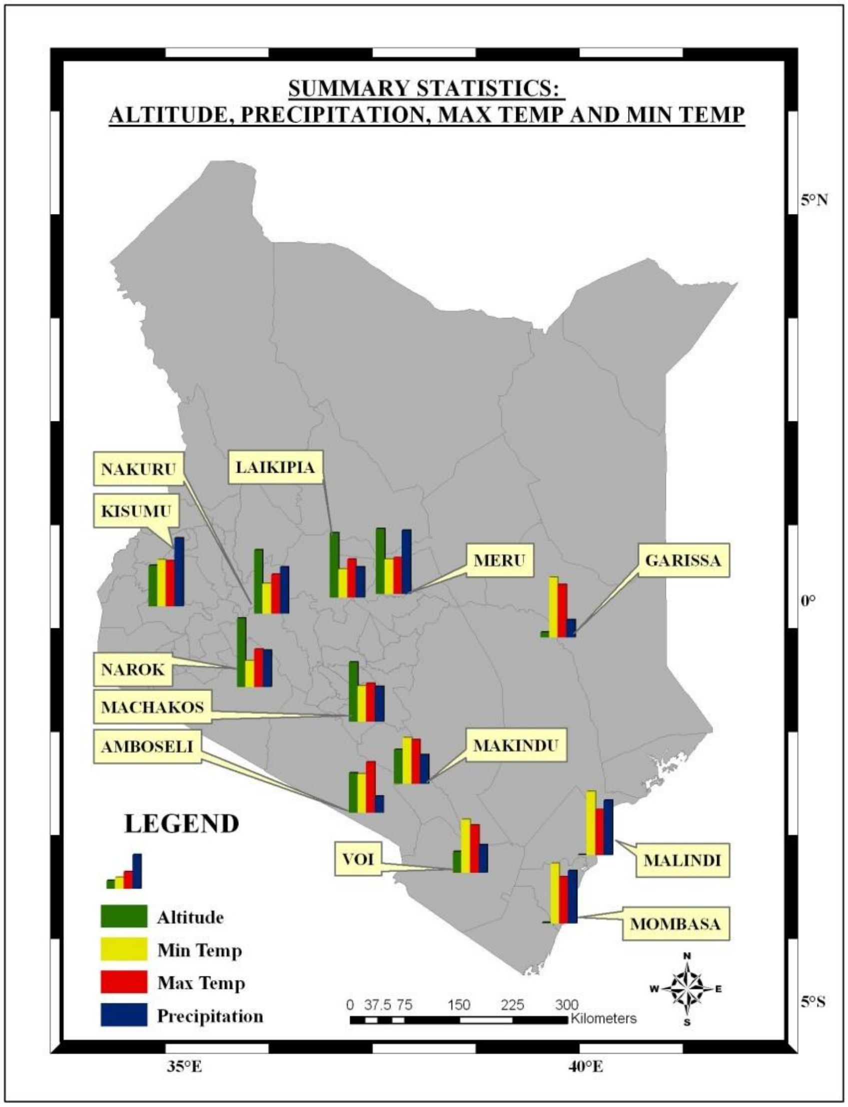

Figure 1: Distribution of Weather Stations in Southern Kenya

The line graph of Precipitation indicates that there are two wet seasons and two dry seasons.

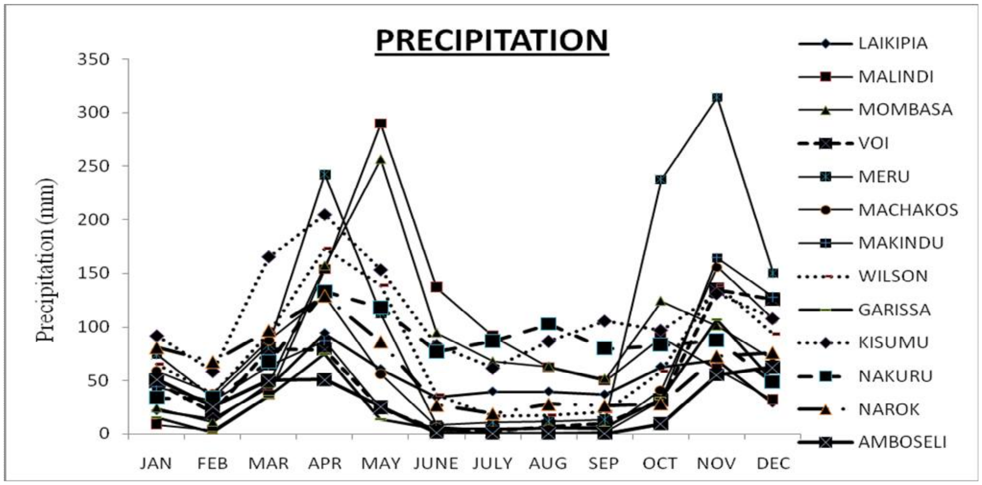

Figure 2: Average monthly precipitation

3.0 Results

Analysis indicated strong correlation between Min-Temp and Altitude. Seasonal Min-Temp and Average Min-Temp also showed strong correlation with Altitude. When the stations closest to the Indian Ocean were omitted, it was noted that the correlation between Max-Temp and Altitude was considerably stronger. The correlation between the seasonal Max-Temp, Average Max-Temp and Altitude were also considerably stronger when the stations closest to the ocean were omitted from the analysis. Analysis of Variance (ANOVA) for all regression done with temperature data indicated that it was possible to model minimum temperature and maximum temperature at the monthly, seasonal, and annual temporal scale with good accuracy.

The correlation between the distance from the ocean (Distance) and the respective weather stations was strong for the first dry season. For the first wet season and second dry season, there was good correlation between Distance and Precipitation only when data from the stations closest to the ocean were omitted from analysis. For the second wet season, no correlation between Precipitation and Distance was observed. ANOVA for all regression indicated that it is possible to model precipitation for the two dry seasons, and the first wet season with high accuracy. ANOVA indicated that there was no correlation between distance from the ocean and the second dry season. The results of the regression analysis are summarized in Table 1.

For a regression of the form ***Y=a +bx***, the table shows the two regression coefficients ***a*** and ***b***, R^2, Standard Error and Significance F. Values of Significance F that are within the confidence level (1-P>0.95) are highlighted in bold and underlined.

Table 1: Summary of the regression analysis

REGRESSION SUMMARY

MIN-TEMP	R^2	Standard Error	Significance F	a	b
DS1	0.64	2.20	**<u>0.0019</u>**	34.18	-0.0037
WS1	0.67	2.26	**<u>0.0011</u>**	33.77	-0.0040
DS2	0.55	2.38	**<u>0.0058</u>**	30.78	-0.0033
WS2	0.65	2.31	**<u>0.0016</u>**	33.03	-

					0.0039
Average Min-Temp	0.96	1.02	**0.0000**	23.29	-0.0063
MAX TEMP					
DS1	0.64	2.20	**0.0019**	34.18	-0.0037
WS1	0.67	2.26	**0.0011**	33.77	-0.0040
DS2	0.55	2.38	**0.0058**	30.78	-0.0033
WS2	0.65	2.31	**0.0016**	33.03	-0.0039
Average Max-Temp	0.63	2.27	**0.0022**	32.66	-0.0037
MAX TEMP WITHOUT MOMBASA AND MALINDI					
DS1	0.80	1.78	**0.0005**	36.90	-0.0054
WS1	0.86	1.63	**0.0001**	36.92	-0.0060
DS2	0.80	1.77	**0.0005**	34.02	-0.0053
WS2	0.81	1.86	**0.0004**	35.95	-0.0058
Average Max-Temp	0.82	1.71	**0.0003**	35.73	-0.0056
PRECIPITATION					
DS1	0.54	15.79	**0.0042**	11.87	0.0808
DS2	0.01	49.00	0.7568	95.85	0.0221
WS1	0.01	36.17	0.8126	29.91	0.0125
WS2	0.02	50.05	0.6469	81.44	0.0335
Average Precipitation	0.05	28.34	0.4584	57.93	0.0310
PRECIPITATION WITHOUT MOMBASA AND MALINDI					
DS1	0.37	17.25	**0.0459**	11.53	0.0816
DS2	0.58	30.32	**0.0063**	8.35	0.2194
WS1	0.66	19.33	**0.0023**	-37.96	0.1655
WS2	0.01	54.62	0.8077	83.92	0.0280
Average Precipitation	0.55	20.09	**0.0088**	11.07	0.1366

3.0 Discussion

Numerous studies have shown that temperature decreases with an increase in altitude, whereas precipitation increases with an increase in altitude (Boon 1997; Godale *et al.,* 1998). However, the observed influence of altitude on both rainfall and temperature is not constant and varies from location to location depending on the proximity to local geographical features such as hills, mountains, valleys and large water bodies such as oceans and lakes. Boon (1997) noted that mountains can increase precipitation in regions by slowing the movement of storms, and causing uplifts of air masses, increasing precipitation. Hayward and Clarke (1996) noted that, while there was an increase in precipitation in monsoon facing slopes of mountain areas in Sierra Leone, the catches of rain gauges on the opposite side were considerably lower in the wet season. Distance from the large water bodies has also been shown to have an effect on local temperature and precipitation. Boon (1997) indicated that large water bodies such as the ocean cool the surrounding areas in hot months while warming the adjacent areas in cold months. Precipitation is also high neat large water bodies. The effect of large water bodies on local temperature and precipitation diminished as one moves away. For Southern Kenya, the high precipitation recorded in the stations close to the ocean during the first wet season, the second dry season and the second wet season can be attributed to a strong local effect of the nearby Indian Ocean. These stations also recorded lower than expected maximum temperatures. For the weather stations sampled, it was noted that there was no correlation between altitude and precipitation whereas the correlation between distance from the ocean and precipitation was strong. The second wet season showed variable rainfall between sites, with no clear patterns that could be modeled. This suggested that the precipitation recorded by the respective weather stations was strongly influenced by the local geography. It is recommended that more weather stations be placed in the region to enable better understanding of the second wet season.

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