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The Interdependence between Temperature and Rainfall in Rwanda

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ABSTRACT

Rainfall and temperature are important climatic inputs for agricultural production, especially in the context of climate change. However, accurate analysis and simulation of the joint distribution of rainfall and temperature are difficult due to possible interdependence between them. As one possible approach to this problem, five families of copula models are employed to model the interdependence between rainfall and temperature. Rwanda like other countries has been affected by climate change induced by temperature and increased precipitation. Historical climatic data for Rwanda is used to demonstrate the modeling process. Heteroscedasticity and autocorrelation of sample data are also considered to eliminate the possibility of observation error. The results indicate that in Rwanda, there are negative correlations between rainfall and temperature for the months January and February. Using copula model is the bivariate distribution of rain fall and temperature were modeled based on AIC and BIC. Using the Kendall correlation, we simulated temperature and rainfall simultaneously. The resulting models can be integrated with research on agricultural production and planning to study the effects of changing climate on crop yields.

Keywords: Rainfall, temperature, climate change

1. INTRODUCTION

Various human activities like agriculture, crop yield are affected by weather in the context of climate change. [1-3] Some studies revealed that catastrophic weather contributed to a loss of 93% of due to the unfavorable weather. [4] Rainfall and temperature are the important weather factors that affect significantly agriculture and crop yield. [5-7] In order to make accurate modeling and prediction in order to assist farmers in taking advantages of better weather conditions by reducing their exposure to unsuitable climatic conditions, multivariate weather distributions have shown to accurately facilitate in forecasting future water conditions. [8]

A lot of researches addressed the effects of temperature and rainfall agriculture and crop yield. Rainfall has shown to account for approximately 79.8% of the variance of seed yield. [9] It has shown also to have effect on health of the population. [10, 11]

Certain study found that lower temperature can increase the length of time that the maize could intercept radiation and hence grow. [12] Another study revealed that roughly 17% relative decrease corn and soybean for each increase in temperature. [13]Actually temperature and rainfall are significant determinants of agriculture crop

yield across the continent, therefore accurate simulation of rainfall and temperature is of crucial concern for meteorology as well as for agricultural economics. However, the interdependence between rainfall and temperature makes it difficult to simulate rainfall and temperature simultaneously. [14, 15] In spatial perspective, it is believed that a significant correlation between temperature and rainfall over tropical oceans and land exists, [16-18] In temporal point of view, it is has been show that the correlation between rainfall and temperature varies between months. [19,20] Multivariate probability simulation is suitable for addressing the interdependence that exists between temperature and rainfall using copula method. [21]

2. MATERIALS AND METHODS

2.1. Study Area

Rwanda is a landlocked country in the Great Rift Valley where the African Great Lakes region and East Africa converge Located a few degrees south of the Equator. It is highly elevated with its geography dominated by mountains in the west and savanna to the east, with numerous lakes throughout the country. The climate is temperate to subtropical, with two rainy seasons and two dry seasons each year

2.2. Data Collection and Preliminary Analysis

Monthly temperature and rainfall data for Rwanda from 1961 to 2016 was obtained from climate knowledge portal of the World Bank. [22]

2.3. Statistical analysis

Descriptive statistics with mean, standard deviation, minimum, maximum, median, and Interquartile ranges were performed on the rainfall and temperature in Rwanda from 1961 to 2016. In addition, Kendall correlations were used to model the interdependence between the probability distributions of a certain month's temperature and rainfall. All statistical calculations were performed using R 3.6.3.

3. RESULTS AND DISCUSSION

3.1. Monthly rainfall in Rwanda from 1961~2016

Monthly average rainfall in Rwanda shows a clear seasonal cycle from 1961 to 2016. The average temperature usually reaches its peak in April and its bottom in July (Table 1, figure 1). This is mainly due to the fact that the rainy season in Rwanda long rainy season starts from march too may which is usually persistent, heavy and regular. The short rainy season that starts from October to November varies geographically across the country, with the west and northwest parts of the Rwanda receiving more annual precipitation than southeast and the eastern part of the country. Rain usually fall during the night or the early morning hours but the sun comes out again during the day.

Table1: Annual rainfall in Rwanda from 1961~2016

	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
Jan	17.8	77.7	97.2	100.5	120.5	211.9
Feb	16.8	78.9	101.9	102.9	123.4	273.0
Mar	47.5	120.4	139.9	140.3	163.6	241.7
Apr	49.9	129.6	158.6	154.8	183.8	268.4
May	33.5	83.7	107.1	111.7	139.4	219.0
Jun	0.2	13.7	26.1	34.0	48.7	131.1
Jul	0.1	6.0	11.4	18.0	21.5	110.8
Aug	1.0	24.4	37.2	42.0	59.5	119.9
Sep	19.3	69.8	86.9	95.8	113.6	507.0
Oct	48.1	95.2	108.7	114.3	128.6	255.4
Nov	49.1	104.6	132.7	135.7	155.7	281.4
Dec	33.9	98.0	122.9	120.3	136.5	224.0

3.2. Monthly temperature in Rwanda from 1961~2016

Despite a clear seasonal cycle shown by rainfall, monthly temperature in Rwanda also doesn't show a clear seasonal cycle from 1961 to 2016(Table 2, figure 1). The average monthly temperature is similar across the year. Global warming has caused

a change in the pattern of the rainy seasons. Probably due to the climate change, the numbers of rainy days experienced during a year have been reduced however increase in the frequency of torrential rains has been observed. Sometimes rain is restricted to certain areas during the day whereas others remain dry. Mostly it rains more frequently and heavily in the northeast, where the volcanoes are covered by rainforest.

Table2:

	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
Jan	16.0	18.6	19.3	19.1	19.6	21.2
Feb	16.3	18.8	19.4	19.3	19.9	22.6
Mar	16.2	18.8	19.3	19.2	19.8	21.4
Apr	16.1	18.6	19.1	19.0	19.5	21.2
May	16.2	18.6	19.1	19.0	19.5	21.1
Jun	15.8	18.3	18.8	18.7	19.3	20.4
Jul	16.0	18.0	18.6	18.5	19.0	20.8
Aug	16.8	18.9	19.4	19.3	19.8	21.5
Sep	16.7	19.2	19.5	19.5	19.9	21.0
Oct	16.8	19.1	19.4	19.4	19.8	21.1
Nov	16.3	18.8	19.1	19.1	19.6	21.4
Dec	15.6	18.4	19.0	18.8	19.3	22.4

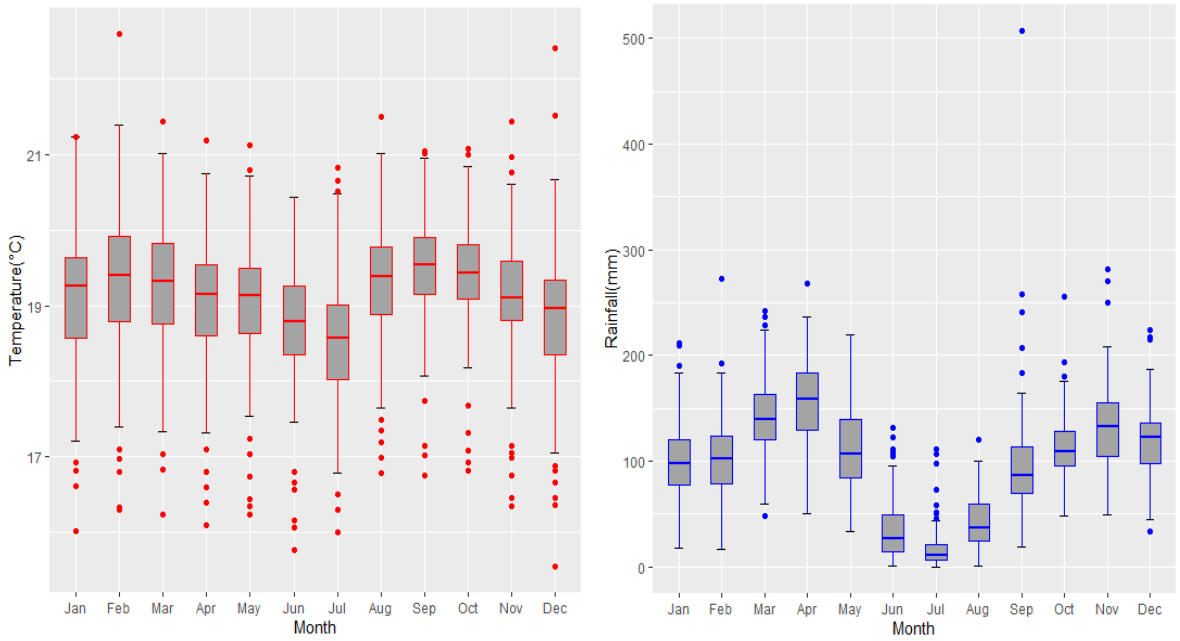

Figure 1: The monthly distribution of temperature and rainfall in Rwanda 1961-2016

Table3:

	Jan	*Feb*	*Mar*	*Apr*	*May*	*June*
Kendall correlation coefficient	0.222	-0.1301	-0.068	-0.098	-0.017	0.017
P-Value	**0.0003**	**0.038**	0.2787	0.1175	0.781	0.781
	Jul	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Kendall correlation coefficient	-0.0334	-0.003	0.021	0.05	-0.047	-0.085
P-Value	0.594	0.96	0.727	0.424	0.4494	0.174

3.3. Correlation analysis for monthly rainfall and temperature in Rwanda from 1961 to 2016.

The physical rationale behind the rainfall-temperature relationship is that rainfall can affect soil humidity, which can in turn affect surface temperature by controlling the partitioning of sensitive and latent heat fluxes. [23] As the sample data is non-Gaussian distributed and skewed, Kendall correlation coefficient was adopted to calculate the correlation between monthly temperature and rainfall. The positive correlation between rain fall and temperature were found in January (0.222, P<0.0003) and a strong negative correlation

between rainfall and temperature observed in February (-0.1301, P<0.038) (Table 3).

4. CONCLUSIONS

This paper assessed the correlation between rain fall and temperature in Rwanda from 1961 to 2016. The positive significant correlation was found in January and the significantly negative correlation was found in February. These study findings are of great interest in agricultural production in Rwanda especially in the context of climate change.

5. REFERENCES

1. Black, J.R. and S.R. Thompson, Some Evidence on Weather-Crop-Yield Interaction. American Journal of Agricultural Economics, 1978. 60(3): p. 540-543.
2. Alexandrov, V.A. and G. Hoogenboom, The impact of climate variability and change on crop yield in Bulgaria. Agricultural and Forest Meteorology, 2000. 104(4): p. 315-327.
3. Vining, K.C., Effects of weather on agricultural crops and livestock: an overview. International Journal of Environmental Studies, 1990. 36(1-2): p. 27-39.
4. Vergara, O., et al., Modeling the Potential Impact of Catastrophic Weather on Crop Insurance Industry Portfolio Losses. American Journal of Agricultural Economics, 2008. 90: p. 1256-1262.
5. Runge, E.C.A., Effects of Rainfall and Temperature Interactions during the Growing Season on Corn Yield1. Agronomy Journal, 1968. 60(5): p. 503-507.
6. Abbate, P.E., et al., Climatic and Water Availability Effects on Water-Use Efficiency in Wheat. Crop Science, 2004. 44(2): p. 474-483.
7. Medori, M., et al., The Impact of Root Temperature on Photosynthesis and Isoprene Emission in Three Different Plant Species. The Scientific World Journal, 2012. 2012: p. 525827.
8. Jones, J.W., et al., Potential benefits of climate forecasting to agriculture. Agriculture, Ecosystems & Environment, 2000. 82(1): p. 169-184.
9. Erskine, W. and F. Ashkar, Rainfall and temperature effect on lentil (Lens culinaris) seed yield in Mediterranean environments. The Journal of Agricultural Science, 1993. 121: p. 347-354.
10. 10. Rudasingwa, G. and S.-I. Cho, Determinants of the persistence of malaria in Rwanda. Malaria Journal, 2020. 19(1): p. 36.
11. Guillaume, R., Determinants of the Prevalence of Malaria in Rwanda. 2019, 서울대학교 대학원.
12. Muchow, R.C., T.R. Sinclair, and J.M. Bennett, Temperature and Solar Radiation Effects on Potential Maize Yield across Locations. Agronomy Journal, 1990. 82(2): p. 338-343.
13. Lobell, D.B. and G.P. Asner, Climate and Management Contributions to Recent Trends in U.S. Agricultural Yields. Science, 2003. 299(5609): p. 1032-1032.
14. Tanarhte, M., P. Hadjinicolaou, and J. Lelieveld, Intercomparison of temperature and precipitation data sets based on observations in the Mediterranean and the Middle East. Journal Of Geophysical Research-Atmospheres, 2012. 117.
15. Jaswal, A., V. Singh, and S. Bhambak, Relationship between sea surface temperature and surface air temperature over Arabian Sea, Bay of Bengal and Indian Ocean. Indian Geophysical Union, 2012. 16: p. 41-53.
16. Adler, R., et al., Relationships between global precipitation and surface temperature on interannual and longer timescales (1979-2006). Journal of Geophysical Research-Atmospheres, 2008. 113: p. D22104.
17. Aldrian, E. and R. Susanto, Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. Int. J. Climatol., 2003. 23: p. 1435-1452.
18. Black, E., The relationship between Indian Ocean sea-surface temperature and East African rainfall: One contribution of 24 to a Discussion Meeting 'Atmosphere-ocean-ecology dynamics in the Western Indian Ocean'. Philosophical Transactions of The Royal Society A: Mathematical, Physical and Engineering Sciences, 2005. 363: p. 43-47.
19. Rajeevan, M., D.S. Pai, and V. Thapliyal, Spatial and temporal relationships between global land surface air temperature

anomalies and Indian summer monsoon rainfall. Meteorology and Atmospheric Physics, 1998. 66(3): p. 157-171.
20. Huang, Y., et al., Correlation of precipitation to temperature variation in the Huanghe River (Yellow River) basin during 1957–2006. Journal of Hydrology, 2009. 372: p. 1-8.
21. AghaKouchak, A., A. Bárdossy, and E. Habib, Conditional simulation of remotely sensed rainfall data using a non-Gaussian v-transformed copula. Advances in Water Resources, 2010. 33(6): p. 624-634.
22. World Bank Group, Climate Data, in Historical data, W. Bank, Editor. 2016: Geneva.
23. Huang, J. and H.M. van den Dool, Monthly Precipitation-Temperature Relations and Temperature Prediction over the United States. Journal of Climate, 1993. 6(6): p. 1111-1132.

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