ISSN 0354-8724 (hard copy) | ISSN 1820-7138 (online)

The Future Climatic Variabilities in the Mano River Union, its Implications on Socio-Economic Development

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Received: February 27, 2022 | Revised: June 29, 2022 | Accepted: June 30, 2022
doi: 10.5937/gp26-36677

Abstract

Knowledge of climatic variability of any country or region is essential to socio-economic development. This is particularly important as most sectors of national development can be altered if the climatic conditions are unsuitable. A hypothetical case lies in the fact that agriculture largely depends on apposite climate for fruitful production. The Mano River Region consists of some of the world's poorest and least developed nations (Guinea, Sierra Leone, Liberia, Cote D'Ivoire). The primary means of sustenance in this region is rain-fed agriculture. Knowledge of current and future climatic conditions in the region will be of significant benefit to the economy of the region. This work investigates the current and future state of climate in the region using six climatic parameters (Maximum and minimum temperature, Precipitation, Relative Humidity, Wind Speed and Solar Radiation) spanning 1975—2018. To model the impact/relationship, Kalman Filter was used. These variables were grouped into state transition and control variables. Transfer functions which depict relationships between every two variables at a time with one being input and the other considered as output were used to determine state transition and control variable matrices. Control variables (population and land use) were introduced to control the dynamism of the model in MATLAB environment. Results show that there is a drastic variation in climate in the region within the period of the data. This work establishes that there are rapid variabilities in these parameters which can be attributed to increase in population and loss of vegetation.

Keywords: Kalman Filter; Transfer Function; Climatic Variability

Introduction

The world over is faced with the increasing devastating effects of climate change. Developed countries have a better understanding of the nature of their climate, hence, there are mitigation strategies in place to ameliorate the adverse effect of climate change and other environmental issues on its citizens and economy (Butler, 2018). On the contrary, although Africa is most likely to experience extreme negative consequence of climate change, there is particularly low level of understanding of climate change variability within the region. Additionally, lack of institutional framework, high climate variability and high dependence on rainfed agriculture (Sultan et al., 2016; Abrams, 2018) and inconsistencies in model prediction (Sorland et al., 2018) could worsen the consequences. Countries of this region which are predominant-

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ly least developed nations have low adaptive capacity for climate change, hence, the need for immediate and urgent study to enhance climate change monitoring. It has been indicated in previous works that the highest concentration of vulnerability is located along coastal zones of West Africa. Political instability in the West African sub region has made development of institutional framework impossible (Seiyefa, 2019). In an effort to institute mitigation strategies in countries of this nature, knowledge of the climate dynamics in the region is highly essential.

Climatic variabilities can be attributed to both natural and anthropogenic causes. While solutions to the natural causes are somehow beyond the capacity of humans, those of anthropogenic causes can be reduced when the right mechanisms are instituted. Dominating the list of anthropogenic causes is the drastic increase in population which subsequently breeds urbanization. As urbanization occurs, land no longer remains the same. As a result, loss of vegetation in the region has assumed a threatening dimension.

The impact of climatic variabilities on man and the environment can be of serious consequence since it touches on factors that are fundamental to human existence such as agriculture/vegetation, soil/land, water, air, and temperature among others all at local and global scales (Maviza & Ahmed, 2021). Bearing in mind the fact that West African sub-region and particularly the MANO River Union (MRU) survives predominantly on Agriculture (Asare-Nuamah & Botchway, 2019), bearing also in mind that climatic variabilities can exert grave consequence on agriculture, it is therefore important to undertake a research on climatic variabilities in the region. Results of the research will provide the required information for mitigating any foreseeable negative consequences on agriculture in particular and the environment in general.

There exist few literatures on climatic variability in the MRU region, therefore information about variabilities was scanty. Soro et al. (2017) showed that temperature in Cote D'Ivoire will increase by 1.2°C to 3°C by the year 2060 whereas rainfall will increase by 5% to 23% during this period. These findings are in agreement with Kouakou et al. (2012) for average temperature (3°C to 4.1°C) with slight disagreement in rainfall prediction (31.40% to 55.4%). It is predicted that these variations might have adverse effects on future cocoa production which will subsequently affect the national economy given the fact that cocoa contributes significantly to the national revenue of that MRU nation (Coulibaly et al., 2017).

Although Liberia is highly vulnerable to the impacts emanating from climatic variabilities, not much has been done in addressing climate change. According to the United States Agency for International Development (USAID) 2014 published report, an average increase in annual temperatures in Liberia is expected by the 2050s to vary anywhere between 1.4°C – 4.7°C from 2008 (Stanturf et al., 2013). Available climate model suggests that an overall increase in average annual rainfall as well as in the number of heavy rainfall events will occur in Liberia in the coming years (USAID, 2012). A country with agriculture supporting approximately 75% of rural dwellers, any change in the climate system will gravely affect food security and floods especially when 58% of the country's population reside in coastline areas (Stanturf et al., 2013).

The climate of Sierra Leone has some differences as compared to other parts of the MRU. This is due to the sharp topographic and ecological gradients of the country (Jalloh et al., 2011). Sierra Leone lacks adequate climatic information required for decision making. Therefore, researchers used global models of the Sierra Leone climate system to make local derivation (Trzaska et al., 2017). Global models have made long term predictions of Sierra Leone with an increasing value of average annual temperature between 1.5°C to 4°C from 2016.

The Republic of Guinea is expected to experience high variabilities with average temperature ranging between 0.3°C to 4.8°C by the year 2050 from year 2000, precipitation is expected to drop by 36.4% (Distefano, 2012). Loua et al. (2017) analyze meteorological parameters (1931-2014) trends with some agroclimatic risks in Guinea. The study ascertained that there is a variation in rainfall with September of each year being the highest recorded month. It was also found that the current average temperature in the study area ranges between minimum 15°C – 21°C and maximum 26°C – 33°C.

These studies are however limited in that they did not consider other factors of climatic varaibility namely: Relative Humidity, Wind Speed, Solar Radiation, Atmospheric Pressure, etc. These parameters play specific roles in the dynamism of any climatic system. Therefore, this study employs additional parameters along with Temperature and Precipitation to explain the climate system in the region.

A climate system can be approximated to any dynamic system in which changes in constituent members alter the dynamics of the overall system (state). Knowledge of the past and current conditions of a state is central to determining the future of the state. Kalman Filter as a state estimator can be used in climatic studies since it is capable of providing information of a state (climate) at any point in time (past, present and future) in the presence of external disturbance given the rightful input parameters (Soubdhan et al., 2016). Various studies have been conducted to examine the effect of various filtering methods on ability to predict climatic vraibilities, the Kalman filter is considered to be most preferred method for these methods based on the accuracy of the results obtained (Neslihanoglu et al., 2021). It must however be noted that Kalman filter may not be the best method for a non-linear situations. The linear system demonstrated in some literatures as being able to accurately predict climate (Sreehari & Pradeep-Ghantasala, 2019) is assumed in this study.

It is against this background that this study uses Kalman Filter to model climatic variabilities in the MRU region using historical climatic data and control variables of population and land use. Kalman Filter as a state estimator, is used to approximate the dynamic nature of the climate in the region and making accurate predictions for future purposes.

Study area

The Mano River Union (MRU) was originally established between Liberia and Sierra Leone on October 3, 1971. Guinea and Cote D'Ivoire later joined on October 25, 1980 and May 15, 2008 respectively. The core objective of the union is to accelerate economic growth, social progress and cultural advancement amongst members by active collaboration and mutual assistance in matters of common interest in economic, social, technical scientific and administrative fields (MRU, 1974). The union faced series of challenges in meeting its objective due to political instability which engulfed the region between 1989 and 2003 (USAID, 2003). The region remains one of the poorest parts of the world with majority of the citizens of these nations living below the poverty line (World Bank, 2018).

The Mano River Union consists of four West African countries as shown in Figure 1. The name of the Union was derived from the Mano River which begins in the Guinea highlands and forms a border between Liberia and Sierra Leone. The region lies between latitude 4oN and 13oN and longitudes 3oW and 15oW with the southern part of the region covered by the Atlantic Ocean. The Northern part of the region is predomantly occupied by the Sahel region. The current population in the region is approximately 47 Million (UNDP, 2017).

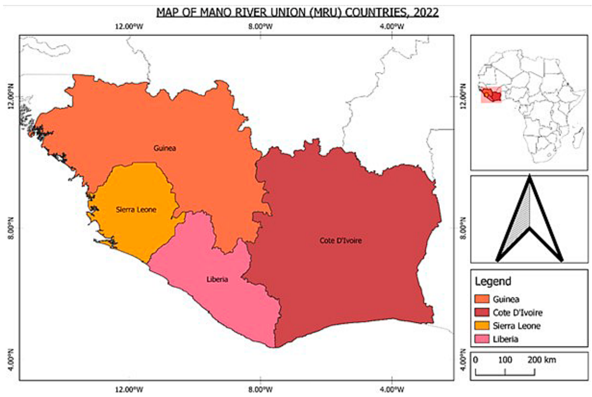

Figure 1. The study area (MRU Countries)
Source: Author, 2022

Materials and methods

Data

As indicated in Table 1, the data used for this study were obtained from different sources and reconciled for all years between 1975 and 2018. Average temperature was computed from maximum and minimum temperature values. The data was recorded on a daily basis and loaded in Microsoft Excel in a pivot table with yearly average computed.

Kalman Filter

Linear Quadratic Estimation (LQE) or otherwise known as Kalman filtering is an algorithm that uses a series of measurements observed over time, containing statistical noise and other inaccuracies, and produces estimates of unknown variables that tend to be more precise than those based on a single measurement alone (Welch and Bishop, 2001). The Kalman

Table 1. Data and Sources

No.	Data	Source	Period
1	Longitude, latitude, elevation (m), maximum temperature1(°C), minimum temperature (°C), precipitation (inch), wind speed (m/s), relative humidity (%), solar radiation (mj/m²)	National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) https://globalweather.tamu.edu	1901-2018
2	Land Use (km²)	West Africa: Land Use and Land Cover Dynamics (30m resolution) https://eros.usgs.gov/westafrica/land-cover/land-use-and-land-cover-trends-west-africa	Epochs 1975, 2000, 2013
3	Population	United Nations World Population Prospects 2017 https://esa.un.org/unpd/wpp/	1950 – 2018

Filter can be divided into two stages, **prediction** and **update** as indicated in Figure 2. Details of the Kalman Filter equations are in Table 2.

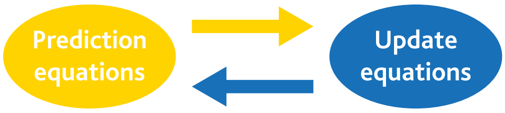

Figure 2. Fundamental of Kalman Filter
Source: Author, 2022

Data Gaps

The period of the data vary with respect to the dataset. Therefore, the data were reconciled with 1975 – 2018 being the common period for all data. Most of the data obtained are daily records. They were averaged to determined monthly values. The linear interpolation formula in equation (7) was used to account for data gaps.

$$(y-y_1)=\left(\frac{y_2-y_1}{x_2-x_1}\right)(x_2-x_1) \qquad (1)$$

- Where y= the value to be interpolated, y_1 = the previous climatic data at time x_1, y_2 = the next climatic data at time x_2. Table 3 is a list of all working variables used in this study with symbolic representation.

State Transition Matrix

The State Transition Matrix of Kalman Filter is the matrix that relates the input of the system to the model. Six parameters (Maximum Temperature, Minimum Temperature, daily Precipitation, Relative Humidity, Wind Speed and Solar Radiation) made up the input parameters.

Table 3. Definition of Working Variables

No	Parameter	Representation
1	Maximum Temperature	Mx
2	Minimum Temperature	Mn
3	Precipitation	Pr
4	Wind Speed	Ws
5	Relative Humidity	Rh
6	Solar Radiation	Sr
7	Population	Po
8	Land Use	Lu

Control Variables

These are variables responsible to control the dynamism of the system. The control variables relate the model to the climatic variables. In this case, land use and population were selected as Control Variables. The control variables were chosen as indicated in previous literature (Galanis et al., 2006).

Table 2. Kalman Filter Equations

Prediction Equations		
Name and Equation	**Definition of terms**	**Equation No.**
Predicted State $X_{k_p}=Ax_{k-1}+B\mu_k+w_k$	X_{kp} is the Current State A is the State Transitional Matrix x_{k-1} is the previous state B is a transition Matrix μ_k Control Variable Matrix w_k Error	(2)
Process Covariance $P_{k_p}=AP_{k-1}+A^T+Q_k$	P_{kp} is the Process Covariance Matrix P_{k-1} Previous Covariance Matrix Q_k Process Covariance Error	(3)
Update Equations		
Kalman Gain $K=\frac{P_{k_p}H}{HP_{k_p}H^T+R}$	K is the Kalman Gain H is an identity matrix the same dimension as A R is the error. Note 0<K<1	(4)
Measurement update $Y_k=CY_k+Z_k$	Y_k the New Measurement C is a vector which is the same as the Identity matrix Y_k Measurement from sensor (data) Z_k Error related to the sensor	(5)
State Update $X_k=X_{kp}+K\left[Y_k-HX_{k_p}\right]$	X_k Updated measurement X_{kp} is the predicted state Y_k measured value	(6)
Process Covariance $P_k=(I-KH)P_{k_p}$	P_{kp} predicted previous process covariance matrix	(7)

Transfer Functions

These are functions that relate input to output of a system. For a continuous system, it is the Laplace Transform of output to input. To determine the transfer functions which will be used for the State Transition and Control Variable matrices, the data was converted to polynomial using Lagrange Interpolation for unequal interval. The Laplace Transform of the resulting equation taken, and using least square, the unknowns were determined. These were now aggregated into the State Transition and Control Variables Matrices.

The state transition matrix (A) for the Kalman Filter process becomes all transfer function determined as given in Equation 8.

$$A = \begin{bmatrix} MxMx & MxMn & MxPr & MxWs & MxRh & MxSr \\ MnMx & MnMn & MnPr & MnWs & MnRh & MnSr \\ PrMx & PrMn & PrPr & PrWs & PrRh & PrSr \\ WsMx & WsMn & WsPr & WsWs & WsRh & WsSr \\ RhMx & RhMn & RhPr & RhWs & RhRh & RhSr \\ SrMx & SrMn & SrPr & SrWs & SrRh & SrSr \end{bmatrix} \quad (8)$$

Similarly, the control variable matrix becomes:

$$B = \begin{bmatrix} LuMx & PoMx \\ LuMn & PoMn \\ LuPr & PoPr \\ LuWs & PoWs \\ LuRh & PoRh \\ LuSr & PoSr \end{bmatrix} \quad (9)$$

Equation (10) is the final model determined throughout the process for all six climatic variables in the region.

$$\begin{pmatrix} Mx \\ Mn \\ Pr \\ Ws \\ Rh \\ Sr \end{pmatrix} = \begin{pmatrix} MxMx & MxMn & MxPr & MxWs & MxRh & MxSr \\ MnMx & MnMn & MnPr & MnWs & MnRh & MnSr \\ PrMx & PrMn & PrPr & PrWs & PrRh & PrSr \\ WsMx & WsMn & WsPr & WsWs & WsRh & WsSr \\ RhMx & RhMn & RhPr & RhWs & RhRh & RhSr \\ SrMx & SrMn & SrPr & SrWs & SrRh & SrSr \end{pmatrix} \begin{pmatrix} Mx_{k-1} \\ Mn_{k-1} \\ Pr_{k-1} \\ Ws_{k-1} \\ Rh_{k-1} \\ Sr_{k-1} \end{pmatrix} + \begin{pmatrix} LuMx & PoMx \\ LuMn & PoMn \\ LuPr & PoPr \\ LuWs & PoWs \\ LuRh & PoRh \\ LuSr & PoSr \end{pmatrix} \begin{pmatrix} Po \\ Lu \end{pmatrix} + \begin{pmatrix} w_{Mx} \\ w_{Mn} \\ w_{Pr} \\ w_{Ws} \\ w_{Rh} \\ w_{Sr} \end{pmatrix} \quad (10)$$

Where

$\begin{pmatrix} Mx \\ Mn \\ Pr \\ Ws \\ Rh \\ Sr \end{pmatrix}$ = Current State , $\begin{pmatrix} MxMx & MxMn & MxPr & MxWs & MxRh & MxSr \\ MnMx & MnMn & MnPr & MnWs & MnRh & MnSr \\ PrMx & PrMn & PrPr & PrWs & PrRh & PrSr \\ WsMx & WsMn & WsPr & WsWs & WsRh & WsSr \\ RhMx & RhMn & RhPr & RhWs & RhRh & RhSr \\ SrMx & SrMn & SrPr & SrWs & SrRh & SrSr \end{pmatrix}$ = State Transition Matrix, $\begin{pmatrix} Mx_{k-1} \\ Mn_{k-1} \\ Pr_{k-1} \\ Ws_{k-1} \\ Rh_{k-1} \\ Sr_{k-1} \end{pmatrix}$ = Previous State

$\begin{pmatrix} LuMx & PoMx \\ LuMn & PoMn \\ LuPr & PoPr \\ LuWs & PoWs \\ LuRh & PoRh \\ LuSr & PoSr \end{pmatrix}$ = Control Variable Matrix, $\begin{pmatrix} Po \\ Lu \end{pmatrix}$= Control Variables, $\begin{pmatrix} w_{Mx} \\ w_{Mn} \\ w_{Pr} \\ w_{Ws} \\ w_{Rh} \\ w_{Sr} \end{pmatrix}$ = Error

The model is generalized below:

$$x_{(1:m,\,1)} = \boldsymbol{A}_{m\times m} x_{[(1:m,\,1)-1]} + \boldsymbol{B}_{(1:m,1:l)}\, u_{l\times 1} + w_{m\times 1} \quad (11)$$

- Where,
  m, m = size of $\boldsymbol{A}$
  l = Number of columns in $\boldsymbol{B}$

Equation (10) is the Kalman Filter prediction equation for the entire process. The current state which is the state of interest and is based on the previous state, the initial process covariance matrix and the control variable matrix. At each stage of the process, the state of the climate in the region can be approximated.

Spatial Interpolation

The data was spatially interpolated to create a spatial distribution over the region for each climatic variable in ArcGIS 10.4 using the Kriging algorithm.

Rate of Change

After the computation of the state (status of the climatic system) at each year of interest, it is compared with the previous year of the initial year of the entire dataset. Due to this, the dataset was divided into decades commencing from 1980 to the year of interest. The model is now capable of computing the change in the climate system after every ten years for each country for the entire West African Region. Equation (12) was used to determine the change in each parameter.

$$Y = \frac{x_2 - x_1}{x_1} \cdot 100\% \quad (12)$$

- Where Y is the percent change, x_2 is the value at the previous year and x_1 is the value at the current year.

Results and discussion

The results from this study was categorized into decadal values beginning with the year 2020 and ending 2050. The rate of change equation in Equation (12) was used to compute the decadal change for each country. The second part of this section deals with visualization, model validation and performance. To begin with, Table 4 shows results from the model represented in decadal form for all countries in the region.

Table 4 shows the summarized result of the parameters for the four countries in the Mano River Union after the implementation of the model with target year being 2050. Overall, Cote D'Ivoire is expected to have the highest recorded values of Average Temperature followed by Guinea. Solar radiation and wind speed are also expected to increase for the projected years. The least recordings of Average Temperature is expected to occur in Liberia followed by Sierra Leone. On the contrary, Liberia will experience the highest recording of precipitation for the projected years, followed by Sierra Leone while Guinea is expected to receive the least projected precipitation. Liberia is also expected to receive the highest values of relative humidity which subsequently supports the findings that increase in precipitation positively affects relative humidity. From the table, it is evident that densely populated countries have the highest increase in average temperature.

Considering these results in Table 4, Table 5 shows the rate of change for each country in the study area. From Table 5, the Mano River Union is expected to experience increase in annual average temperature by approximately 8%, annual precipitation of 3%, a change of 0.7% in wind speed, relative humidity of -14% and Solar Radiation of 5%. While percentage temperature obtained from a Celsius scale are generally considered unreliable, the results in this study

Table 4. Summary of Results

Country	Year	Ave. Temp (°C)	Precipitation (inch)	Wind Speed (m/s)	Relative Humidity (%)	Solar Radiation (mj/m²)	Land Use (km²)	Population
COTE D'IVOIRE	2020	27.07367	5.023181	1.806645	0.86425	18.30604	63,872	27,509,794
	2030	27.87305	4.696118	2.190408	0.784826	18.78541	60,841	37,261,376
	2040	28.75358	4.706665	2.238524	0.751066	19.65938	57,954	50,469,668
	2050	28.92612	4.719031	2.069686	0.761901	19.31016	55,204	68,359,991
GUINEA	2020	26.72547	5.257016	2.430891	0.700531	19.36799	16,209	13,842,319
	2030	27.36835	5.312469	2.417552	0.63562	20.12407	15,933	17,379,246
	2040	28.32824	5.72602	2.59795	0.577374	20.75238	15,663	21,819,913
	2050	28.35551	5.188646	2.303221	0.615088	20.21015	15,397	27,395,238
LIBERIA	2020	25.9289	8.413921	1.273107	0.973969	16.34489	65,787	5,133,237
	2030	26.40276	7.950083	1.506757	0.918969	16.64167	65,435	6,393,896
	2040	26.82904	8.961138	1.357428	0.914135	16.67668	65,085	7,964,156
	2050	27.11463	7.895248	1.437664	0.913442	16.4801	64,736	9,920,053
SIERRA LEONE	2020	26.58135	8.267902	1.691439	0.893027	17.66483	9,927	8,064,060
	2030	26.84456	7.924362	2.023584	0.854139	17.66575	9,581	9,623,757
	2040	27.28321	8.148898	2.053618	0.83009	18.07016	9,248	11,485,120
	2050	27.60995	7.489075	1.766792	0.829621	17.75088	8,926	13,706,496

nevertheless supports the idea that increase in atmospheric temperature results to decrease in relative humidity (Coffel et al., 2017). The projected value of annual temperature for 2050 is in agreement with the Intercontinental Panel of Climate Change value of 0.5 to +4oC and those of Sylla et. al (2016) for the West African Subregion (IPCC, 2013).

Table 6 shows the covariance between climatic parameter for each country in the region. As shown, there are numerous relationship that can be deduce from the table above. Notably among them is the covariance between parameters in Liberia and Cote D'Ivoire. These values are relatively similar with the only difference occurring in precipitation and solar radiation. In Liberia, Solar Radiation has a positive

Table 5. Rate of Change of Parameters

Country	Year	Average Temperature (%)	Precipitation (%)	Wind Speed (%)	Relative Humidity (%)	Solar Radiation (%)
COTE D'IVOIRE	2030	0.00295	-0.00651	0.02124	-0.00919	0.00262
	2040	0.00316	0.00022	0.00220	-0.00430	0.00465
	2050	0.00060	0.00026	-0.00754	0.00144	-0.00178
GUINEA	2030	0.02405	0.01055	-0.00549	-0.09266	0.03904
	2040	0.03507	0.07785	0.07462	-0.09164	0.03122
	2050	0.00096	-0.09385	-0.11345	0.06532	-0.02613
LIBERIA	2030	0.00183	-0.00551	0.01835	-0.00565	0.00182
	2040	0.00161	0.01272	-0.00991	-0.00053	0.00021
	2050	0.00106	-0.01189	0.00591	-0.00008	-0.00118
SIERRA LEONE	2030	0.00099	-0.00416	0.01964	-0.00435	0.00001
	2040	0.00163	0.00283	0.00148	-0.00282	0.00229
	2050	0.00120	-0.00810	-0.01397	-0.00006	-0.00177
Total		0.07511	-0.02559	-0.00692	-0.14452	0.05100

Table 6. Covariance Matrix for parameters in the region

COUNTRY	PARAMETERS	Average Temperature	Precipitation	Wind Speed	Relative Humidity	Solar Radiation
COTE D'IVOIRE	Ave. Temperature	0.734	-2.796	0.117	-0.041	0.482
	Precipitation	-2.796	16.153	-0.734	0.195	-1.849
	Wind Speed	0.117	-0.734	0.037	-0.009	0.089
	Relative Humidity	-0.041	0.195	-0.009	0.003	-0.028
	Solar Radiation	0.482	-1.849	0.089	-0.028	0.353
GUINEA	Ave. Temp	0.628	1.981	0.009	-0.038	0.396
	Precipitation	1.981	37.787	0.706	-0.206	2.485
	Wind Speed	0.009	0.706	0.015	-0.002	0.031
	Relative Humidity	-0.038	-0.206	-0.002	0.003	-0.029
	Solar Radiation	0.396	2.485	0.031	-0.029	0.324
LIBERIA	Ave. Temp	0.268	-0.539	0.024	-0.013	0.037
	Precipitation	-0.539	158.332	-0.805	0.043	0.482
	Wind Speed	0.024	-0.805	0.01	-0.002	0.009
	Relative Humidity	-0.013	0.043	-0.002	0.001	-0.004
	Solar Radiation	0.037	0.482	0.009	-0.004	0.024
SIERRA LEONE	Ave. Temp	0.209	-3.017	0.012	-0.012	0.043
	Precipitation	-3.017	76.022	0.194	0.16	0.315
	Wind Speed	0.012	0.194	0.033	-0.003	0.02
	Relative Humidity	-0.012	0.16	-0.003	0.001	-0.004
	Solar Radiation	0.043	0.315	0.02	-0.004	0.037

covariance with Precipitation but this value is negative in Cote D'Ivoire. For all countries, there is an inverse relationship between Average Temperature and Relative Humidity. There is also inverse relationship between relative humidity and wind speed in the region whereas a positive correlation exists between average temperature and solar radiation. With the exception of Cote D'Ivoire, solar radiation in the region has a positive covariance with relative humidity. The values in red are the respective variance in each country. It shows how each value deviates from the mean. It can be seen that precipitation has the highest variance in each case. This is because, there are some months of the year where precipitation recordings can be as low as 0 and for some months, precipitation recordings can reach values about 200mm.

MRU Future Climate and Impacts

The variabilities in any climate system have the ability to alter agriculture, water resources and biodiversity to a greater extent. According to the Intercontinental Panel on Climate Change (IPCC), warming above 2°C may counteract the positive effects of more rain on millet, cocoa, sorghum and other agriculture produce. Similarly, these variabilities could have an adverse effect on livestock production across the region.

As shown in Figure 3, coastal areas in the region will continue to experience regulated temperature. This is however due to the proximity of the area to the Atlantic Ocean. The increase in temperature varies as one moves from coastal areas to inland areas. For year 2050 (D), it can be seen that the spatial distribution of average temperature is gradually moving to the south east of the region. The northern parts of Cote D'Ivoire and Guinea shall experience the highest increase in temperature for the predicted years with annual average temperature reaching up to 31°C. These variabilities could have negative impacts on agricultural activities which serve as a means of livelihood for the population. In addition, loss of vegetation could stress cattle rearing and as such farmers and herdsmen could move further south to continue their activities. It is known that the movement of herdsmen has associated security implications.

In Figure 4, the decadal spatial distribution of precipitation over the MRU region is shown. The figure clearly show variability across the four decades. The intensity of precipitation in the region will be higher around coastal areas especially Liberia and Sierra Leone. From the central region to the north which is largely Guinea and Cote D'Ivoire, precipitation is expected to be lower than the coastal areas especially during the second half of the century. Increase in precipitation in the coastal region could indicate a possibility of flooding which is already being experienced in these countries (Nka et al., 2015; EM-DAT, 2018). The central and Northern regions are expected to experience drought at those areas are prone to drought (Climat Environnement Societe, 2012). The decrease in rainfall can lead to human and cattle migration to-

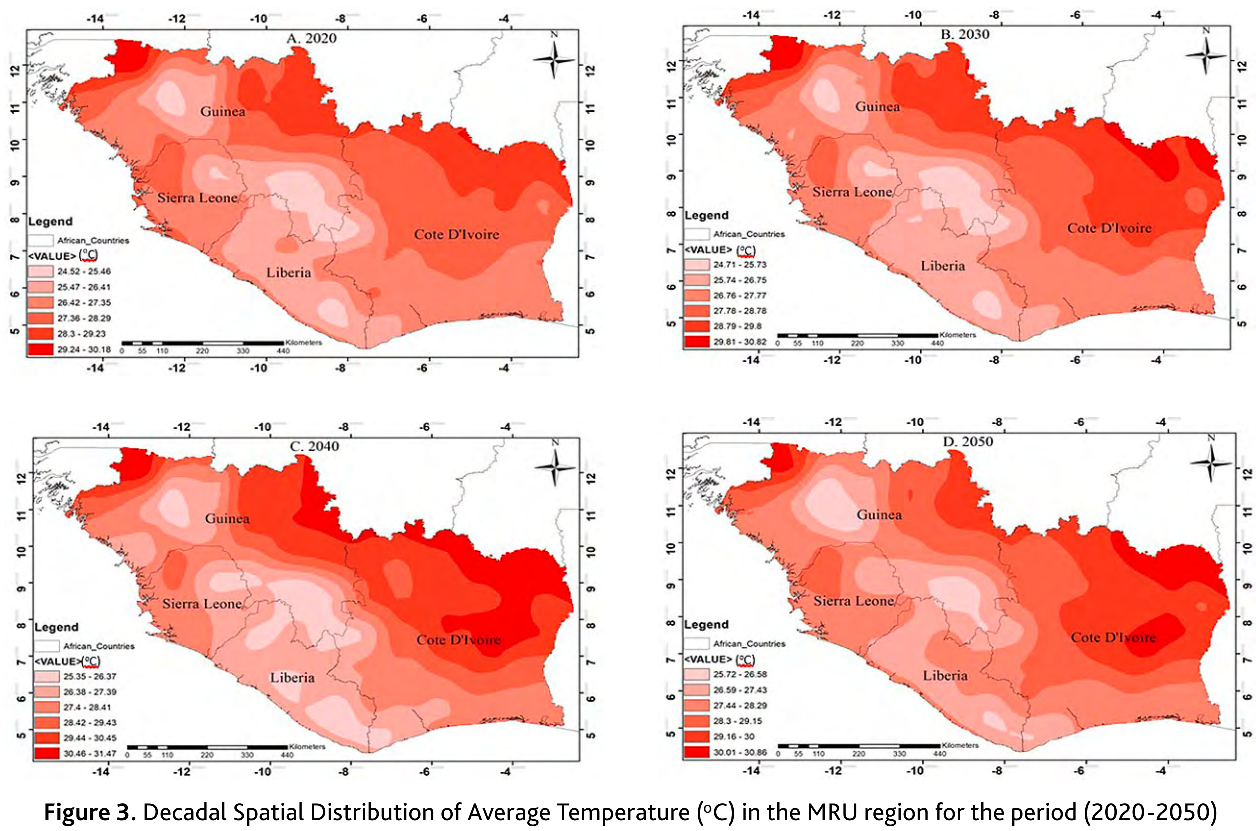

Figure 3. Decadal Spatial Distribution of Average Temperature (°C) in the MRU region for the period (2020-2050)

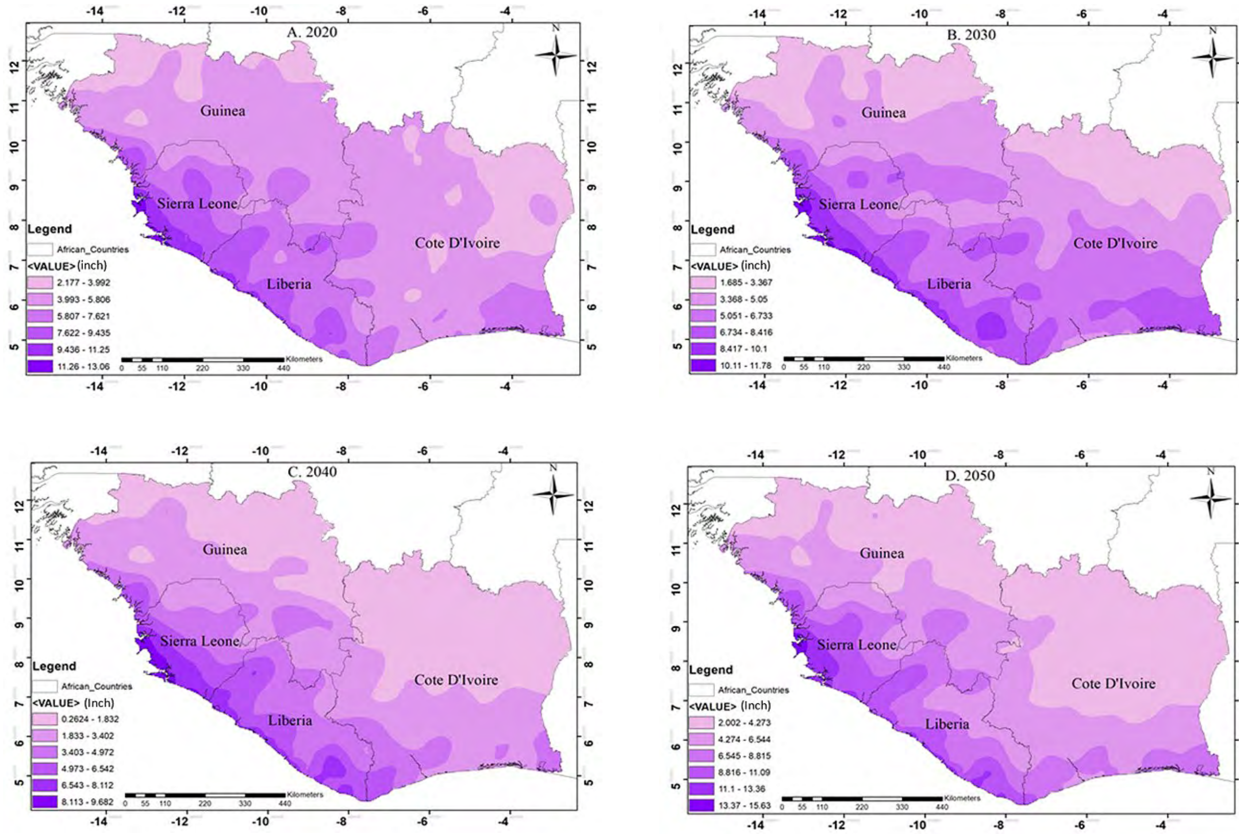

Figure 4. Decadal Spatial Distribution of Precipitation (inch) in the MRU region for the period (2020-2050)

wards areas where fodder crops are available (ECOWAS-SWAC, 2008). Cases have been seen in other West African nations where these migrations brought issues of security concern.

Figure 5 appears to be the opposite of Figure 3 which supports the finding that increase in atmospheric temperature results to decrease in relative humidity (Coffel et al., 2017). The density of relative humidity is gradually decreasing in the southern part of the region. Relative humidity indicates the likelihood of precipitation, dew, or fog which suggests that there is a direct relationship between relative humidity and rainfall. Coastal areas particularly Liberia and Sierra Leone will have the highest predicted values of relative humidity. The northern part, particularly Cote D'Ivoire and Guinea shall receive the lowest predicted values of relative humidity. The region is set to experience heat stress because of rapidly growing population, severe threat to human health and energy infrastructure. Changes in Relative Humidity have the propensity to obstruct radio signals which can also affect GPS signals and other wireless networks (Luomala & Hakal, 2015).

Figure 6 shows the spatial distribution of Wind Speed across the study area for the period 2020 – 2050. As shown, the intensity of wind speed increases from coastal areas to northern parts. It is also shown that there is a positive correlation between the average temperature and wind speed in the region. The northern part which includes parts of Guinea and Cote D'Ivoire will receive the highest of wind speed as those areas are closer to the Sahel region. Areas with high wind speed have the potential for the utilization of wind energy. These are some of the few climatic parameters that have positive effects due to their variation.

As shown in Figure 7, solar radiation in the study area is lowest in the southern parts especially for Liberia, Sierra Leone and the middle belt of Cote D'Ivoire. The northern parts of the region shall experience high solar radiation as opposed to the south. This study agrees with Bazyomo et. al., (2016) that solar radiation in Liberia and Sierra Leone is on a downward trend but disagrees with the values obtained for Guinea and Cote D'Ivoire as solar radiation values are on the increase in these two countries (Guinea and Cote D'Ivoire). Solar radiation in some instances may exert significant negative impact on humans. Some of these effects include sunburns, skin cancer and cataract (Maria et al., 2013). Those areas in the region of high solar radiation can benefit for the utilization of solar potential for photovoltaic applications. This is one of the positive effects of climatic variabilities.

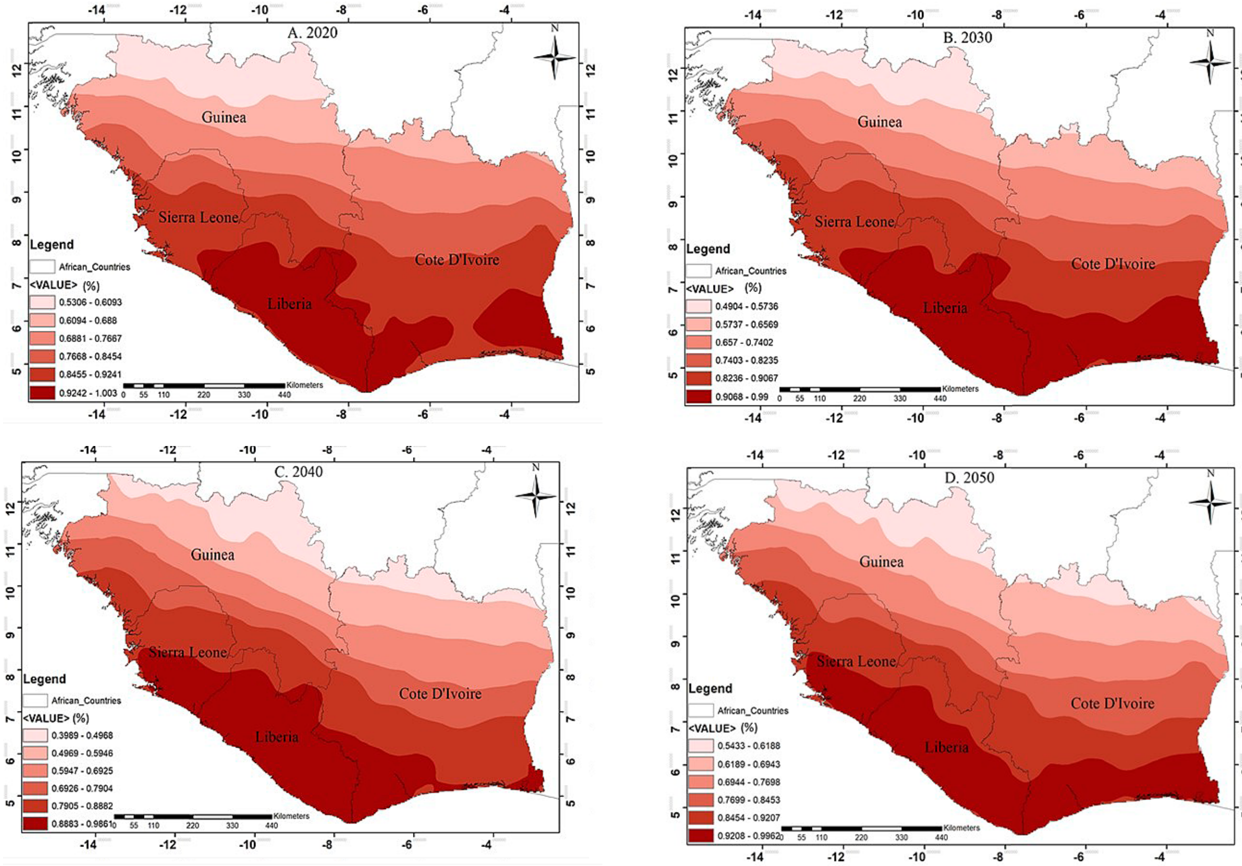

Figure 5. Decadal Spatial Distribution of Relative Humidity (%) in the MRU region for the period (2020-2050)

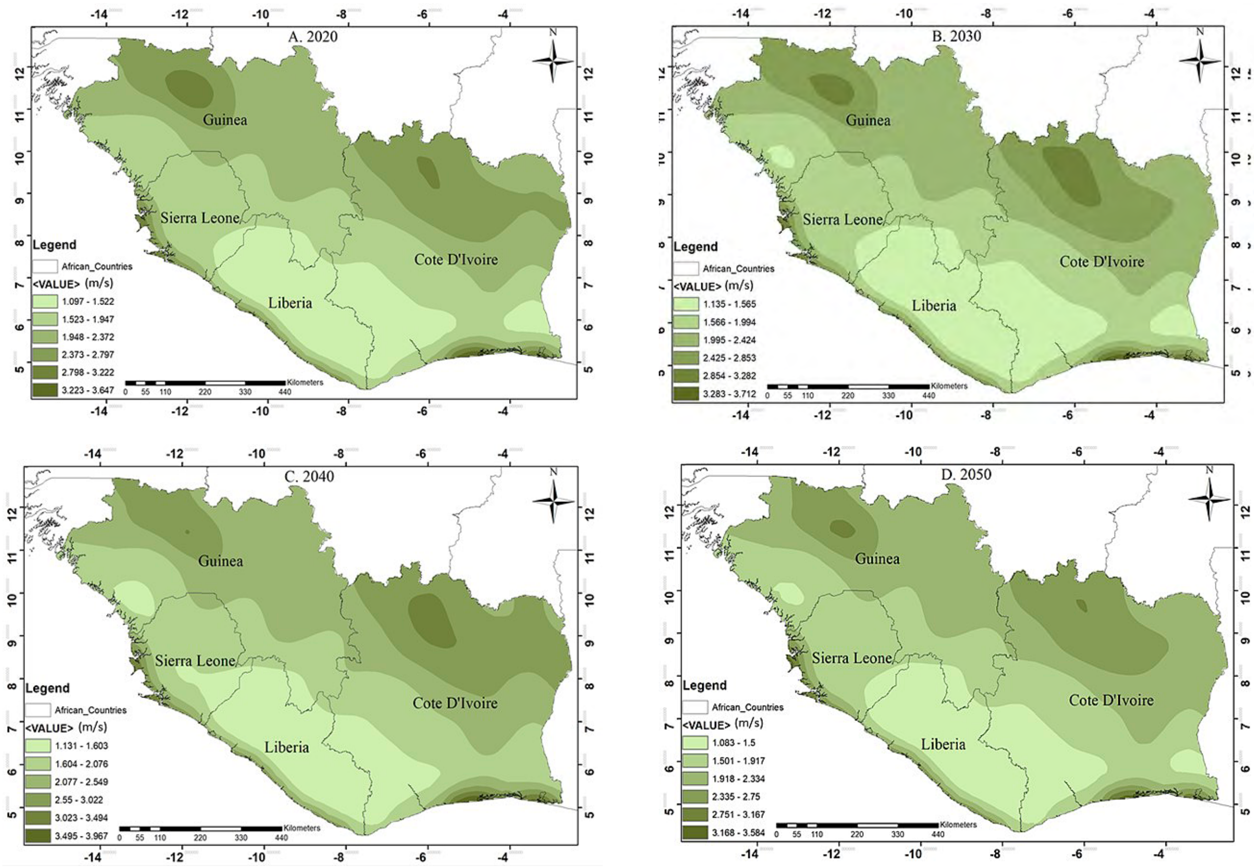

Figure 6. Decadal Spatial Distribution of Wind Speed (m/s) in the MRU region for the period (2020-2050)

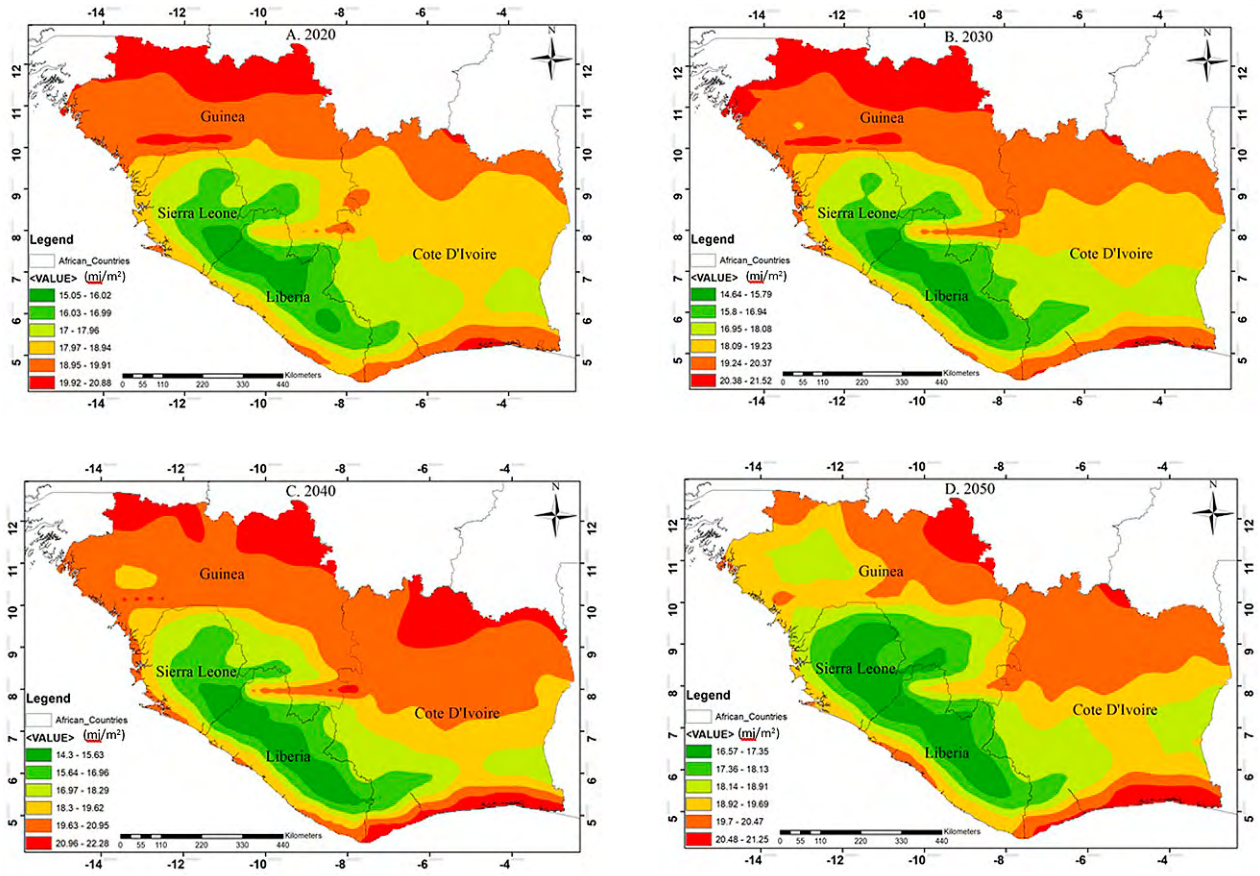

Figure 7. Decadal Spatial Distribution of Solar Radiation (mj/m²) in the MRU region for the period (2020-2050)

Conclusion and recommendation

This work presented a novel approach for modeling the climatic variability in countries making up the Mano River Union. The work has analytically showed that the control variables used in this study (population and land use) have serious impact on climate change variations in the study area. Noting the fact that population and land use both depend on human factors, it can be deduced that this study established a relationship between climatic variabilities and anthropogenic activities in the region.

This study shows that temperature is generally moderate at the coastal region but increases towards the middle and the northern region. However from the 2050 prediction, it can be seen that increase in average temperature is gradually moving to the south east of the region (Figure 3D). The intensity of precipitation is observed to be growing higher at the coastal region and much less in the northern region (Figure 4). Depending on various factors, this could be warning signal to flooding in the southern part. Results also show that density of relative humidity is gradually decreasing in the southern part of the region. A decreasing relative humidity, increasing temperature and rapidly growing population could set a possibility for heat stress in the region. The intensity of wind speed from the results is observed to increase from coastal areas to northern parts. (Figure 6). Increased intensity of wind speed is predicted to be moving southwards as seen in Figure 6 (D). Solar radiation as predicted in the study area is lowest in the southern parts and stretch to the middle belt of the region. The northern part is predicted to experience higher solar radiation as opposed to the south.

The results of this study suggest that predicted climate variabilities can trigger negative outcome on man and the environment. It was noted earlier that Agriculture is the majour occupation of people living in the MRU region. Agriculture could be seriously affected by the predicted results of variations in temperature, precipitation, relative humidity, wind speed and solar radiation, either individually or collectively. This could threaten food security in the region and could have spillover effect on neighbouring countries.

Cognizant of the results obtained, the study recommends the following:

1. Countries in the region formulate policies for the protection of forest since the region has the largest forest cover available in the West African Sub Region;
2. The establishment of institutional framework for public awareness on climate resilient and collaboration among countries in this region;
3. Countries in the MRU region need to consider appropriate policy that can reduce population growth rate since increased population can trigger majour land use changes;
4. Adoption of a common strategy for land use sustainability across West Africa is important to forestall possible spillover effects from neighbouring countries to MRU region;
5. Stakeholders should consider the establishment of centers that will be responsible to gather meteorological data;
6. MRU nations should ensure that the implementation of UNFCCC is fully adhered to;
7. Additional work be done to include atmospheric pressure, moisture and aerosol and also to quantify these variabilities.

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