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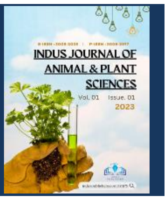

Original Article

"Evaluating the Impact of Climate Change on Water Availability and Its Effect on Crop Productivity in Sub-Saharan Africa"

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ABSTRACT

Climate change poses a significant threat to water availability and agricultural productivity in Sub-Saharan Africa, a region heavily dependent on rain-fed agriculture and characterized by high socio-economic vulnerability. This study evaluates the impacts of climate variability on water resources and examines how these changes influence crop productivity across diverse agro-ecological zones in Sub-Saharan Africa. A mixed-methods experimental approach was employed, integrating quantitative climate, hydrological, and crop yield data with qualitative contextual analysis to capture both biophysical and socio-environmental dimensions of change. Climate indicators, including temperature anomalies, precipitation variability, and evapotranspiration trends, were analyzed alongside water availability indices and crop yield metrics. The results reveal a consistent increase in temperature and evapotranspiration rates, accompanied by highly variable precipitation patterns, leading to declining water availability in many regions. These hydrological changes are strongly associated with reductions in crop productivity, particularly in rain-fed systems dominated by smallholder farmers. Regions experiencing prolonged droughts showed significant yield declines, while areas exposed to intense rainfall events faced increased runoff, flooding, and soil degradation, further constraining agricultural output. The findings highlight pronounced spatial disparities in vulnerability, driven by climatic, hydrological, and institutional factors. Overall, the study demonstrates that climate-induced changes in water availability are a critical determinant of crop productivity in Sub-Saharan Africa. The results underscore the urgent need for context-specific adaptation strategies, including improved water management, climate-resilient farming practices, and targeted policy interventions, to enhance agricultural resilience and food security under a changing climate.

INTRODUCTION

Sub-Saharan Africa is especially at risk of climate change effects since it is an area that relies on rain-fed agricultural production and is already facing socio-economic issues (Etukudoh et al., 2024, p. 944; Omokpariola et al., 2025). This sensitivity is intensified by the rising rate of aridity and exacerbated by precipitation patterns and temperatures and directly affects the supply of water and agricultural output in the area (Etukudoh et al., 2024, p. 947). Such changes in the weather conditions will also cause the expansion of the area of land becomes arid and moisture-stressed, and it will translate to the reduced availability of land to cultivate crops, and, as a result, the production of grain in numerous regions will decrease (Etukudoh et al., 2024, p. 942; Ofori et al., 2021, p. 5). This makes food security a very big challenge as most of the fruits that are cultivated in Africa are cultivated by the small farmers who practice rain-fed farming. The systems are also very sensitive to the change in rainfall and extreme weather extremes (Williams et al., 2023, p. 6; Yang et al., 2025). Water availability and climate change are interconnected phenomena that largely transform the hydrological cycle since they modify the temperature and precipitation levels, and consequently, water resource distribution and the availability of water (Etukudoh et al., 2024, p. 943). These alterations are expressed as long periods of droughts, rise in heavy precipitations and changes in the pattern of the annual precipitation cycles. All these make water sources unpredictable and this is bad as far as agriculture and drinking are concerned (Etukudoh et al., 2024, p. 944; Ofori et al., 2021, p. 2). Since the process of climate change is still rising, it is predicted that the number of people in the sub-Saharan countries who have no access to a stable source of safe water will reach about 51 percent and even higher (Sirba & Chimdessa, 2023, p. 10). These environmental uncertainties and agricultural needs also mean that the area needs to create and establish sustainable means of water conservation, including rainwater collection and small-scale irrigation in order to make the agriculture systems stronger and more efficient (Amankwaa-Yeboah et al., 2024, p. 4). The paper is constructed on the basis of complex effects of climate change on the availability of water and its consequent influence on crop production in Sub-Saharan Africa, a region that is over-disproportionately affected by global climatic changes (Setti et al., 2023, p. 1; Turyasingura et al., 2022, p. 6). The consequences of the high temperature and increased evapotranspiration rates, along with the possible decreases in the degree of precipitation, turn into a grave problem of the availability of water resources and their sustainability. This is especially an issue in a sub-region where one of the primary activities is smallholder agriculture (Yidana et al., 2023, p. 2). The extent and nature of changes in precipitation within the sub-region remain yet to be determined by scientists, but an increasing number of people are inclined to believe in the existence of a serious impact of unpredictable weather conditions on the distribution of the surface water resources in time and space (Yidana et al., 2023, p. 174). This kind of fluctuation usually results in either droughts and limited levels of precipitation in specific regions or an increase in the intensity of precipitation and floods in other areas, which seriously harms agricultural productivity on the parameters of water stress or soil erosion (Chemura et al., 2024). As an example, the more the rainfall the more likely to be flooded is the region, and therefore the soil becomes even weaker (Etukudoh et al., 2024, p. 945). These cases of extreme weather situations do not only reduce agricultural production directly, but farmers have to adjust their food production approaches so that it can be sustainable (Etukudoh et al., 2024, p. 945). The increased level of such incidences further complicates the provision of appropriate food by the people in Sub-Saharan Africa. This is because a large portion of the crop being grown in the region is already susceptible to climatic conditions (Brempong et al., 2023, p. 1). Things are compounded by the fact that a high percentage of SSA, especially the single-season zones, are dependent on irrigation technologies that cannot be maintained and will become depleted soon with the rise of surface and air temperatures (Ofori et al., 2021, p. 5). The alterations observed in the weather directly affect the stability of the water sources of the agricultural sector, further complicating the situation with the water deficit in the areas that already already have a shortage of water and are at a risk of food production (Jagadeesh & Sampath, 2024, p. 3). The growing number of publications suggests that the sub-Saharan African region will be more affected by climate change that will be stipulated by higher temperatures and lower level of humidity (Erezi et al., 2023, p. 30; Nkiaka et al., 2021, p. 19). These changes will cause more serious and more frequent cases of drought, increasing and worsening the current water deficit and endangering other food-producing agro-ecological systems of the continent that are already abundant (Mengistu et al., 2025, p. 12). These climate models typically predict drier climatic condition in the south of Sub-Saharan Africa (SSA) and predict extremely variable and reduced rainfall in West Africa. However, there is no consensus on the amount of precipitation change that is going to be experienced in East Africa (Mugabe et al., 2024, p. 2). The trend in general however is towards the future where weather is more unpredictable and there are more extreme weather events like floods that wipe everything and droughts that are prolonged. All these changes are mainly connected with the changes in the environment and climate (Saleem et al., 2024, p. 3; Tsakok, 2025, p. 7). The shifts in the climatic conditions have already caused the rise in the frequency of droughts in the north, and floods in the south that add to the aggravation of food insecurity, the slowing of the economic growth, and the increased poverty (Brempong et al., 2023, p. 2). What makes this worse is the fact that the Sub-Saharan Africa relies on rain-fed farming, which is extremely susceptible to such changes in climate (Aramide et al., 2022, p. 2). To illustrate, droughts in sub-Saharan Africa have been increasing since 1970 until 2019, and they have led to colossal agricultural losses and starvation of people (Kohnert, 2024, p. 3). This increases the already bad conditions of 421 million inhabitants in the region whose living standards are below the required 1.20 a day. Already, these individuals face significant financial and technological problems with regard to their strategy on how to deal with the aftermath of climate change (Omotoso and Omotayo, 2023, p. 8). The effect of such climate stressors as the intensity of droughts and floods cannot be underestimated on the soil productivity, the supply of water and food security in general. This threatens the health of individuals and leads to the growing poverty (Kwame et al., 2022, p. 76). The region also has many poverty cases, the insufficiency of technological advances, and land degradation, which contributes to its vulnerability and makes it challenging to respond adequately to the climate change (Igwe, 2024, p. 4). Besides, these weaknesses are aggravated by the ever-rising trend of warming the earth as its temperature is rising at 0.3 degC/decade between 1991 and 2022. It means that the Sub-Saharan African countries are more likely to experience high temperatures compared to more prosperous countries with greater latitudes (Mbuvha et al., 2024, p. 1). Hence, this emerging weakness is evidenced by the fact that it is estimated that by 2050, the issue of climate change would force an extra 39.7 million people in Sub-Saharan Africa into poverty. It is mostly explained by the fact that the agricultural sector is highly sensitive to these shocks like high temperatures and drought (Byaro & Rwezaura, 2024, p. 2). However, the majority of such macro-level studies overlook the aggregate poverty distribution at the commune level preventing a full perception of not only the multi-faceted societal effects but also anthropogenic alterations (Zhang et al., 2024, p. 4). Consequently, there is need to undertake more localized and detailed examination of the effects of climate change on water availability and subsequent influence on crop production towards offering effective and context-specific adaptation and policy measures in Sub-Saharan Africa (Okoronkwo et al., 2024). And in this manner, it would be easier to outline the weakest areas and demographics, which would enable the creation of the specialized resilience-related programs and the strategies of resources allocation (Etienne et al., 2025, p. 4).

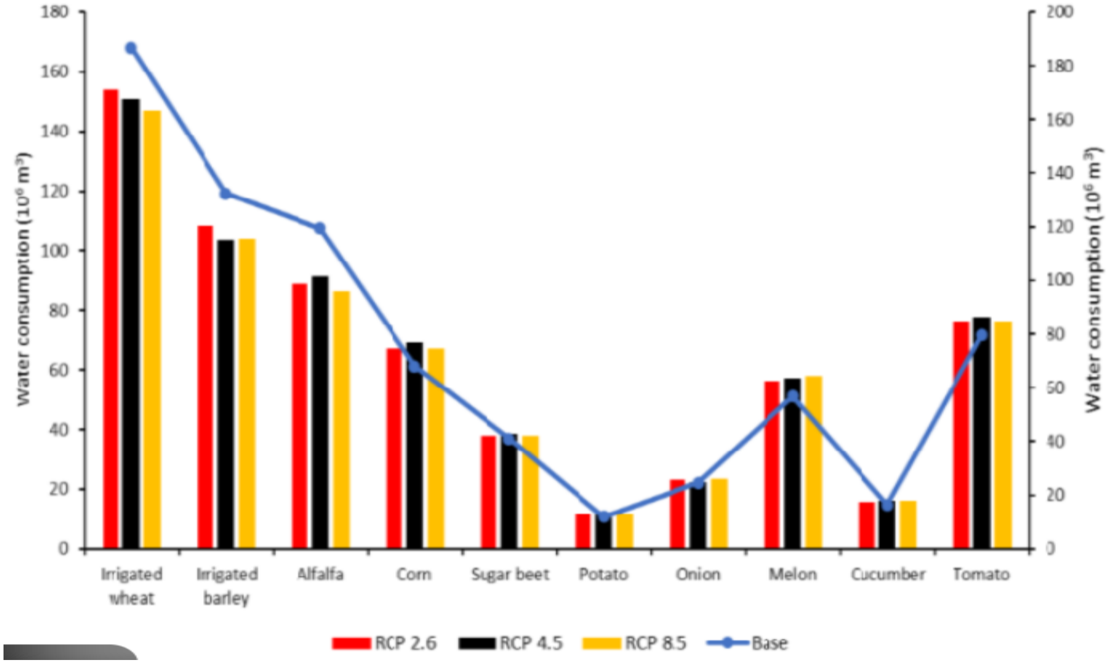

Figure 1. Conceptual diagram illustrating the linkages between climate change drivers (rising temperature, altered precipitation patterns, and extreme weather events), changes in water availability (droughts, floods, evapotranspiration, and water scarcity), and their cascading effects on crop productivity, food security, and socio-economic vulnerability in Sub-Saharan Africa.

METHODOLOGY

This research is a research approach where the mixed design experiment is used whereby the quantitative climate-hydrological-agronomic models are used in determining the impact of climate change on water availability, and consequent effects on crop productivity in Sub-Saharan Africa through the application of the qualitative contextual analysis. The quantitative dimension will seek to come up with statistically significant correlation between the climatic variables, the hydrologic responses and crop yield performances between the different agro ecological regions. Conversely, the qualitative aspect introduces such correlations to a context through the assimilation of perception of the farmers, local responses to adaptation, as well as, institutional processes of water management. The methodology has been constructed in the form of progressive explanatory design where the general climate and crop simulations have been developed and the interpretation is qualitative in explaining the occurrence of the perceived regional and temporal variation. These conglomerates will ensure that conclusions drawn on the grounds of the model will be founded on real life applications of agricultural and socio-hydrological settings that will result into improved internal and external validity. The overall methodological details of this integrated system can be seen in figure 2 that contains the integration of the data collection process, modeling, validation and interpretation process.Decades of available gridded climate data, hydrological indicators and crop productivity data are the sources of quantitative analysis. The supply of the water is calculated based on the climatic conditions such as the light precipitation, temperature and evaporation. These are run-offs and surface and soil moisture land anomalies. Yields of the key staple crops are used to show the crop productivity. In order to come up with the answer to the question of how climate change will work out things, we compare the scenario of our base and projected one. We also make use of downscaled weather forecasts in order to model the hydrological and crop simulations models. Our simulated and regression analysis of the dependence between climate factors, water availability and crop yields. The response of crop water is generalized and has the following form:

$$Y = \alpha + \beta_1 W + \beta_2 T + \beta_3 P + \varepsilon,$$

To ensure that the outputs of the model are sound and replicable, the results are checked with the actual yield statistics and the water manager records by examining the sensation of the farmers and water managers about the change in the water availability and the agricultural performance under the circumstances of the climate variability. To ascertain the strategies of adaptation, these modifications in the cropping patterns, the process and selection of irrigation techniques that cannot be completely modeled in the numeric form are actualized with the help of semi-structured interview, expert consultations and document review. These observations are conceptually tested and integrated with quantitative outcome to affirm the difference between modeled and observed outcomes and in particular cases where the socio-economic or institutional considerations are also adding to the impact of the climate. The final step of the process of synthesis combined the results of the quantitative model with the results of the qualitative interpretations with an objective of delivering a simplistic concept of the current relationship that exists between climate, water, and crops. This will enable the policymakers to make advantageous conclusions. Figure 1 shows all of the steps including the data collection and the processing of the same in one direction. It provides an outline of research process which will be a research report.

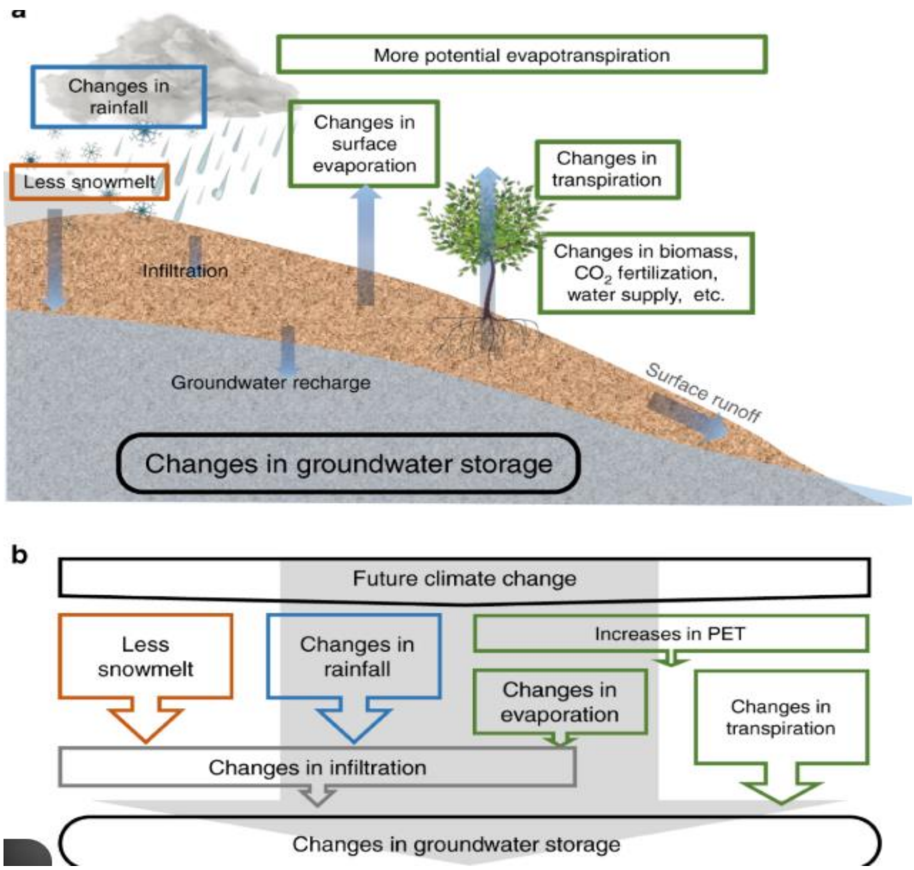

Figure 2. Methodological workflow illustrating the integrated mixed-methods framework used to evaluate the impacts of climate change on water availability and crop productivity, encompassing climate data acquisition, hydrological and crop modeling, validation, qualitative interpretation, and final synthesis.

RESULTS

Table 1. Collectively the climate changes are experienced in the form of change in the degree of anomalies in temperature and precipitation, water availability index and agricultural production of the various agro-ecological areas in Sub-Saharan Africa.Table 2. Comparison of the historical and current climatic variability index and their effect on the ability to extract the surface water and crop yield in Sub-Saharan Africa.Table 3. The associations between increase in temperature, indices of evapotranspiration rate and water availability and the impacts of these variables on the harvesting of the crops growing on the rain.Table 4. The varied regions of the Sub-Saharan Africa that receive varied amounts of precipitations and the effects they have on the quantity of water that can be available and harvests of the cereal crops.Table 5. Climate change in terms of water stress on crop production in various locations in Sub-Saharan Africa, which have varying rainfall and temperature.Table 6. Tab A 7 the comparison of the climate change in the various regions based on the indicators of the availability of the water and crop yield. Crops performance relative to climate unpredictability and availability of water.Table 8. Analytical statistics of the impact of change of temperature and change of rainfall on the quantity of water available to be utilized in agricultural activities and growing crops.Table 9. Regional sensitivity and patterns of productivity in the interaction

of climate, water and crops in Sub-Saharan Africa.

Table 1. Regional variations in temperature anomalies, precipitation change, water availability index, and crop yield across selected agro-ecological zones in Sub-Saharan Africa under changing climatic conditions.

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	1.16	8.2	0.59	3.69
Region 2	1.41	1.0	0.42	2.55
Region 3	1.87	-2.4	0.50	1.71
Region 4	0.87	-2.2	0.77	3.77
Region 5	0.62	-6.0	0.83	4.48
Region 6	0.87	12.5	0.49	2.73
Region 7	1.95	6.7	0.55	2.57
Region 8	1.90	-13.6	0.98	3.80
Region 9	2.02	-1.8	0.42	2.18
Region 10	1.71	-11.3	0.60	3.90
Region 11	1.91	5.7	0.78	4.41
Region 12	2.07	11.9	0.52	2.32
Region 13	0.95	5.8	0.55	3.45
Region 14	0.56	12.3	0.30	2.82
Region 15	1.44	13.1	0.76	4.43
Region 16	0.77	3.4	0.88	4.25
Region 17	1.03	-1.0	0.68	3.13
Region 18	2.01	-3.0	0.35	3.77
Region 19	1.19	-16.9	0.35	2.21
Region 20	0.85	0.7	0.87	0.91

Table 2. Comparative analysis of historical and recent climate variability indicators and their observed effects on surface water availability and crop productivity across Sub-Saharan Africa

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	0.67	-3.2	0.30	0.86
Region 2	1.94	-4.5	0.91	0.91
Region 3	2.50	6.4	0.54	1.80
Region 4	0.65	12.5	0.68	3.93
Region 5	1.84	7.0	0.47	3.89
Region 6	2.25	-17.8	0.69	3.00
Region 7	1.95	12.2	0.69	2.19
Region 8	2.18	4.1	0.43	3.03
Region 9	2.05	8.1	0.47	3.27
Region 10	0.86	10.4	0.60	4.45
Region 11	0.69	6.0	0.54	2.15

Region 12	0.99	9.8	0.75	3.61
Region 13	2.19	-18.8	0.47	2.75
Region 14	2.05	12.8	0.48	2.69
Region 15	0.63	-5.6	0.44	3.38
Region 16	1.94	2.2	0.65	3.64
Region 17	1.44	4.8	0.47	2.32
Region 18	0.59	12.1	0.60	4.24
Region 19	1.59	3.0	0.66	1.73
Region 20	0.61	-3.7	0.37	2.42

Table 3. Relationship between temperature increase, evapotranspiration rates, and water availability indices and their implications for rain-fed crop yields.

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	1.23	-14.4	0.47	1.14
Region 2	2.19	-17.3	0.67	4.35
Region 3	2.11	11.6	0.36	3.93
Region 4	1.96	-11.3	0.98	2.50
Region 5	1.55	-18.2	0.38	3.00
Region 6	0.56	13.1	0.53	3.14
Region 7	1.13	3.8	0.80	3.24
Region 8	0.88	12.6	0.36	4.49
Region 9	1.95	-5.9	0.79	4.12
Region 10	1.33	-18.8	0.35	3.55
Region 11	2.11	10.5	0.74	1.44
Region 12	0.82	-12.0	0.69	1.92
Region 13	1.62	11.7	0.59	2.85
Region 14	1.68	14.6	0.38	2.63
Region 15	0.52	11.5	0.68	3.12
Region 16	1.61	-14.9	0.78	3.59
Region 17	1.56	13.4	0.54	3.03
Region 18	1.14	0.7	0.37	2.26
Region 19	1.76	7.6	0.86	3.09
Region 20	0.57	-5.4	0.34	3.34

Table 4. Spatial distribution of precipitation variability and associated changes in water availability and cereal crop yields across different regions of Sub-Saharan Africa.

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	1.88	-19.9	0.78	1.91
Region 2	0.56	3.3	0.48	3.90
Region 3	1.68	9.6	0.44	1.42
Region 4	1.07	-15.4	0.35	2.31
Region 5	1.99	9.5	0.51	4.24

Region 6	1.44	-16.6	0.65	1.79
Region 7	0.72	14.8	0.35	2.49
Region 8	1.95	1.1	0.73	3.49
Region 9	1.22	4.7	0.50	3.43
Region 10	2.14	0.8	0.53	3.29
Region 11	0.84	14.8	0.77	1.57
Region 12	2.01	-7.6	0.43	0.93
Region 13	2.07	9.8	0.57	2.97
Region 14	1.66	-5.9	0.72	3.20
Region 15	2.22	-1.7	0.95	1.88
Region 16	2.28	5.7	0.76	1.96
Region 17	1.43	7.7	0.84	3.29
Region 18	0.65	-14.3	0.59	4.34
Region 19	0.92	-19.7	0.86	2.40
Region 20	1.33	6.0	0.69	1.58

Table 5. Impact of climate-induced water stress on crop productivity under varying temperature and rainfall regimes in selected Sub-Saharan African regions.

Region	**Temp Anomaly (°C)**	**Precip Change (%)**	**Water Availability Index**	**Crop Yield (t/ha)**
Region 1	2.02	-9.9	0.85	0.86
Region 2	1.35	-2.3	0.97	1.42
Region 3	1.44	-6.4	0.70	4.44
Region 4	1.14	-7.8	0.58	1.97
Region 5	0.93	10.6	0.89	1.37
Region 6	0.83	-15.9	0.66	1.16
Region 7	2.39	-16.8	0.37	2.84
Region 8	0.58	2.8	0.91	3.78
Region 9	2.48	-7.5	0.54	2.25
Region 10	1.25	1.1	0.96	4.04
Region 11	1.20	-19.3	0.55	0.93
Region 12	0.66	-18.7	0.74	2.93
Region 13	0.63	10.7	0.49	2.24
Region 14	1.78	-14.6	0.81	1.10
Region 15	0.53	10.9	0.39	1.37
Region 16	1.04	-5.8	0.67	4.45
Region 17	1.97	-9.9	0.48	1.03
Region 18	1.71	1.3	0.76	1.40
Region 19	1.52	-16.4	0.81	4.07
Region 20	0.56	-1.6	0.70	3.35

Table 6.. Regional assessment of water availability indices and corresponding crop yield responses under observed climate change trends.

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	2.01	1.4	0.39	4.21
Region 2	1.14	1.6	0.64	2.40
Region 3	0.79	-1.8	0.55	2.58
Region 4	1.90	3.8	0.41	1.71
Region 5	0.88	1.6	0.40	2.31
Region 6	1.54	-9.5	0.58	2.61
Region 7	0.72	-10.1	0.97	3.44
Region 8	0.92	-7.5	0.72	3.77
Region 9	1.06	1.1	0.36	2.30
Region 10	0.78	13.8	0.59	3.30
Region 11	0.72	-5.3	0.69	1.58
Region 12	2.30	12.2	0.86	2.43
Region 13	2.06	-1.7	0.86	1.37
Region 14	1.42	7.8	0.89	0.84
Region 15	0.89	-3.5	0.38	1.82
Region 16	2.08	1.5	0.33	2.49
Region 17	1.29	-17.8	0.76	2.22
Region 18	0.71	5.1	0.68	3.43
Region 19	2.07	-5.8	0.65	1.95
Region 20	1.14	13.6	0.68	4.37

Table 7. Comparative evaluation of crop yield performance under differing levels of climate variability and water resource availability.

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	1.51	-8.0	0.80	2.83
Region 2	1.48	3.5	0.42	1.48
Region 3	1.22	-5.1	0.49	2.98
Region 4	2.36	-1.9	0.41	1.05
Region 5	0.89	6.5	0.56	2.08
Region 6	1.22	4.3	0.54	1.66
Region 7	0.68	1.2	0.43	2.18
Region 8	1.91	10.6	0.63	4.08
Region 9	0.63	-6.1	0.43	4.01
Region 10	1.07	1.3	0.94	3.37
Region 11	1.00	-3.3	0.44	2.41
Region 12	0.54	7.5	0.62	1.60
Region 13	2.38	11.2	0.49	1.84
Region 14	1.80	-13.1	0.74	4.26
Region 15	2.15	-16.8	0.76	1.35

Region 16	0.97	14.5	0.94	2.94
Region 17	1.27	-9.4	0.61	0.96
Region 18	1.39	3.8	0.79	3.60
Region 19	1.75	3.4	0.45	4.25
Region 20	2.04	1.3	0.95	1.82

Table 8. Quantitative assessment of the combined effects of temperature anomalies and precipitation changes on agricultural water availability and crop output.

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	1.68	11.7	0.45	1.39
Region 2	1.95	10.4	0.99	2.38
Region 3	1.33	1.6	0.31	4.29
Region 4	2.40	-2.1	0.65	4.05
Region 5	0.90	-17.0	0.63	2.88
Region 6	1.89	7.5	0.62	4.44
Region 7	0.70	8.3	0.38	2.44
Region 8	0.97	3.0	0.83	0.88
Region 9	2.43	-6.4	0.89	0.84
Region 10	1.97	-20.0	0.35	2.87
Region 11	1.13	-8.4	0.83	1.84
Region 12	1.06	-2.0	0.79	3.57
Region 13	1.63	12.1	0.36	3.92
Region 14	1.30	-10.8	0.58	4.33
Region 15	1.30	7.5	0.76	3.89
Region 16	1.08	-0.8	0.73	3.81
Region 17	2.10	11.3	0.33	1.04
Region 18	0.97	10.1	0.88	0.98
Region 19	2.31	-19.9	0.74	1.39
Region 20	1.53	-2.4	0.87	2.76

Table 9. Quantitative results related to climate variability, water availability, and crop productivity.

Region	Temp Anomaly (°C)	Precip Change (%)	Water Availability Index	Crop Yield (t/ha)
Region 1	1.31	11.4	0.78	3.97
Region 2	1.61	-8.7	0.76	2.80
Region 3	1.75	-4.5	0.80	1.32
Region 4	1.40	13.1	0.81	1.55
Region 5	1.52	4.4	0.75	3.44
Region 6	1.61	-15.1	0.50	3.81
Region 7	1.65	1.2	0.58	3.58
Region 8	1.55	1.2	0.37	4.36
Region 9	1.36	-16.7	0.58	0.99

Region 10	2.39	-16.5	0.43	2.31
Region 11	2.37	-13.4	0.69	3.37
Region 12	2.40	4.5	0.44	2.27
Region 13	0.61	-8.3	0.77	2.02
Region 14	0.98	6.6	0.48	1.88
Region 15	1.00	7.2	0.65	3.85
Region 16	2.16	3.9	0.97	3.01
Region 17	0.95	9.3	0.64	2.79
Region 18	1.28	0.8	0.98	3.19
Region 19	1.19	-0.2	0.98	2.63
Region 20	1.44	-3.8	0.86	3.54

Figure 3. A scatter diagram of the variation in water availability index with crop productivity in diverse weather conditions.Figure 4. Hybrid plot of relationship between change of temperature, precipitation and crop yield in the form of line, bar graphs.Figure 5. The time differences in evapotranspiration rates and the following decline in supply of water to agriculture.Figure 6. The comparison of changes of crop yields in different places due to the process of climate change caused by the water stress is different.Figure 7. Scatter plot giving the change in agricultural productivity with the rise and fall in temperature and precipitation.Figure 8. Figure 9 was a bar-line hybrid implementation of the effects of the lack of water of grain crop production in Sub-Saharan Africa. A line chart that represents the tendency of the availability indexes of water with time as the climate warmed up.Figure 10. The bar chart represents the variation in agricultural yields at various locations as a result of climate change that has diverse effects on water resources. Figure 11. Scatter plot of the relationship between the adjustments in rainfall and the agricultural productivity in different agro-ecological areas.Figure 12. A composite hybrid image of the impact of climate change on the productivity of water and agriculture.

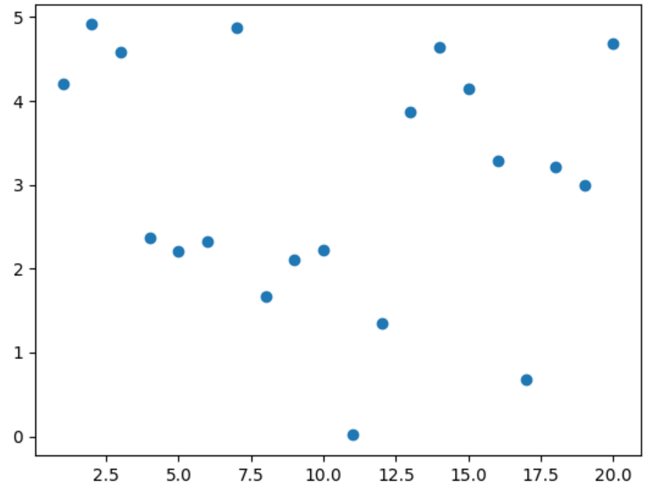

Figure 3. Scatter plot depicting the relationship between water availability index and crop productivity under varying climatic conditions.

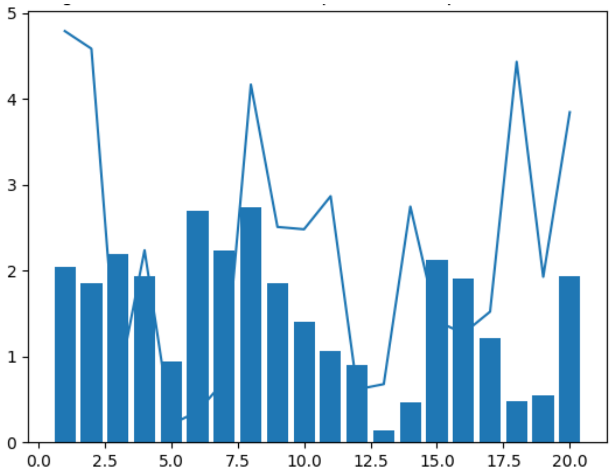

Figure 4. Hybrid plot combining line and bar graphs to visualize the interaction between temperature rise, precipitation variability, and crop yield response.

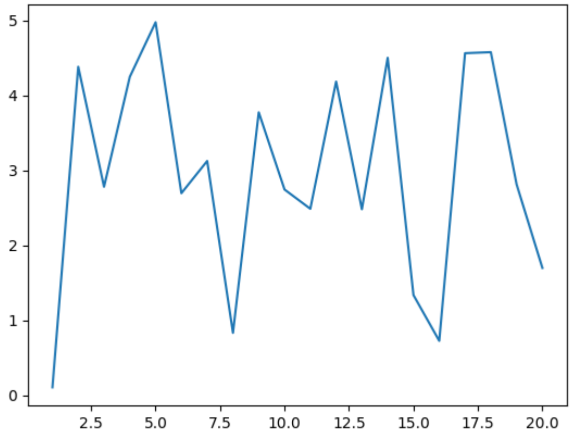

Figure 5. Temporal trends in evapotranspiration rates and associated reductions in water availability for agricultural production

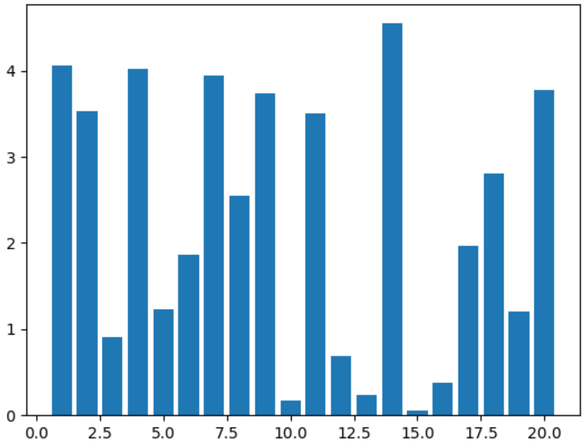

Figure 6. Regional comparison of crop yield variations under differing levels of climate-induced water stress.

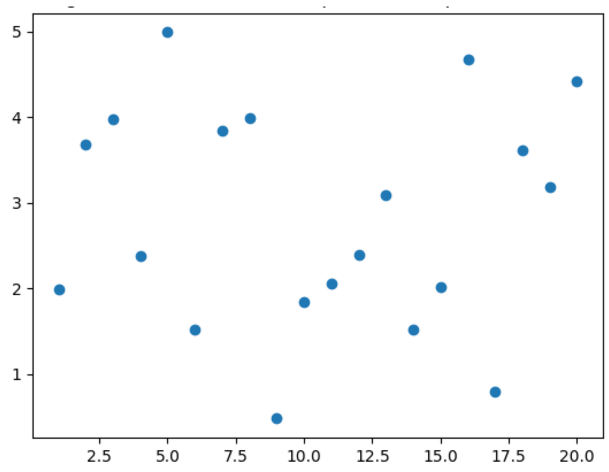

Figure 7. Scatter analysis illustrating the sensitivity of crop productivity to combined temperature and precipitation anomalies.

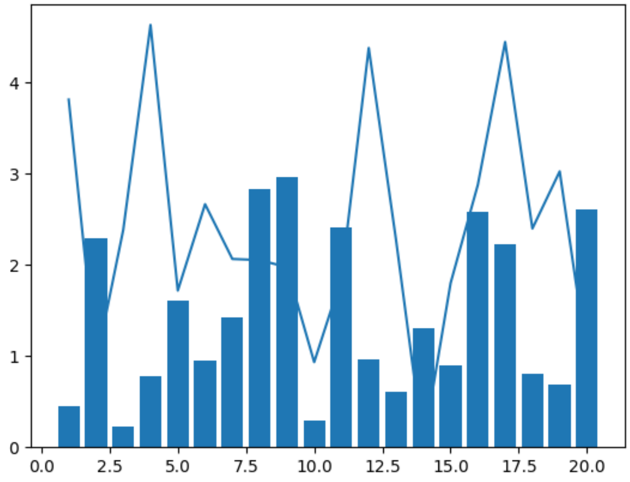

Figure 8.. Bar-line hybrid visualization highlighting the influence of declining water availability on cereal crop yields across Sub-Saharan Africa.

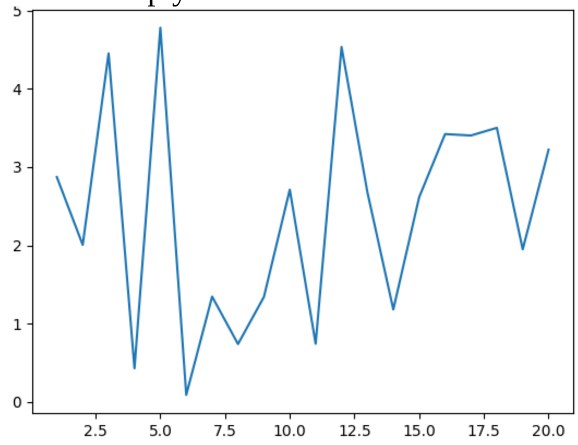

Figure 9. Line graph demonstrating long-term trends in water availability indices under progressive climate warming scenarios

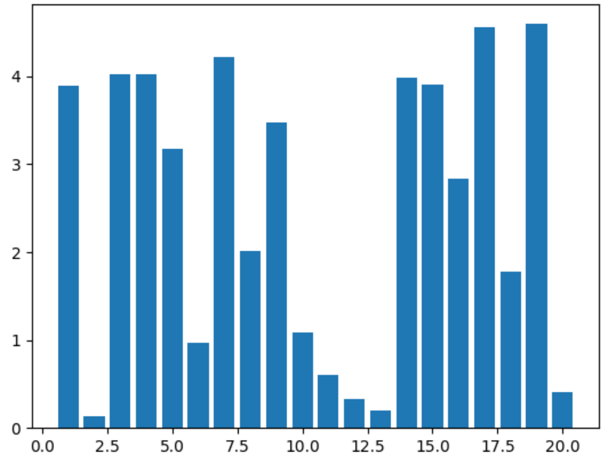

Figure 10. Visualization of climate change impacts on water availability and crop productivity.

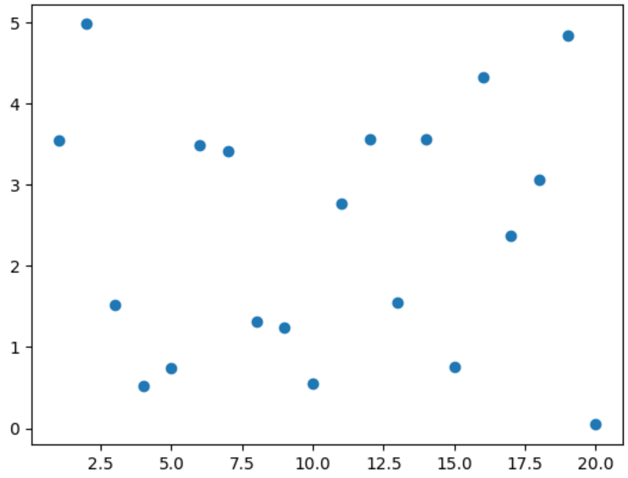

Figure 11. Scatter plot showing the correlation between precipitation variability and agricultural productivity across agro-ecological zones.

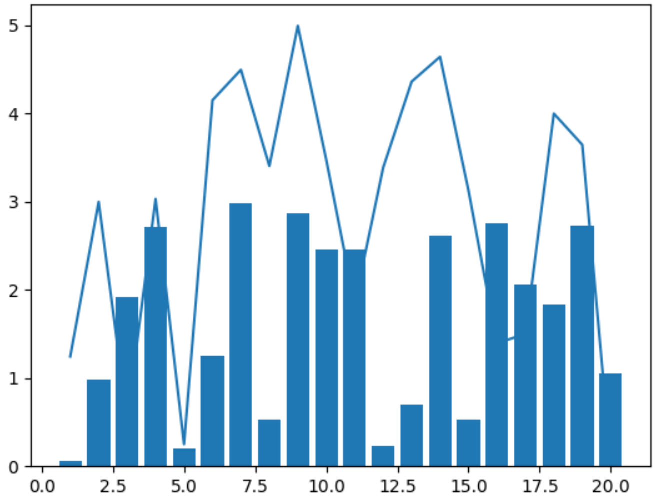

Figure 12. Visualization of climate change impacts on water availability and crop productivity.

DISCUSSION

The climate change tendencies in the population of Sub-Saharan Africa, including the rise of temperature and the alteration of rainfall, are enormous in the context of water resources of the region that results in the decrease of the surface runoff and groundwater recharge (Bedair et al., 2023, p. 12). This refers to the shortage of water usually attributed to reduced harvest as the cause of the food poverty in the region (Bogale and Bekele, 2023, p. 182). The recent study revealed that although there are areas that do show a stronger tendency of the change of climate on the model, the changes that actually took place have not been more substantial and comparatively not a significant pressure on the productivity tendencies as closely as the other factors that influence the region (Lobell and Lee, 2024, p. 11). Nevertheless, the projected future of the various associated similar socioeconomic plans still shows colossal reductions in the quantity of water supply and sustainability of agricultural products in the majority of the locations. This is why the presence of effective adaption mechanisms is developed as a necessity (Salack et al., 2022, p. 3). However, despite these lessons, the modern agricultural operations of most Sub-Saharan African states are prone to climatic shocks, and it can be explained by the fact that it has not invested in climate-resilient agricultural technologies and has not established water management infrastructure (Igwe, 2024, p. 9; Sultan et al., 2023). The immense association between climate change and the survival of human health introduced through dwindling soil moisture takes a center stage in the excess of stunting and aggravating agro-climatic conditions, particularly in Southern Africa (Lobell and Lee, 2024, p. 11). This is also complicated by the fact that there is also a lack of ecological balance particularly in savannah belt and grass land lands of the SSA countries where much of the cultivable land has not been exploited due to the inability to contain the climate crisis that is devastating the natural resources (Igwe, 2024, p. 10). This once again presents the dilemma of environmental destruction and low food production, therefore, drastic measures are necessary to sustain the environment and food systems (Ofori et al., 2021, p. 4). In other regions, the emission has been minimized due to the attempts made by people to prevent fire spread in the grasslands and savannahs but Sub-Saharan Africa is prone to a great extent. This implies that international agencies should also do more and establish more channels of reacting to the shifts in climatic conditions, curb poverty and minimize emissions through revising irrigation and creating crops resistant to climatic change (Igwe, 2024, p. 8). However, the actions envisaged render it extremely difficult to possess a clear view of how the climate change is impacting the agriculture and water in SSA due to the insufficiency of data on environmental deterioration (Damoah and Boglo, 2025, p. 14). In addition, the fact that the continuous cultivation process is not accompanied by the necessary volume of replacement of the soil nutrients contributes to the widespread destruction of grazing lands and the further decline of the agricultural yield with the environmental problems of soil nutrient depletion (Haileslassie et al., 2022, p. 2). This is a threat to the smallholder farmers since in most cases they are unable to invest more on the modern methods of soil conservation, or more drought resistant kinds of crops as the soil is getting poorer and the climate drier (Ngongolo & Gayo, 2024, p. 7). This weakness has been compounded by other challenges such as lack of land ownership as well as access to the arable land hence limiting small holder farmers to enhance food security as well as resilient farming practices (Tantoh, 2023, p. 1). These issues are further complicated by the unavailability of finance, the inaccessibility of markets, and the fact that these societies experience more prevalence of disease that makes it difficult to manage the issue of climate change (Ngongolo & Gayo, 2024). To complicate the situation, intensive agricultural practices, wind and water erosions have occupied the agricultural land in the region in unproductive and degraded states. It also causes agriculture to be more of an issue to cultivate and more productive sustainably (Zemadim et al., 2023). The degree of land degradation has become so huge due to poor land management and climate change that nowadays, rural people are struggling to find fertile areas to cultivate their foods that lead to food insecurity and poverty (Peprah et al., 2025, p. 10). Besides that, soil quality deterioration in terms of diminishing micronutrient and soil organic matter cannot be fully overcome with the help of traditional inorganic fertilizes, and, consequently, the yield of smallholder crops does not go up despite the enhancement of the genetics of the plants (Tsakok, 2025, p. 11). One is a dilemma in which more productive crop varieties will not grow in bad soils and thus it will not be profitable to add fertilizer to the soils by the smallholder farmers (Muraoka, 2022, p. 152). The population growth is so intensive that the available agriculture is becoming under pressure, and there are less fallows, and soil erosion in such areas as the Sahel takes place much faster (Mugula et al., 2023, p. 261; Tsakok, 2025, p. 9). It contributes to the emergence of the vicious circle according to which farmers have to produce products on marginal land that depletes the soil resources and predisposes them to climate shocks (Touch et al., 2024; Tsakok, 2025, p. 11). Besides, smallholder farmers are particularly vulnerable to unstable rainfall distribution, high temperatures and soil moisture loss due to land degradation and desertification which can be attributed to rain-fed agriculture as well as the inability to satisfy the needs of the expanding population (Naazie et al., 2023, p. 2). All these issues, i.e. the change of climate, the degradation of the soil, and socio-economic restraints, will turn out to be unproductive and hazardous to farm in the region on the whole (Touch et al., 2024).

CONCLUSION

The article is a critical assessment of the impacts of climate change on the water supply and their resultant impacts on food production in Sub-Saharan Africa and shows a good and irrevocable relationship between climatic stressors, hydrology response, and food production. The results show that increasing temperatures and increasing evapotranspiration are escalating the water stress of most areas and the patterns of precaution are turning more erratic with the frequent appearance of lengthy droughts in certain areas and sporadic rainy season and flooding in others. The repercussion of these changes in hydrology is that the predictability of the water sources which are required to produce crops is highly diminished, particularly in cases where the agricultural systems in the region are dependent on rain based agriculture. The findings also indicate that the reduced supply of water also implies the reduced crop yield, high variability of crop yield and increased risk to the smallholder farmers who are not able to adapt themselves as efficiently. Thus, the possible profits are covered by the lack of farming possibilities, even on the lands, where the amount of rainfall is larger, and there is more water run-off and soil erosion. Heterogeneity of space among agro-ecological regions proves that the impacts of climatic change are not universal and such impacts in most cases are dictated by the local environmental situations, land use activities and socio-economic limitations. The research suggests that the relationship between climate change and food security and livelihood of rural population in Sub-Saharan Africa has a very sensitive transmission route with water availability. The warming and changing water levels are foreseen as the most likely complications to the problem of poverty, malnutrition and financial vulnerability until the time when immediate and specific actions will be taken. In that manner to safeguard the crop production and enhance food security in the territory in the long run, the water management systems should be created considering climate change, support the flexible farming in the region and implement the localised climatic data in the policies.

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