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Dryland Pastoralism Climate Landscape and Food Security in the Suam River Basin of Kenya

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Abstract

River basins in the drylands of Sub-Saharan Africa have traditionally been utilized for pastoral livelihoods under communal land tenure. Communities in West Pokot in Kenya have continued to experience increased precipitation and temperature as a result of climate variability and change. This study aimed at assessing the impact of climate variability and change at micro-basin level in order to address research and policy gaps on climate change and food security as policy arena shifts from centralized to decentralized governance in Kenya. Primary quantitative data was collected from 387 households' perceptions of climate variability and change and its implications on food security were measured. Food security index score was calculated. The annual rainfall trend over Suam river basin for the period (1981-2020), was characterized by a linearly increasing annual rainfall trend. Mann Kendall test Z-statistics and Tau were at 2.3578 and 0.0720 respectively. The basin experienced the highest rainfall variability during the first decade (1981-1990) with the highest coefficient of rainfall variation noted at 11.5%. The highest temperature was recorded in the third decade (2001-2010) and fourth decade (2011-2020) at 27.0 and 28.2 degrees Celsius respectively. However, the overall index score for food security was 55.78 with food availability scoring the highest index, mean (SD) of 63.41 (36.52). This was attributed to households' practice of both nomadic pastoralism and agro-pastoralism activities. Climate variability and change, have resulted in increased amount of rainfall received providing for opportunity investment in rain water harvesting to support both pastoralism and agro-pastoralism production to enhance food security.

Keywords

Climate Variability and Change, Dry Land, Food Security, Pastoralism, Suam River Basin

1. Introduction

Climate variability and change have for decades been considered the main risk to agricultural activities, the main means of subsistence and livelihoods of rural poor among smallholder farmers, pastoralists and agro-pastoralists in the drylands of Sub-Saharan Africa. While these climate change risks remain well documented, at international level discussions on climate change mitigation and adaptation remain politically motivated without overarching agreements (Vrålstad, 2010). At national and local levels, policies are created without implementation, however, greenhouse gases emission continues while pastoralists and smallholder farmers are left on their own to struggle with adaptation. FAO (Food and Agriculture Organization of the United Nations (FAO), 2016) indicated that climate change through its impacts on agricultural production, whether smallholder farming, pastoral and or agro-pastoral, will have negative effects on food security in all dimensions. To make it worse, drylands of Sub-Saharan Africa are constrained with limited production capacities since its main natural resources (land and water) are either degraded, scarce and overstretched by the demands of the growing human and animal populations. One way through which climate affects food security, is through its impacts on natural resources such as water and land which are essential in agricultural production (Čadro, Cherni-Čadro, & Žurovec, 2019; Bilali, Bassole, Dambo, & Berjan, 2020). Increased temperatures shift precipitation patterns contributing to unpredicted droughts and floods thus affecting land productivity in different seasons. Studies suggest that without appropriate interventions, climate variability and change will affect agricultural yields, food security and add to the presently unacceptable levels of poverty in Sub-Saharan Africa (Zougmoré, Partey, Oué-draogo, Torquebiau, & Campbell, 2018), dryland river basins included. Further, studies have warned that changes in the mean climatic characteristics will not only affect the hydrological cycle and crop production but also accelerate land degradation and its associated human suffering (Easterling, 2007; Sivakumar & Ndiang'ui, 2007).

Previous studies which utilized food insecurity and climate change vulnerability index have revealed that today the highest levels of vulnerability to climate-related food insecurity are in Sub-Saharan Africa (Programme, 2017). Climate change will always have far reaching impacts on the agricultural sector, and will actually affect smallholder farmers whose livelihoods are precisely dependent on rain fed agriculture and have a low capacity to adapt (Mashizha, Monga, & Dzvimbo, 2017). Climate change has the potential to transform food production, especially the patterns and productivity of crop, livestock and fishery systems, and to reconfigure food distribution, markets and access. Future impacts of climate change and land cover changes on livestock production, which is the main source of livelihood among the pastoralists and agro-pastoralists, are likely to be both direct through productivity losses owing to temperature increases and indirect through changes in the availability, quality and prices of inputs such as fodder, energy, disease management, housing and water (Thornton, 2010).

Schilling and others (Schilling, Akuno, Scheffran, & Weinzierl, 2014) observed that in East Africa, debates about climate change mainly focus on increasing temperatures and higher rainfall variability, with a growing likelihood of more frequent and extended droughts. Usually, when droughts occur pastoralists and agro-pastoralists ability to access food and water among the livelihood necessities are threatened (ILO, 2019). Although recently, there have been many discussions on the potentials of drylands resources for economic development in Kenya, climate change has been identified as the main threat to economic development in the Vision 2030 as well as the dryland development blueprint (Mutimba & Wanyoike, 2013). Climate variability and change are projected to increase drought episodes, food insecurity, irreversible decline in herd sizes and deepening poverty among the pastoralists and agro-pastoralists communities in the drylands (Tawane & Wakhungu, 2018). Recent studies on climate change in North Western Kenya found that the average temperature in the county is on the rise. Rainfall patterns have shifted and become more erratic, long rains have shortened and become drier while the short rains have become hotter and wetter, with low levels of annual rainfall (Schilling, Akuno, Scheffran, & Weinzierl, 2014).

Although studies have constantly emphasized that affected communities strive to adapt to climate variability in the dryland of Sub-Saharan Africa (Opiyo et al., 2012), the importance of dryland river basin in balancing the effects of climate variability and food security has received little attention among researchers in Africa. Dryland counties in Kenya, have continued to be warned that the region has recorded increased precipitation and temperature as a result of climate variability and change (MoALF, 2016; Koei, 2013; Shongwe et al., 2011; Kogo, Kuma, & Koech, 2021), these have been done at a macro-level and generalized the effect of climate variability and change on households' food security. Therefore, the need to assess the impact of climate variability and change at micro-basin level was seen as a gap that necessitated this study for purposes of addressing research and policy gaps on climate change, food security and environmental management in the dryland river basins as policy arena shifts from centralized to decentralized governance in Kenya. This is after realization that studies have concentrated on the negative impacts of climate change without emphasizing the opportunities that come with climate change and food security such as increased precipitation in the drylands. Just the same way anthropogenic global warming theorists put it, human activities are the main contributors of emission of Green House Gasses leading to global warming thus changes in climate (Gore, 2006; Intergovernmental-Panel-on-Climate-Change, 2007) in this study we find it necessary also to put forward that same human are in a better position to explore opportunities that come with those changes to ensure water and food security in the dry land river basins.

Widespread changes in climate as well as the environment are not only noted and observed by pastoralists but also agro-pastoralists communities in the drylands. This makes these communities uncertain about the ongoing processes in their landscapes but also accounts for their understanding and perception of space (ILO, 2019). In the basin, drought is a persistent hazard associated with climate variability. Droughts have become more expected phenomena, in one decade (2000-2010) for example four drought periods were recorded (Mude et al., 2010). With climate change raising the challenges of dryland farming; pastoralism and agro-pastoralism are becoming increasingly important as a means of livelihoods in the basin. Regular exposure to drought means that both pastoralist and agro-pastoralist households have to develop coping, adaptation and innovation strategies to deal with the situation. As a result, pasture and water are sought from outside of the traditional grazing and migration areas as main adaptive strategies. This has led to increased cases of conflicts between the Pokot and other pastoralist communities (Marakwet and Turkana) over access to pasture and water in the basin (Schilling, Akuno, Scheffran, & Weinzierl, 2014; Opiyo et al., 2012). This study aimed at establishing the trends in climate variability and change and the status of food security based on household perceptions in the dryland of Suam River basin West Pokot County, Kenya.

2. Materials and Methods

2.1. Study Area

This study was carried out in the drylands of North Western Kenya, Suam River Basin in West Pokot County. The Basin lies between latitudes 1˚N and 2˚N and longitudes 34˚E and 36˚E (**Figure 1**) along the Kenya-Uganda border. It is characterized by typical semi-arid rangeland falling within Agro-climatic zone IV and VI. The climate is hot and dry throughout the year with mean annual temperature varying from 28˚C to 41˚C (Opiyo et al., 2012). The basin experiences unreliable and erratic rainfall in both space and time. Further, rainfall is bi-modal, distributed as long rains experienced in April to May while short rains are experienced in September to October in normal climatic periods. Ministry of Agriculture, Livestock and Fisheries (MoALF, 2016) point that 70% of households in the entire West Pokot County suffer from food poverty while 69% live below the poverty line (Government-of-Kenya, 2013). River Suam has been experiencing severe seasonal changes resulting in dry beds and interrupted flows and reduced downstream flow recharges into Lake Turkana (Ajele, 2016).

2.2. Study Design

To answer the main research question, the study examined the characteristics of climate variability using two main parameters: rainfall and temperature patterns, and food security in the Suam River Basin. Interdisciplinary approaches involving an exploratory sequential mixed methods design were used. Data on household food security was collected in the period between November, 2019 and November, 2021, a period of two years. Climatic data was obtained through

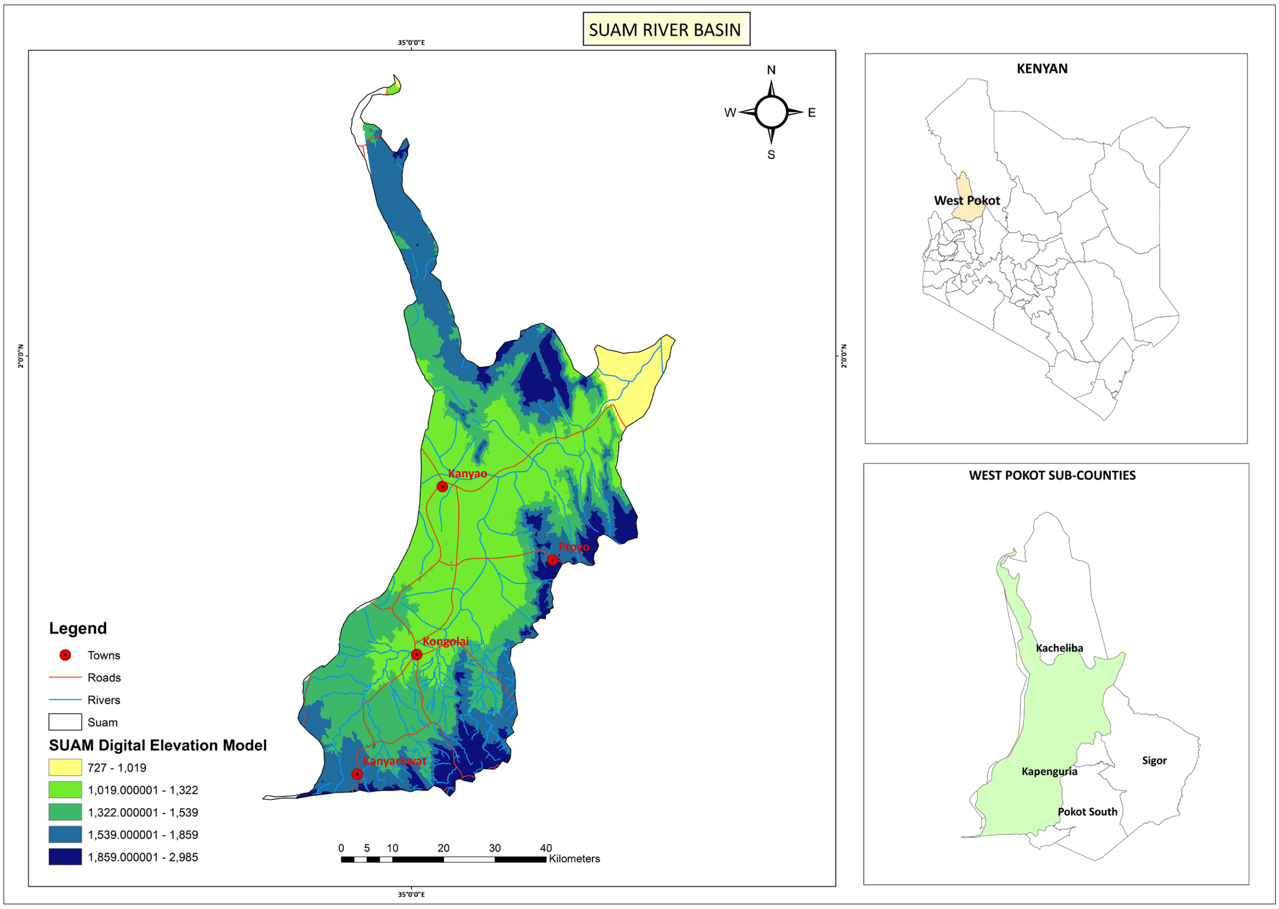


Figure 1. Map of suam river basin.

secondary data acquired from Climate Hazard Group Infrared Precipitation with Stations (CHIRPS). CHIRPS-v2 rainfall product provides reliable high spatial resolution information on amount of rainfall that can complement sparse rain gauge network in rain-fed agricultural systems in Eastern and Southern Africa (ESA) region (Muthoni et al., 2019). Monthly gridded rainfall data with a spatial resolution of 0.05˚ by 0.05˚ and spanning the period 1981-2020, were obtained from Climate Hazard Group Infrared Precipitation with Stations (CHIRPS). Monthly gridded Maximum and Minimum Era5 temperature data at a spatial resolution of 0.25˚ by 0.25˚ and spanning the period 1981-2020 were accessed from Copernicus Climate data store, ECMWF reanalysis from global climate. This was used to reconstruct monthly average temperature dataset for spatial analysis.

1) Mann-Kendall trend analysis

Temporal analysis employed Mann-Kendall trend test which was used to detect the presence of monotonic trends in rainfall within Suam river basin and to determine whether the trend was statistically significant or not Sen Slope estimator (Helsel & Hirsch, 2002). The median of those slopes is the Sen Slope Estimator (Sen, 1968). Since there are chances of outliers to be present in the dataset, the non-parametric MK test is useful because its statistic is based on the (+

or −) signs, rather than the values of the random variable, and therefore, the trends determined are less affected by the outliers (Birsan, Molnar, Burlando, & Pfaundler, 2005). Rainfall Trend analysis was done for Seasonal and annual temporal scales in the entire Suam river basin. The MK test statistic "S" was calculated based on (Mann, 1945; Kendall, 1975) and (Yue, Pilon, & Cavadias, 2002) as shown in Equation (1).

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\operatorname{sgn}\left(x_j-x_i\right) \tag{1}$$

2) Spatial Trend Analysis

The seasonal and annual spatial rainfall trends were computed in Climate Data Operator (CDO) using the command operator. Analysed spatial rainfall trends (seasonal and annual) were mapped in ArcMap (Schulzweida, Kornblueh, & Quast, 2010). Classified symbology embedded within ArcMap interface was used to reclassify spatial rainfall coverage into different classes based on the rainfall range and variation.

3) Variability Analysis

Coefficient of Variation was used to examine the variability of rainfall at annual scales Hare (Hare, 2003). A high value of CV is an indicator of high variability in rainfall, while, low value of CV is an indicator of low rainfall variability. Rainfall variability was computed using coefficient of variation (CV). The CV is as shown in Equation (2).

$$\mathrm{CV}=\left(\frac{S}{\bar{X}}\right)\times 100 \tag{2}$$

where CV is the coefficient of variation; S is sample standard deviation of the rainfall and X is the sample mean of rainfall. CV was computed by dividing rainfall sample standard deviation by rainfall sample mean and expressing as a percentage.

4) Household survey

Purposive sampling was used to select the two sub-counties within which Suam river traverses Pokot North and West Pokot in West Pokot County, thus forming a common hydrological basin. Quota sampling was used to select respondents who constituted focus group discussion teams. Primary quantitative data was basically drawn at the individual household level. A two-level multistage sampling was conducted to select a representative number of households. In the first level, simple random sampling technique was used to select at least 10% of the locations hence two locations from each of the sub-counties whereas in the second level, two sub-locations from each selected location were identified using simple random sampling technique.

Proportionate sampling was used to distribute the samples in the sub-locations based on their population in the sample frame. Finally, a simple random technique was used to select the households that formed the unit of analysis while the household heads formed the unit of observation during data collection process. A sample size of 387 was obtained using Yamane's formula for small populations (Yamane, 1967). A structured questionnaire with both close and open-ended question was use to collect data from the households on their perceptions on climate variability, change and food security.

5) Food security index score

The 17 constructs of dependent variables (food security) were re-coded into binary (0 "no" and 1 "yes") outcome where "1" indicated presence of food security and "0" showed food insecurity in the households. All the 17 variables for the food security dependent variable were included in calculation of index score of food security since the reliability tests showed tight coherence with a Cronbach's alpha of 0.917 showing high quality data. In order to generate coherent results, we singled out "1" as an interested figure and summed up to generate sum scores from 0 to 17 using the formula in Equation (3).

$$\text{FSSUM} = \sum_{i=1}^{17} F_i,\ i = 1, 2, \cdots, 17 \tag{3}$$

where; FSSUM = Food security sum score; F_1 =variable 1 which is "HHs willingness to change food production"…, and F_{17} is last variable which is "HHs skills and knowledge to ensure good nutrition, food safety and sanitation".

The results (sum scores) were linearized by subjecting to percentage i.e. on a scale of 0 - 100 interval) for each household and a new variable called "food security index score" was generated by applying formula in Equation (4).

$$\text{FSI} = \frac{\text{FSSUM}}{17} \times 100 \tag{4}$$

where FSI = Food security index score

The above formulae were used to generate the index scores for each category of food security for instance availability of food index score. Thereafter, mean and standard deviation were computed to measure central tendency and dispersion of the data in addition to overall index score for food security. The overall index for food security score was then categorised into two namely: Food insecure HHs (0) and Food secure HHs (1) implying those households scored FSI less than 50% and 50% and more, respectively.

3. Results and Discussion

3.1. Socio-Demographics of the Respondents

From a sample of 387 households, the majority (62.8%) were from West Pokot forming the agro-pastoral ecological zone whereas 37.2% were from Pokot North Sub-County that is predominantly in the pastoral ecological zone respectively. Majority (50%) of the households practiced agro-pastoralism while 33.6% practiced pure pastoralism as their main household occupation. The average monthly income per household was very low. About two-third of the households (59.7%) had average monthly income of less than KES 3000, equivalent to USD 30, while majority 65.9% depended on food from their own farms. Rivers were main source of water to the majority (83.7%) of the households in the basin.

Results show that households observed that the amount of rainfall, temperature, droughts, floods, pests and livestock diseases, and soil erosion had either increased or decreased (Table 1). On the other hand, humidity and incidences of landslides were perceived not to have changed. On the average, 59.2% perceived that drought and flood seasons had increased while 61.8% perceived that pests and livestock diseases had increased in the basin for the past forty years. These findings agree with the Mann-Kendall analysis of trends of rainfall and temperature over the period. Interviews with the sub-county livestock officer revealed that prevalence of livestock diseases and pests in the basin varied based on the variations of climatic variables.

3.2. Rainfall Trend Analysis

3.2.1. Annual Rainfall Trends

Temporal rainfall trends were observed in Suam river basin for the period 1981-2020 in decadal time steps. The results of Annual Mann-Kendall trend analysis are shown in Figure 2. The figure illustrates temporal rainfall trend pattern for decad 1 (1981-1990), decad 2 (1991-2000), decad 3 (2001-2010) and decad 4 (2011-2020). Decads 1, 3 and 4 showed increasing rainfall trends with Mann-Kendall tau being; 0.05, 0.02 and 0.07 respectively. The Sen's slope for each of these three decads showed an increasing trend. However, second decad (1991-2000) rainfall trend was characterised with decreasing rainfall trend; Mann-Kendall tau (0.015). The increasing rainfall trend observed in Suam river basin is in agreement with other studies which have been done in the arid and semi-arid lands of Kenya.

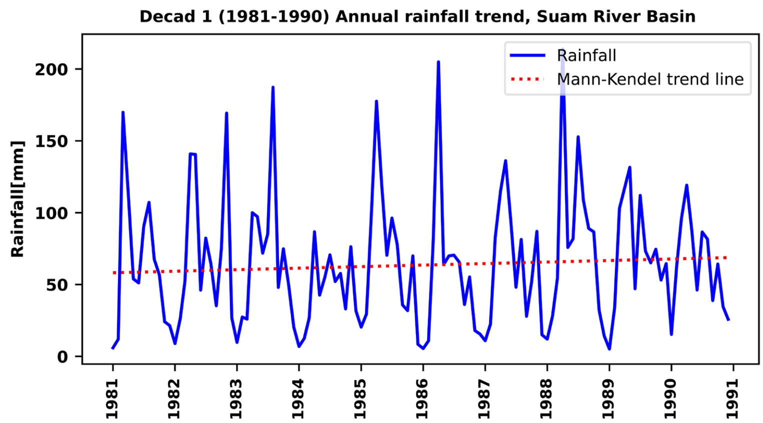
Table 2 below illustrates annual rainfall trends over Suam river basin for the periods 1981-2020.

Table 1. Households' knowledge on climate variability and climatic hazards.

Parameters for climate variability and climatic hazards	Household head knowledge (N = 387)			
	Don't Know (0)	Not Changed (1)	Increased (2)	Reduced (3)
Rainfall	0.8	26.4	30.7	42.1
Temperature	0.8	36.4	56.6	6.2
Humidity	27.4	32.6	9.0	31.0
Droughts	1.3	27.4	59.2	12.1
Floods	0.8	21.4	59.2	18.6
Pests and Livestock diseases	2.3	24.8	61.8	11.1
Landslides	35.4	41.1	14.2	9.3
Gullies	7.0	33.1	49.9	10.1

Table 2. Annual Mann-Kendel test statistics Suam MK test results.

	Trend	h	P-value	Z-statistics	Tau	Slope
First decad (1981-1990)	Increasing	false	0.41289	0.81883	0.05070	0.08884
Second decad (1991-2000)	Decreasing	false	0.80472	0.24724	0.01541	0.02332
Third decad (2001-2010)	Increasing	false	0.74566	0.32435	0.02016	0.03708
Fourth decad (2011-2020)	Increasing	false	0.24828	1.15453	0.07143	0.16294
1981-2020	Increasing	true	0.01838	2.35781	0.07201	0.03545



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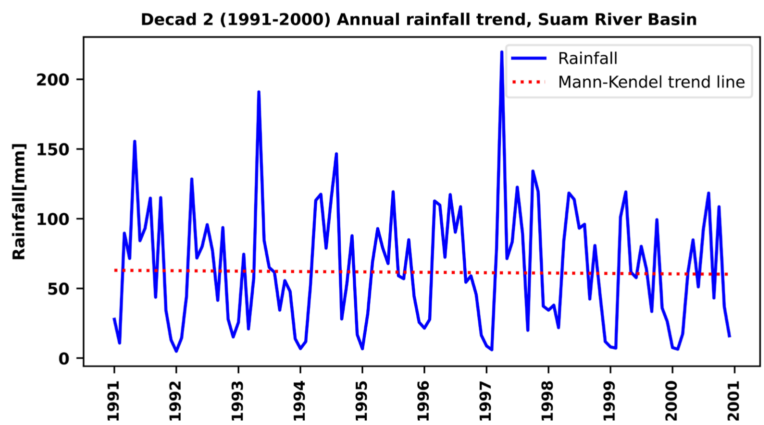

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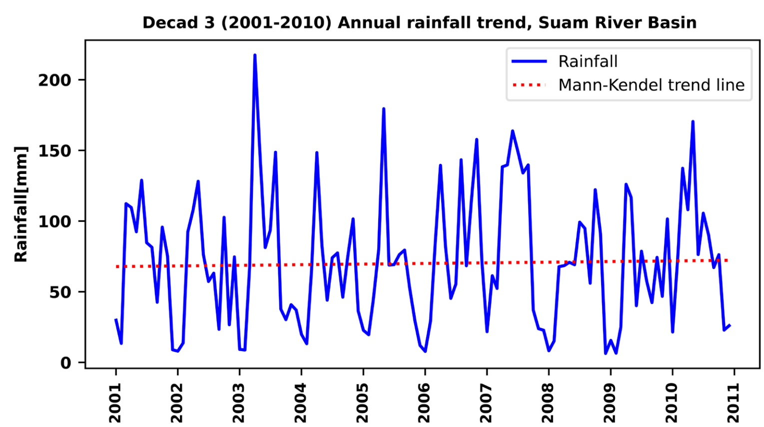

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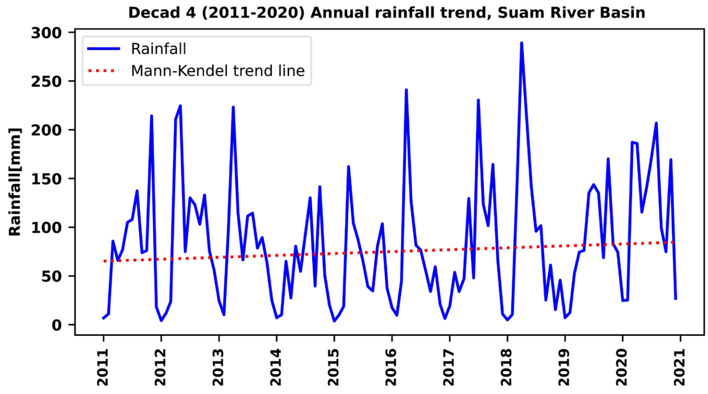


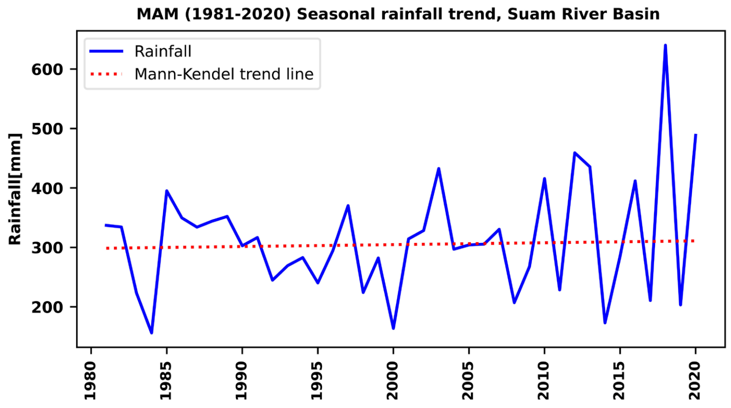
(d)

Figure 2. Decadal Annual rainfall trends. (a) First decade (1981-1990); (b) Second decade (1991-2000); (c) Third decade (2001-2010); (d) Fourth decade (2011-2020).

3.2.2. Seasonal Rainfall Trend

Figure 3 shows seasonal rainfall trend analysis for Suam river basin during the period 1981-2020. The seasons analysed included March-April-May (MAM), June-July-August (JJA), September-October-November (OND) and December-January-February (DJF). The findings show that different seasons have different rainfall trends over the study period 1981-2020. The Mann Kendall statistical test results for the seasonal rainfall trends done showed that trends existed for rainfall during June-July-August (JJA) and September-October-November (SON) seasons over the region over the period 1981 to 2020 with Mann-Kendall tau of 0.05 and 0.02 respectively. However, the increasing trend depicted for December-January-February (DJF) is not significant at the levels tested and requires further investigation. Mann Kendall trend analysis showed that March-April-May (MAM) season did not have either increasing or decreasing trend. This is supported with z-statistics and tau values of (0.1747 and 0.0205) respectively which were close to zero. DJF season correspondingly did not have either increasing or decreasing trend.

The June-July-August (JJA) and September-October-November (SON) seasons were characterized by increase in rainfall trend as indicated by z-statistics and tau values; (2.0156 and 0.2230) for JJA and (2.3885 and 0.26410) for SON (**Table 3**) The increase in rainfall trend as further explained by Sens's slope (2.4760 and 2.3413) for JJA and SON respectively is attributed to climate variability and climate change which have impacts on systems controlling climate over the region like Congo air mass, topography and inter tropical convergence zone. The spatial-temporal trends and variability in rainfall which have been observed in the region are important for planning of pastoral and agro-pastoral sectors in the study area (Muthoni et al., 2019) It is important to note that although MAM depicts a linear trend of seasonal rainfall, the amount of rainfall received remains higher compared to JJA, SON and DJF respectively. This could be attributed to the global systems especially the ITCZ that traverses the East African region setting the beginning of the long rains season. These seasonal rainfall patterns are similar to those that sweep over the Lake Victoria Basin from Kisii station in the Southern part and Kapcherop, Elgeyo Marakwet Kapenguria towards the northern western part covering the dryland sub counties (Mugalavai et al., 2008; Kipkorir, Raes, Bargerei, & Mugalavai, 2007) During the focus group discussions, agro-pastoralist indicated that their farming activities were based on traditional rain patterns MAM, this finding however, reveals the need to shift to JJA in order to maximize on use of rains received within this period. It was further observed that best practices require integration of both community indigenous knowledge (IK) and the conventional methods used by the Kenya Meteorological Department (KMD).



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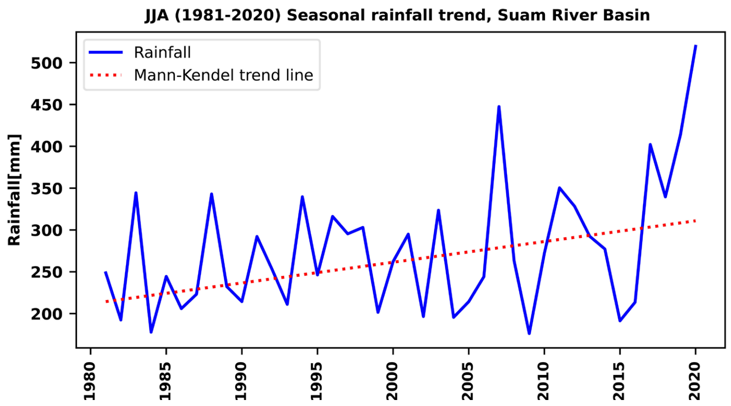

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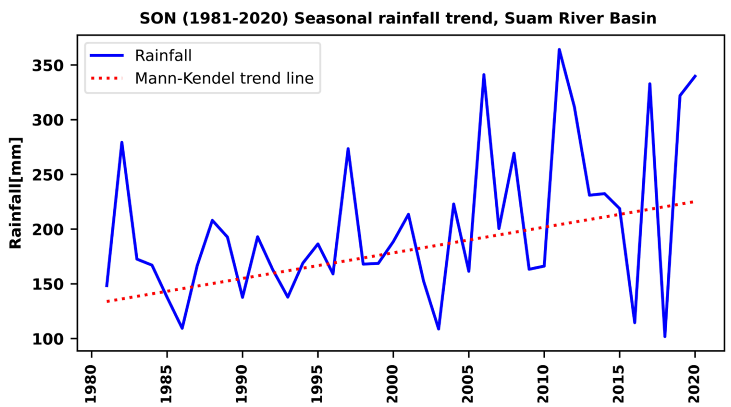

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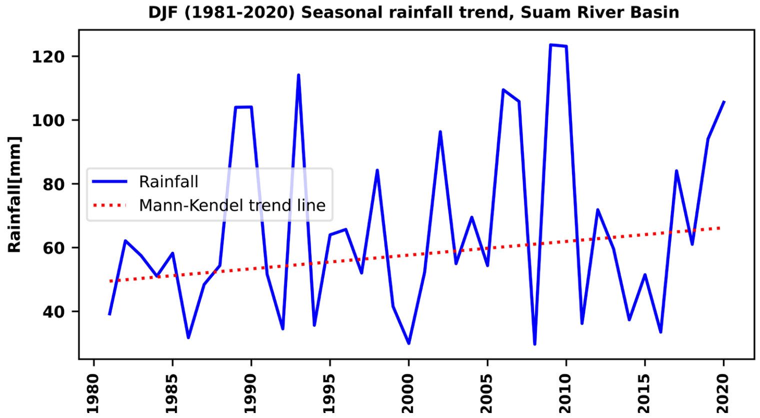

(d)

Figure 3. Seasonal rainfall trends over Suam river basin MAM (a), JJA (b), SON (c) and DJF (d) 1981-2020.

Table 3. Summary of Mann Kendall rainfall trend analysis.

Suam MK test results	Trend	h	P-value	Z-statistics	Tau	Slope
MAM Season (1981-2020)	No	False	0.8613	0.1747	0.0205	0.3161
JJA Season (1981-2020)	Yes	True	0.0538	2.0156	0.2230	2.4760
SON Season (1981-2020)	Yes	True	0.0169	2.3885	0.26410	2.3413
DJF Season (1981-2020)	No	False	0.18798	1.31656	0.14615	0.42931

3.3. Rainfall Variability

As depicted from the decadal coefficient of rainfall variation results, Suam river basin exhibited a westerly progression of rainfall variability with widespread moderate variability during the period 1981-1990 (**Figure 4**). During the period 1991-2000 the patterns showed a southerly progression with moderately high to high variability to the south increasing to very high to extremely high variability towards the north. The period 2001-2010 showed a southerly progression with high variability occupying the southern part and small portions of extreme variability in the north. Finally, the period 2011-2020 exhibited a southerly progression with moderate to high variability on the southern part, with the central part of the basin showing very high to extremely high variability to the northern part. This analysis provides patterns that are useful for planning of both pastoralists and agro-pastoralists livelihood activities (Mugalavai & Kipkorir, 2013).

Suam basin experienced highest rainfall variability during the first decadal (1981-1990) with highest coefficient of rainfall variation noted at 11.5%. During the same period, the western part of the basin was associated with high variability while the eastern part of the basin was characterized with moderate to very high rainfall variability. The basin noted a decrease in rainfall variability during the second decadal period (1991-2000), in the third decadal (2001-2010), rainfall variability in terms of magnitude decreased even in the fourth decadal (2011-2020). However, in the last decade, the southern part of the basin has been

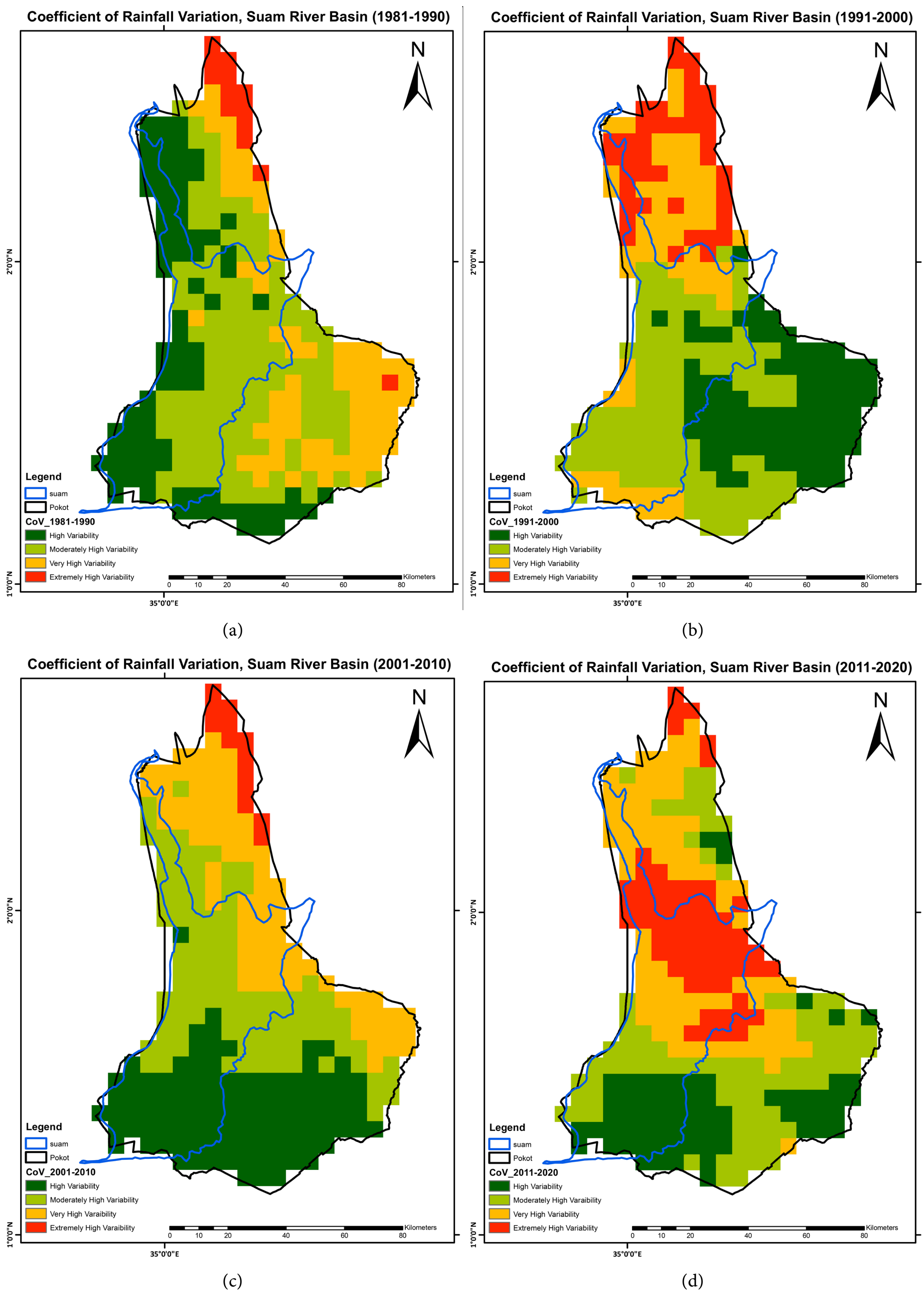

Figure 4. Rainfall variability coefficient of rainfall 1981-1990 (a), 1991-2000 (b), 2001-2010 (c) and 2011-2020.

under extremely high rainfall variability while the northern part of the basin has been experiencing moderate to high rainfall variability. These phenomena could be linked to climate change and climate variability. Generally, the results of these findings agree with previous studies, for example, (Moyo et al., 2012; Wagesho, Jain, & Goel, 2013) across Eastern Africa region revealed that there has been high inter-annual rainfall and temperature variability in the region, especially within the arid and semi-arid environments.

3.4. Spatial Temperature Patterns

As illustrated in **Figure 4** above, historically the basin has been under high temperatures which are attributed to its location in the desert climate; hot and dry. The highest temperatures noted were in the third decad (2001-2010) and fourth decad (2011-2020) at 27.0 and 28.2 degrees Celsius respectively. These high temperatures were noted towards the northern part of the basin. Generally, the southern part of the basin has been experiencing low temperatures while the northern part of the basin has been experiencing high temperatures.

During the period 1981-1990 and 1991-2000 the temperature patterns generally exhibited a southerly progression with low temperatures in the southern part increasing towards the north with isolated fluctuations (**Figure 5**). On the other hand, the periods 2001-2010 and 2011-2020 showed a south westerly progression with the eastern parts of the county exhibiting generally high temperatures. The rainfall and temperature patterns indicate that the northern part of the Suam river basin experiences harsher climate compared to other parts however these patterns are useful for planning purposes.

3.5. Households Level of Food Security

According to the World Food Summit (1996), globally the multidimensional nature of food security includes an analysis of: food access, food availability, food use and stability (FAO, 1996). Despite the increasing threats caused by climate variability and change in the dryland river basin of Suam, the results in **Table 4** show a contrary perception from the households on their level of food security. To measure households' food availability as an aspect of food security, five indicators were tested: change in food production practices; access to productive technologies and practices; access to resources, labour, finance, agricultural inputs; secure and timely access to fertile land, water and ecosystem services; and knowledge and skills to improve food production. Results show recorded households' food availability mean index of 63.41 with a standard deviation of 36.52. This finding implied that food availability in the basin was above average. In the focus group discussion, participants attributed this to the practice of nomadic pastoralism which was more resilient during droughts and agro-pastoralist activities which are mainly practiced during the rainy season along the river, and trade between the borders with Uganda and Kenya. El Bilali and others (Bilali, Bassole, Dambo, & Berjan, 2020) noted that in Sub-Saharan Africa where most

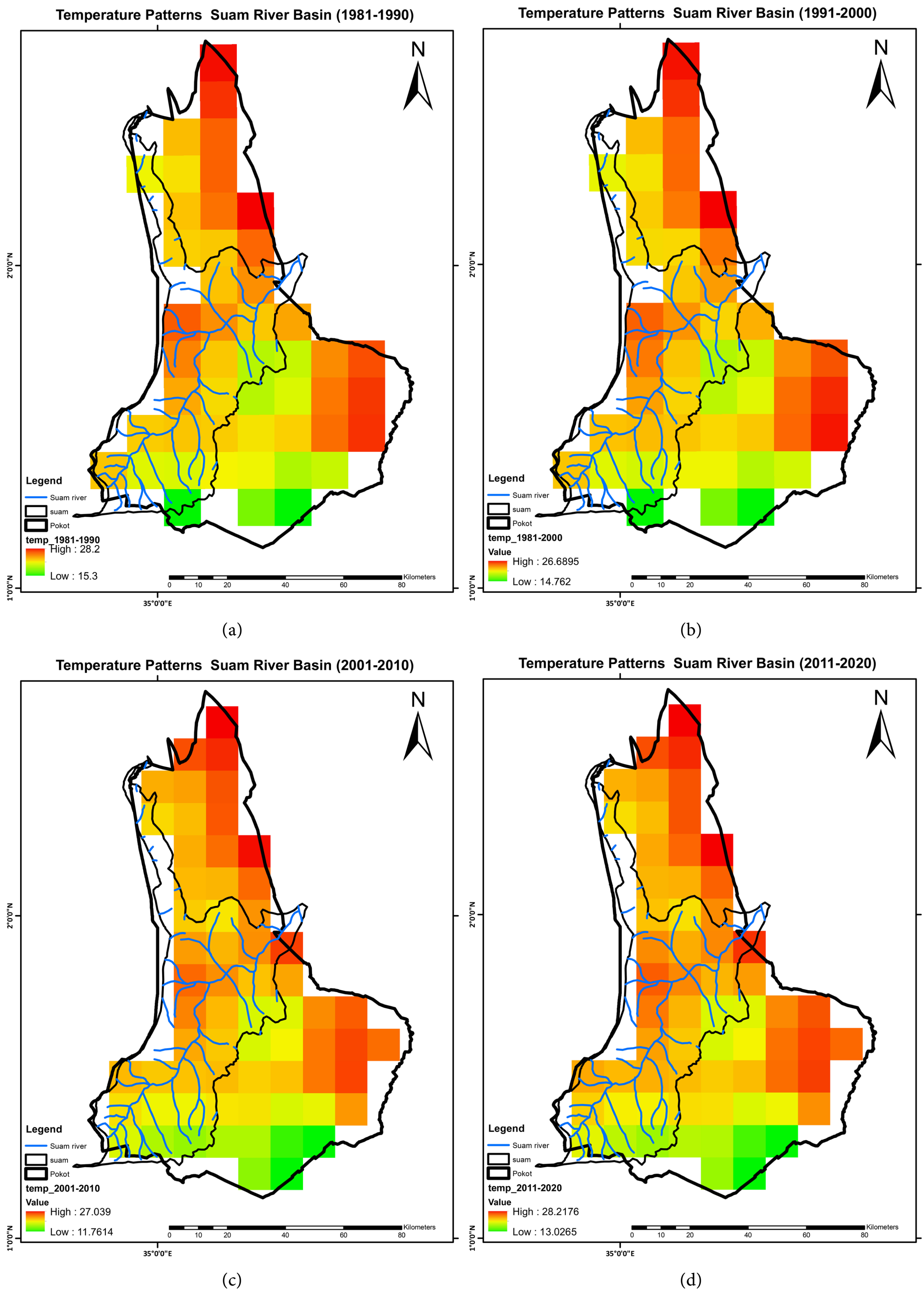

Figure 5. Decadal temperature patterns over Suam river basin; 1981-1990 (a), 1991-2000 (b), 2001-2010 (c) and 2011-2020 (d).

Table 4. Food security dimensions index score.

Description of Aspects of Food Security	Number	Percent
Availability of food		
HHs willingness to change food production practices, yes	300	77.5
HH farmers/pastoralist access to productive technologies and practices, yes	241	62.3
HH farmers/pastoralist access to resources, labour, finance, agricultural inputs, yes	232	59.9
HH farmers pastoralist/secure and timely access to fertile land, water and ecosystem services, yes	206	53.2
HHs knowledge and skills to improve food production, yes	248	64.1
Availability of food index score, Mean (SD)	**63.41 (36.52)**	
HHs accessibility to food		
Women have a strong say in HH economic decision making, yes	183	47.3
Increased HH income, yes	182	47.0
HH engage in secure income generating activities, yes	210	54.3
HHs accessibility to food index score, Mean (SD)	**49.53 (38.94)**	
Food stability		
Farmers/pastoralist grow climate adapted crops/breeds, yes	260	67.2
HH are energy efficient, yes	138	35.7
Land restoration including soil and water conservation and management, yes	191	49.4
HHs have and implement preparedness plans to protect lives and assets, yes	191	49.4
HH have coping strategies, yes	199	51.4
Resource assets, income exists which can be mobilized by HHs, yes	227	58.7
HHs stability to food index score Mean (SD)	**51.94 (37.11)**	
Effective use of food and water		
Access to clean water, yes	180	46.5
HHs willingness to change diets, yes	250	64.6
HHs skills and knowledge to ensure good nutrition, food safety and sanitation, yes	232	59.9
Food utilisation index score	**57.02 (37.16)**	
Overall index score: Food security	**55.78**	**31.94**
Food insecure HHs (0)	153	39.5
Food secure HHs (1)	234	60.5

of the population is food insecure, climate variability and change affects food availability through its adverse impacts on crop yields, and fish and livestock productivity.

Three indicators: women having a strong say in household economic decision making; increased household income; and engaging in secure income generating activities were used to compute households' access to food. The results show that overall, the households recorded accessibility to food mean index was 49.53 with a standard deviation of 38.94. This finding recorded below average compared to the overall food security mean of 55.78. With low levels of income as shown in this study, climate change was blamed during key informant interviews and group discussions as it contributed to reducing access to food through reduced livestock and crop yield and negative impacts on both food prices. The findings agreed with the earlier conclusion that rural livelihoods and as a result rural populations will suffer from the increase of food prices as well as the negative impacts of climate change on their sources of income and livelihood strategies relating to agriculture (Bilali, Bassole, Dambo, & Berjan, 2020).

Food utilization was measured using three indicators: households' access to clean water; willingness to change diets; and skills and knowledge to ensure good nutrition, food safety and sanitation. The results gave a food utilization mean index of 57.02 with a standard deviation of 37.16. This index score is attributed to existence of multiple actors in the basin who work to promote good nutrition, water, sanitation and hygiene programmes. Climate variability will change food utilization with impacts on the nutrition status of the populations, especially poor and vulnerable people. Citing example from FAO 2016 (Food and Agriculture Organization of the United Nations (FAO), 2016), it is evident that higher temperatures could create enabling environment for the development of pathogens, while water scarcity induced by droughts affect water quality and hygiene habits thus increasing the burden of diseases especially among the poor children in the drylands of Sub-Saharan Africa.

According to El Bilali and others (Bilali, Bassole, Dambo, & Berjan, 2020) climate variability and the increasingly frequent and intensive extreme climate events could affect the stability of food availability, access and use. In this study, households' food stability was measured using six variables: growing of climate adapted crops/breeds; households are energy efficient; land restoration including soil and water conservation and management; having and implementing preparedness plans to protect lives and assets; having coping strategies; and existence of resources and income which can be mobilized by households. The results show household stability of food mean index was 37.11 with a standard deviation of 51.94. From this finding, it is imperative to note that efficient responses to climate change require an understanding of the full spectrum of potential climate impacts on food utilization, access and availability, as well as on the underlying natural, built and governance systems in the dryland river basin (Keller et al., 2018).

The overall index score for food security in the basin was 55.78 implying that majority of the households were food secure based on the seventeen variables that were used to measure food security (**Table 4**). Therefore, the results show that 60.5% of the households were perceived to be food secure compared to 39.5% who were perceived to be food insecure. Although studies show that climate variability and change affects food security in the drylands directly and indirectly through the impacts on livestock and crop production, in the focus group discussions and key informant interviews, this finding was attributed to the fact that the households diversified their livelihoods by practicing both pastoralism and agro-pastoralism in the basin. This prepared the households in adapting to different seasons with extreme weather conditions such as droughts and floods. To create a balance between climate adaptation and mitigation, Loboguerrero and others (Loboguerrero et al., 2019) suggested climate-smart agriculture could help foster synergies between productivity, adaptation, and mitigation thereby ensuring sustainable food production in highly climate sensitive ecosystems such as drylands river basins. Elsewhere, studies in the drylands in Kenya showed that the recurrence of droughts and flood events associated with climate variability and change has adversely affected food security, especially among the pastoralist and small-scale farmers in the drylands of Turkana, Mandera, Marsabit, Garissa, Wajir, Isiolo, Tana River, Machakos, Makueni and Kitui (Kogo, Kuma, & Koech, 2021; Demombynes & Kiringai, 2011; Rao, Ndegwa, Kizito, & Oyoo, 2011).

Interestingly, results in **Table 5** show that the type of ecological zone where the household is located did not show statistical significance with food security. Households main source of food was strongly related with food security at 1 % significance level (*p*-value = 0.003). Own farm activities were seen as main source of food followed by the buying. Further, the results show that the household main occupation and main source of water were found to be statistically significant to the household level of food security. Interestingly, household average monthly income did not show statistical significance with household food security status.

The results in **Table 6** show the association between climatic variables (rainfall, temperature and humidity), climatic hazards (droughts, floods, landslides and soil erosion), and water variability with food security. There was a weak, positive correlation between food security variables and climatic variables including water. For instance, climate variables and food security index scores were positively related though slightly weak at $r = 0.23$ and statistically significant at 1% significance level at *p*-value of 0.000***. Overall, all the four categories; climate variables, climatic hazards/risks and water variability showed statistically significant relationships with the overall food security index score at *p*-value of 0.000*** although the correlation was weak i.e. $0.1 > r < 0.4$. The overall food security index score showed strong positive correlation with overall climatic variability index score at 1% significance level. Although there was positive relationship between the two variables, the strength was weak ($r = 0.27$). Therefore, the variables were significant in determining the status of dryland pastoralist and agro-pastoralist households' food security along the Suam river basin. From these findings it is evident that during the past droughts and floods episodes for instance, 1980-1981, 1983-1985, 1987, 1992-1993, 1995-1996, 1999-2001, 2004-2006 and 2008-2009 (Kogo, Kuma, & Koech, 2021; Biamah, 2005; Downing, 1992) were accompanied by food insecurity especially in the drylands. Previous studies emphasize the fact that Kenya and Sub-Saharan drylands will continue to experience general loses in pastoral and agro-pastoral production of key staple foods due to complexities and impacts of projected climate change (Kogo, Kuma, & Koech, 2021). The debate on food security cannot be separated from agriculture and its associated activities in the drylands. However, agriculture is probably the most climate-dependent human activity and is both victim and responsible for climate change, while it can also be a solution to the climate change crisis (Bilali, Bassole, Dambo, & Berjan, 2020).

Further results in **Table 7** revealed that rainfall and humidity were climatic variables that showed strong relationship(s) with food security at *p*-value 0.000,

Table 5. Relationship between background factors and food security.

Background factors	Categories	Level of Food Security (%)		X^2	*P*-Value
		Food insecure HHs (n = 153)	Food secure HHs (n = 234)		
Sub County	Pokot North	36.6	37.6	0.04	0.841
	West Pokot	63.4	62.4		
Type of ecological zone	Agro-pastoral	63.4	62.4	0.04	0.841
	Pastoral	36.6	37.6		
HH main occupation	Farmer agro-pastoral	47.1	52.1	16.962	0.002***
	Pure Pastoral	43.1	27.4		
	Pure crop farming	0.7	5.6		
	Civil servant/Employee in private/labourers	5.2	6.0		
	Business	3.9	9.0		
Household average monthly income	<3000	58.8	60.3	1.061	0.588
	3000 - <10,000	22.9	25.2		
	10,000 and above	18.3	14.5		
Household main source of food	Own farm	66.7	65.4	11.712	0.003***
	Buying	28.8	34.6		
	Government/NGOs Food Aid	4.6	0.0		
Household main source of water	River	89.5	79.9	7.053	0.070*
	Piped water	4.6	9.0		
	Borehole	5.2	8.1		
	Others	0.7	3.0		

*$p > 0.1$ ***$p > 0.01$ statistically significant between food security and background factors.

Table 6. Correlation (r) and level of significance (p-value) between Climatic Variability and Food security variables.

Food Security **Climatic Variability**	HHs Availability of food	HHs accessibility to food	HHs stability to food	Food utilised effectively	**Food security Overall Index score**
Climate Variables (r and *P*-value)	0.12 (0.014**)	0.21 (0.000***)	0.24 (0.000***)	0.23 (0.000***)	0.23 (0.000***)
Climatic hazards/risks (r and *P*-value)	0.10 (0.058*)	0.22 (0.000***)	0.17 (0.001***)	0.16 (0.002***)	0.18 (0.000***)
Water variability (r and *P*-value)	0.20 (0.000***)	0.29 (0.000***)	0.32 (0.000***)	0.25 (0.000***)	0.31 (0.000***)
Climatic variability, Overall index score (r and P-value)	0.14 (0.005***)	0.27 (0.000***)	0.26 (0.000***)	0.26 (0.000***)	0.27 (0.000***)

*$p > 0.1$ **$p > 0.05$ ***$p > 0.01$ statistically significant between food security and climatic variability.

Table 7. Relationship between climatic variability (mean scores) and food security.

	Level of Food Security levels (Mean scores)			
	Food insecure HHs (n = 153)	Food secure HHs (n = 234)	X^2 or F	*P*-Value
Rainfall	2.1	2.2	34.855	0.000***
Temperature	1.6	1.7	7.994	0.046**
Humidity	1.0	1.7	40.019	0.000***
Index mean score (SD): Climate Variables	**52.1 (21.3)**	**62.6 (21.1)**	**22.205**	**0.000*** **
Droughts	1.7	1.9	7.545	0.056*
Floods	1.7	2.1	34.387	0.000***
Pests and Livestock diseases	1.8	1.8	9.352	0.025**
Landslides	0.9	1.0	24.984	0.000***
Gullies	1.6	1.7	9.377	0.025**
Index mean score (SD): Climatic hazards/risks	**51.8 (12.2)**	**56.6 (12.6)**	**13.69**	**0.000*** **

*$p > 0.1$ **$p > 0.05$ ***$p > 0.01$ statistically significant between food security and climatic variability.

99% confidence level, compared to temperature at *p*-value of 0.046 (5% level of significance). Climate hazards like floods and landslides on the other hand showed strong relationship(s) with food security at *p*-value of 0.000, 99% confidence interval compared to droughts at *p*-value of 0.056, 10% level of significance; and pests and livestock diseases, and gullies at *p*-value 0.025, 5% level of significance.

3.6. Conclusions and Recommendations

From this study, rainfall and temperature patterns show increasing seasonal trends though with a lot of variations, making it unpredictable and unreliable for traditional pastoral and agro-pastoral planning and utilization of river basin resources. Although agro-pastoralists largely rely on traditional methods (IK) in predicting climatic events it was observed that best practices require integration of both these methods and the conventional methods used by the Kenya Meteorological Department (KMD).

The level of food security remains to be above average as households continue to diversify pastoralism and agro-pastoralism activities. Agro-pastoralist farming activities were based on traditional rain patterns of MAM however, there is a need to shift towards JJA and SON with significant increasing trends in order to maximize the rains received within these seasons. Increase in rainfall however, is an opportunity that has not been exploited for intensification of agro-pastoralism production that comes as result of climate variability and change in the dryland of Suam River basin. Furthermore, it is also important to note from the findings that to ensure food security given the current threats of climate variability and change in the dryland river basin of Suam, it is necessary for the policy makers and implementers to ensure a balance in policy interventions that will address the needs of both the pastoralist and agro-pastoralist communities.

The study further established that efficient responses to climate change require an understanding of the full spectrum of potential climate impacts on food utilization, access and availability, as well as on the underlying natural, built and governance systems. Targeting only one mode of livelihood is likely to increase vulnerabilities to the impacts of climate change. It is therefore necessary to promote both pastoral and agro-pastoral policies and interventions in the dryland river basins to enhance food security. This could be achieved through mainstreaming pastoralism and agro-pastoral activities in devolved policies on climate change, environment and agriculture as a supportive system.

Tapping into existing institutionalized modes of climate change governance provided under decentralized governance systems including the county government system, regional development authorities and devolving financing mechanisms could provide more opportunities to utilize the increased rainfall for agricultural production for food security.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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