Report on Historical Climate Baseline Statistics for Taita Taveta, Kenya

Vol 1

ICPAC
IGAD Climate Prediction & Applications Centre

ADAPTATION FUND
WORLD METEOROLOGICAL ORGANIZATION
Food and Agriculture Organization of the United Nations

ACKNOWLEDGMENTS

The report was prepared with substantial inputs and feedback from Kenya Meteorological Department, IGAD Climate Prediction and Application Center, World Meteorological Organisation, Food and Agricultural Organization. In particular inputs and comments were made by Mary Githinji, Bahati Musilu, Oliver Kipkoge, Abdi Jama, Guleid Artan, Sebastian Grey, Deborah Duveskog.

Analysis of climate change data and drafting of the report was made possible with inputs from Linda A. Ogallo, Paulino Omay, George Kababka, and Ismael Lutta.

Editor: Bahati Musilu, Kenya Meteorological Department

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1. INTRODUCTION

The Greater Horn of Africa is extremely vulnerable to climate variability. Available research records indicate extremes in rainfall and temperatures have been very common in the region including recurrences droughts and floods (Ogallo Linda et al. 2017; Omay et al., 2016; Sabiiti, et al., 2016; Awange, et al., 2007; Kinguyu, Ogallo L. A. and Anyamba 2000; Ogallo L. A., 1993; among many other authors). Extreme precipitation changes over Eastern Africa such as droughts and heavy rainfall events have been experienced more frequently during the last 30-60 years (IPCC, 2014a). Changes in temperature and precipitation patterns have also been reported in many parts of the world including other parts of GHA by all the past IPCC assessments on the state of the global climate (IPCC, 2014a, IPCC 2014b).

The risk of loss of rural livelihoods and income due to climatic hazards is particularly real in arid and semi-arid regions largely inhabited by communities engaged in pastoral and agro-pastoral livelihood systems. These communities have limited access to information, technical support and financing for adaptation options hence responding to local climate variability and predictions is very limited. Therefore, enhancing the capacity of communities to cope and adapt to climate variability and change helps to build resilient communities.

About 84% of Kenya, 50% of Ethiopia and 30% of Uganda are classed as either arid or semi-arid lands. Annual evapotranspiration in Arid and Semi-Arid lands (ASALs) exceeds the amount of rainfall received. Agricultural productivity is also limited by poor availability of moisture thus affecting the food and nutrition security of populations. Prolonged and widespread drought is a recurrent feature of the ASALs that is exacerbated by the climate change phenomena, advancing desertification and ecological degradation. International Federation of Red Cross and Red Crescent Societies (IFRC) (2011) reports that most pastoral communities in the ASAL region are overwhelmed by the realities of the current weather and climate patterns in search of pasture especially during drought periods. Traditional pastoral routes, national park fences and farm enclosures limit access to grazing and water points, and pursuing the available pasture and water points can lead to violence within the region.

Enhanced desertification in the Horn of Africa's dry-lands is another key challenge in the region. The harsh ecological circumstances of the ASALs contribute to severe hardships amongst the affected communities, including poverty, hunger, malnutrition, dislocation and conflicts over natural resources both within and across boundaries in the region. The vulnerability of the Horn of Africa's arid and semi-arid Lands has been especially evidenced over the last decades by the occurrence of drought induced famine in many parts of the region, notably in the early 1980s and most recently in 2011, when millions of people were affected by drought causing untold suffering and death of both livestock and human populations.

Generally, the Horn of Africa consists of fragile ecosystems that are highly vulnerable to climate change, and thus the livelihood strategies undertaken by dry-land communities are equally fragile and vulnerable in this regard. The task of building resilience to climate change and supporting community adaptation to climate change is therefore closely linked to the sustainable management of natural and productive resources. The IGAD Drought Disaster Resilience and Sustainability Initiative (IDDRSI) strategy states that due to this interplay of factors, “efforts to increase the capacity of communities and households in the ASALs to cope with and adapt to greater prevalence of drought events requires a holistic approach that addresses the need for information (including climate information and information on climate resilient practices), access to appropriate technology, capacity building, new livelihood opportunities and a supportive policy regime”.

According to the United Nations Development Program (UNDP), countries that have a high percentage of dry-lands like Uganda and Ethiopia, are highly dependent on the development, efficient and effective use (and also resilience) of these parts of the countries for development. Therefore, the dry-lands in the Horn of Africa can be said to be socially, economically and ecologically important areas where building of climate resilience can effectively contribute to poverty alleviation and economic retardation of the resident populations and their countries as a whole.

The Agricultural Climate Resilience Enhancement Initiative (ACREI) is a 3-year partnership program funded by the Adaptation Fund within the auspices of the World Meteorological Organization (WMO), the Food and Agriculture Organization of the United Nations (FAO) and the IGAD Climate Prediction and Applications Center (ICPAC). The program is working in Ethiopia, Kenya and Uganda to support community adaption practice, climate proofing of extension systems and climate informed decision making. ACREI attempts to improve climate forecasts using a regional approach and build the capacity of communities to understand and appropriately use climate information and related agro-advisories in decision-making to climate-proof their livelihoods; and thus enhance their water, food and nutrition security.

The main goal of the ACREI is to develop and implement adaptation strategies and measures that will strengthen the resilience of vulnerable smallholder farmers, agro-pastoralists and pastoralists in the Horn of Africa to climate variability and change in line with the IGAD Drought Disaster Resilience Sustainability Initiative (IDDRSI) programme, the National Adaptation Plans of Action (NAPAs) and Development Strategies/Visions of participating countries. The overall objective of the project is “Improved adaptive capacity and resilience to current climate variability and change among targeted farmers, agro-pastoralists and pastoralist communities.” The three components of the project include:

1. Community Adaptation practice through sustainably enhanced productivity, production, and livelihood diversification and income levels among targeted communities;

2. Climate proofing of extension systems through enhanced technical capacity of development and extension actors (national, sub-national, and private sector, NGOs, CBOs) to support community level climate adaptation strategies; and

3. Climate informed decision making through improved climate informed decision making in regional, national and sub-national institutions.

In close partnership with the National Meteorological and Hydrological Services (NMHSs), ICPAC leads component 3 of the project while FAO and WMO lead Components 1 and 2 respectively.

Data Processing and Forecasting Systems (DPFS), appropriate information packaging, dissemination channels and policy gaps are major limitations to provision of effective climate services to farming communities by the National Meteorological and Hydrological Services (NMHSs) in the region. The infrastructure and facilities for data processing and forecasting systems have continued to deteriorate leading to great difficulties in providing weather and climate services in to meet national and regional needs. The human resource capacities of the NMHSs are also insufficient to meet the evolving challenges. These shortcomings have continued to negatively impact on the availability, timeliness, efficiency, accuracy and quality of actionable climate service delivery.

In order to effectively implement the Project's three components, baseline data and information that is easily accessible to the users has been key activity for the project. The users must also be able to understand and appreciate the significance of these baseline data as well as basic weather and climate concepts such as normal, above normal, below normal, risk management, among other terms. Analysis of the baseline climate was therefore one of the first major activity of the project to support the project components. Baseline climate data analysis in the three countries was undertaken by organizing workshops for the focal points from each member state under the support of ICPAC's climate scientists. The workshops also enabled integrated planning and outcome mapping roadmap of the project agreed upon by each participating Member State and specific users in the project area.

This project report provides a summary of the Climate Baseline Statistics for Taita Taveta, Kenya, as derived from the workshop on area specific analysis of climate data. Similar reports for East and West Hararghe (Ethiopia), and Isingiro/ Sembabule Districts (Uganda) will be presented independently as separate volumes. The locations of the three study areas are shown in **Figure 1.1-1** below

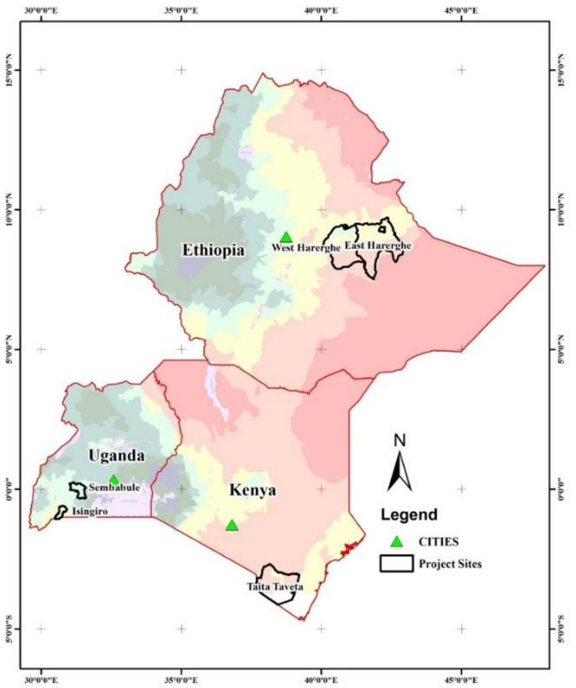


Figure 2.1-1 ACREI project Sites

The analysis generated and mapped location-specific basic statistics including mean, trends, Maximum and Minimum temperatures as well as other space- time climate characteristics that are required to provide local climate risk knowledge including those required for climate change adaptation and mitigation.

The other products created during the workshops included rain-fed cropping start, progression and end of season, number of rain days, seasonal rainfall distribution in space and time, probability of damaging dry spells and or storms occurring including when, where and for how long, percentile of precipitation, and related seasonal water balance variables, seasonal peak, etc. These climate baselines will serve as information material for all components of the project including the partners and stakeholders.

2. KENYA AND THE STUDY SITE

According to the Ministry of Agriculture, Livestock and Fisheries (MoALF), agriculture is the main economic sector in Kenya and accounts for over 25% of the gross domestic product (GDP), over 65% of Kenya's total exports and provides more than 18% of formal employment. Production is carried out on farms averaging 0.2–3 hectares, mostly on a mixed subsistence and commercial basis. This small-scale production accounts for over 75% of the total agricultural output and over 70% of marketed agricultural produce. Growth of the national economy is therefore highly correlated to growth and development in agriculture. However, Kenya's agriculture is 98% rain-fed and predominantly small-scale, especially in the medium to high-potential areas, covering about 15% of the country.

Therefore, productivity in the sector is directly influenced by climatic conditions. The livestock subsector employs 50% of the agricultural labour force and is the mainstay for over 10million Kenyans (34% of the country's population) living in the Arid and Semi-Arid Lands (ASALs). According to the 2009 livestock census, the country had a livestock population of 17.5 million cattle; 27.7 million goats; 17 million sheep; and 31.8 million domestic birds, among other livestock kept in the country. Kenya's national forest cover is approximately 6.9%, much lower than the internationally suggested minimum of 10%. The fisheries and aquaculture subsector also plays an important role in food and nutrition security and is composed of both freshwater and marine fisheries, which contribute about 0.5% of the country's national GDP.

Overall, dependence on rain-fed agriculture and declining soil health have increased the vulnerability of farming systems and exposed rural households to food insecurity and poverty. Kenya is now increasingly seeing changes in the onset, duration and intensity of rainfall across the country, while the frequency and intensity of the extreme weather events such as drought and floods are on the rise, with devastating impacts on the national economy and the livelihoods of the people. Drastic and innovative measures are needed to help farmers adjust to these changes in current and projected weather patterns.

The ASALs of Kenya cover 84% of the country's total land area, account for 34% of Kenya's human population (approximately 10 million people of whom 4 million are pastoralists) and an estimated 46% of the country's livestock population. Livestock raised by pastoralists in Kenya dry-lands is estimated to be worth up to US$800 million annually (AU-IBAR, 2013; Jode, 2010).

However, pastoralist areas have the highest incidences of poverty, food and nutrition insecurity and the least access to basic services particularly in the northern districts of the country. According to the Kenya Demographic and Health Survey (KHDS, 2014), about 26% of Kenyan children under 5 years are stunted, with some counties in ASALs bearing the largest burden. 4% of Kenyan children are wasted, with wasting concentrated in the north (ASAL counties) having over 11% of their children wasted. ASALs in Kenya contain 18 of the 20 poorest constituencies in Kenya. In some parts of the vast northern districts of Turkana, Marsabit, Wajir and Mandera between 74% - 97% of people live below the absolute poverty line. Droughts are common in the ASALs, and it has been suggested that they have increased in frequency over recent decades thus placing further stress on the livelihoods of those who live in these areas. Taita Taveta County has been used as the Kenyan project site for this project. The next section provides more information on this Kenyan project site.

2.1 Taita Taveta County

Taita Taveta County **(Figure 2.1-1)** is located in the Coastal region of Kenya and borders Kajiado County to the North West, Makueni County, Kitui County and Tana River County to the North, Kilifi County and Kwale County to the East and the United Republic of Tanzania to the South and South-west. The County population was 329,383 in 2015 and is projected to rise to 345,800 in 2017 (KNBS, 2009). An estimated 57.2% of the population is absolute poor, meaning that they live on less than Kshs 1,562 per month.

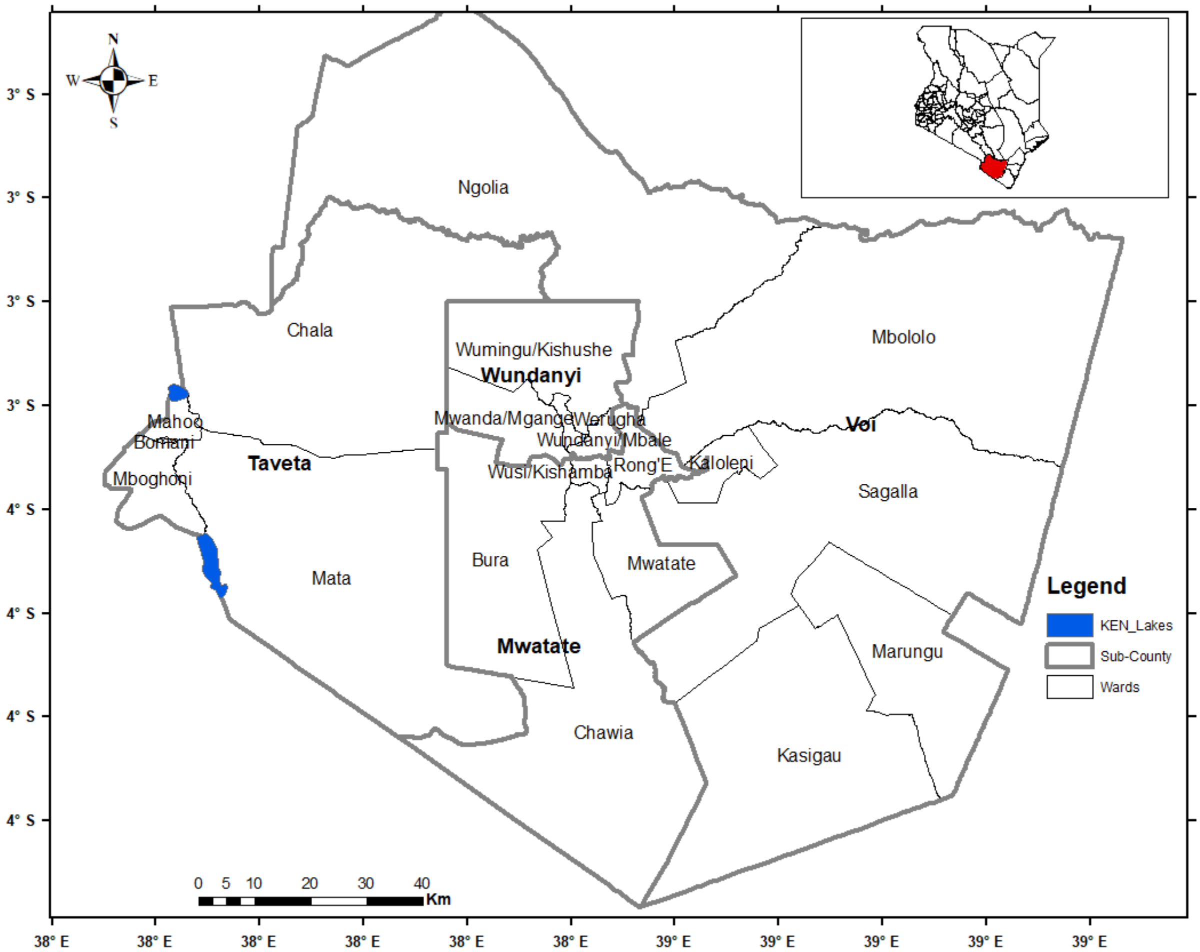


Figure 2.1-1 Taita Taveta Sub-Counties and Ward

It covers an area of 17,084.1km^2 with 62% or 11,100Km^2 being within Tsavo East and Tsavo West National Parks. Taita Taveta County is one of Kenya's ASAL regions with 89% of the County area characterized by semi-arid and arid conditions. Only 2.5% of the County (located in the highlands) is classified as high potential area. Taita Taveta consists of four Sub-Counties namely Voi, Mwatate, Wundanyi and Taveta. The sub-counties are further divided into twenty wards (**Figure 2.1-1**).

The National Parks coupled with high human population pressure in the lowlands has resulted in human-wildlife conflict. The crop and livestock sub-sector are the largest employers and contributors to household incomes in the County. The average farm holding in the areas that have agricultural potential ranges between 0.5ha to 30ha, while that of rain fed ranges between 2ha - 20ha. The average farm size for small scale farmers is about 0.4ha in the highlands, 1.3ha in the midlands, and 4.8ha in the lowlands. The County has a bimodal rainfall pattern with two rainy seasons. The long rains occur between March and May with a maximum in April. The short rains take place between October and December. Rainfall distribution is uneven, with the highlands receiving higher rainfall than the lowland areas. During the long rains season, the highlands record an average of 265mm while the lowlands record 157mm whereas, during short rains season, annual rainfall is 1,200mm and 341mm for highlands and lowlands respectively. The annual mean rainfall is 440mm. The average temperature in the County is 23^0C, with temperatures getting as low as 18.2^0C in the hilly areas, while on lower zones, temperatures rise to about 25^0 C..

The main crops grown ranked similarly in order of profitability include maize, beans and pigeon peas. The County is a major livestock rearing zone with the main types of livestock being beef cattle, dairy cows, sheep, goats, camels, pigs and poultry. Chicken is the main poultry reared, although guinea fowl rearing is emerging in some parts of the County. Bee keeping is also a livestock enterprise that is undertaken in the County.

Climate change and variability remains a threat to sustainable development in the County. Although climate data from the Kenya Meteorological Department for the County is scanty, there is observed changes in the seasons whereby the rainy seasons have reduced and the onset of the rains delayed. These changes present additional challenges to the socio-economic development of the County in a number of ways. Within the agricultural sector, which is the most vulnerable, farmers have experienced reduced yields and substantive post-harvest losses leading to food insecurity in the County.

Rising temperatures are associated with high prevalence of pests and diseases which affect productivity both in crops and livestock. Extreme cold is responsible for frost experienced in some parts of the County.

Moreover, shifting seasons means changes in planting period which in turn affects crop performance, while drought results in reduced pasture. The Government of Kenya listed Taita Taveta County as one of the hardest hit Counties by intermittent cycles of drought and floods. In 2012, an estimated 87,000 people were affected by famine caused by drought, forest fires and the subsequent invasion by wild animals that destroyed surviving food crops. (Government of Kenya, 2016).

3. CLIMATE BASELINES WORKSHOP

ICPAC and National Meteorological and Hydrological Services from Kenya, Ethiopia and Uganda held a workshop in Naivasha from April 15 to 19 to generate historical climate analysis for the ACREI project sites. The workshop programme also included capacity enhancement for the focal points on climate data analysis tools. The team used standard appropriate tools and procedures developed by ICPAC to analyse historical data and generate useful climatological baseline products. The workshop was targeted to contribute three out of the four outputs to be implemented by ICPAC including:

i. Output 3.1: Downscaled, location-specific seasonal climate forecasts and future projections generated regularly;
ii. Output 3.3: Agro-climatic advisories appropriately packaged and timely disseminated; and
iii. Output 3.4: Evidence based climate information feeds into policy dialogues in the region.

This Workshop preceded national site specific workshops where some of the outputs from the inaugural workshop were presented to the local users and partners for comments and also as part of the planned national capacity building forums.

3.1 DATA

The ACREI project sites for the intervention were identified based on a number of criteria, including their vulnerability to climate change, relevance in terms of resilience building, and fragility of the natural resource base and level of land degradation. Further, locations were sought that have less on-going or past efforts towards climate change as to avoid duplication of efforts. Some level of extension capacity and past experience with group extension methodologies was however desired. Since the project is characterised by learning and innovation, access to the project site was considered as to allow frequent support and backstopping, thus the selection criteria included; road infrastructure, security and peace . Country station data together with satellite rainfall data was used in the study from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset (CHG, 2016). CHIRPS is a global dataset (50° S-50° N, 180° E-180° W), with a resolution of 0.05°, ranging from 1981 to near-present gridded precipitation time series. CHIRPS data are produced by scientists at the University of California, Santa Barbara (UCSB) Climate Hazard Group (CHG) and the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center. The data was developed to support the United States Agency for International Development Famine Early Warning Systems Network (FEWS NET).

4. BASELINE STATISTICS FOR TAITA TAVETA

Several baseline climate products including maps were generated through the capacity building workshop. Examples of the products presented in this report include:-

i. Mean Annual Rainfall;
ii. Extremes in Mean Annual Rainfall
iii. Monthly and Seasonal Rainfall Distribution;
iv. Inter-annual Variability/ Anomalies;
v. Rainfall Trends;
vi. Rainfall Intensity;
vii. Onset, Cessation dates and Length of Growing Period; among many other basic statistics.

4.1 Mean Annual Rainfall

Mean annual rainfall represents the expected total amount of rainfall at the specific location. Since most of socio-economic activities in the area are rain dependent, information regarding the mean annual rainfall baseline statistics together with the expected minimum and maximum annual rainfall (**Figure 4.1-1, 4.1-2, and 4.1-3**) are extremely important climate variables for the development of effective climate resilient strategies for any location.

Figure 4.1-1 also shows that Wundanyi Sub County generally receives the highest amounts of rainfall, when compared to the rest of the sub-counties with the high amounts of recorded Wundanyi/ Mbale Ward. High amounts of rainfall are also seen in part of Voi sub-country and particularly in some parts of Ngolia ward, however parts of Mbololo and Sagalla wards generally experience the lowest amounts of rainfall in the county as seen in **Figure 4.1-1**.

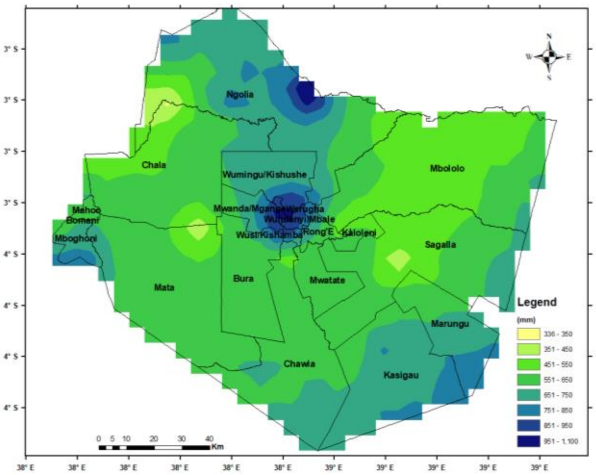


Figure 4.1-1 Mean annual rainfall 1981-2010

Weather and climate extremes have far more serious socio-economic impacts including water and food availability within the county with severe social, environmental and economic implications. It was observed that some parts of the county which receives over 700mm of rainfall annually, sometimes receive over 1200-1600 mm of rainfall annually, and less that than 500mm of rainfall in a year in some worst hit drought years.

The distribution of the driest and wettest scenarios in Taita County is summarized in **Figure 4.1-2 & 4.1-3**.

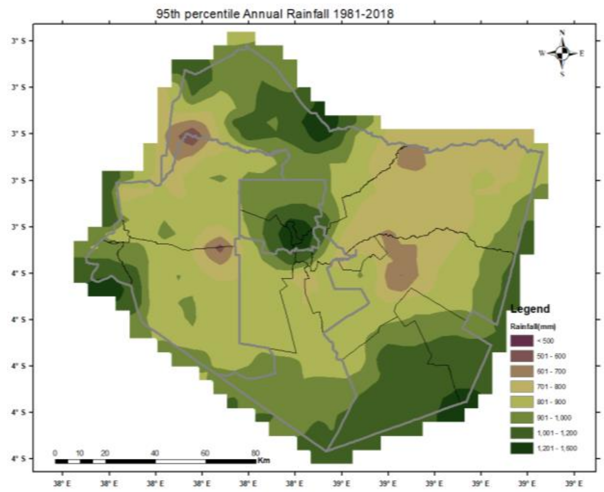


Figure 4.1-2 *Annual maximum rainfall extremes 1981-2010*

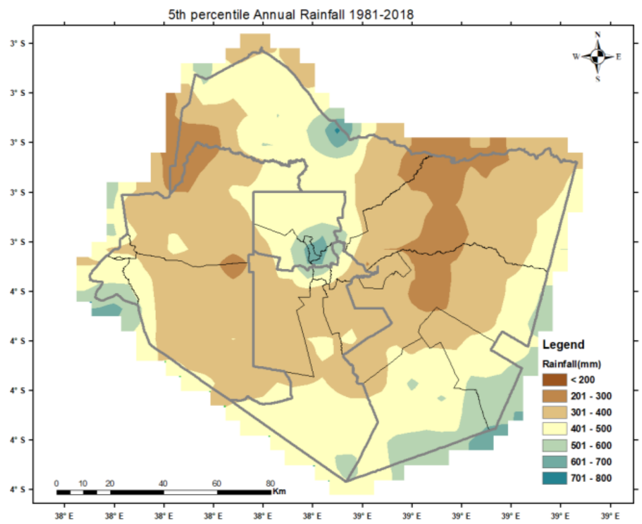


Figure 4.1-3 Annual minimum rainfall extremes 1981-2010

4.2 Monthly and Seasonal Rainfall Climatology

Figure 4.2-1 presents the mean monthly rainfall for Taita Taveta County. Two distinct rainfall seasons are evident centred with March - May and October - December months. It is evident from the figure that unlike some parts of Kenya where March - May rainfall season is more important, both March- May and October - December rainfall seasons are important for Taita Taveta County.

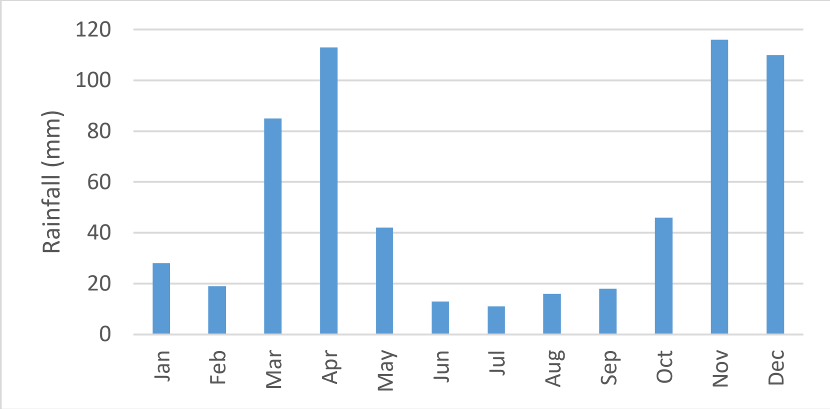


Figure 4.2-1 Mean Monthly rainfall (1981-2010)

The spatial distribution of the individual months from January to December as well as for March - May (MAM) and October - December (OND) seasons are shown on **Figure 4.2-2** to **4.2-4**, while percent of the specific season contribution to annual rainfall is shown in **Figure 4.2-5** and **4.2-6**. The figures also highlight significant spatial rainfall differences even within the individual seasons that must be considered while developing climate resilient policies for the county.

Wundanyi and Wusi/ Kishamba sub-Counties are recorded to experience the highest amounts of rainfall during both the MAM and OND season as shown in **Figure 4.2-2** and **4.2-3.** During the MAM season, most of Mbololo and parts of Sagalla Sub- counties experience the lowest amounts of rainfall in the district during the MAM season as shown in **Figure 4.2-2**. The northern western part of Taita Taveta County generally experiences larger amounts of rainfall in OND season than the MAM season.

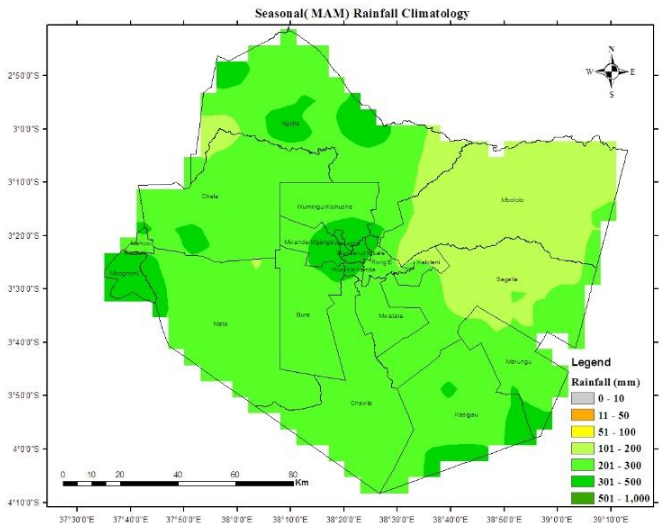


Figure 4.2-2 March – May (MAM) seasonal rainfall (1981-2010)

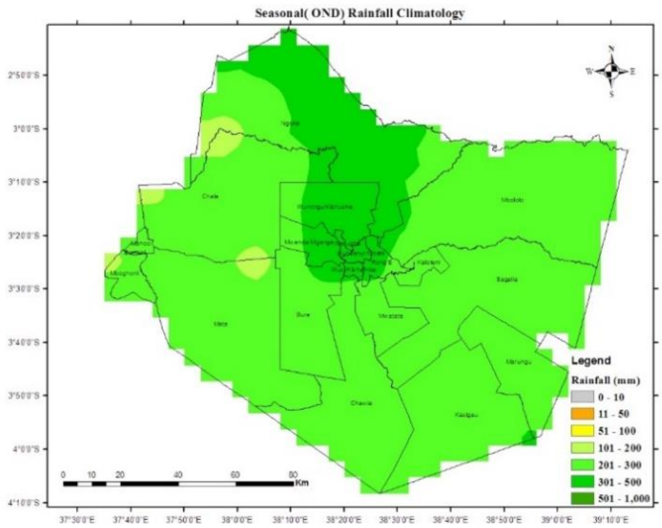
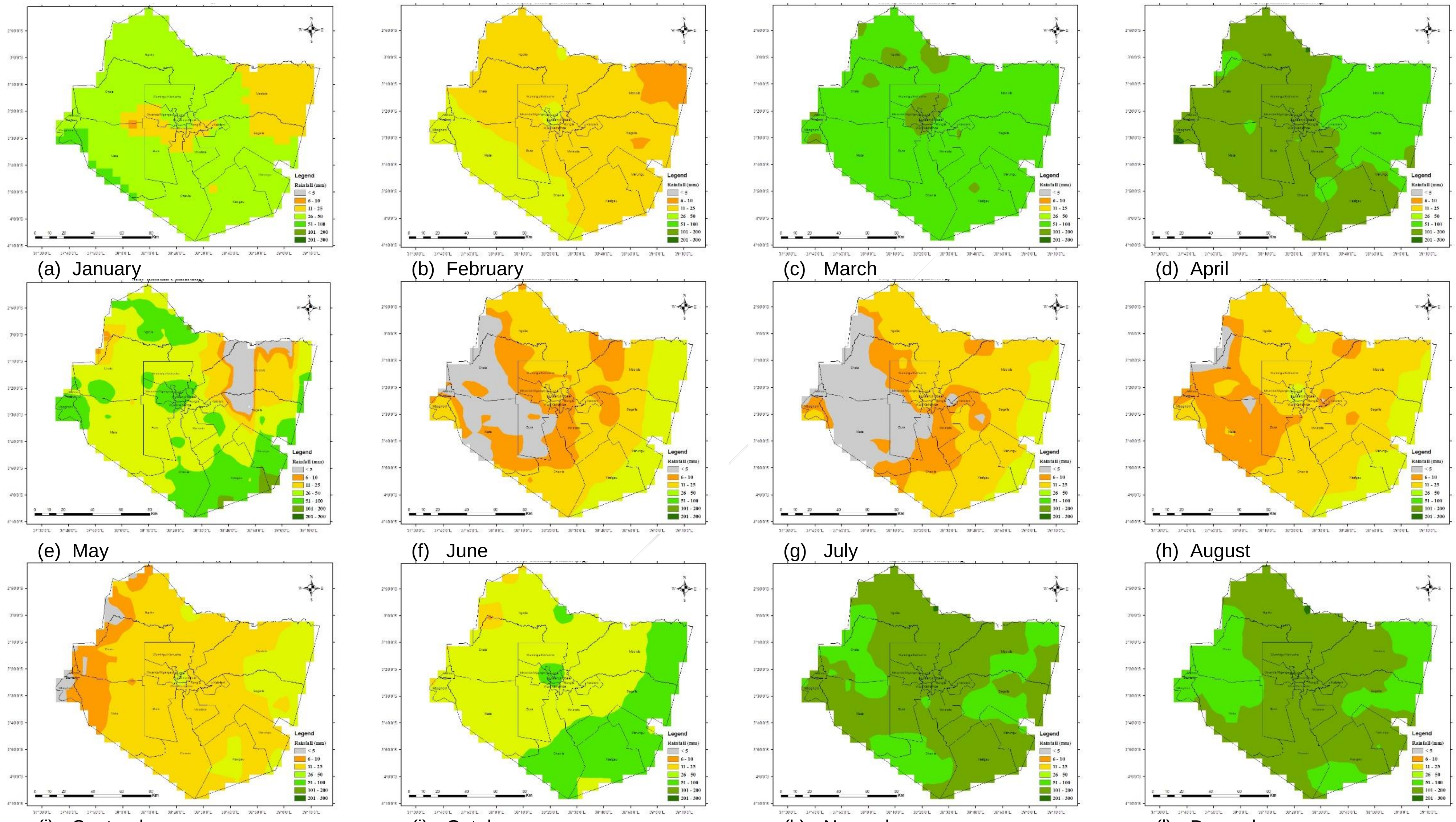


Figure 4.2-3 October – December (OND) seasonal rainfall (1981-2010)

Figure 4.2-4 shows the rainfall distribution from January to December.



(a) January (b) February (c) March (d) April

(e) May (f) June (g) July (h) August

(i) September (j) October (k) November (l) December

Figure 4.2-4 Mean Monthly rainfall climatology in Kenya (1981-2010)

While the MAM season is generally considered the long rain season in Kenya (Government of Kenya, 2010), in Taita Taveta County, the OND season generally contributes close to the same amount of rainfall as the annual total when compared with MAM. It is evident from the figures that some areas have OND as the main rainfall season. For example parts of Voi Sub County, where the MAM contribution to the annual total is less than 30% as shown in **Figure 4.2-5**. Other parts of the county like Mbohoni and Mahoo wards and some parts of Chala, Mata, Chawia, Kasigau, Marungu and Ngolia wards, have OND rainfall contributing to less than 40% of the annual total **Figure 4.2-6** making MAM their main season.

The rainfall variability within each Sub County is notable, particularity in Voi where some parts experience their annual peak rainfall in OND while other parts in MAM in **Figure 4.2-6.**

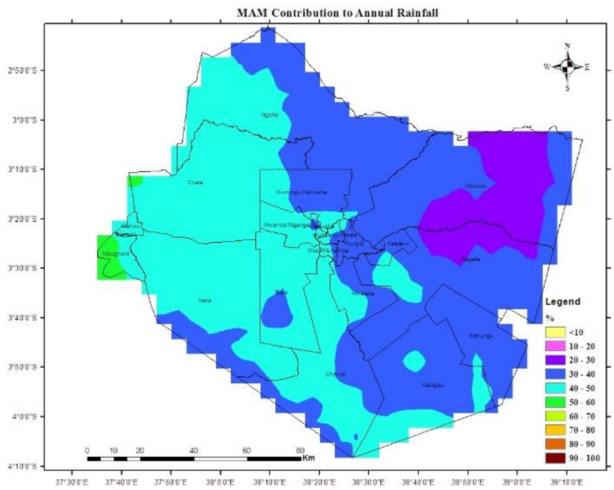


Figure 4.2-5 Seasonal Contribution of March – May (MAM)

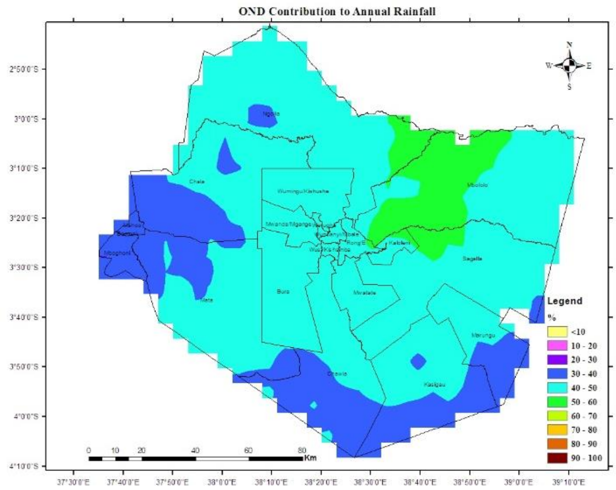


Figure 4.2-6 Seasonal Contribution October – December (OND)

4.3 Inter-annual Variability

Figure 4.3-1 and 4.3-2 give examples of the inter-annual rainfall patterns in Taita Taveta County between 1981 -2010 for MAM and OND seasons. The figures indicate year to year variability of rainfall at all locations within the County. The recurrences of high and low rainfall amounts are reflective of recurrences of excessive and deficit rainfall often associated with floods and droughts.

Some of the extremely wet and dry years occurred during El Niño / La Niña (ENSO) and negative / positive Indian Dipole years (Ogallo L. A., 1993; Omany et al., 2016). The standard ENSO index is represented by Oceanic Niño Index (ONI) quantified from mean Sea Surface Temperatures (SST) anomalies in the Niño 3.4 region (**5ºN-5ºS, 120º-170ºW**).

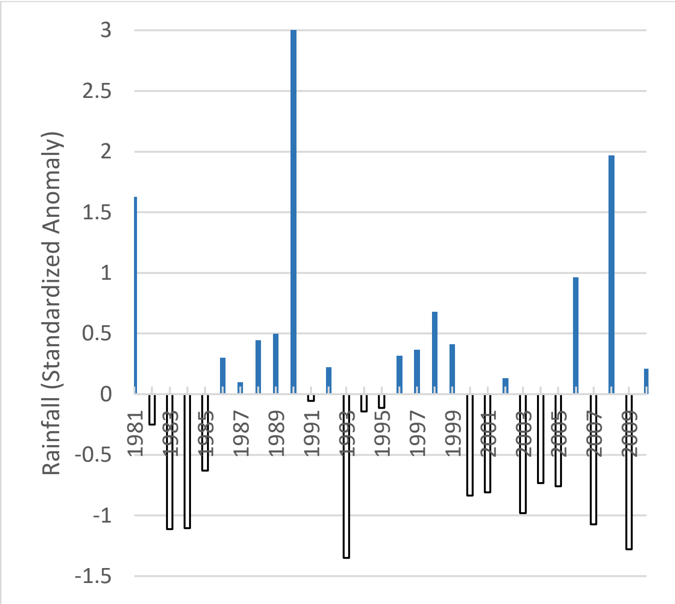


Figure 4.3-1 Rainfall anomaly in MAM (1981–2010) for the Taita Taveta region (Source: observed data blended with CHIRPS)

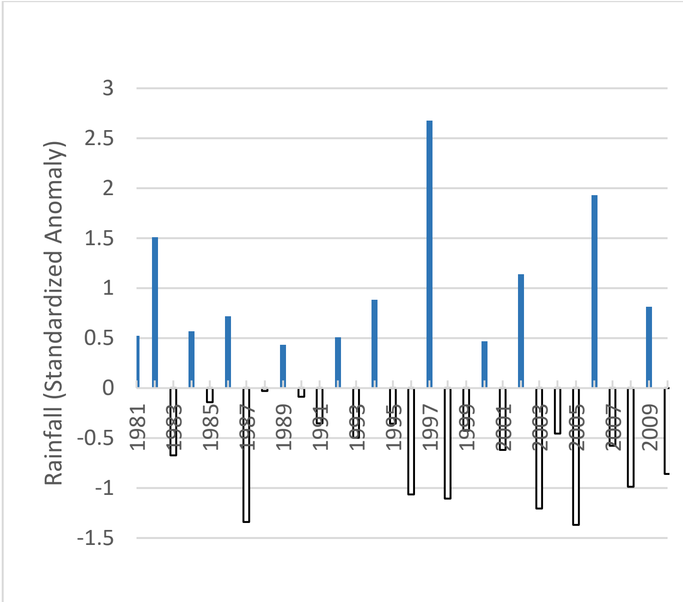


Figure 4.3-2 Rainfall anomaly in OND (1981–2010) for the Taita Taveta region (Source: observed data blended with CHIRPS)

Mean month to month spatial patterns of rainfall for El Niño / La Niña years are shown in **Figure 4.3-4 and 4.3-5.** The maps show significant rainfall persisting over many months during some El Niño years, while the opposite is true for La Niña years. In general both ENSO (**Figure 4.3.3**) and Indian Ocean Dipole (IOD) (**Table 1& 2**) indices had significant impacts on the county rainfall more evident impacts in OND season. This calls for more research to enhance ENSO/IOD and County rainfall anomalies tele-connection knowledge.

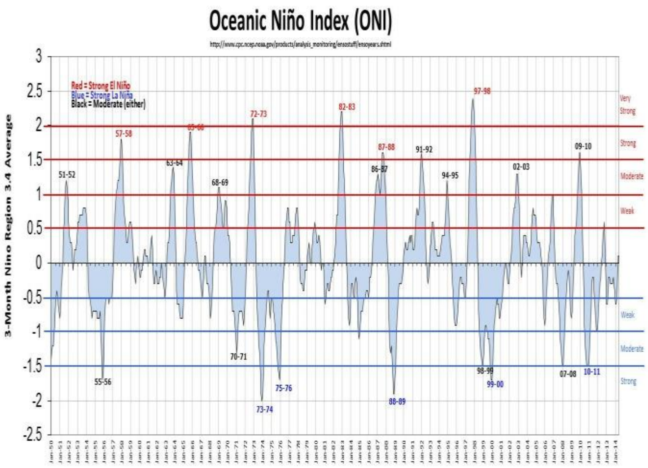


Figure 4.3-3 El Nino/ La Nina index quantified by Nino 4.3 ONI index (NOAA)

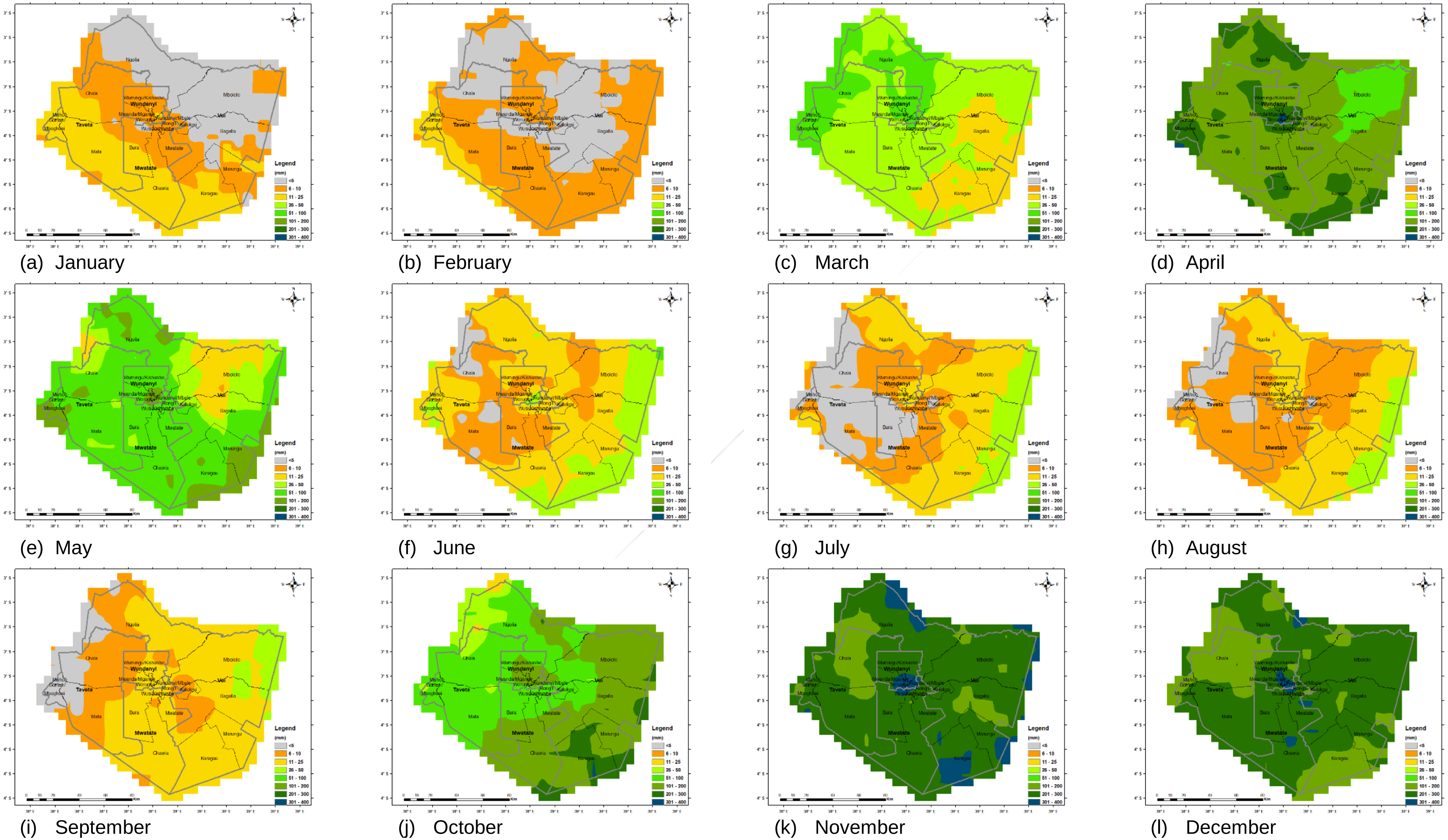
Table 1a: Major +IOD Years, 1960 – 2016 (NOAA)

1961	1963	1972	1982	1983	1994
1997	2006	2012	2015		

Table 2: Major -IOD Years, 1960-2016 (NOAA)

1960	1964	1974	1981	1989	1992
1996	1998	2010	2014	2016	

The Government of Kenya (2016) has shown that agriculture in Taita Taveta County contributes 95% of household income. The data supports the need for timely downscaled forecast for this community that is reliant on agriculture. The Taita Taveta climate risk profile lists out possible adaptation options based on that the sectors in the county are at a risk as a result of climate variability in climate (Government of Kenya, 2016).

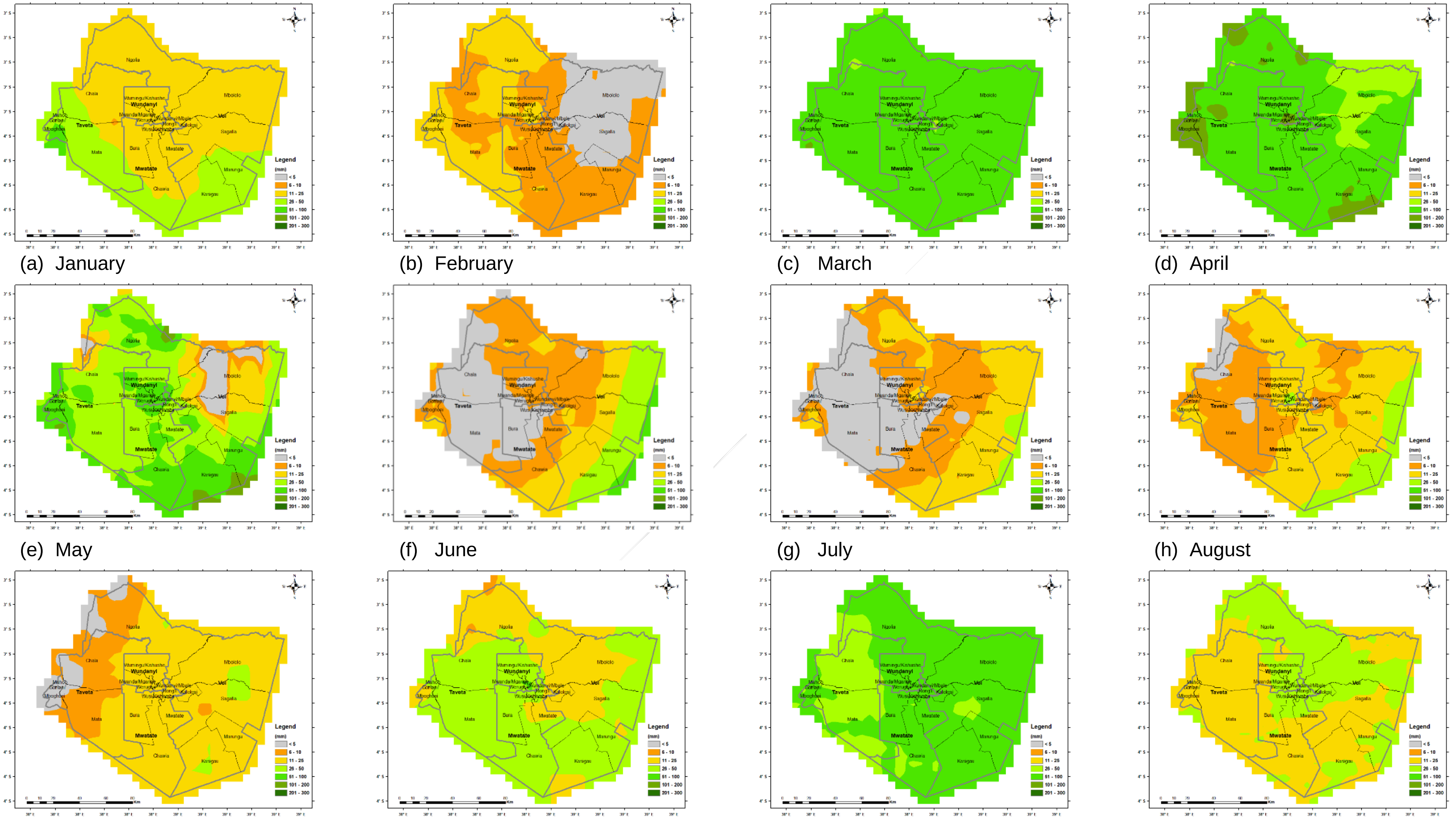


(a) January (b) February (c) March (d) April

(e) May (f) June (g) July (h) August

(i) September (j) October (k) November (l) December

Figure 4.3-4 Monthly Rainfall during 1997 strong El Niño occurrence



(a) January (b) February (c) March (d) April

(e) May (f) June (g) July (h) August

(i) September (j) October (k) November (l) December

Figure 4.3-5 Monthly Rainfall during 2005 La Niña occurrence

4.4 Rainfall Trends

Trends define the long term pattern of the rainfall time series at the specific location within the county. Negative/positive trends indicate decreasing/increasing mean rainfall tendency. Results show that in Taita Taveta is generally experiencing a negative trend during both the MAM and OND season (**Figure 4.4-1 & 4.4-2).**

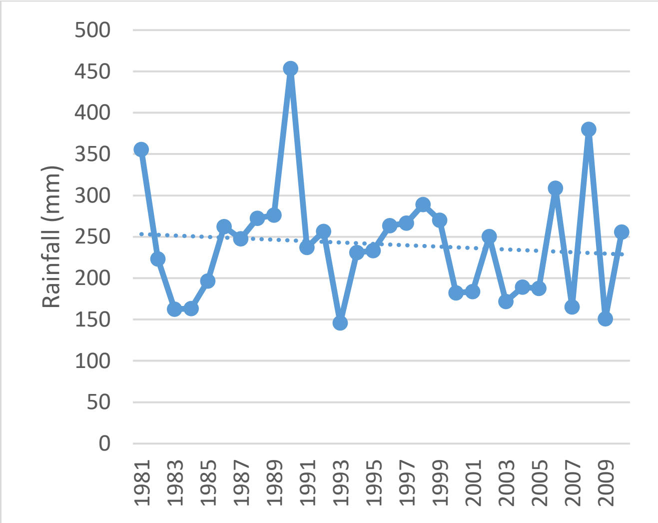


Figure 4.4-1 Rainfall Time Series Over Taita Taveta in MAM Season (1981-2010)

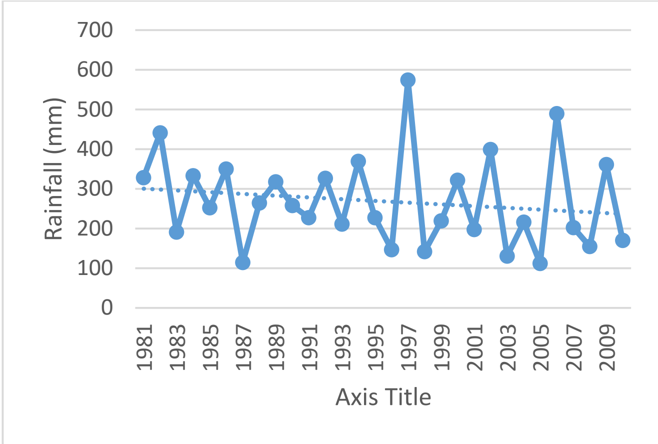


Figure 4.4-2 Rainfall Time Series Over Taita Taveta in OND Season (1981-2010)

Both **Figure 4.4-3 & 4.4-4** show spatial variability in the observed trends with a slightly negative trend generally in the MAM rainfall, however some parts of Kasigau, Marungu and Sagalla Wards experienced a slight positive rainfall trend. During the OND season, the general negative rainfall trend as shown in **Figure 4.4-4,** persists throughout the county contrary to the national rainfall trend observed in the same season (Government of Kenya, 2010). Some parts of Kasigau ward however experienced a slightly positive trend.

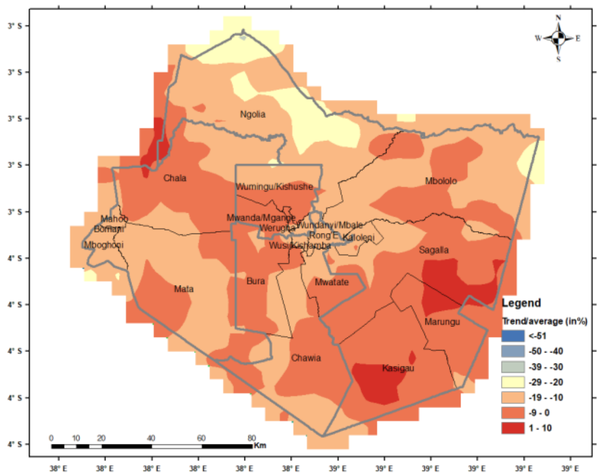


Figure 4.4-3 %Rainfall Trend over Taita Taveta in MAM Season (1981-2010)

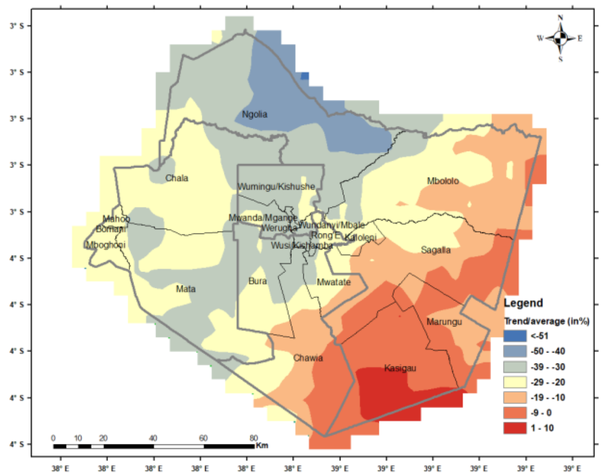


Figure 4.4-4 % Rainfall Trend over Taita Taveta in OND Season (1981-2010)

Figure 4.4-5 shows the rainfall trend experienced in Ngolia ward during MAM season which as shown in **Figure 4.4-3** is generally experiencing negative rainfall trend. **Figure 4.4-6** however shows the trend in the parts of Kasigau which seems to be experiencing a slightly positive rainfall trend.

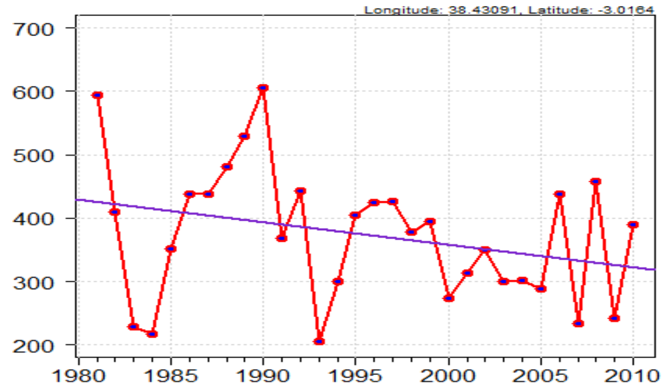


Figure 4.4-5 Rainfall Time series over Wundanyi during MAM Season (1981-2010)

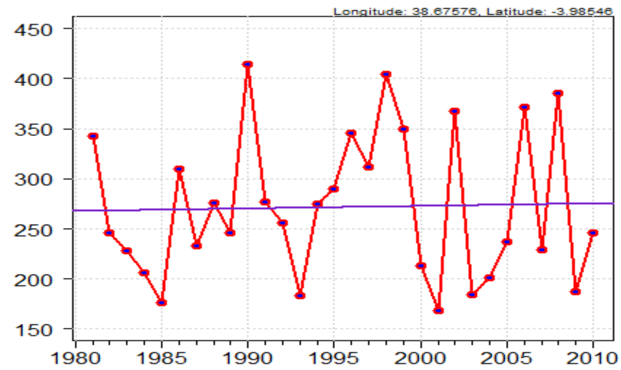


Figure 4.4-6 Rainfall Time series over Kasigau during MAM Season (1981-2010)

This study has not examined the relationship between the observed rainfall over the county with climate change signals due to the relatively short period of the available time series data. The significant spatial differences in the observed rainfall trends calls for tailor made adaptation intervention strategies in the county.

Apart from the baseline rainfall characteristics that have been discussed in the previous sections, there are many other important rainfall baseline statistics that are required by specific user sectors for drought and flood risk management. These include among others, rainfall intensity and associated variance; probability of exceedance of specific rainfall thresholds and associated variance; mean characteristics of wet/dry days and associated variance; probability of occurrence of specific wet/dry spells; onset, cessation and length of growing seasons. Part of the report will be devoted to address these special baseline rainfall statistics

4.5 Mean Rainfall intensity

Rainfall intensity represents the amount of rainfall received per specific unit time. The parameter may reflect surface runoff, rain water erosion potentials, etc. Mean rainfall intensity presented in this section were derived from the amount of rainfall in millimeters per day. **Figure 4.5-1 & 4.5-1** show significant differences in the spatial patterns of rainfall intensity for both MAM and OND seasons. For example, Wundanyi/Mbale receives high rainfall intensity when compared with the rest of the county in both MAM and OND seasons while parts of Mbololo and Sagalla generally receive the lowest rainfall intensity in the county especially during MAM season. The next section provides some highlight on the variance characteristics of rainfall in Taita Taveta County.

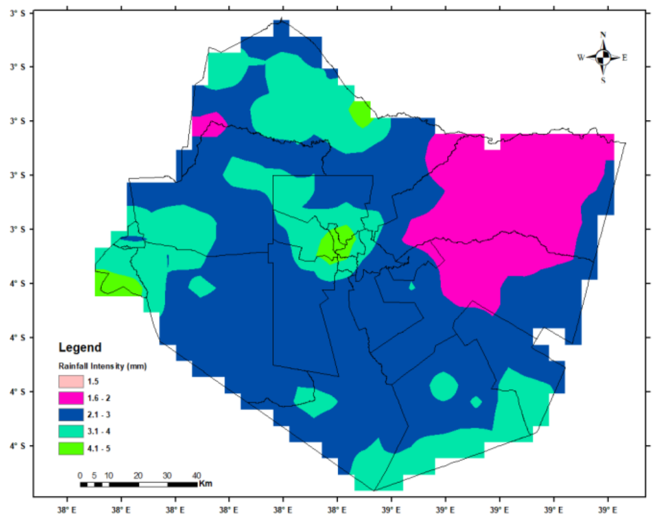


Figure 4.5-1 Mean rainfall intensity in mm per day during MAM (1981-2018)

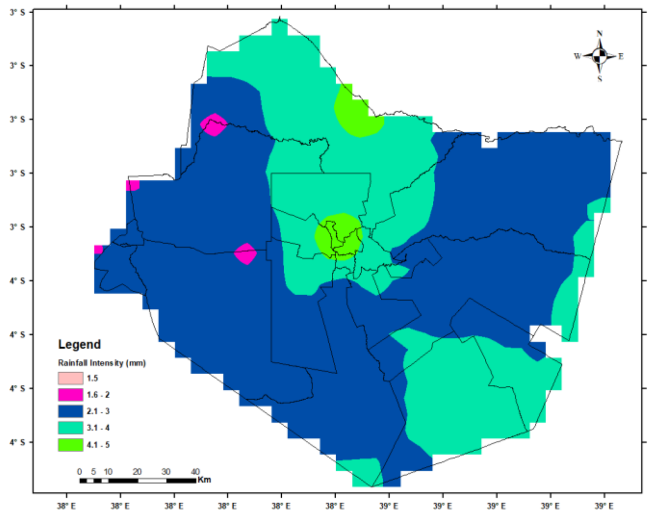


Figure 4.5-2 Mean rainfall intensity in mm per day during OND (1981-2018)

4.5.1. Observed Variance in Rainfall intensity

This section presents the degree of variability of rainfall intensity within the county using coefficient of rainfall variability index (standard deviation divided by the mean). **Figures 4.5-3 & 4.5-4** show that the rainfall intensity is generally less variable during MAM season than during OND. Such knowledge is very critical for climate risk management planning purposes for the county.

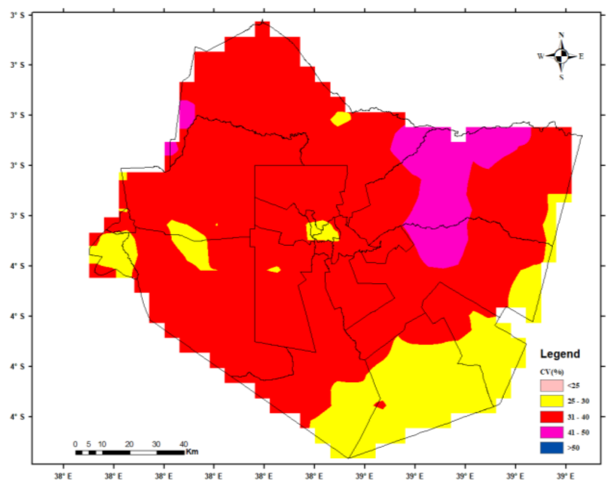


Figure 4.5-3 Rainfall Intensity: Coefficient of Variance in MAM in Taita Taveta (1981-2018)

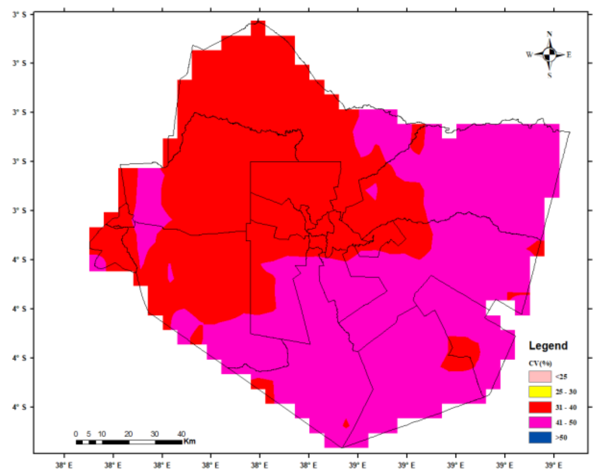


Figure 4.5-4 Rainfall Intensity: Coefficient of Variance in OND in Taita Taveta (1981-2018)

4.5.2. Probability of Exceeding Specific Rainfall Thresholds

Many activities that use water have critical rainfall thresh hold needs, outside which some degree of stress on the thresholds negatively impacts the specific water use. This section presents the probability of receiving rainfall intensity exceeding 5mm, 10mm and 20mm per day in Taveta County (**Figure 4.5-5**). The figures show that the probabilities were generally low in the entire county in both MAM and OND with Wundanyi ward having the highest probability of 36-40% during OND and 26-30% during MAM for the 5mm intensity per day.

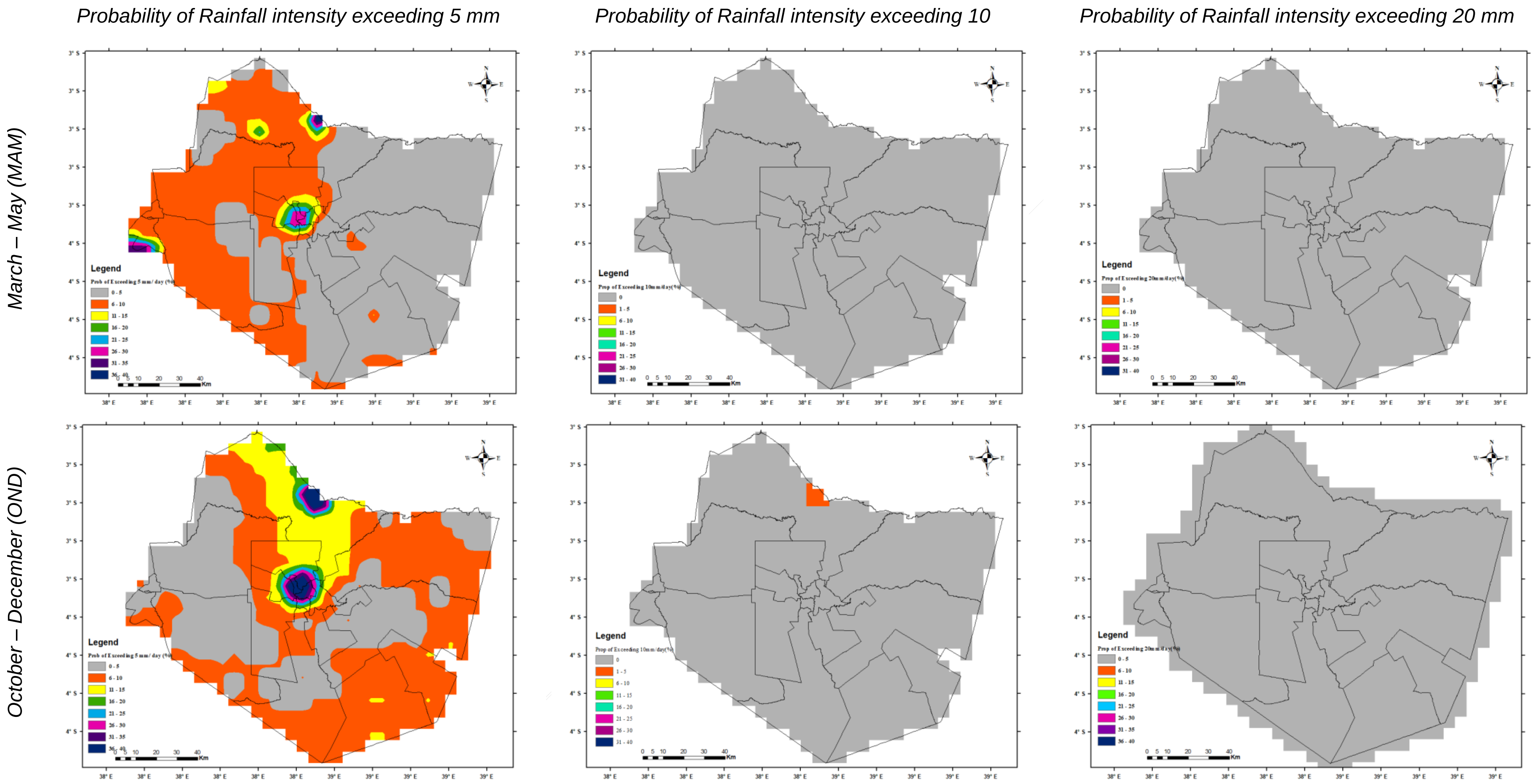


Figure 4.5-5 Probability of rainfall intensity in MAM & OND exceeding 5mm, 10mm and 20mm

4.6 Mean Wet Days

A threshold for a wet day was set as a day receiving 1mm or more rainfall per day, while any day receiving less is set as a dry day. The characteristics of wet/ dry days are very important for many water use activities including applications of fertilizer, spraying, movement of heavy farm machines, construction, etc. This section presents the characteristics of wet days at the county for MAM and OND Months. The results as seen in **Figures 4.6-1 & 4.6-2** show that there are generally more wet days in Taita Taveta during the MAM season than during the OND season. The number of wet days however varies spatially from location to location. The coefficient of variation of the computed wet days are presented in the next section.

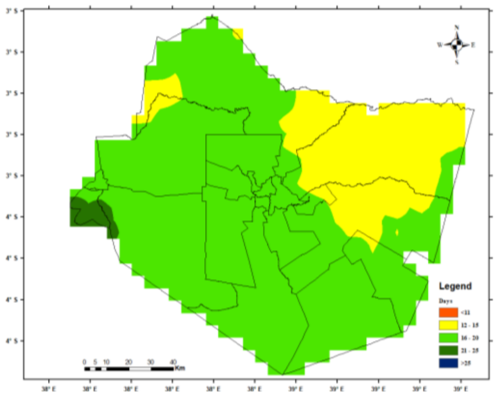


Figure 4.6-1 Average Number of Wet days in the MAM Season in Taita Taveta (1981-2018)

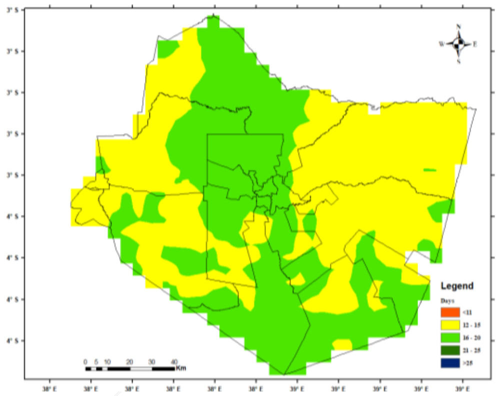


Figure 4.6-2 Average Number of Wet days in the OND Season in Taita Taveta (1981-2018)

4.5.3. Observed Variance in Wet Days

The coefficients of variation of the computed wet days are shown in **Figures 4.6-3 & 4.6-4** for MAM and OND seasons. The figures show that variability in the number of wet days differs significantly spatially and within the various seasons (**Figures 4.6-3 & 4.6-4**) with the least variability being seen largely around Mata ward during OND.

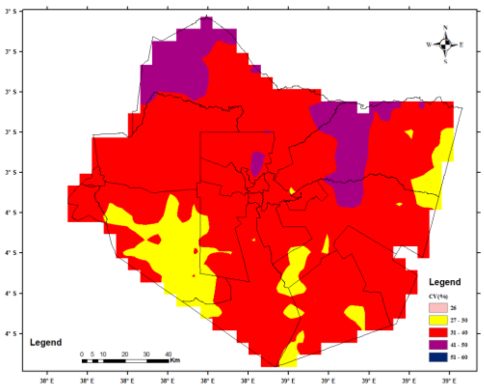


Figure 4.6-3 Wet Days: Coefficient of Variance during MAM in Taita Taveta (1981-2018)

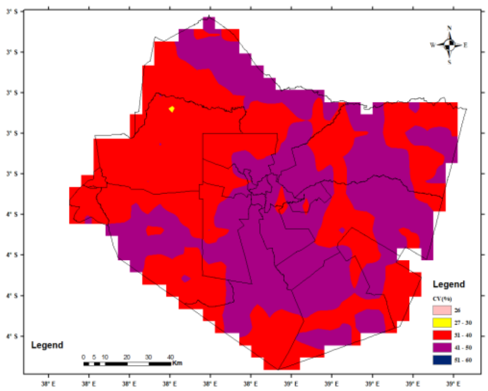


Figure 4.6-4 Wet Days: Coefficient of Variance during OND in Taita Taveta (1981-2018)

4.5.4. Probability of Number Wet Days

This section presents baseline statistics for the probability of the number of wet days in Taita Taveta.

Probability of the number of wet days exceeding 20 days | *Probability of the number of wet days exceeding 30 days* | *Probability of the number of wet days exceeding 45 days*

March – May (MAM) season

October – December (OND)

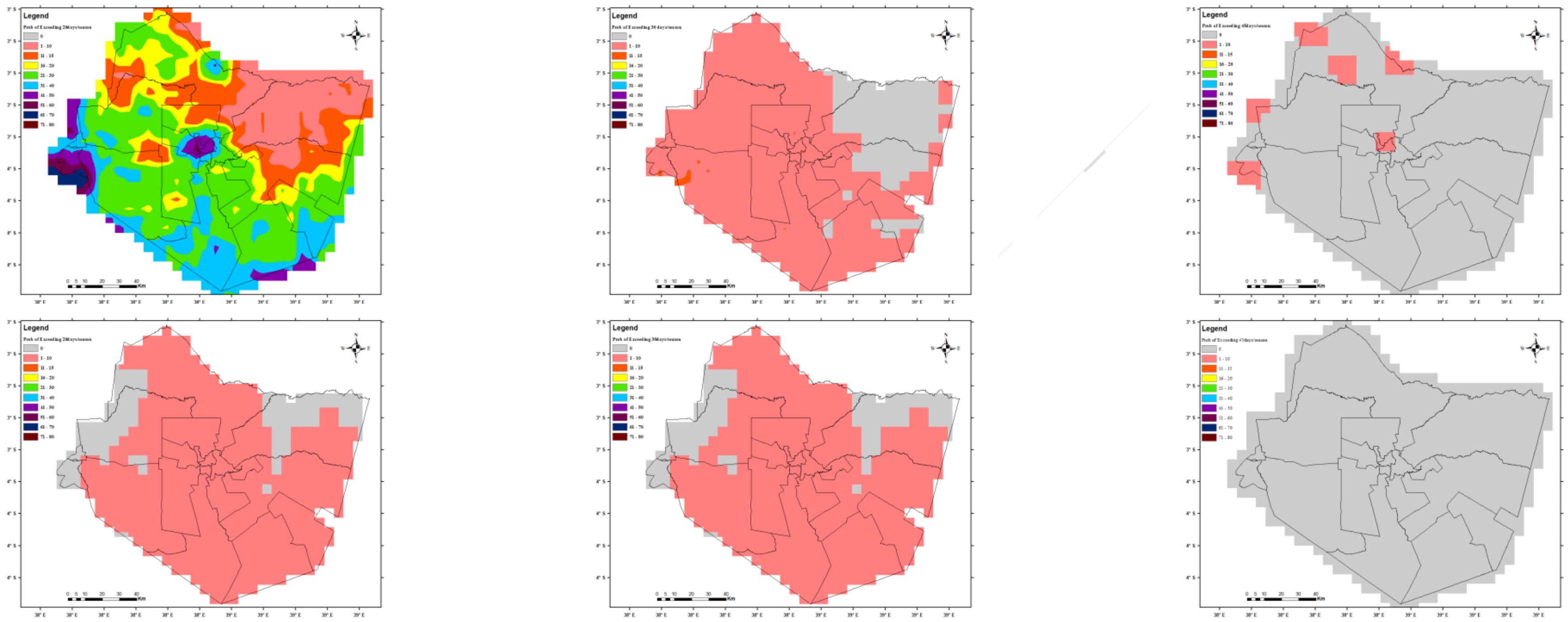


Figure 4.6-5 Probability of the number of wet days in the MAM & OND season exceeding 20, 30 & 45 days (1981-2018)

The figures show that the probability of the number of Taita Taveta having over 20 wet days during MAM season is generally less than 40 % with the exception of parts of Wundanyi/Mbale and Mboghoni wards with some parts of Mboghoni ward where the probability is 60% (**Figure 4.6-5**). During OND however the probability of the County of having over 20 wet days is generally less than 10%.

4.7 Mean Wet Spells

A wet spell of *n* days (for example 3 days), is taken to represent a case where at least 1mm daily rainfall threshold with received for *n* (3) continuous wet days. The figures below show that parts of the county received at least one wet spell more in MAM season than in OND season (**Figures 4.7-1 & 4.7-2)**.

It was noted that occurrences of longer wet spells were less in both MAM and OND. The next section provides some probabilities for occurrences of some specific wet spells.

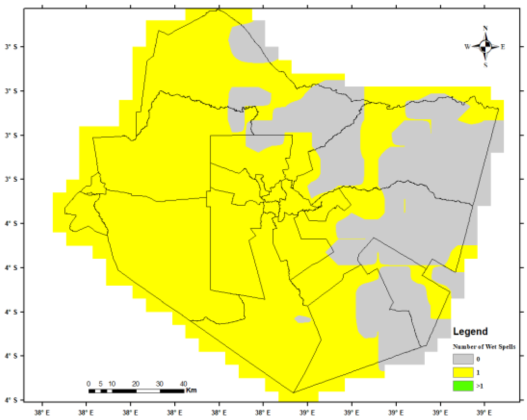


Figure 4.7-1 Average Number of Wet Spells in the MAM Season (1981-2018)

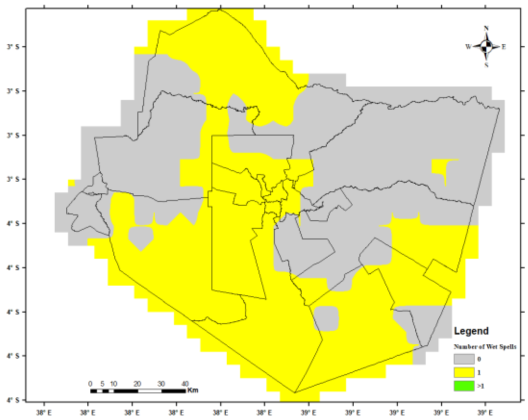


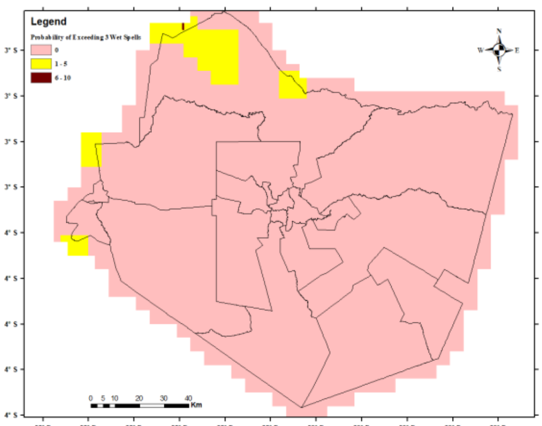
Figure 4.7-2 Average Number of Wet Spells in the OND Season (1981-2018)

4.7.1 Probability: Wet Spells

The previous section presented baseline statistics for wets days. It noted that occurrences of longer wet spells were less in both MAM and OND. This section presents examples of the probabilities for occurrences of some specific wet spells, using the 3 days wet spells. The probability of number of wet spells in Taita Taveta exceeding 3 consecutive days in both OND and MAM is generally zero as shown in **Figure 4.7-3.**

Probability of the number of wet spells exceeding 3 spells

March – May (MAM) season



October – December (OND)

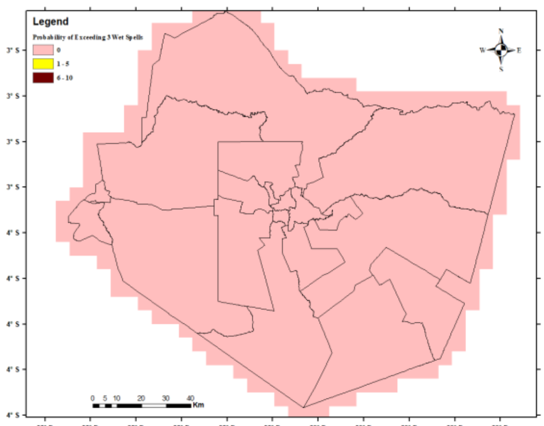


Figure 4.7-3 Probability of the number of wet spells in MAM & OND Season exceeding 3 Spells

It was observed from the study that the probability of the higher wet days decreased as the number of wet spell increased. Similar results were observed by Otengi et al.

4.8 Mean Dry Days

The number and distribution of the dry days can be used to highlight drought potentials of a given location as highlighted in the following sections. **Figures 4.8-1& 4.8-2** present mean number of dry days observed in Taita Taveta County. The figures indicate that the number of dry days in the County generally ranges between 71 and 85 days in both MAM and OND. However, there seems to be generally more dry days throughout the county during the OND season than MAM season.

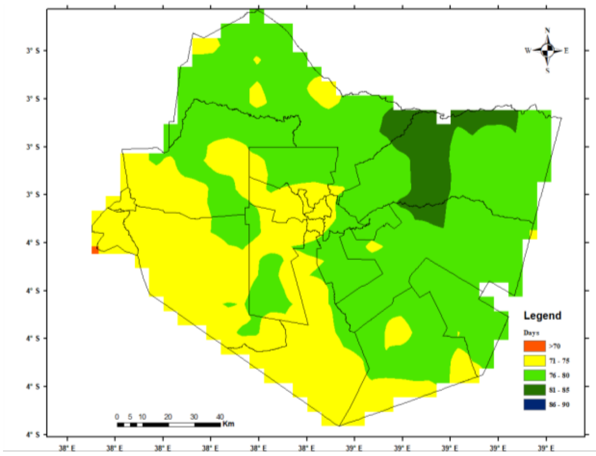


Figure 4.8-1 Average Number of Dry days in the MAM Season (1981-2018)

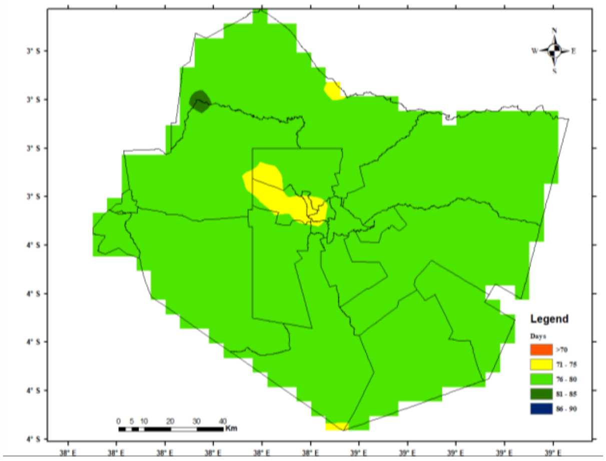


Figure 4.8-2 Average Number of Dry days in the OND Season (1981-2018)

4.8.1 Coefficient of variation: Dry Days

The spatial patterns of the variance of the dry days in Taveta County is given in **Figures 4.8-1& 4.8-2.** The figures indicate that the variability in the number of dry days is low with the coefficient of variation in both MAM and OND generally being around 6-10%.

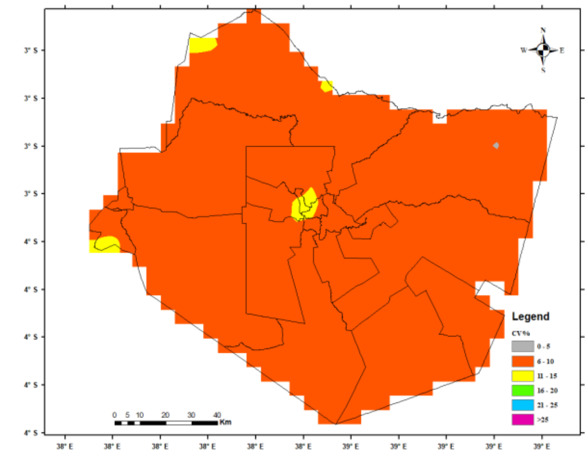


Figure 4.8-3 Dry Days: Coefficient of Variance during the MAM (1981-2018)

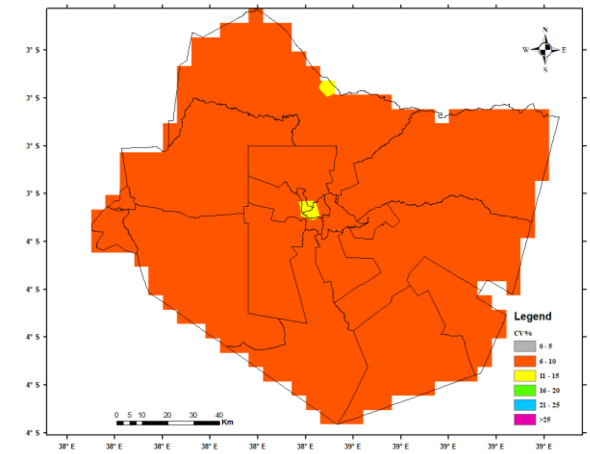


Figure 4.8-4 Dry Days: Coefficient of Variance during the OND (1981-2018)

4.8.2 Probability: Dry Days

Figures 4.8-5 highlights the spatial patterns that were observed for 20, 30 and 45 dry days in Taita Taveta. The figures show the high probability values for 20, 30 and 45 dry days with the probability of number of dry days exceeding 45 days is 100% in both the MAM and OND.

Probability of the number of dry days exceeding 20 days

Probability of the number of dry days exceeding 30 days

Probability of the number of dry days exceeding 45 days

March – May (MAM) season

October – December (OND) season

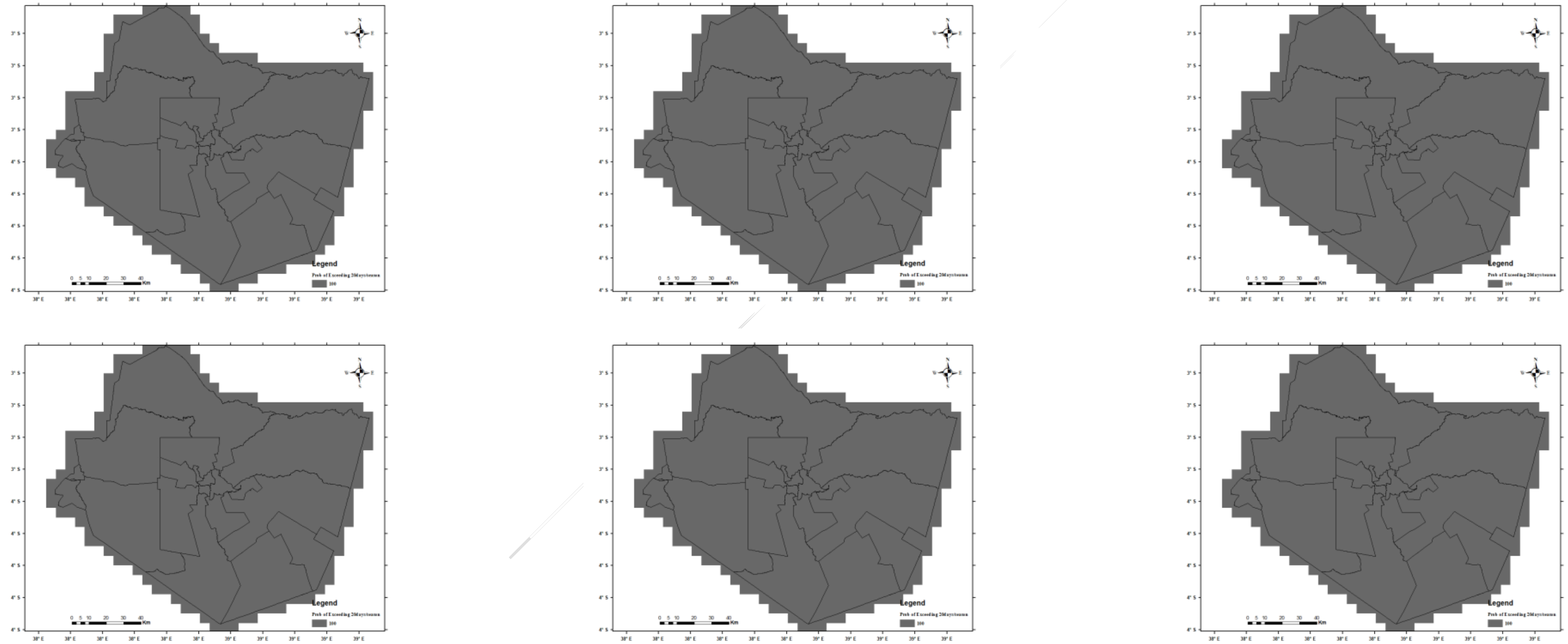


Figure 4.8-5 Probability of the number of dry days in the MAM & OND season exceeding 20, 30 & 45 days (1981-2018)

4.9 Mean Dry Spells

Like in the case of wet spells, a dry spell of *n* (e.g. 7) days represent a case of *n* (7) days without receiving any wet day (at least 1 mm rainfall). Results show that the number of dry spells in both MAM and OND rainfall seasons **Figures 4.9-1 & 4.9-2**. Longer spells were evident in some years where no wet day was reported during the whole month in a rainfall month. The variance and probability of these dry spells are presented in the next sections.

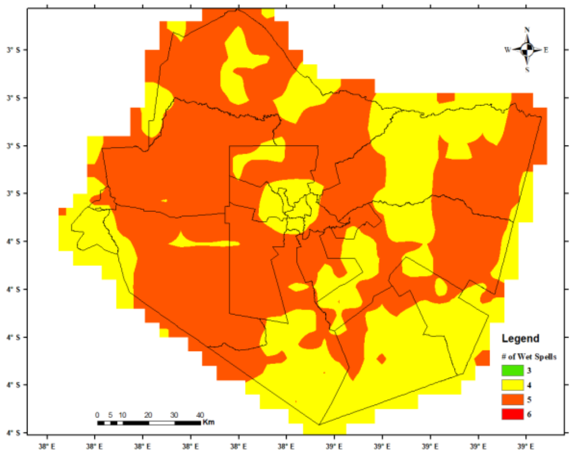


Figure 4.9-1 Average Number of Dry Spells in the MAM Season (1981-2018)

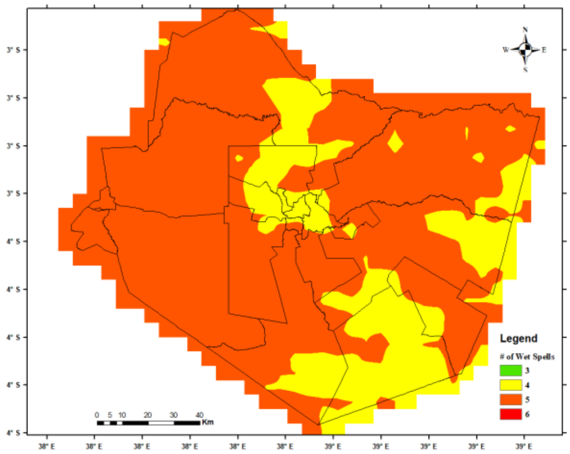


Figure 4.9-2 Average Number of Dry Spells in the OND Season (1981-2018)

4.9.1 Coefficient of variation: Dry Spells

The coefficient of variation in both MAM and OND generally ranges between 21% and 30% as seen in **Figures 4.9-3 & 4.9-4.** This shows that the variability from the long term mean in the number of dry spells is generally low, signifying the degree of persistence of the dry spells.

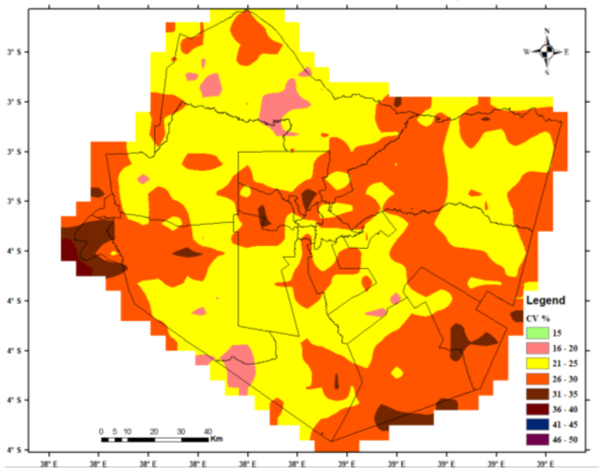


Figure 4.9-3 Dry Spell: Coefficient of Variance in the MAM Season (1981-2018)

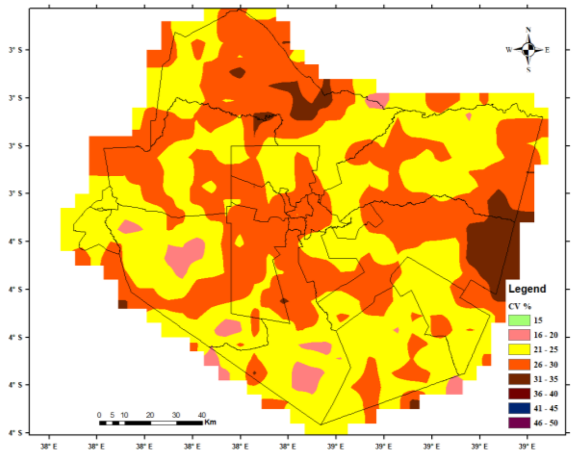


Figure 4.9-4 Dry Spell: Coefficient of Variance in the OND Season (1981-2018)

4.9.2 Probability: Dry Spells

The probability of the dry spells exceeding 3 in both OND and MAM seasons is generally high as shown in **Figure 4.9-5.** The probability of exceeding 5 dry spells is as high as 50% in both OND and MAM seasons. It reduces to around zero percent probability for dry spells exceeding 7 dry spells in both seasons.

Probability of the number of dry spells season exceeding 3 spells

Probability of the number of dry spells season exceeding 5 spells

Probability of the number of dry spells season exceeding 7 spells

March – May (MAM)

October – December (OND

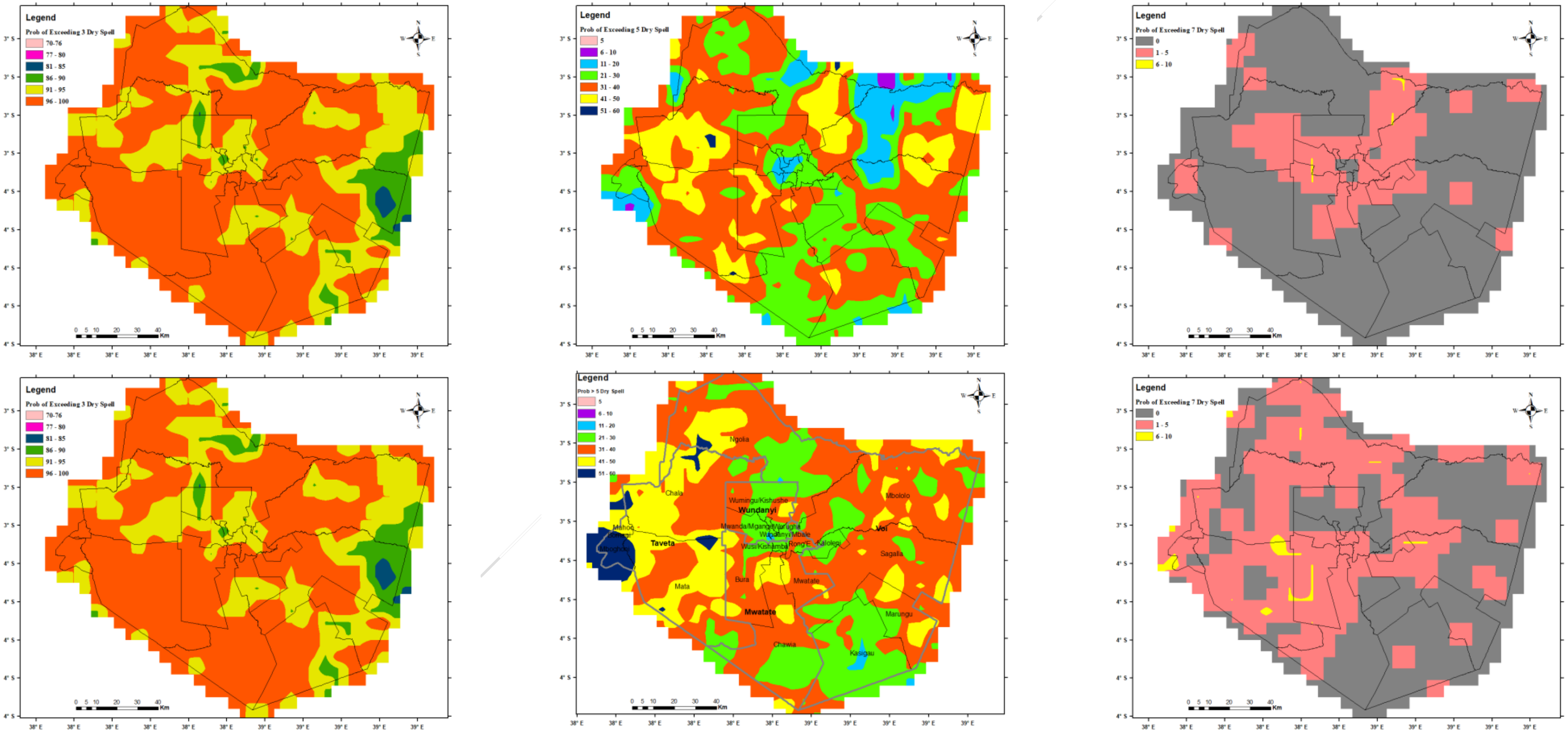


Figure 4.9-5 Probability of the number of dry spells in the MAM & OND season exceeding 3, 5 and 7 dry spells

4.10 Climatological Baselines for Onset, Cessation dates and Length of Growing Period

The onset marks the beginning of the rains while cessation marks the end. The length of time between the onset and cessation dates gives the length of the growing season assuming that the water requirement for specific crop is met throughout the period. The climatological baselines for Onset, Cessation dates and Length of Growing Period are discussed in the following sections.

4.10.1 Onset

The onset was calculated with a threshold 1mm of rainfall per day, having a rainfall total of 5mm in five days with at least two rainy days with a dry spell not exceeding seven days. **Figure 4.10-1** shows the mean onset of the March to May season is in the second dekad of March. There are however cases of early onsets occurring as early as early February, with some late onsets occurring in April.

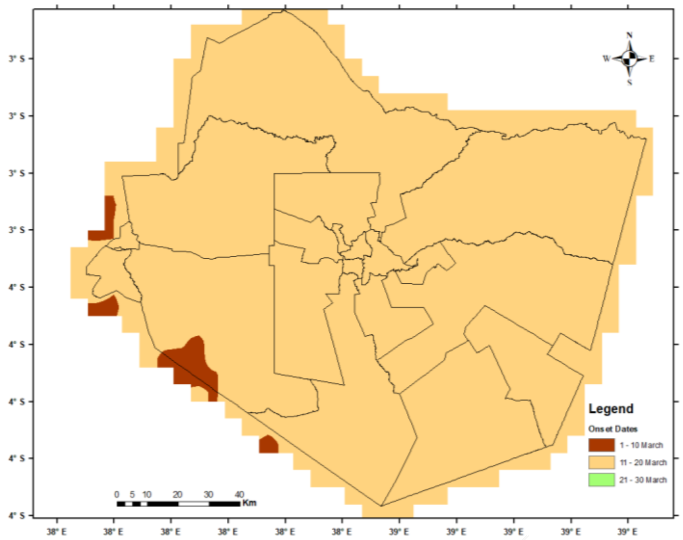


Figure 4.10-1 Historical onset in the MAM Season (1981-2018)

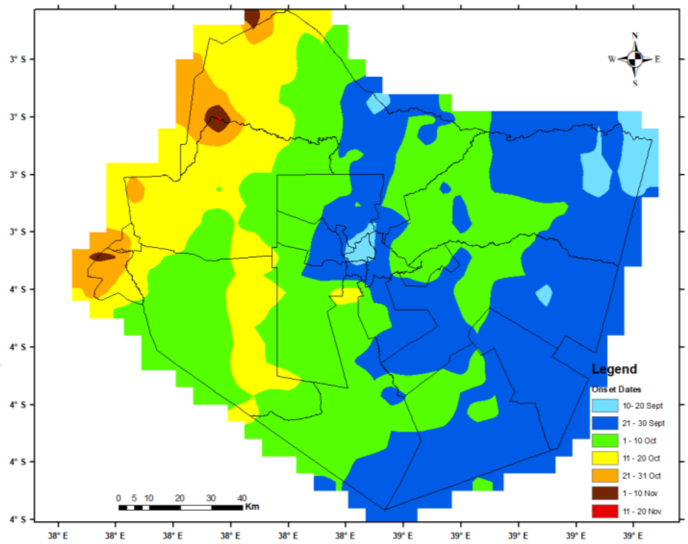


Figure 4.10-2 Historical onset in the OND Season (1981-2018)

During the OND season, some parts of the county received an early onset in the fourth dekad of September. This occurs mainly in parts of Voi and Wundanyi Sub-Counties. The rest of the county generally experiences onset around the first and second dekad of October in **Figure 4.10-2**.

4.10.2 Cessation

Cessation of the season was calculated with the threshold of a drop in water balance below 5mm for a period of three days. The results show that the mean cessation of the MAM rainfall season in the Taita Taveta County generally occurs in the second dekad of April (**Figure 4.10-3).** Generally the mean cessation date for OND rainfall is during the first and second dekad of December (**Figure 4.10-4**).

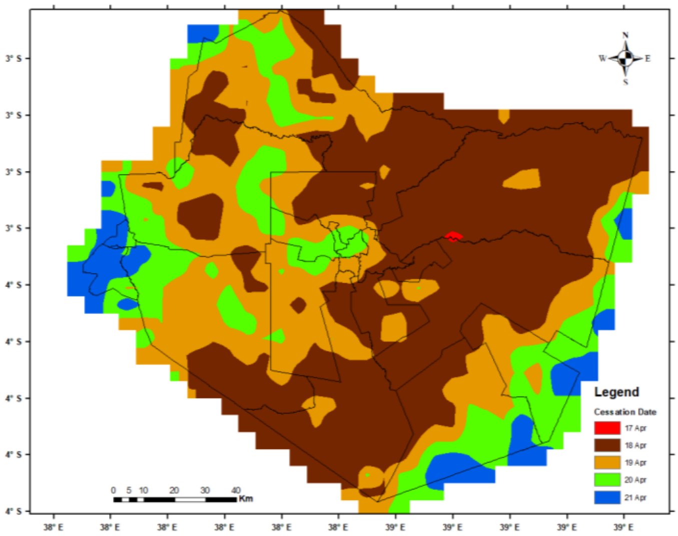


Figure 4.10-3 Historical cessation in the MAM Season (1981-2018)

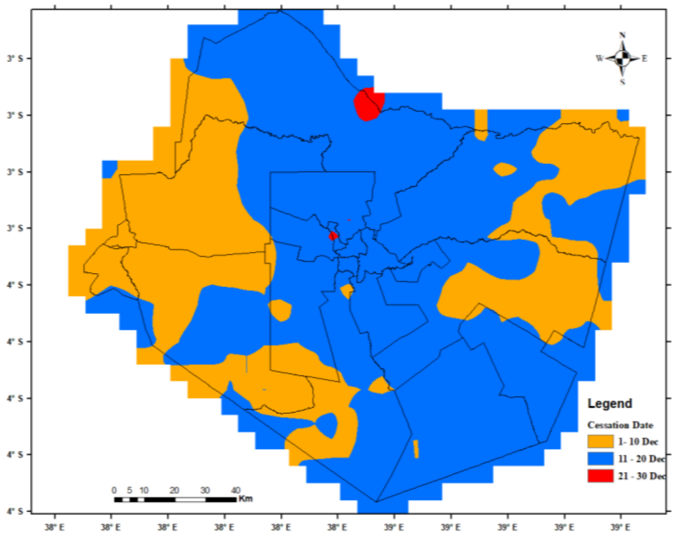


Figure 4.10-4 Historical cessation in the OND Season (1981-2018)

Apart from the above climatological statistics for the rainfall onset and cessation dates, very unique patterns were evident in some years associated with strong positive and negative ENSO and IOD events when early and late onset and cessation dates are observed (**Figure 4.10-5 to 4.10-8)**.

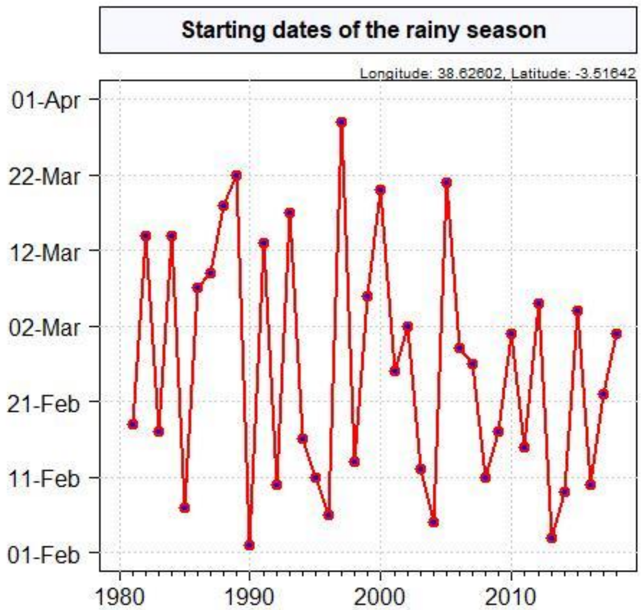


Figure 4.10-5 Time Series of Onset for a point in Taita Taveta county during the MAM Season (1981-2018)

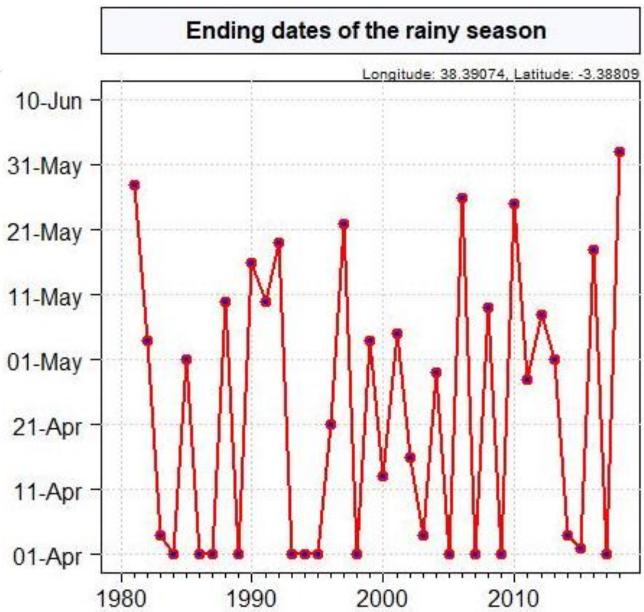


Figure 4.10-6 Time Series of Cessation for a point in Taita Taveta county during the MAM Season (1981-2018)

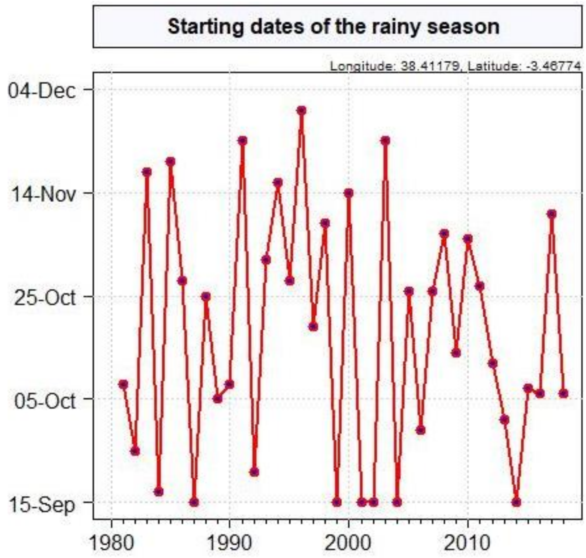


Figure 4.10-7 Time Series of Onset for a point in Taita Taveta county during the OND Season (1981-2018)

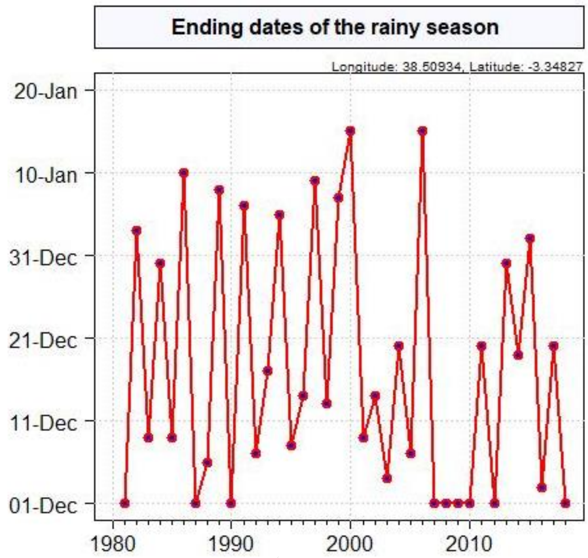


Figure 4.10-8 Time Series of Cessation for a point in Taita Taveta county during the OND Season (1981-2018)

4.10.3 Length of Season

The mean length of the March to May rainfall season generally is approximately 31 to 40 days as seen in **Figure 4.10-9**. The October to December season on the other hand is generally longer ranging from 51 to 80 days with some areas in the county as many as 90 days as depicted in **Figure 4.10-10**.

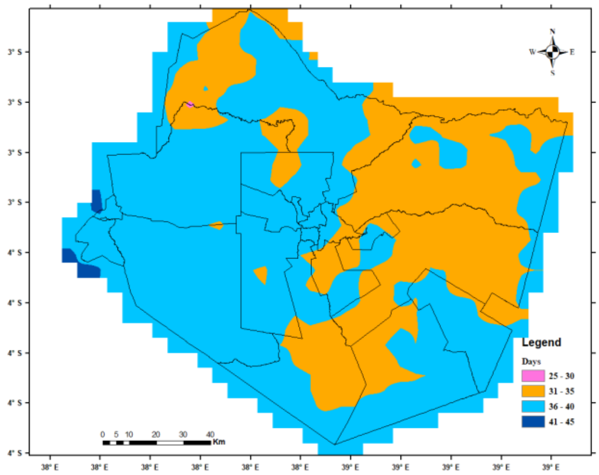


Figure 4.10-9 Historical Length of Season in the MAM Season (1981-2018)

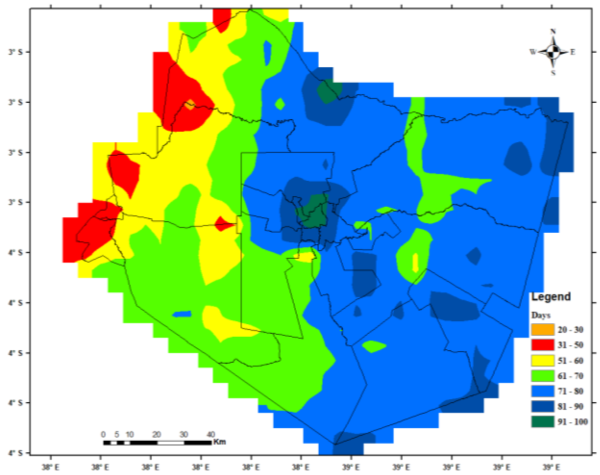


Figure 4.10-10 Historical Length of Season in the OND Season (1981-2018)

Since the length of the seasons is determined by the rainfall onset and cessation dates, very unique patterns were also evident in some years with strong positive and negative ENSO and IOD events, when shorter or longer than normal growing season length are observed. In some of these cases, the short growing season led to total crop failure, food deficits, which resulted in hunger and some deaths. In some cases, the wet days extend beyond the standard MAM and OND rainfall seasons giving long growing periods.

4.11 Temperature

Temperature is also of great significance in the ASAL areas. Temperature stress has physiological impacts on all ecosystems among many other effects. The Government of Kenya (2016), reports that Kenya has experienced increasing temperature trends in many parts of the country. The ASALs are reported to have witnessed a reduction in extreme cold temperature occurrences (Government of Kenya, 2016b). Furthermore, warmer temperatures were reported to be reducing plant and vegetation productivity in semi-arid environments, affecting wildlife diversity and distribution.

The observed results has been wild-life competing with domestic livestock and human beings for both food and water. High temperatures and intense rainfall, which are some of the effects of climate change, are known to be critical factors in initiating malaria epidemics in Kenya. The following sections present the observed temperature characteristics in Taita Taveta County.

4.11.1 Annual Mean Temperature

The annual mean temperature was obtained from average monthly temperature for the twelve months within the period 1981-2010. Mean climatology for annual mean, maximum and minimum temperatures are shown in **Figure 4.11-1** to **4.11-3**.The mean temperatures are generally at all locations with relatively higher/ lower temperatures observed around Mbololo and Mboghoni respectively where the mean highest/ lowest temperatures were about 27ºC, and 22ºC respectively **Figure 4.11-1**.

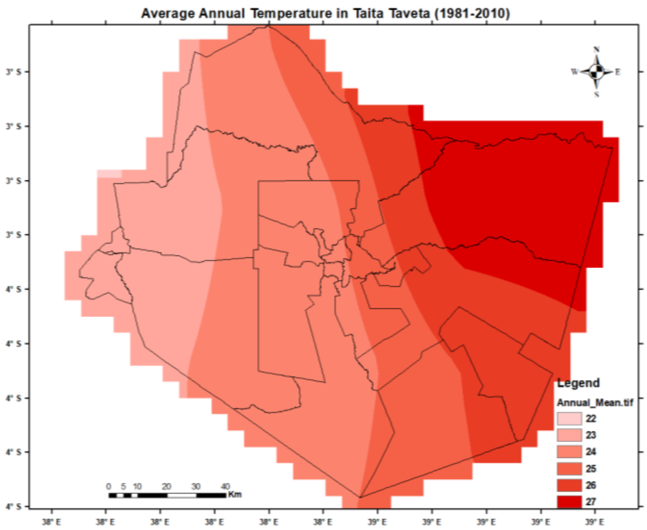


Figure 4.11-1 Mean annual surface temperature climatology (1981–2010) for GHA region

The pattern observed in the annual temperature is also seen in the Minimum and Maximum Temperature shown in **Figure 4.11-2** and **Figure 4.11-3** respectively. Parts of Mbololo ward record a mean maximum temperature of 31ºC annually.

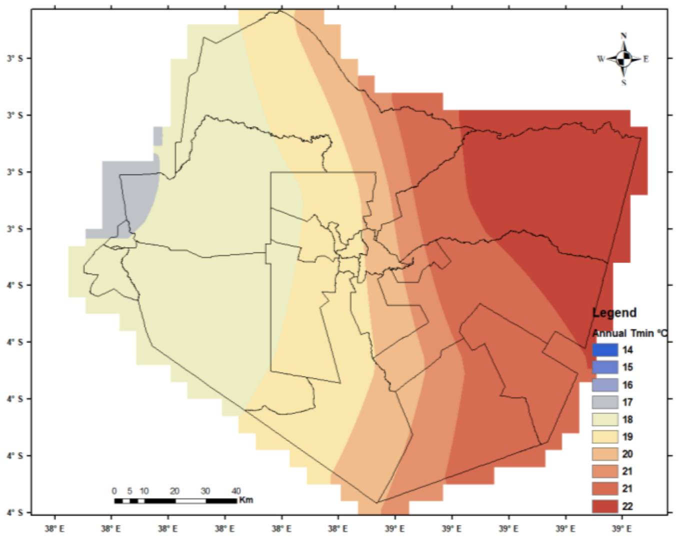


Figure 4.11-2 Mean annual minimum surface temperature climatology (1981–2010) for the GHA region

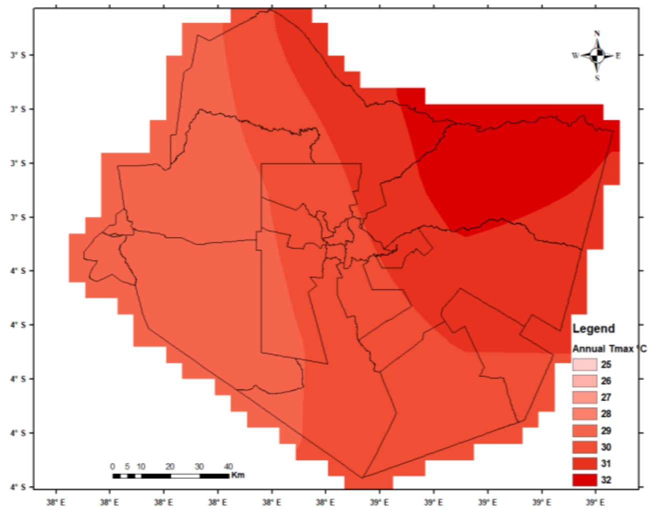


Figure 4.11-3 Mean annual maximum surface temperature climatology (1981–2010) for the GHA region

The highest mean temperature in the county seems to occur in January and February while the lowest mean temperatures are experienced in July and August **Figure 4.11-4**.

The maximum mean temperature in Voi Sub County particularly around Mbololo ward is high all year round, ranging between 29ºC - 35ºC **(Figure 4.11-5)**. The lowest minimum mean temperature in Taveta Sub County is experienced in Mboghoni, Bomani, Mahoo and parts of Chala wards between June and October, with temperatures ranging between 15ºC -16 ºC as seen in **Figure 4.11-6**.

The temperature characteristics that were common with the monthly records are still evident from the respective seasonal temperature climatology. **Figure 4.11-7** shows that June–August (JJA) season was relatively cooler in comparison to the rest of the seasons.

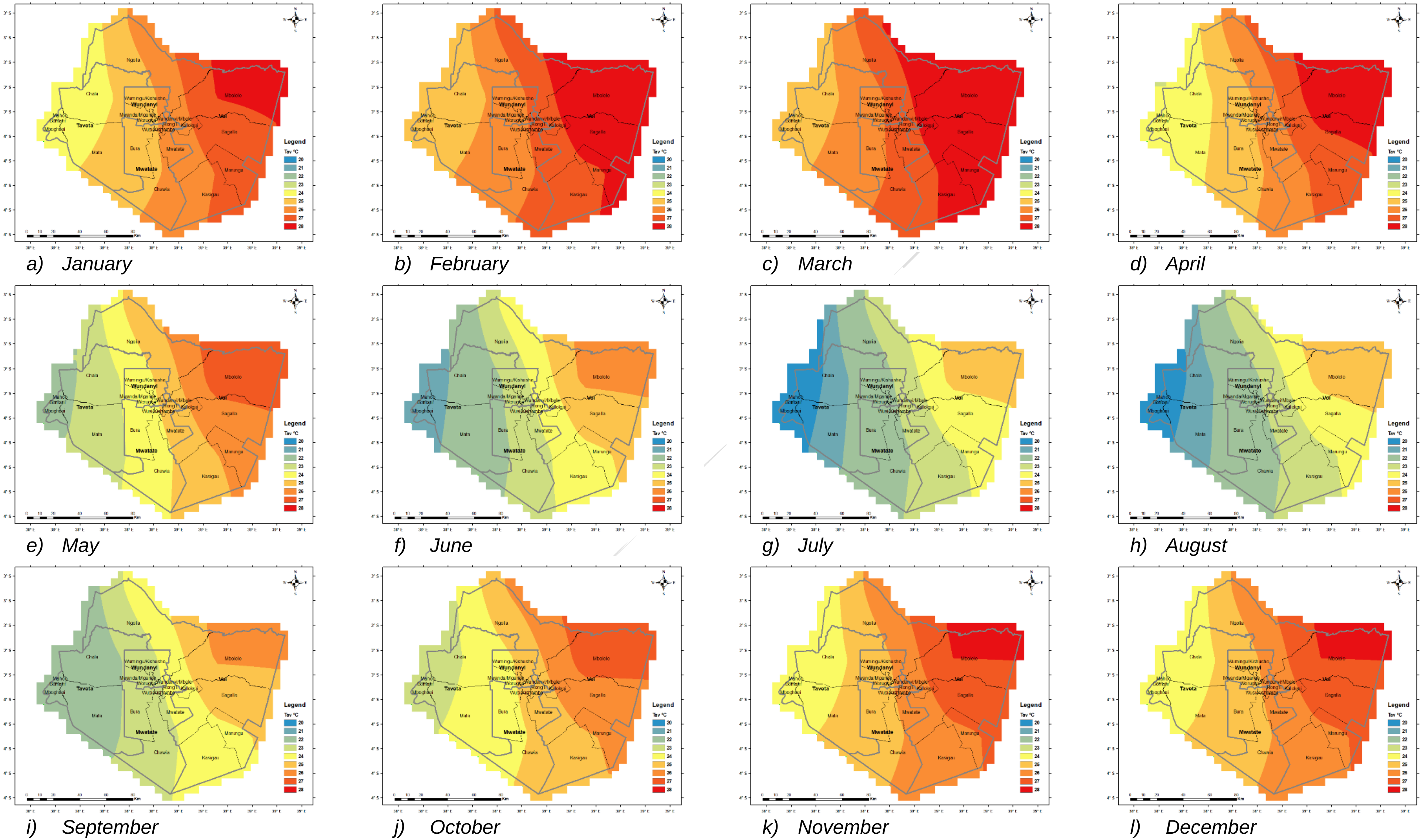


Figure 4.11-4 Monthly Average Temperature over Taita Taveta (1981-2010)

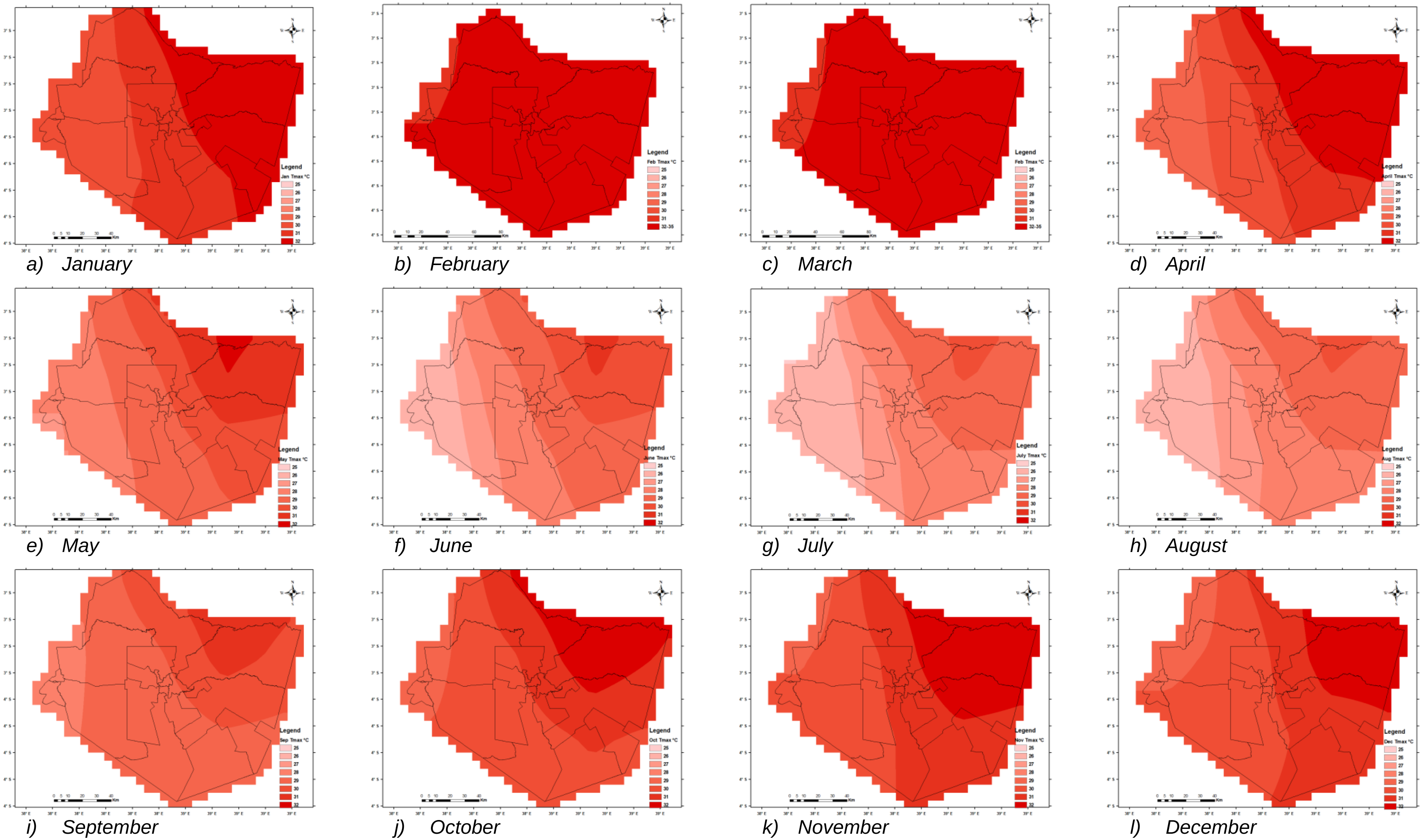


Figure 4.1.1-5 Monthly Average Maximum Temperature over Taita Taveta (1981-2010)

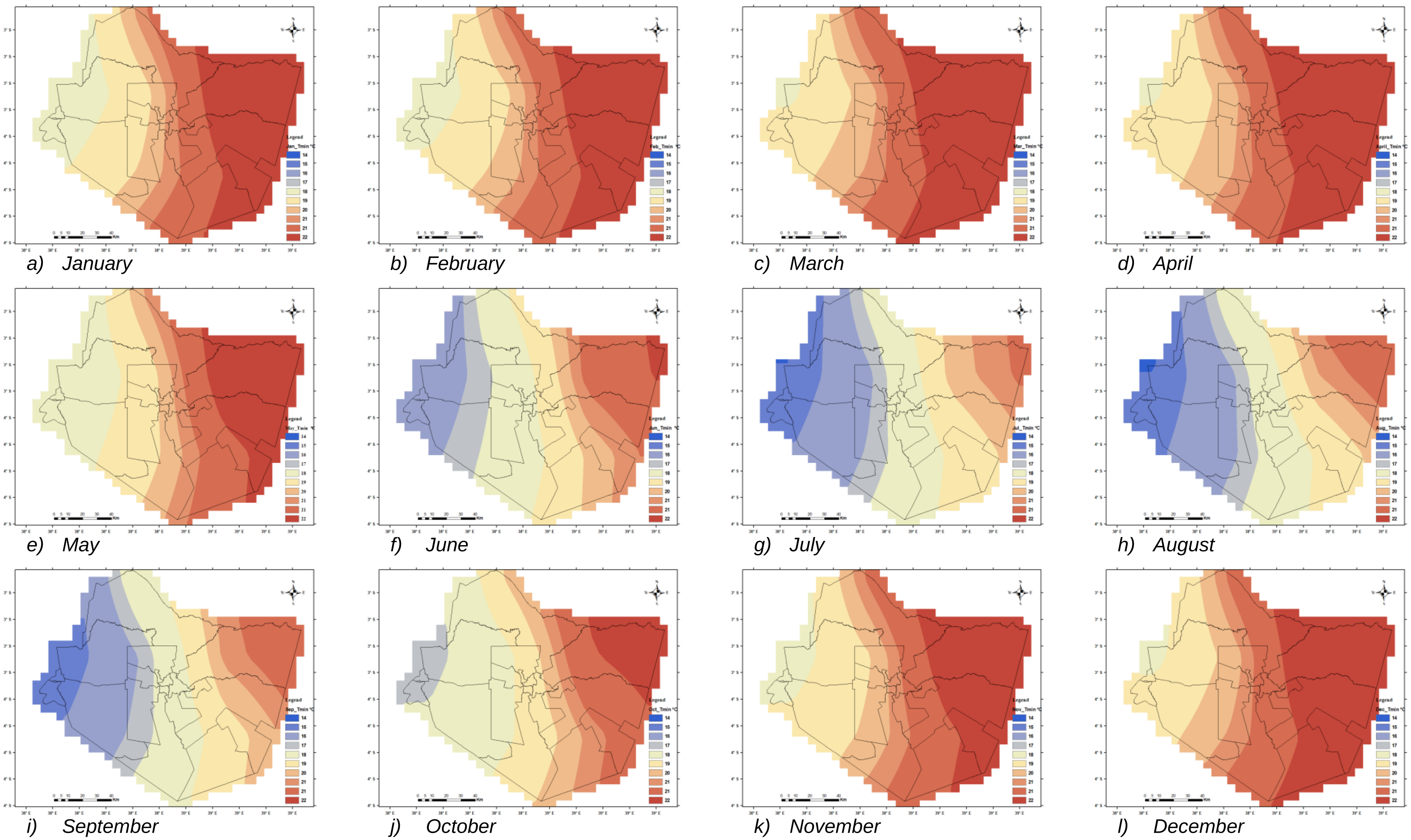


Figure 4.11-6 Monthly Average Minimum Temperature over Taita Taveta (1981-2010)

4.11.2 Seasonal Temperature Climatology

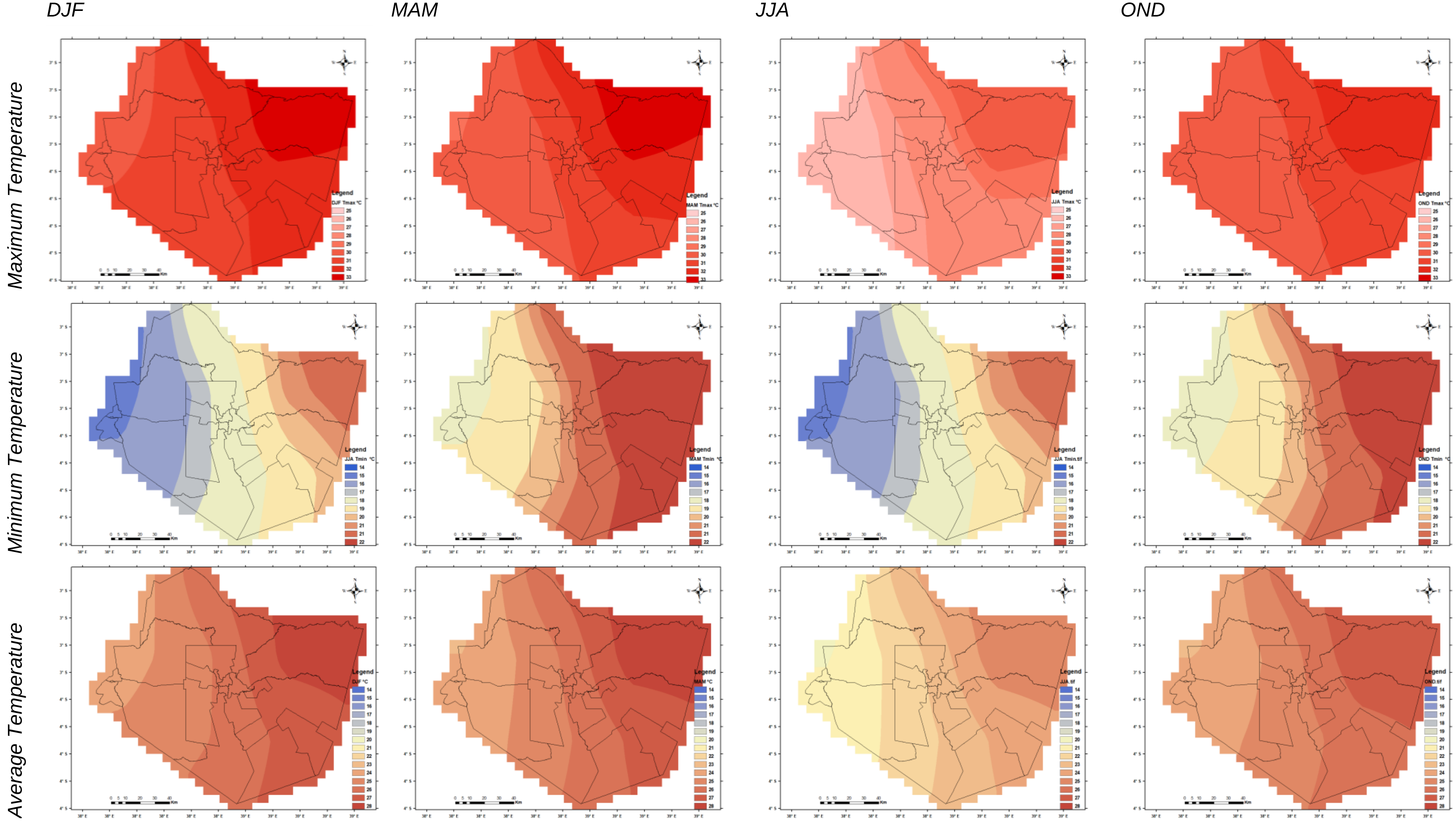


Figure 4.11-7 Seasonal Maximum, Minimum and Mean Temperature over Taita Taveta in DJF, MAM, JJA & OND (1981-2010)

4.11.3 Temperature Trends

Spatial and temporal patterns of the mean, maximum and minimum temperature trends for Taita Taveta are shown in **Figures 4.11-8** to **4.11-11**. Although some variations were observed in space and time characteristics of temperature, the space-time variabilities were relatively consistent when compared to rainfall. The overall temperature trend observed in Taita Taveta ranges between 0.55 to 1ºC per decade**.** Mean surface temperature globally is reported to have increased by 1ºC (ICPAC, 2018; IPCC, 2014). The observed increase in temperature in the county has reportedly resulted in increased incidences and emergence of new pests and diseases affecting both livestock and crops (Government of Kenya, 2016).

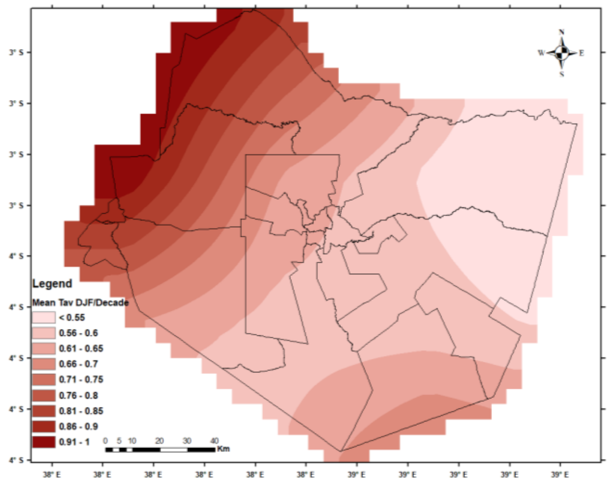


Figure 4.11-8 Trends in Mean surface temperature for DJF season

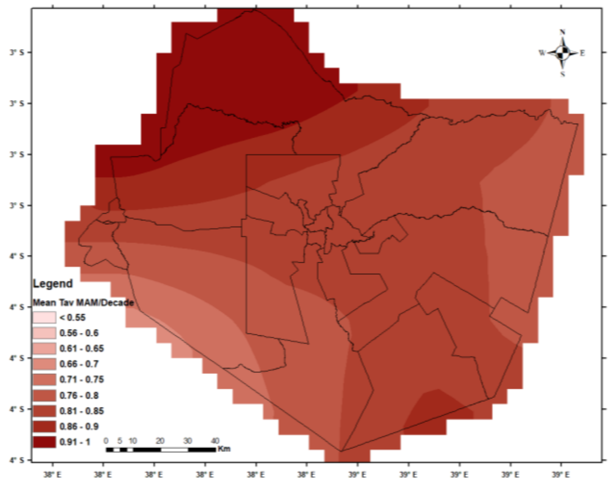


Figure 4.11-9 Trends in Mean surface temperature for MAM season

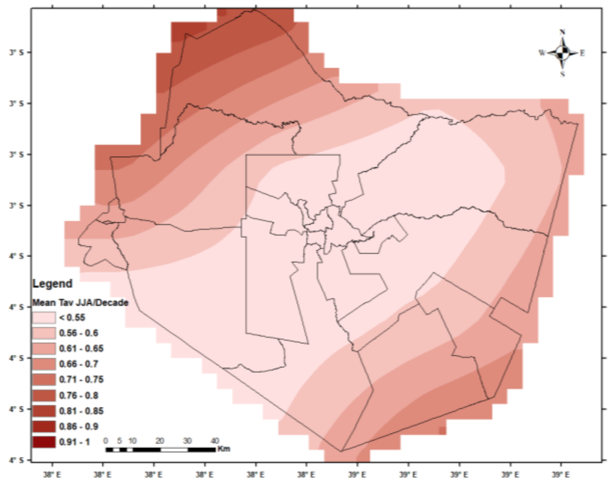


Figure 4.11-10 Trends in Mean surface temperature for JJA season

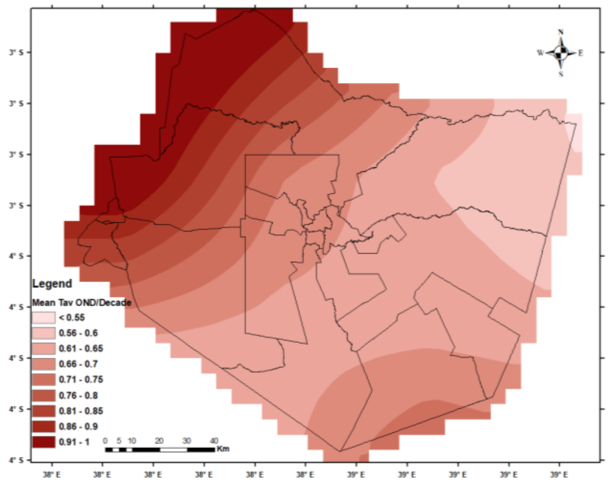


Figure 4.11-11 Trends in Mean surface temperature for OND season

Taita Taveta temperature time series are shown in **Figures 4.11-12** to **4.11-19**. A general increasing trend is observed at all locations, although the magnitude of the increase is not the same at all locations. The observed positive trends were significant at 95% confidence.

Although observed increasing trends in the mean, minimum and maximum temperatures are consistent with global warming trends that are being observed worldwide, the short duration of data used could not enable us associate the observed warming trends in Taita Taveta to climate change and global warming signals.

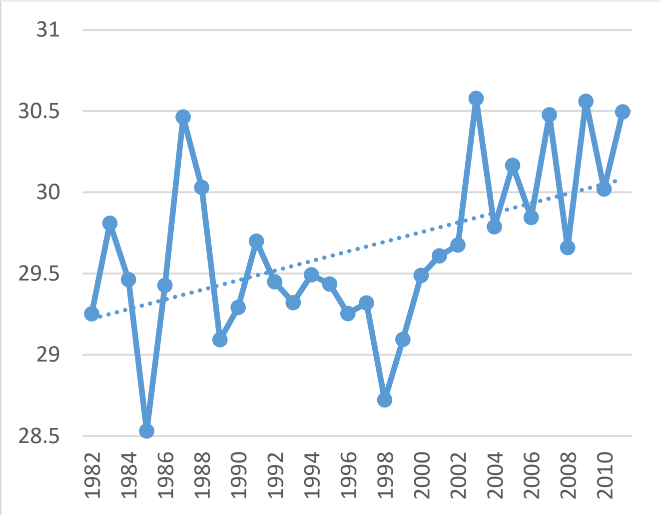


Figure 4.11-12 Time series for mean surface temperature for DJF season

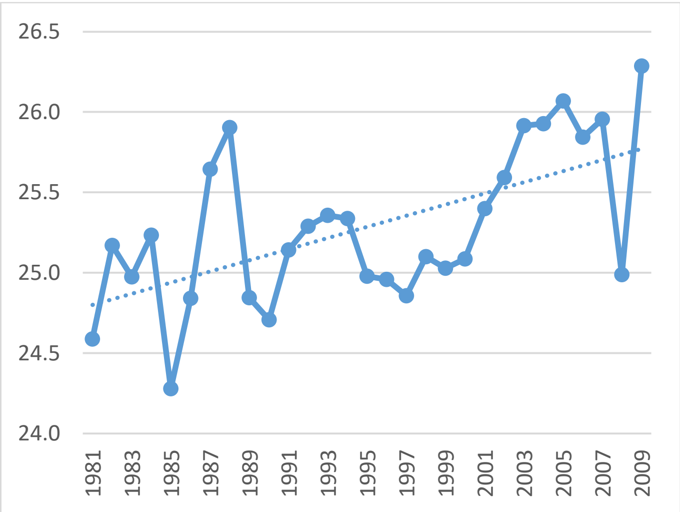


Figure 4.11-13 Time series of surface temperature for MAM season

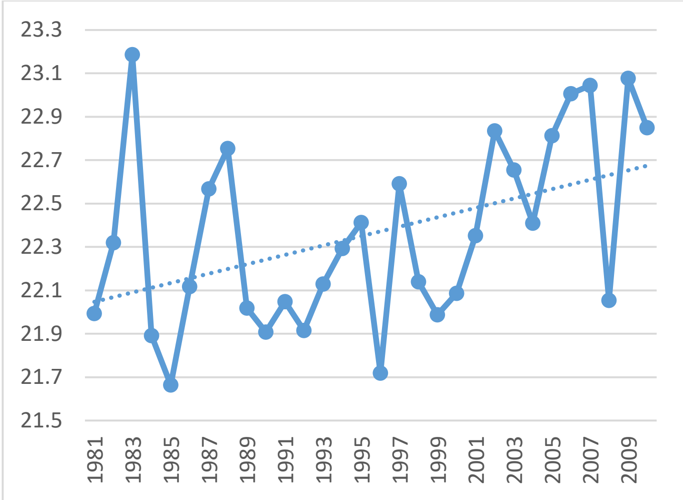


Figure 4.11-14 Time series of mean surface temperature for JJA season

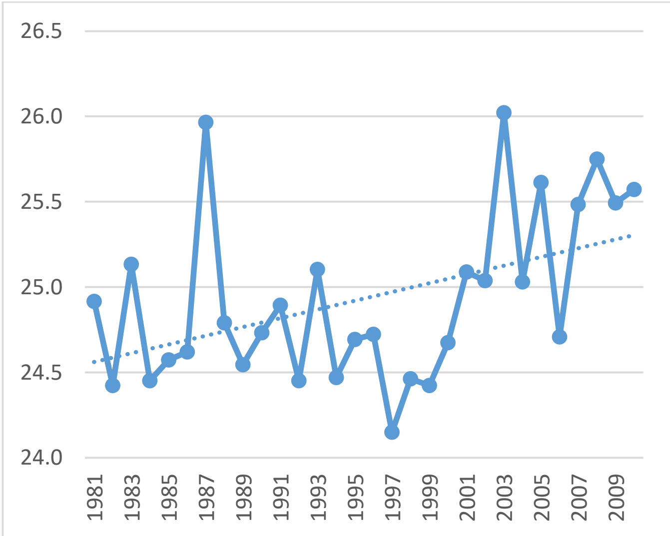


Figure 4.11-15 Time series of the surface temperature for OND season

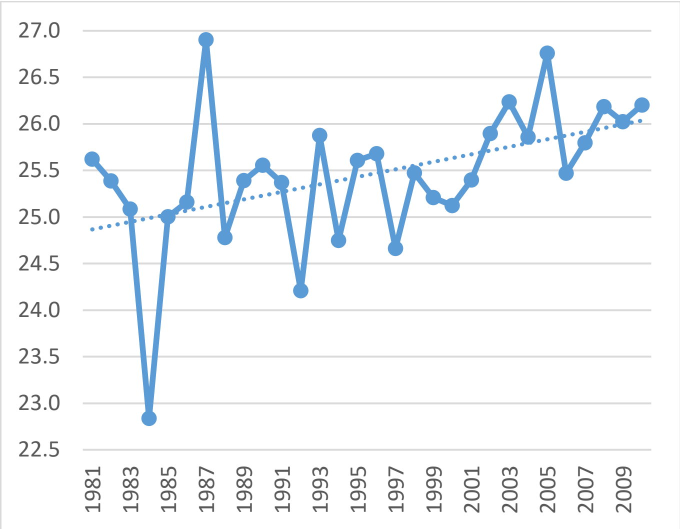


Figure 4.11-16 Time series of Max surface temperature for DJF season

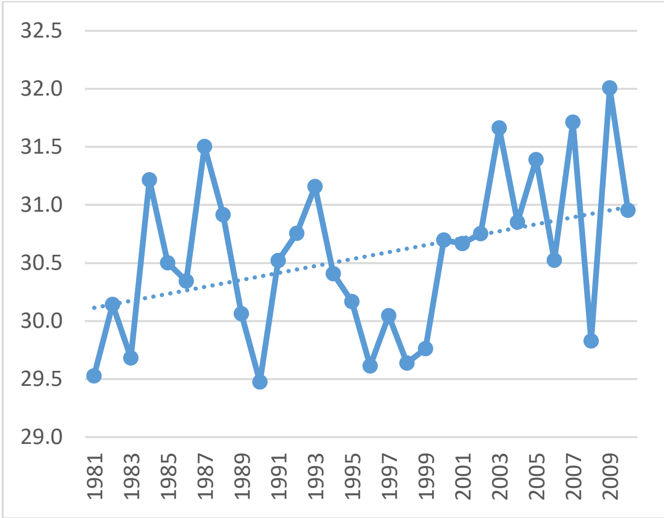


Figure 4.11-17 Time series of the maximum surface temperature for MAM season

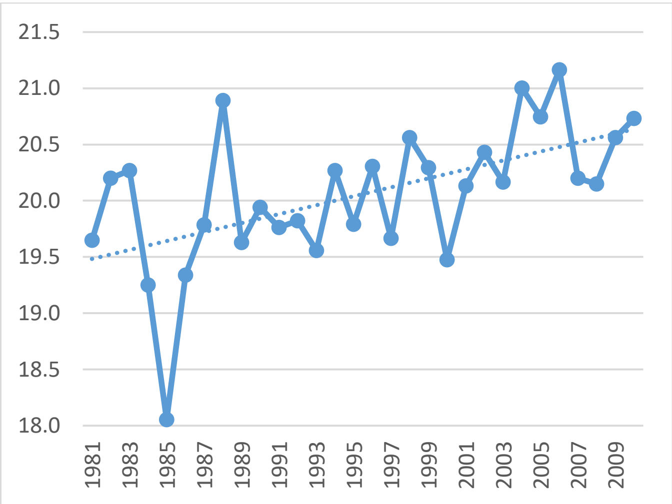


Figure 4.11-18 Time series of the Minimum surface temperature for MAM season

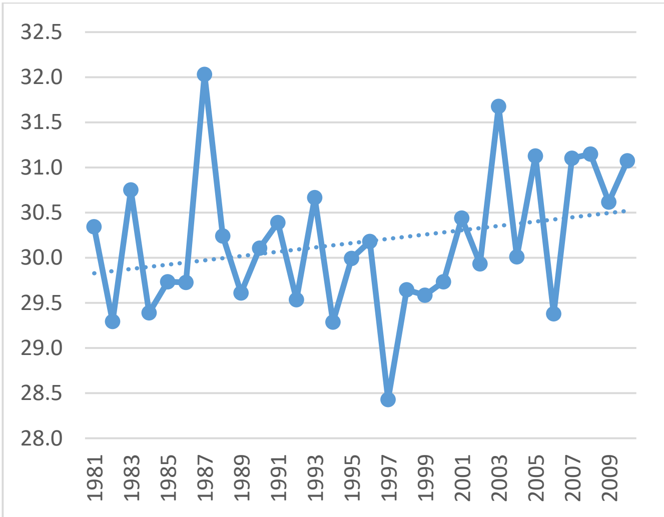


Figure 4.11-19 Time series of the Maximum surface temperature for OND season

5. CONCLUSIONS

Baseline climate statistics obtained from long term climate data are required for deriving the knowledge of past, present and future states of the climate of any specific location. They also form the foundation for monitoring, prediction, early warning, and development of integrated and sector specific resilient strategies for coping with climate risks. Baseline climate statistics are also critical for climate change science, projections of future climate change scenarios, assessment of climate change impacts, vulnerabilities, as well as for the development of resilient climate change adaptation and mitigation strategies. Providing baseline climate statistics was therefore a key and first priority activity for the project.

The main goal of the ACREI is to develop and implement adaptation strategies and measures that will strengthen the resilience of vulnerable smallholder farmers, agro-pastoralists and pastoralists in the Horn of Africa to climate variability and change in line with the IGAD Drought Disaster Resilience Sustainability Initiative (IDDRSI) programme, the National Adaptation Plans of Action (NAPAs) and Development Strategies/Visions of participating countries. In close partnership with the National Meteorological and Hydrological Services (NMHSs), ICPAC leads component 3 of the project while FAO and WMO lead Components 1 and 2 respectively. In order to effectively implement the above three components, baseline data and information that is easily accessible to the users is one of the key activities as highlighted under project activity 3.1.4. Baseline climate data analysis in the three countries were undertaken by organizing a workshop in Naivasha between April 15 and 19 This was followed with site specific workshop in each of the three member countries.

This report provides a summary of the of the observed baseline rainfall characteristics including rainfall intensity and associated variance; probability of exceedance of specific rainfall thresholds and associated variance; mean characteristics of wet/dry days and associated variance; probability of occurrence of specific wet/dry spells; Onset, cessation and length of growing seasons. Mean, maximum and minimum temperature baseline statistics were also presented. The report shows significant variations in rainfall characteristics in Taita Taveta County. The trend patterns were not consistent for the whole county as cases of slight positive and negative trends were evident over parts of Taita Taveta .There was however clear evidence of increase in frequency and recurrences of the above and below rainfall events at all locations.

Increase in Mean, maximum and minimum temperatures were observed at all locations within Taita Taveta County. Although increasing trends were evident in all places that is consistent with global warming trends that are being observed worldwide, the short duration of data used could not enable us associate the observed warming trends in Taita Taveta to climate change and global warming signals.

The climate baselines from this report will serve as information material for all components of the project as well as the partners and stakeholders. It will also help to achieve project output 3.4.1 on Documentation and dissemination of good practices and lessons learned on the use of climate information in agricultural decision making; output 3.4.2 on Conducting regional and national learning forums; and output 3.4.3 on Improved regional food and nutrition security assessment coordination including capacity building on attribution of food insecurity to various climate related hazards. The workshop outcomes include among others:-

i. Capacity building of NMHs on latest climate products and tools available for analysis of historical climate;
ii. Provided training materials to NMHs on the use of Climate Data Tools (CDT) and other related tools;
iii. Availability of climatological baseline based on analysis of historical climate of project sites including monthly climatology, rainfall intensity, historical onsets, rainfall and temperature trends among others;

iv. Availability of location specific climate products and services on which the climate hazard and other risk management maps can be created;
v. Review of the ACREI project work plan and development of site specific integrated roadmap with local communities and partners for effective project implementation;

The report therefore has provided firm foundation on which all components of the ACREI project are being implemented.

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