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REVIEW ARTICLE

Characterization of wheat production using earth-based observations: a case study of Meru County, Kenya

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Abstract

This research demonstrates the use of Earth-based observations to evaluate factors affecting wheat production. In Kenya, there has been an over-reliance on maize production and this cannot feed the increasing population hence a need to shift to wheat to enhance food security. Wheat farming is faced with the problem of climate change, drought, fertilizer application, pests and diseases, and low prices. The objective of this research is achieved through the characterization of climatic patterns, correlating the effect of change of Land use and wheat growth seasons on wheat production. The analyses carried out are drought, change in Land use Land Cover and wheat growing seasons. Extreme cases of meteorological drought using SPEI-1, occurred in 2001 October, November (− 2.175, − 2.08309) and 2016 July (− 2.2148) Whereas SPEI-3 were in 1997 February (− 2.149), 2001 November and December (− 2.1423, − 2.346), 2002 January and February (− 2.347, − 2.1380) SPEI values respectively. Extreme cases of Agricultural drought months are 1986 September (− 127.986), 1989 November (− 132.258), 1996 September and October (− 130.372, − 145.085) and 2013 February (− 120.184) NDVI Anomaly values. SPEI 1 and 3 were considered best in drought analysis because wheat is rainfed, takes a minimum duration of 3 months to grow hence the intensity of drought easily understood. A strong correlation is in the change of Forestland (R = 0.75) and Bare land (R = 0.66), moderate correlation in Wheat plantations (R = 0.42), a weak correlation in vegetation (R = 0.32) and a very weak correlation between length of seasons (R = 0.16) to wheat production. The year 2000, 2008 and 2009 had low whereas 2017 and 2018 had high wheat production (7600, 5200, 4975, 46,450 and 27,800 tonnes respectively). The future analysis should focus on prediction analysis of both drought, Land use Land Cover Changes and wheat growing seasons.

Keywords Agricultural drought · Meteorological drought · Growth seasons and climate change

Introduction

Wheat production globally has increased by an average of 21.8% per year since 1961 (Pardey 2011). In Africa wheat is a staple cereal wherein Sub-Saharan Africa provides more than 60% of food calorie while in the west and central Africa it provides 30% of food (Gitu 2006). Wheat growth in Africa covers around 10 million ha and is a staple crop for several people. Its consumption has increased due to the result of a growing population, changing food preferences and social-economic change associated with urbanization. Due to the growing importance of wheat has for food security in Africa, Africa union Heads of state-endorsed their Agriculture minister's endorsement in January 2013 to add to the list of strategic crops for Africa (Gupta 2011). The products of wheat are mainly consumed by the urban population and by the majority of middle and high-income earners in the rural areas and its demand exceeds domestic production by more than 50% (Munane 2014). The growing demand for wheat in Africa cannot be met due to low yields as a result of climate change (Rosegrant and Msangi 2009).

Wheat is the most susceptible crop to climate change and is sensitive to heat (Ali et al. 2017). All the developing countries in Africa where wheat is grown experience the impact of climate change on wheat production (Nelson 2009). Global and regional changes in temperature and rainfall have exerted different impacts on the input and agricultural production more so to wheat (Valizadeh et al. 2014).

In Kenya wheat is the second most important cereal after maize and contributes substantially to food security, poverty reduction and promotes employment creation. The demand

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for wheat is expected to increase strongly in the near future as a result of population growth and dietary changes hence how to increase wheat production is a major challenge that Agriculture faces in Kenya (2016). Under Kenya's Vision 2030, the achievement of National food security is a key objective of the agricultural sector if the vision is to be realized (Mofp 2006).

The main places where wheat is grown in Kenya include highland areas comprising of Timau Meru, Uasin Gishu, Narok, and Nakuru where cooler temperatures allow for longer periods of starch accumulation leading to high yields (Noah and Waithaka 2005).

The main conditions influencing wheat farming are a gentle slope, Altitude, moderate rainfall, warm temperatures, deep fertile volcanic soils and warm dry sunny spell (Wanjiku 1991).

The land where wheat is grown should be gentle or level and this allows for Mechanization (Simalenga 2013). Wheat is favored by altitude ranging from 1500 to 2900 m. This reduces the incidences of diseases.

Moderate Rainfall ranging from 500 to 1270 mm is important in wheat growth. Wheat requires warm temperatures between 15 and 20 °C of at least 3 months (Mukherjee et al. 2019). This enables the maturity of the wheat. Warm dry sunny spell enhances the ripening of wheat and harvesting.

Deep fertile volcanic soils lead to high yields. Analysis of soil evaluation done for all counties in Kenya classified the Meru region as a highland region and the soils were considered favorable for food production (NAAIAP 2014).

Meru county is characterized by high agricultural productivity attributed to favorable climatic conditions and fertile lands. It is considered as one of the food secure counties in Kenya. High -input rain-fed agriculture complemented by irrigation is the main source of livelihood in the County, contributing about 80% to the average household income. Floods, change in land utilization and heat stress compromise productivity and food security in Meru county and are expected to pose even greater challenges in the coming years (USAID 2018).

The problems facing wheat production in Meru County, Kenya are drought and climate change which leads to the destruction of the crop, price fluctuations that lead to losses when farmers sell their crops at low prices, changing land use, type of rotation, fertilizer use, pests and diseases that destroy crop leading to low yields.

Earth-based observations are important in addressing the problems of wheat production (Rahman 2014). This is through analyzing climatic patterns and Normalized Difference Vegetation Index to study drought, change detections to show change of land use land cover and analyses of wheat growth seasonal changes.

This study aims at evaluating factors affecting wheat production in Meru County, Kenya. This is achieved through the characterization of the climatic patterns for the period 1985 to 2018, correlating the effect of change of land use to wheat production and correlating growth seasons to the production of wheat.

Characterization of climatic patterns involves analyzing the changing climate of the area. When climate changes it results in drought hence affecting wheat production (Alexander 1995).

Drought is the most complex and damaging disaster (Mukherjee et al. 2019). The effect of a drought can be understood through the analyses of SPEI and NDVI. SPEI considers the rainfall and Evapotranspiration to index droughts (Abdullah 2014).

There are four types of drought namely Meteorological, Agricultural, Hydrological and social-economic (American et al. 2014). In this research, only Meteorological and Agricultural drought are investigated Flooding, dry spells and heat stress are all hazards that contribute to agricultural risk in Meru county.

Meteorological Drought is mostly caused by increasing temperature in the world and this has a negative impact on wheat while Agricultural drought is a result of deficient soil moisture (Tack et al. 2015). The use of earth-based observations places remote sensing as the best method of studying drought (Alwesabi 2012). Agricultural drought is analyzed by the use of NDVI and NOAA-AVHRR (Chopra 2006).

Correlating the effect of change of land use to wheat production involves analyses of Land use Land cover classification and correlating their changes to wheat production (Worku and Deribew 2018). Correlating growth seasons to the production of wheat involves analyzing growth seasons and correlating to wheat production (Yu et al. 2014).

This study is significant to policy makers and all stakeholders in the wheat trade the key stakeholder being the Ministry of Agriculture. Growth of wheat seasons is useful to farmers for it enables timing for planting, fertilizing and irrigating. Drought analyses are important to the government for it enables efficient planning of the drought (2007).

Data and methodology

Study area

The area of study is in Timau, Meru County, Kenya situated at 0° 5′ 20 N and 37° 14′ 29 E. It covers about 154.7 km^2 (Fig. 1). The area receives rainfall of 805 mm per annum and average temperatures of 15.2 °C. The Altitude is 2300 m above sea level and the soil is mainly deep fertile volcanic soil (Karuku 2018).

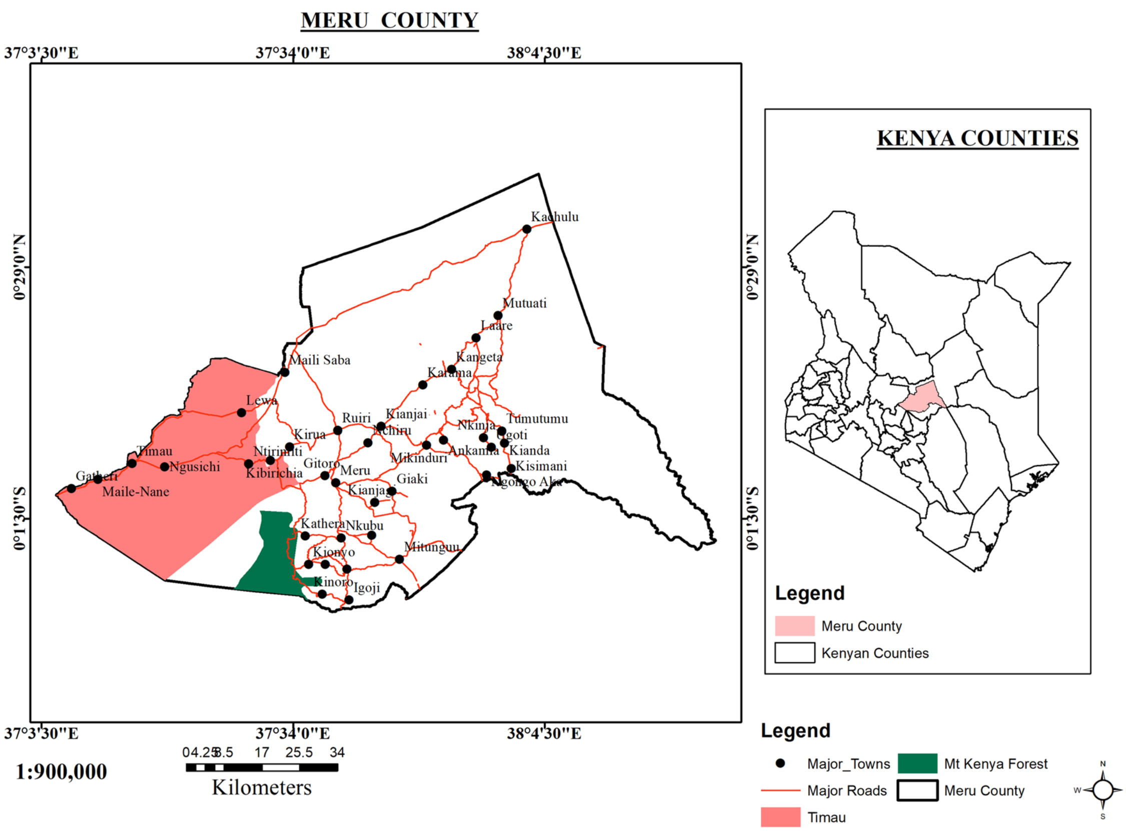


Fig. 1 Area of study

Research approach

Figure 2 shows a flow chart of the whole methodology.

Data collection

Table 1 shows the data used in this research which was acquired from various sources.

The data include wheat, Landsat, NOAA AVHRR (NDVI), Modis (13A2), and climatic data (rainfall and temperature).

Data analysis and results

Each data is analyzed as follows:

Wheat data

The type of wheat mostly grown in the region is durum. The other types grown on a small scale are Robin, KS- Chui, Kenya eagle and Kenya Kingbird. The wheat data used in this research is from 1985 to 2018, provided in tonnes by the ministry of Agriculture comprising of these attributes: planting and harvesting period, year, type and colour. The wheat production trend for 1985 to 2018 is plotted against the years.

Landsat

For this research, Landsat images for the dry season was used at an interval of 10 years. They are for January 1985 Landsat TM 5, January 1995 Landsat TM 5, January 2005 Landsat TM 7, January 2015 Landsat TM 8 and January 2018 Landsat TM 8. The reason for choosing the month of January is because, in the characterization of climate conditions in Kenya, January is considered a dry month and gives cloud-free images (Mekonnen et al. 2018).

The process of change detection analyses involves importing multispectral images in Eldars Imagine 2014-layer stacking, re-projection, and clipping. Information extraction was then carried out through unsupervised classification and direct recognition of features where four classes were established. Using GPS co-ordinates, informed knowledge of the area and historical Google earth images, accuracy assessment was carried out. The analysis for the Land uses Land cover changes were carried out at this stage. Data Merging was then carried out using the ArcGIS 10.4 software which has the capability

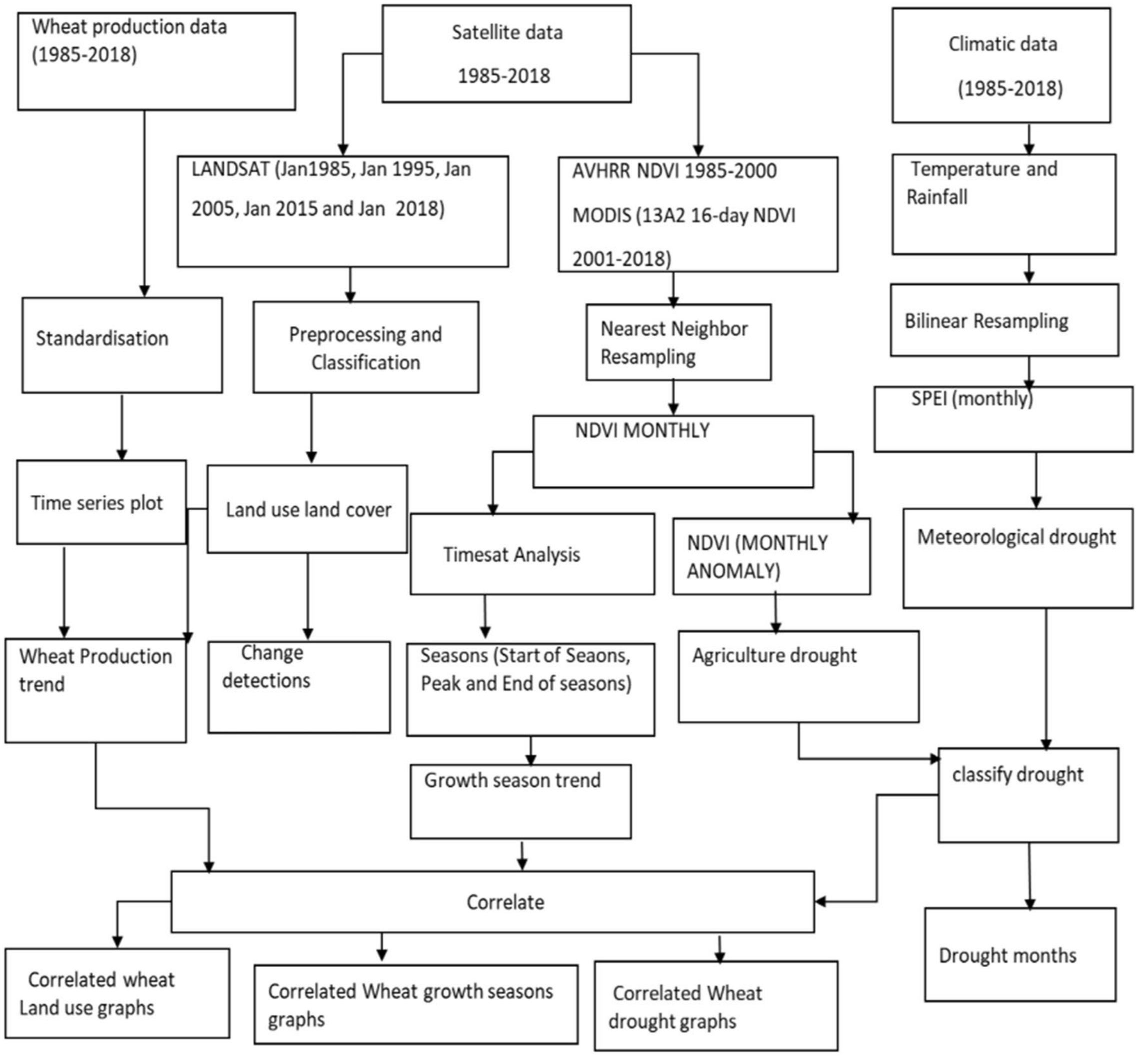


Fig. 2 Methodology of various factors affecting wheat production

Table 1 Data sources

Data type	Sources	Resolution	Year
Wheat	Ministry of Agriculture	154.7 km^2	1985–2018
Temperature	Climate Research Unit (CRU)	55 km	1985–2018
Rainfall	CHIRPS precipitation	5 km	1985–2018
Landsat	USGS	30 m	1985–2018
NOAA AVHRR (NDVI)	USGS	8 km	1985–2000
MODIS 13A2 (NDVI)	USGS	1 km	2001–2018

of integrating the other data with the extracted information. It was also used to prepare the various maps for the respective land use land cover changes for the years 1985, 1995, 2005, 2015 and 2018. Shapefile Editing and area calculation and Change Detection Post classification method were employed for the change detection which provides a change matrix where different transfers from one land use/cover type to another can be visually appreciated. It involves comparative analysis of spectral classifications for times t1, t2, t3, t4and t5 produced independently (Singh 1989).

NOAA AVHRR (NDVI) and Modis (13A2)

In this research, Monthly NOAA AVHRR 8 km by 8 km and Modis (13A2) 1 km by 1 km spatial resolution from USGS earth explorer was used. Images were rescaled through multiplying by 0.0001 in order to get the NDVI values ranging between (− 1 + 1). The monthly NDVI values summed up, mean obtained, Subtracting the Actual NDVI value from mean and then multiplying by 100 to obtain monthly NDVI anomaly. This was used to classify Agricultural drought. The drought months are classified as a very severe, severe, moderate and slight. In order to study growth seasons, Average monthly NDVI images were converted to text files, analyzed with the TIMESAT program to automatically retrieve key stages (Eklundh and Jönsson 2011). The key stages generated are Time for the start of the season, Time for the end of the season, Length of the season, Base level, Time for the mid of the season, Largest data value for the fitted function during the season, Seasonal amplitude, Rate of increase at the beginning of the season, Rate of decrease at the end of the season, Large seasonal integral and Small seasonal integral.

Climatic data

The climatic data used is the monthly temperature from the Climate Research Unit (CRU) and precipitation from CHIRPS 1985–2018. SPEI was carried out to determine Meteorological drought. The procedure involved getting the average monthly rainfall and temperature, the use of the Hargreaves method to calculate potential Evapotranspiration (PET), Calculation of climatic water balance = (PET-observed rainfall) and the later generation of SPEI months lag to show drought (1 and 3 months lag). SPEI was calculated using time series of climatic water balance: precipitation minus potential evapotranspiration. The equation used is Hargreaves which computes the monthly potential evapotranspiration, Climatic Water balance accompanied by the R program studio which enables the generation of SPEI, timescales values for long term series and Moving total time series constructed from the data computed from precipitation and temperature and finally, SPEI graphs categorized Meteorological droughts. Drought months were classified as Extremely dry, Very dry and moderately dry.

Hargreaves evapotranspiration equation

The equation subsequently published by Hargreaves1975 (Hargreaves and Allen 2003) is

$$\mathrm{ET}o = 50.0075\ Rs\ \mathrm{TF} \tag{1}$$

where ETo and Rs = the same units of water evaporation. For temperature in degrees Celsius TC the equation is written

$$\mathrm{ET}o = 50.0135\ Rs[\mathrm{TC} + 17.8] \tag{2}$$

Correlation

Correlation refers to the inter-relation between separate characters by which they tend to some degree at least to move together (Calories et al.). The correlation was done between wheat production, change of Land use Land cover changes and drought. The threshold adopted to determine if their exist correlation (R-values) is 0–0.19 very weak correlation, 0.20–0.39 weak correlation, 0.4–0.59 moderate correlation, 0.60–0.79 strong correlation and 0.8–1.0 very strong correlation (Of 2015).

Results and discussions

Temporal trend of rainfall and temperature

Figure 3 shows the temporal trend of rainfall and temperature from 1985 to 2018.

The months with a high amount of rainfall are April and October whereas months with a low amount of rainfall are January, February and September. Characterization of high and low rainfall months in Kenya coincides with these analyses which classify the central highland area with two seasonal rainfall mainly between March to May and October to December (Ayugi et al. 2016). Characterization of wet months was influenced by peak rainfall seasons whereas dry months characterized by low rainfall. There was a moderate decline in temperature from 2011 to 2014 which led to a slight increase in wheat production between 2011 and 2013 and a decline in production 2014. A moderate decline in temperature results in high wheat production since globally wheat depends on moderate temperature (Burke et al. 2015). The year 2016 and 2017 experienced high temperatures which were as a result of extreme meteorological drought experienced in 2016. Meteorological drought occurs when a drought is combined with increased temperatures and lower humidity (Kurnaz 2014). The year 1985 and 2010 were considered to be wet years and this improved their vegetation cover. There is a relationship between rainfall and NDVI (Khisro 2013). The amount of rainfall and temperature in this region is directly dependent on each other. There has been a direct relationship between precipitation, temperature and pressure in the world (Ernest 1995). Temperature and rainfall can be stimulated simultaneously in the study of the crop yield (Cong and Brady 2012).

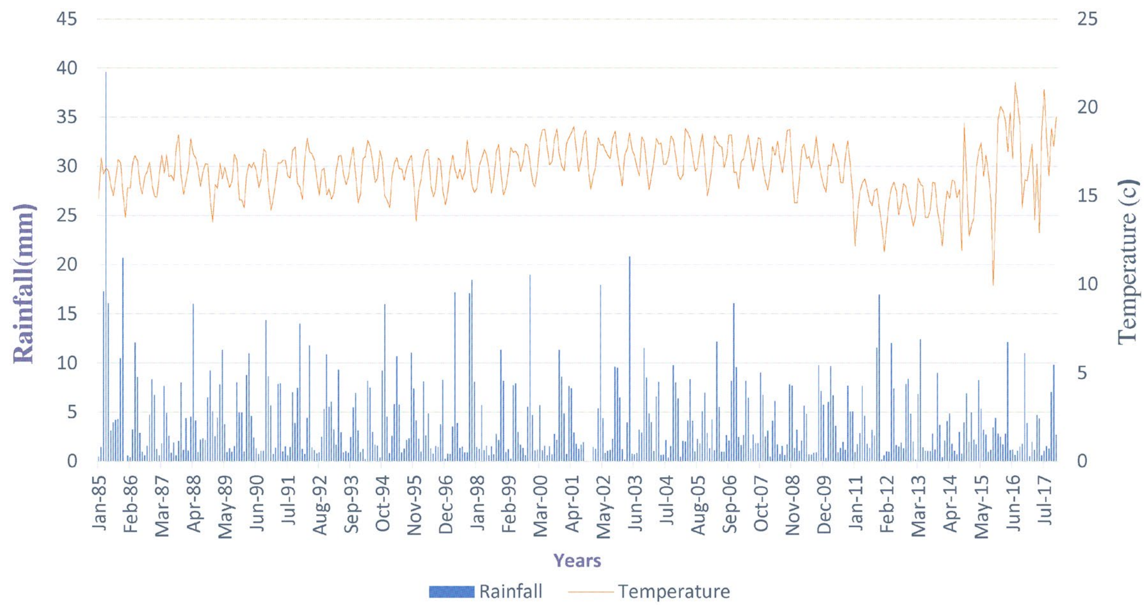


Fig. 3 Temporal trend of monthly rainfall and temperature showing climatic variability in Timau 1985–2018

Meteorological drought characterization using SPEI plots

Figure 4 Shows SPEI Plots. SPEI is based on the climatic water balance (D) and compares the available water with the atmospheric evaporative demand, and provides a more reliable measure of drought severity than considering precipitation. The drought was realized any time the value exceeds (− 1) and extreme drought exceeds (− 2). The SPEI Plots are One-month lag SPEI Plot (evapotranspiration) and 3-months lag SPEI Plot (soil moisture).

In order to conclude, there is drought a threshold for determining meteorological drought was used as shown in Table 2.

SPEI-1 classified extremely dry months in 2001 October, November and 2016 in July. SPEI-3 classified Extremely dry months in 1997 February 2001 November, December, and 2002 January and February. Extremely dry months are caused by increase heat which leads to greater evaporation hence the surface dries and increases the duration and intensity of drought (Trenberth 2011).

Temporal trend of NDVI (monthly 1985–2018)

The temporal trend of NDVI varied from 1985 to 2018. The value for NDVI ranges between − 1 and + 1 as indicated in Table 3. The NDVI values helped to identify vegetation status.

The years with high vegetation cover are 1993, 2002, 2009, 2015 and 2018 whereas low severely low vegetation is 1986 and 1996. Vegetation cover is affected by climate change, soil and topography (Ju-Ying et al. 2008) This relates well with land use land cover changes which classify the year 2015 as the one with high vegetation. The year 1996 experienced severely low vegetation and this is caused by the existence of long meteorological drought experienced during the year.

Figure 5 shows the NDVI anomaly for 1985–2018 which classifies Agricultural drought in the area.

Table 4 forms the threshold for the classification of Agricultural drought.

Extreme cases of very severe Agricultural drought years occurred in 1986, 1989, 1996 and 2013 while the same years experienced a decline in wheat production. This is because the Agricultural drought set in when the soil moisture availability to plants has dropped to such a level that it adversely affects the crop yield (Potopová et al. 2016).

Correlation of SPEI, anomaly, and production

Figure 6 shows a correlation of SPEI, Anomaly, and wheat production. This was done to identify if the meteorological drought and Agricultural drought had a relationship with wheat production.

SPEI-1 and wheat production where $R = 0.25$. There is a weak correlation between SPEI-1 and wheat production. 25% SPEI 1 within 34 years can be used to explain wheat production.

SPEI 3 and wheat production where $R = 0.30$. There is a weak correlation between SPEI-3 and wheat production. 30% SPEI 3 within 34 years can be used to explain wheat production.

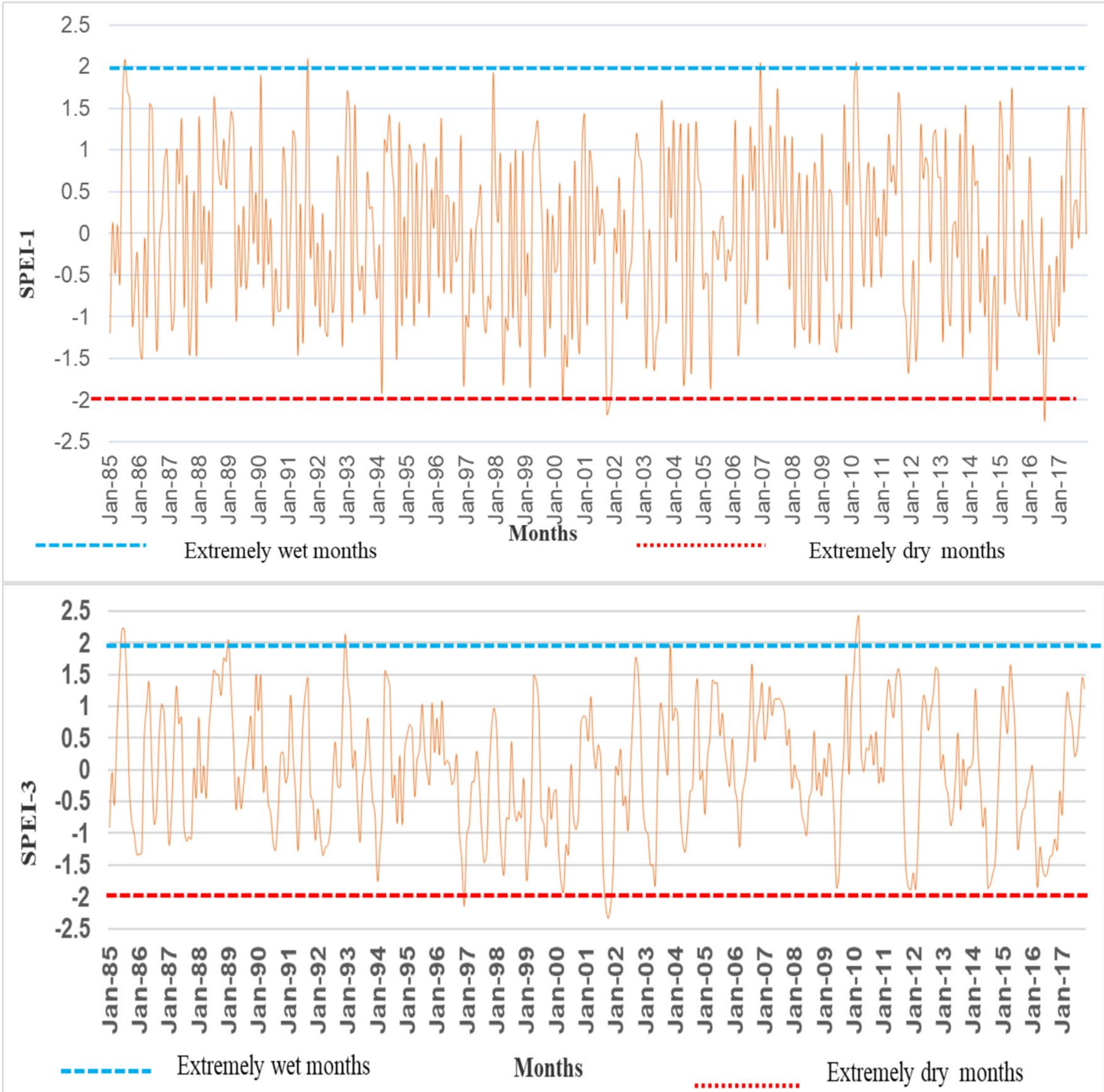


Fig. 4 Drought characterization using SPEI values

Table 2 Meteorological drought classification using SPEI values

Classes of drought	SPEI value
Extremely dry	− 2.0+
Very dry	− 1.5 to −1.99
Moderately dry	− 1.0 to − 1.49
Normal	0.99 to − 0.99
Moderately wet	1.0 to 1.49
Very wet	1.5 to 1.99
Extremely wet	2.0+

Table 3 NDVI value vegetation status

Vegetation status	NDVI value
No vegetation	0
Severely low vegetation	0.1
Slightly low vegetation	0.2
Moderate vegetation	0.3
Better vegetation	0.4
Good vegetation	0.5
High vegetation	0.5>

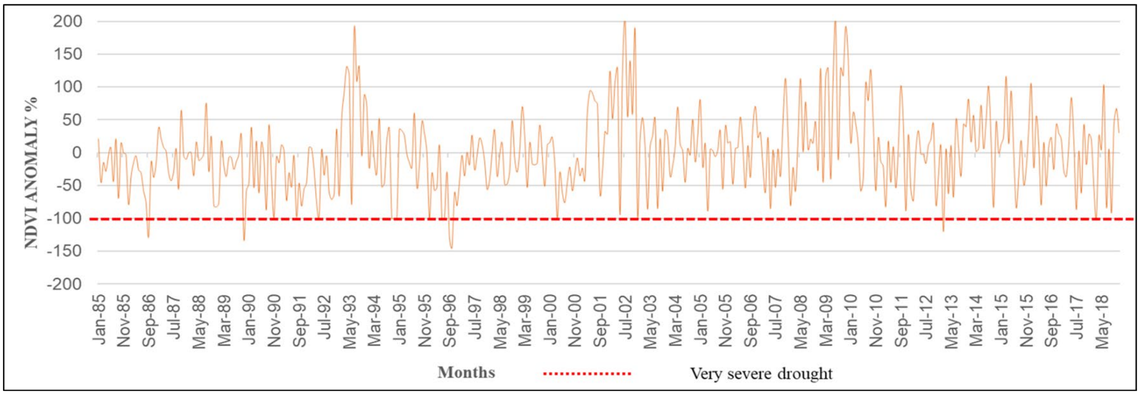


Fig. 5 Trend of NDVI Anomaly 1985–2018

Table 4 Agricultural drought classification using NDVI Anomaly

Classes of drought using NDVI anomaly	Anomaly
Very severe drought	Below − 100
Severe drought	− 50 to − 100
Moderate drought	− 20 to − 50
Slight drought	0 to − 20
No drought	Above 0

Anomaly and wheat Production Where R = 0.07. There is a very weak correlation between anomaly and wheat production 7% anomaly within 34 years can be used to explain wheat production.

From the correlation of Meteorological drought and wheat production, there exists a weak correlation between short term drought to wheat production whereas, from correlation of Agricultural drought and wheat production,

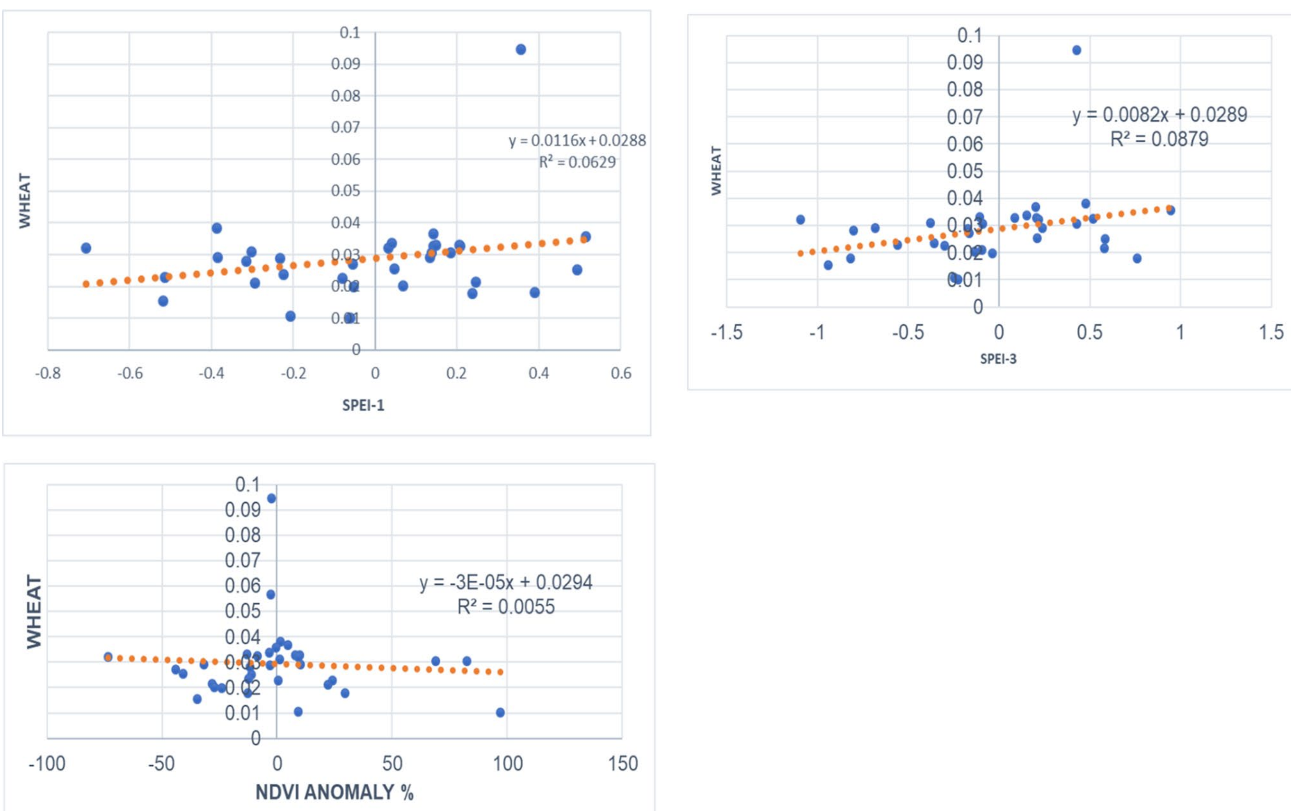


Fig. 6 Correlation between SPEI values, NDVI anomaly to wheat production

there exists a very weak correlation between Agricultural drought to wheat production. A weak correlation between short term drought and wheat production is due to the low intensity of significance where Droughts of lower intensity have little significant negative effects on the yield of wheat (Yu et al. 2018).

Wheat production trend

Figure 7 shows the wheat production trend and the changing Land use. There is a positive wheat production trend from 1985 to 2018.

Global wheat analysis research done for developing and developed countries show the production trend in Kenya increased from 1985 to 1997 at a 1.4% (Pingali 1999). The year 2000, 2008 and 2009 had low wheat production whereas the year 2017 and 2018 had high wheat production. The results of low wheat production are due to heavy rainfall, high temperatures and decline in Wheat plantations (Bajkani et al. 2014). Increased in wheat production experienced between 1985–1987, 1990–1993, 1994–1995, 2000–2002, 2003–2005, 2009–2011, 2014–2017. This is due to an increase in wheat plantations. A decrease in production is between 1987–1990, 1993–1994, 1995–2000, 2007–2008, 2013–2014 and 2017 to 2018. A major decline in production was from 1995 to 2000 a decline of (8500 tonnes) due to the presence of heavy rainfall which caused the destruction of wheat. Persistence of Elnino rainfall from in 1997–1998 caused a decline in food production in the Mt Kenya region (Takaoka 2019).

Land use land cover classification maps

A graphical representation of the areas occupied by the four Land use Land cover is indicated in Fig. 8. The results from the Landsat based image analysis shows four types of Land Use Land cover as Vegetation, Bare land, Wheat plantations and Forest Land.

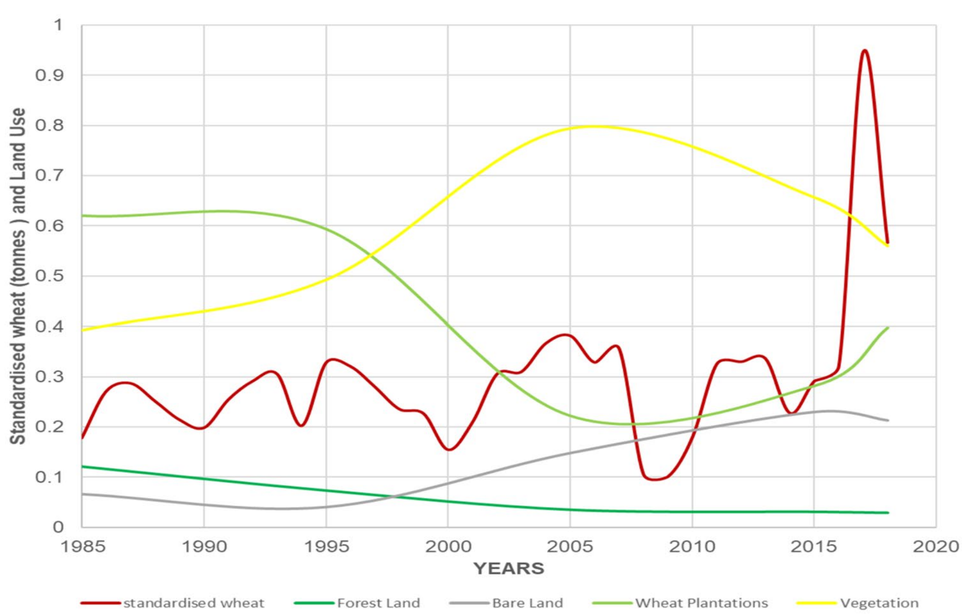
In 1985, Wheat plantations were dominant, compared to other land use with Bare land being minimal. This resulted in high wheat production. A decrease in wheat plantations is caused by changing land use and drought. The year 2005 had an increase in Wheat plantations because of favorite rainfall and temperature compared to 1985, 1995 and 2015 hence high yields (Gábor 2017) Wheat growth areas are represented by Wheat plantations. The patterns of Land use Land cover in Meru County Kenya have been changing since 1976 and this has affected food crop production especially Wheat (Muthee et al. 2015).

Change detections

Figure 9 shows a Change detection analysis from 1985 to 2018.

A declining trend in forestland (from 10.08 to 2.45%) and an increasing trend in wheat plantations and an increase in Bare Land from 1995 to 2018 is observed. Wheat plantations were dominant in 1985, 1995, reduced significantly to 2005 and 2015 and later rises slowly in 2018. Forest land declined from 1985 to 2018. There was an increase in bare land and a decrease in vegetation change. The increase of bare Land is due to climate change and by human activities (Abdel et al. 2019) The distribution of change in each land-use class

Fig. 7 Wheat production trend 1985–2018



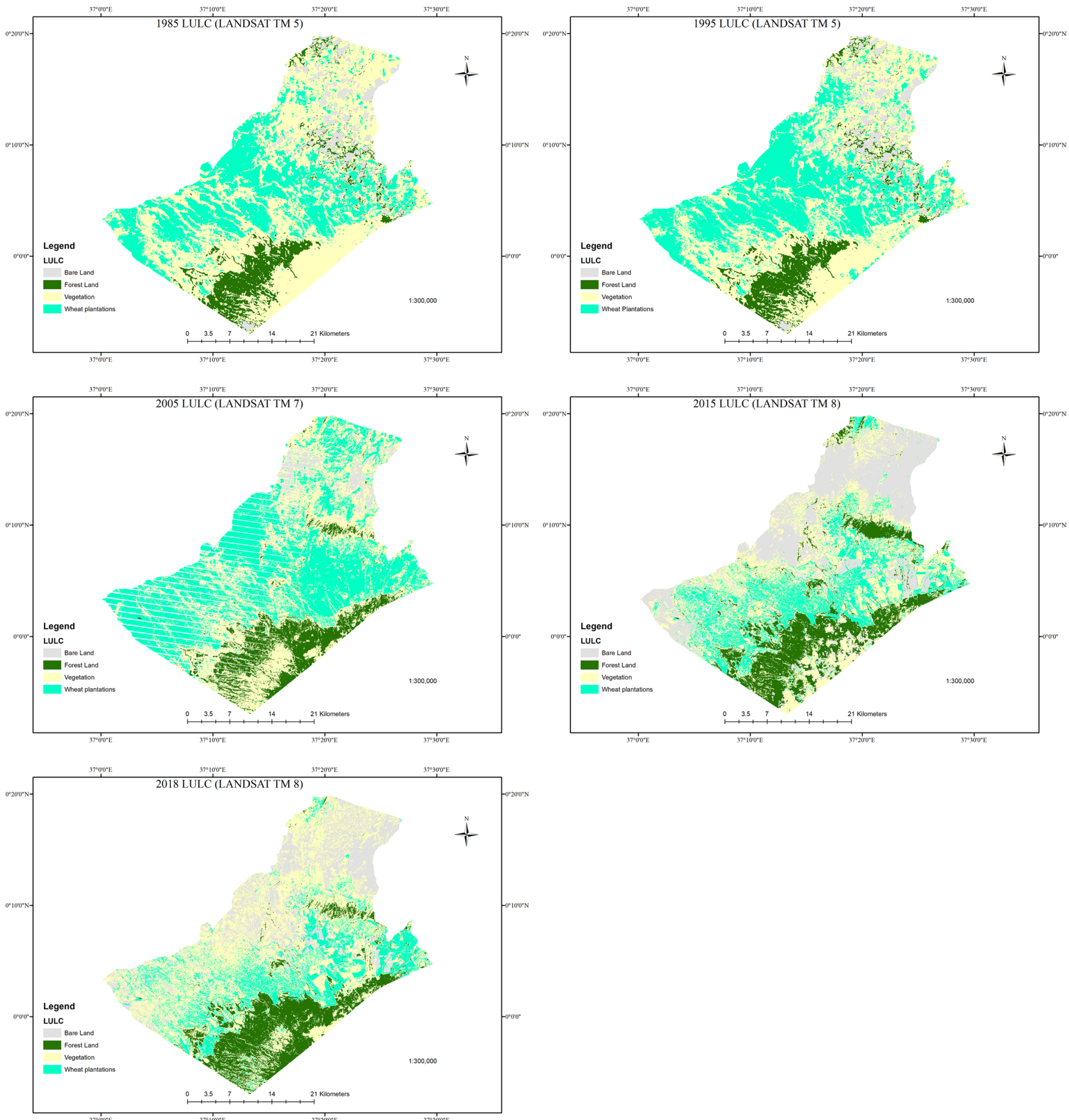


Fig. 8 Land use Land cover classification maps

varied from time to time and it was observed that forestland was losing significantly (Njeru 2018).

Correlation of change of land use to wheat production

This was done to determine if there exists a relationship between change in Land use land cover and production. For Vegetation and wheat production R = 0.32. There is a weak correlation between change in vegetation to wheat production. Weak correlation is caused by climate change to food production. Climate change affects the vegetation (Michelsen et al. 2011) 0.32% change of vegetation within 34 years can be used to explain wheat production.

For Forest Land and wheat production R = 0.75. There is a strong correlation between change in Forest Land to wheat production. When integrated into wheat plantations

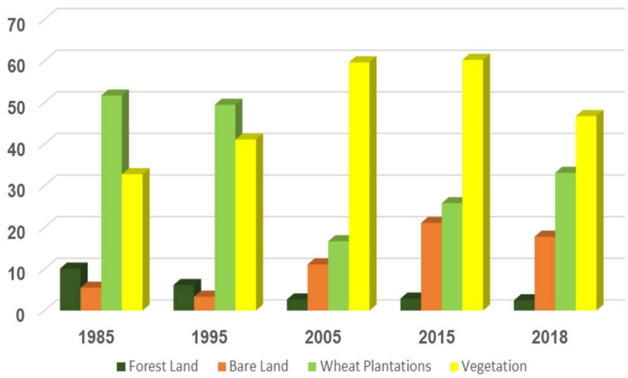


Fig. 9 Graphs illustrating Changes in land cover from the year 1985 to 2018

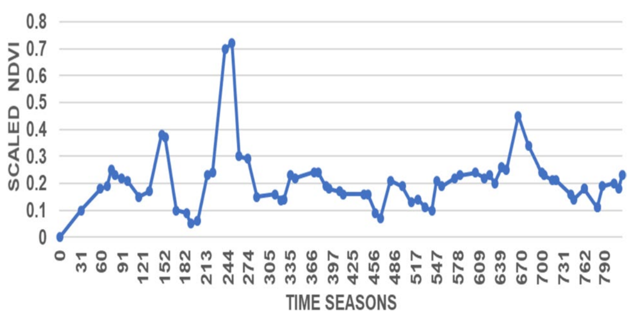


Fig. 10 A plot of the NDVI Versus wheat growth seasons

scapes, forests and trees should increase Agricultural productivity. Forests and trees also help ensure the food security of hundreds of millions of people, for whom they are important sources of food (Challenges opportunities 2016) 0.75% change of forestland within 34 years can be used to explain wheat production.

For Bare Land and wheat production R = 0.66. There is a strong correlation between change in Bare Land to wheat production. Bareland places mostly experience high temperatures hence a strong correlation (Ibrahim et al. 2016) 0.66% change of bare land within 34 years can be used to explain wheat production.

For Wheat Plantations and wheat production R = 0.42. There is a moderate correlation between change in Agricultural land to wheat production. This is because wheat plantations size keeps on changing. 42% change of wheat plantations within 34 years can be used to explain wheat production.

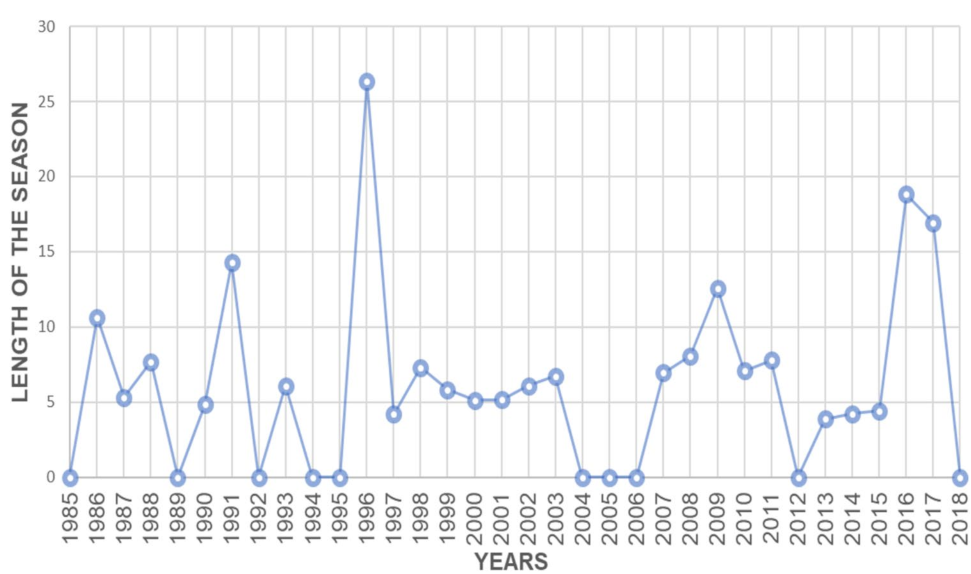
Seasonality parameters

From Fig. 10, seasonality parameters generated are beginning of the season, end of the season, length of the season, base value, time of the middle of the season, maximum value, amplitude, small integrated value, and large integrated value

From Fig. 11 the length of the seasons was plotted against the years

There was a high length of growth season experienced in 1995, 2016 and 2017 and this led to high yields in wheat production. The higher the scaled NDVI the positive implication on the wheat. There is a highly significant positive correlation between the length of the season and grain yield (Sokoto et al. 2012).

Fig. 11 A plot illustrating the time series variations in the wheat-growth season



Correlation of wheat growth seasons and wheat production

The Length of the season was correlated to wheat production where R = 0.16. There is a very weak correlation between the length of seasons and wheat production. 16% length of seasons within 34 years can be used to explain wheat production. A very weak correlation is caused by different stages of wheat growth and they are germination, tillering, stem elongation, flowering and ripening (2018).

Conclusions and recommendations

Conclusions

From the analysis, the productivity of wheat production is partially affected by the change of growing seasons, much affected by land use land cover changes, drought and climatic changes. Characterization of meteorological drought by use of SPEI 1 classified extreme dry months as (2000 October, November and July 2016), SPEI-3 classified (1997 February 2001 November, December, and 2002 January and 2002 February). The most affected years for meteorological drought are 2000, 2001, 2002 and 2016. NDVI anomaly was used as an indicator of Agricultural drought months where Very severe drought months are (1986 September, 1989 November, 1996 September and October and 2013 February). The most affected years for agricultural drought are 1991, 1992, and 1996. There were four classes of land use land cover changes which were identified namely Vegetation, Forestland, BareLand and Wheat plantations. Production increased with an increased in Wheat plantations. A strong correlation was between change in forestland (0.75) and bareland (0.66) whereas the moderate correlation between change in Wheat plantations (0.42) and a weak correlation (0.32) between change in vegetation to wheat production. From seasonality parameters, the length of the season had a minimum effect on wheat production. There is a very weak correlation of 0.16 between the length of seasons and wheat production.

Recommendations

Drought characterization can be analyzed through SPEI (Meteorological) and NDVI Anomaly (Agricultural) drought.

Food insecurity is a global threat, analyses through earth-based observations should be emphasized to venture into factors affecting each crop production.

Future analysis on factors affecting wheat production to emphasize on the prediction of the production, drought menace, Land use Land cover changes and the wheat growing seasons.

Limitation of study

The study is limited to Land use Land Cover classification where the Landsat TM 7 image for 2005 had a high stripping error hence it cannot be fully removed from the image. The gaps cannot define the type of Land use Land cover All the Landsat images for 2005 have a stripping error problem.

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