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RESEARCH ARTICLE

SPATIAL VARIABILITY AND DISTRIBUTION OF MAIN RAINY SEASON ONSET, CESSATION AND GROWING LENGTH AT TEKEZE RIVER BASIN, ETHIOPIA

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ABSTRACT

Main rainy season onset, cessation and growing length are not the same for the entire Tekeze river basin. Knowledge on onset, cessation and growing length of the main rainy season in the river basin is very important for various decision making activities such as agricultural activities for sowing and harvesting, in optimum utilization of limited resources including water, labor and fertilizer, for efficient irrigation water utilization, for interpreting a given seasonal forecast and for drought risk identification and assessment. This study examined the spatial variability and distribution of Kiremt (June to September) season onset, cessation and growing length over Tekeze river basin, Ethiopia. Daily rainfall data were used over the basin based on data available from 23 meteorological stations. Data quality control was done for infilling missing values and main quality tests of outliers and homogeneity tests. Spatial distribution and variability were investigated using ordinary kirging interpolation technique. The results showed that: (1) The Kiremt onset (start of main rainy season) begins earlier in the west part of the Tekeze river basin and is distributed slowly to central and east parts of the basin; (2) Kiremt cessation (end of the main rainy season) is late in the south and west part of the river basin than the other parts; (3) Kiremt growing length which is the difference between Kiremt cessation and Kiremt onset is high over south and west part of the basin and is low over northeast part of the basin. Higher growing length over south part of the basin is due to late kiremt cessation over the area and high growing length over the west part of the basin is due to early kiremt onset and late kiremt cessation over the area. The reason of low kiremt growing length in the northeast part of the basin is due to late kiremt onset and early kiremt cessation over the area; (4) The spatial variability of kiremt onset is higher than the spatial variability of kiremt cessation especially in the east part of the river basin.

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INTRODUCTION

The use of implementing expensive and elaborate rainfall monitoring networks at a basin is to capture and understand the spatial and temporal variability of rainfall. Rainfall is the most important hydrological variable and it varies considerably over space and time. This variability makes it a major source of risk for agricultural production especially for a country like Ethiopia whose economy is dependent on rain-fed agriculture. This sector is highly sensitive to the spatial and temporal variability of rainfall and much below normal rainfall years in the country resulted in low agricultural production and as a consequence it affected millions of people in the country (Wolde-Mariam, 1984, Degefu, 1987, Hurni, 1993, Camberlin, 1997, and Aredo and Seleshi, 2003) The spatial and temporal variability of water resources is also affected due to rainfall variability. Rainfall variability has greater impact on hydrology and water resources (Novotny and Stefan, 2007). The study of rainfall variability in time and space over long period of time is basic for water resources management and decision making strategies. According to (Michaelides, 2009) understanding rainfall variability in time and space helps greatly for agricultural planning, rainfall-runoff modeling, water resources assessments and climate change and environmental impact assessments. Even though rainfall monitoring networks are sparsely distributed at the country, many studies have been conducted to understand rainfall variability using the existing stations in the country. The previous studies on the rainfall variability have been done on different spatial and temporal scales. Examples: Osman and Sauerborn (2002) studied the

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rainfall variability of the central highlands of Ethiopia for the main rain season (June to September) using 11 stations of data from (1898-1997) and noted a decreasing trend of seasonal rainfall in their study. Selesh and Zanke(2004) studied the rainfall variability of Ethiopia at seasonal and annual time scales using 11 stations with data from (1965-2002) and noted no trend of rainfall at annual and seasonal time scales for Central, Northern and Northwestern Ethiopia highlands. But with significant trend over Eastern, Southern and Southwestern Ethiopia. Cheung et.al, (2008) studied the rainfall variability of 13 watersheds of the whole Ethiopia using 134 stations of data between 1960 and 2002 at annual and seasonal time scales. For Tekeze river catchment they utilized nine rainfall stations and found no trend in the rainfall time series. Though analysis of the past weather and climate is useful for helping in planning and design of many types of projects such as irrigation scheduling, water storage systems, the previous researchers tried to understand the climate expressed in terms of annual and seasonal totals and averages but performance of a given rainy season does not only depend on its average or on its total amount. The distribution of the rainfall during the whole season is important as the distribution rainfall is affected from late onset, early cessation. Therefore understanding the dates of onset and cessation of the main rainy season can be very important for various agricultural activities such as preparing a seedbed, sowing, harvesting and drying. This helps in reducing risk to crops and in optimum utilization of limited resources including water, labor and fertilizers and for efficient irrigation water utilization. Knowledge on where and when rainy season starts early and ends late, starts late and ends late in the river basin is very important for various purposes such as good start of main rainy season in one location in the river basin can be an indicative of good rainy season start in another location and as well as for drought identification and assessment in the river basin. This study examined the spatial variability and distribution of main rainy season onset, cessation and growing length extracted from daily rainfall data at the Tekeze river basin. It tried to answer such questions: (i) When does main rainy season starts and ends in the river basin? (ii) To what extents do the onset, cessation and growing length vary in the river basin? (iii) Where, in the river basin, do we find climatologically an early onset and late cessation and vice versa? (iv) How do the onset, cessation and growing length vary from location to location in the river basin?

Description of the study area

Tekeze basin is one of the major river basins of Ethiopia. The basin is located in the Northern western part of Ethiopia Figure 1. The basin consists of the main catchments of Tekeze, Angerb and Goang rivers. This study focused only on the Tekeze river basin. Tekeze river basin is located at $11^0 40' 12.20''$ N to $14^0 45' 42.29''$ N and $36^0 32' 07.70''$ E to $39^0 46' 23.89''$ E in the Northern western part of Ethiopia. The Tekeze river basin has an area of 63,109.1km2 with its out let located at 14.259^0N and 36.560^0E. The river basin has a minimum elevation of 537m.a.s.l and a maximum elevation of 4517m.a.s.l. The annual rainfall variability in the Tekeze basin is very high. The mean annual rainfall in the basin ranges from about 600mm in the north east to over 1200mm in the high lands of south west(Belete, 2007). Generally the rainfall in the basin is high affected by local factors like topography and micro-climate in the basin (Amare, 1996). The year-to- year variability of annual rainfall totals in the basin is very high showing coefficient of variability ranging from 0.2 in the high lands of the basin to 0.4 over its low land part (Belete, 2007). The mean are temperature in the basin varies from about 10oc in the highlands of the basin to over 26oc on its lowlands. There is very high year-to-year variability of dry spell lengths for the months of Kiremt season (June, July, August and September) over Tekeze river basin showing coefficient of variability greater than 0.3 (Gebreselassie and Moges, 2016) The dry spell length for June varies from about 5 days in the west part of the basin to about 17 days in the east part of the basin. The dry spell length for June increases progressively from west to east part of the basin. The dry spell for July varies from about 2 days in the southwest part of the basin to about 5 days in the northwest and northeast part of the basin. South, southwest and central parts of the basin have lower dry spell length in July than other parts. The dry spell length for August varies from about 2 days in the southwest and central to about 6 days in the far northwest and far northeast parts of the basin. Dry spell length for September varies from about 7 days in the south and west part of the basin to about 20 days in the northeast part (Gebreselassie and Moges, 2016).

MATERIALS AND METHODS

In order to examine the spatial variability and distribution of the main rainy season onset, cessation and growing length extracted from daily rainfall data in the Tekeze river basin, the study approach is summarized as follows and details are presented in the subsections below. A Digital Elevation Model (DEM), which is 90 meter spatial resolution, of the Tekeze river basin is downloaded from the website of http://srtm.sci.cgiar.org/SELECTION/input /input Coord.asp. And the location of each meteorological station was obtained from the website of www.nma.org.et of the National Meteorological Agency of Ethiopia. After delineating the Tekeze river basin from the DEM and identifying the meteorological stations which could represent the basin, quality control for the daily data of each station were done. Assessment for quality of the data of each station was done by filling missing data, testing for outliers and testing for temporal homogeneity. After checking for outlier and making adjustment and identifying only stations with homogeneous rainfall data, the rainfall indices were derived and the spatial variability and distribution of the indices over the basin were done.

Data Collection

In this study, daily rainfall data of the Tekeze river basin for the period from 1960-2009 with available data from 1992-2009 for most of the stations were obtained from the archives of the National Meteorological Agency (NMA) of Ethiopia. The dataset contains 23 meteorological stations. The spatial distribution of those meteorological stations is shown in Figure 2. And Table 1 illustrates a generalized geographic location, period of recorded rainfall, and percent of missing values information of each selected stations used for this study.

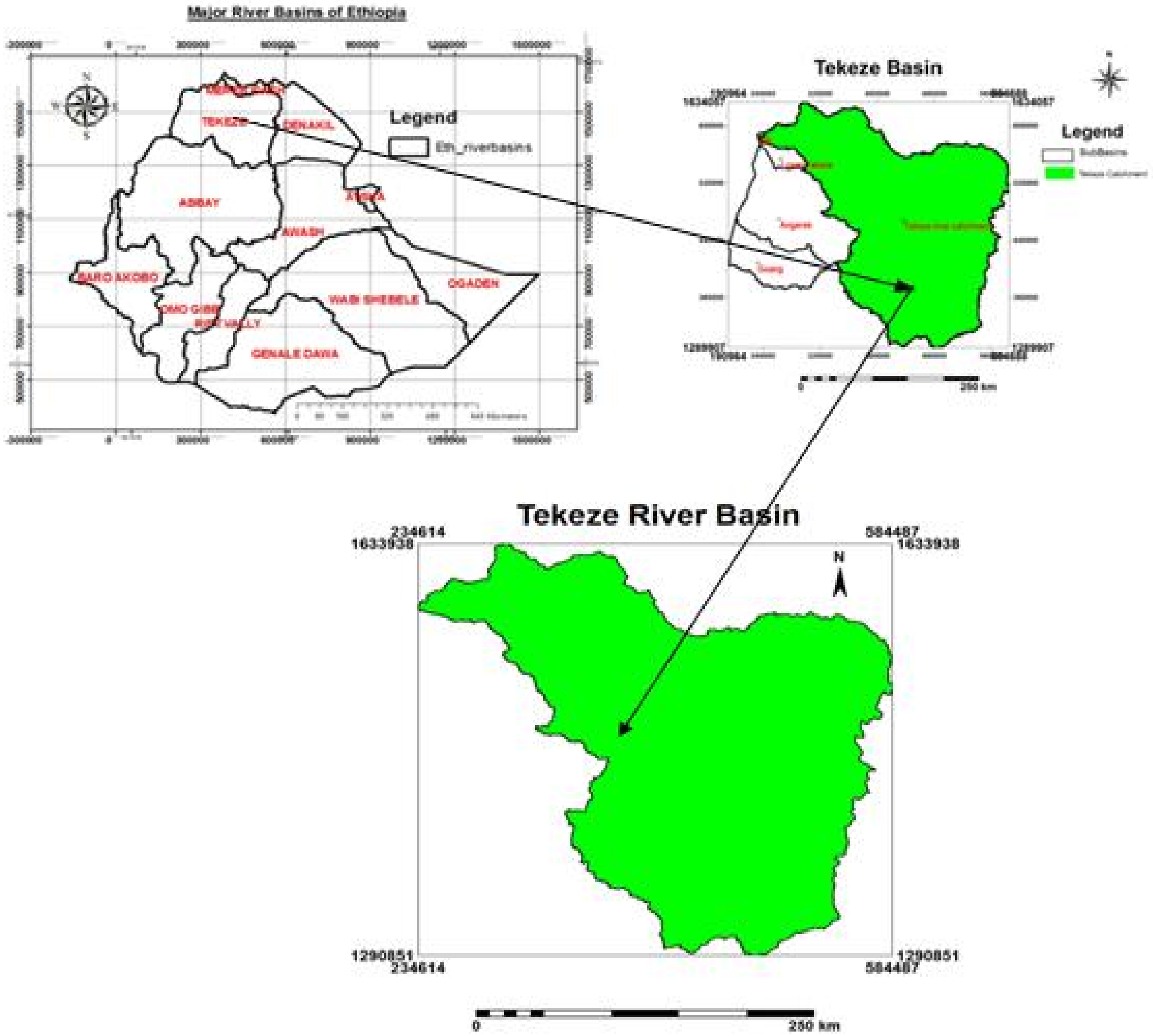

Figure 1. Shows the major river basin of Ethiopia, the Tekeze basin and the Tekeze River basin

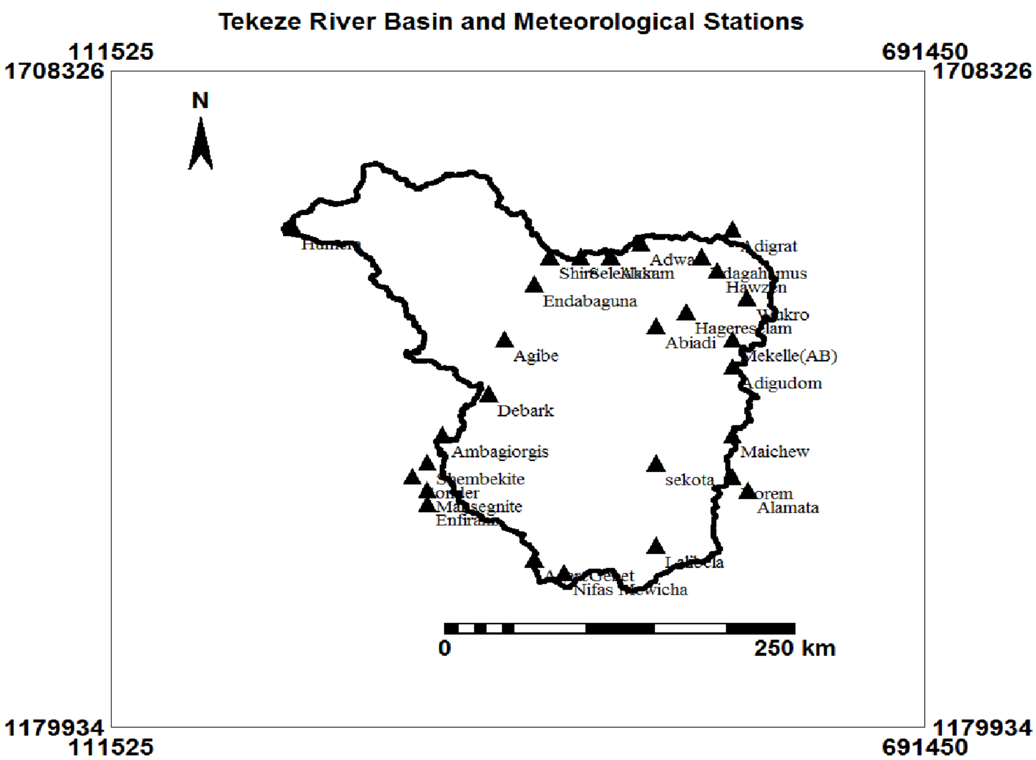

Figure 2. Spatial distribution meteorological stations over Tekeze river basin

Table 1. Geographical location, period of recorded rainfall and percent of missing values

ID	Station Name	Longitude	Latitude	Altitude	Start year	End year	Available year	% of Miss
1	Adigudom	39.5	13.3	2090	1992	2007	16	4
2	Adigrat	39.5	14.3	2485	1992	2007	16	3
3	Adwa	38.9	14.2	1913	1992	2007	16	2
4	Aksum	38.7	14.1	2101	1992	2007	16	3
5	Edagahamus	39.3	14.1	1972	1973	2007	35	10
6	Hawzen	39.4	14	2253	1992	2009	18	3
7	Humera	36.6	14.3	587	1980	2009	18	-
8	Korem	39.5	12.5	2454	1992	2009	18	2
9	Maichew	39.5	12.8	2475	1992	2009	18	2
10	Mekelle(AB)	39.5	13.5	2252	1960	2009	50	8
11	Seleklaka	38.5	14.1	2014	1995	2009	15	5
12	Shire	38.3	14.1	1901	1992	2009	18	1
13	Wukro	39.6	13.8	2077	1992	2009	18	10
14	Ambagiorgis	37.6	12.8	2942	1992	2009	18	7
15	AgereGenet	38.2	11.9	2447	1992	2007	16	10
16	Enfiranz	37.5	12.3	1832	1992	2007	16	10
17	Gonder	37.4	12.5	2033	1960	2008	49	7
18	Debark	37.9	13.1	2807	1992	2009	18	7
19	Lalibela	39	12	2500	1992	2007	16	9
20	Nifas Mewicha	38.4	11.8	2947	1992	2007	16	9
21	Agibe	38	13.5	1128	1998	2007	10	3
22	sekota	39	12.6	2275	1997	2006	10	7
23	Abiadi	39	13.6	1647	1998	2007	10	5

Data quality and control

Infilling missing daily rainfall

Infilling missing daily rainfall data with percent of missing at most 10 of the recorded data can be done by sample mean taking in to account the correlation between the daily rainfalls is negligible (Presti *et al.,* 2010). Therefore, all the stations having daily missing rainfall data at most 10 percent are filled by mean of each day. The Figure 3 below shows how to fill the missing daily rainfall of each station.

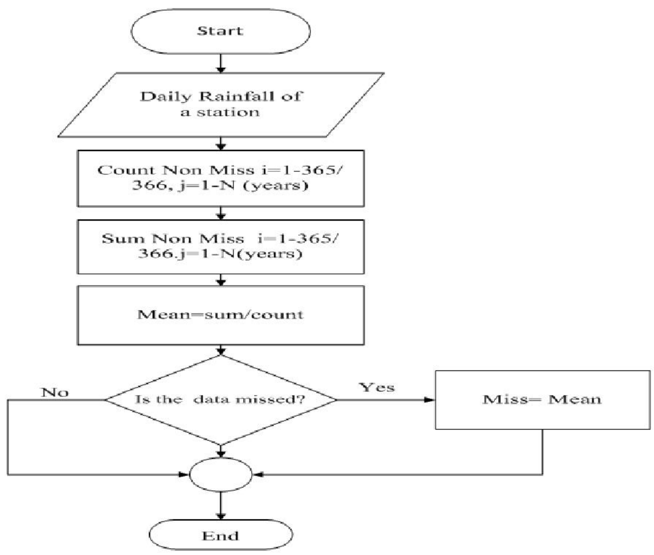

Figure 3. Flow chart showing infilling daily rainfall data by long-term mean

Outlier detection and adjustment

The identification of outliers has been the primary emphasis of quality control work (Gonzalez-Rouca *et al.,* 2001; Göktürk *et al.,* 2008). Outliers are values greater than a threshold value specific for each time series, defined by

$$RF_{out} = RF_{0.75} + 3*IQR$$

Where RF_{out} is a threshold value, $RF_{0.75}$ is the third quartile and IQR is the inter quartile range and any outlier can be replaced by its threshold value as stated by (Gonzalez-Rouca *et al.,* 2001; Göktürk *et al.,* 2008). In order to keep the information of extreme values in the data, outliers can be replaced by the thresh hold value in the data. For keeping the outliers of each rainfall indices of each station, a threshold value was calculated and any outlier in each index could be replaced by the threshold value (RFout) .Flow char how to adjust outlier is shown in Figure 4.

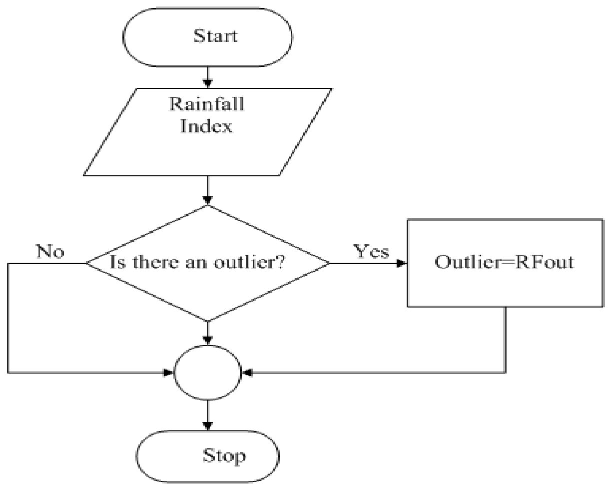

Figure 4. Flow chart showing how to adjust outliers

Homogeneity test

A rainfall time sequence is called homogeneous when its variability is as the result of weather and climate (Conrad and Pollak, 1950). Long period recorded rainfall can be non homogeneous when affected by non-climatic factors that make them unrepresentative of the actual climatic variations occurring over the time (Peterson *et al.,* 1998). Non homogeneity of the time sequence can be occurred due to change in location of the rainfall station, instruments, formula used to calculate the statistical parameters, observing practices and station environments (Gokturk *et al.,* 2008). In order to be sure that daily rainfall recorded by all the stations in this study are representative in their areas of location and their variability is only due to climatic and weather process not other factors, three homogeneity test methods were used the Pettitt's test (Pettitt,1979), the Standard Normal Homogeneity Test (SNHT) (Alexendersson,1986), and the Buishand's test (Buishand, 1982). The homogeneity tests by the three methods were done on daily maximum rainfall (MaxRF), daily mean rainfall (MEANRF) and annual rainfall (ANNUALRF) of each station. The explanations of the three methods of homogeneity test are shown in Figure 5:

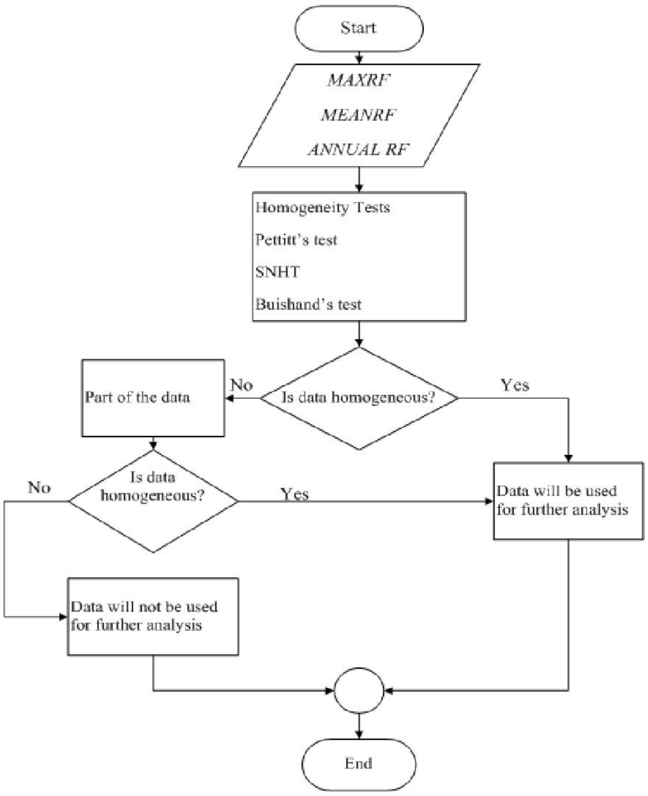

Figure 5. Flow chart of non homogeneity tests

Derivation the Rainfall Indices

Dry Spell: Many authors define a dry spell as n consecutive days without appreciable rainfall (Stern, 1980; Sivakumar, 1992; Sharma, 1996; Ceballos *et al.,* 2004; Gong *et al.,* 2005). In many studies, days with rainfall less than 0.1 mm per day are considered a dry spell.

Onset and Cessation: Different authors use different threshold values and meteorological parameters to determine the onset of the main rain. An onset is a date with a rainfall of 20mm or more over three consecutive rainy days after a specified date and with no dry spell greater than 7 days in the next 30 days (Tesfaye and Walker, 2004). The criterion used in this study was a rainfall of 20 mm or more accumulated over three consecutive rainy days after June first provided there were no sequences of 10 or more dry days in the subsequent 30 days. The condition of having no dry spell of more than 10 days after start of growing season eliminates the possibility of a false start of the season. A period of 30 days is the average length for the initial growth stage of most crops (Allen *et al.,* 1998). Most crops would have emerged and be well established after 30 days. Moreover, the cessation of the season was defined as the first day of dry spell (<0.1mm) of at least 20 days duration that occurred after onset. The length of growing length was calculated as a difference between the onset and cessation dates. Given the above definitions Instat Statistical software package (Version 3.33) (Stern *et al.,* 2003) was used to extract onset, cessation and growing length from daily rainfall data for the river basin.

Rainfall Indices Spatial Distribution and Variability

The spatial distributions of all the indices derived from daily rainfall in the Tekeze river basin are analyzed by variogram models that are adopted for interpolation. The analysis of spatial variability of all the rainfall indices is done by using the Integrated Land and Water Information System (ILWIS) which is an integrated Geographical Information System (GIS) and Remote Sensing software. The best fitting model (Spherical) is identified by adjusting the nugget, range and sill parameters from the experimental semi-variogram of the chosen model by visual inspection.

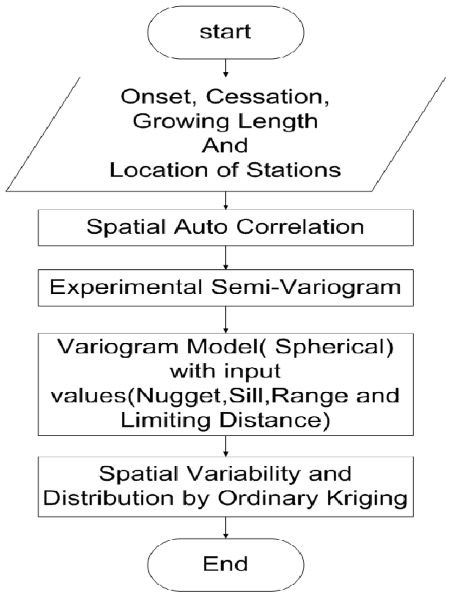

Figure 6. Flow chart in using ordinary Kriging

Model variogram is used to develop interpolated surface to predict spatial continuity in the river basin by ordinary kirging. The limiting distance that is the maximum search radius to find stations which will be taken in to account during the interpolation of the indices is determined by doing pattern analysis of the stations with reference to the area of the basin. The spatial variability of all the indices can be analyzed using ordinary kirging interpolation technique. In Ordinary Kriging the randomized spatial function is non-stationary and the mean varies over the area of interest. Ordinary Kriging amounts to re-estimating the mean at each new location. In Ordinary Kriging, you can influence the number of points that should be taken into account in the calculation of an output pixel value by specifying a limiting distance and a minimum and maximum number of points. Only the points that fall within the limiting distance to an output pixel will be used in the calculation for that output pixel value. Ordinary Kirging needs three steps Spatial Correlation, Empirical Semi-Variogram and modeling semi-variogram as shown in the flow chart Figure 6.

RESULTS AND DISCUSSION

Temporal variability of Kiremt onset, cessation and growing length over Tekeze river basin

There is low year-to-year variability of kiremt onset of the 23 stations over Tekeze river basin exhibiting (CV<0.2) with the exception of the southern station of Nifasmewcha having (CV=0.3). The year to year variability of Kiremt cessation of the 23stations over the basin is also very low having coefficient of variability at most 0.1. The coefficient of variability for Kiremt growing length of the 23 stations varies from 0.1 to 0.3. Northeastern stations show high temporal variability (CV=0.3) than the other stations in kiremt growing length in the basin as shown in Table 2.

Relationship among Kiremt Rainfall, Onset, Cessation and Growing Length

The conditioning plots, in Figure 7, show how the amounts of total Kiremt rainfalls are affected by growing lengths given their starts and ends of the 23 meteorological stations over Tekeze river basin. Smaller total Kiremt rainfalls of stations lower are their growing lengths due to late onsets and early cessations. Higher total Kiremt rainfalls of stations higher are their growing lengths due to early onsets and late cessations. The analysis in Figure 7 was done using R-programming a language and environment for statistical computing (R Core Team, 2015) with Lattice package by (Sarkar, Deepayan, 2008).

Kiremt Onset, Cessation and Growing Length (KOCGL) spatial variability over Tekeze river basin

Spherical semi variogram models are fitted for all KOCGL. Table 3 represents the parameters that were obtained from experimental semi variogram fitting to the mean KOCGL data recorded at the stations in the study area and the figures with their error figures represent the interpolated spatial continuity of the KOCGL distributions in the basin. Below detail interpretation of the fitted models, parameters of the models and figures with is given for their spatial variability of the KOCGL in the Tekeze river basin.

•Interpretation of variogram models of the KOCGL

The three variogram models of KOCGL show a progressive decrease of spatial autocorrelation (equivalently an increase of semi-variance) until some distance in KOCGL in the stations in the river basin as shown in Figure 8 to 10. The KOCGL decrease their spatial dependence with distance spherically in the basin. Even though the variogram models fitted to the variogram models of KOCGL show a common characteristics of decreasing spatial dependence with distance spherically in the basin, the way they lose their spatial dependence with distance in the basin of the KOCGL are different because of fitted to the same variogram model with different model parameters(nugget, sill and range).

•Interpretation of the nugget, sill and range values of the models of KOCGL

The KOCGL show a nugget effect in their variogram models. These nugget values of the models show two important things in the basin. The sampling interval or the lag space between the stations in the study area was taken to be 60km because of sparse rainfall station distributions in the basin. But the nugget values in the KOCGL variogram models indicates the availability of few stations in the basin with distance between them less than the sampling interval (60km) and a sources of spatial variability of the variables in distance less than the sampling interval.

Table 2. Mean and CV of annual, kiremt, Belg rainfalls and kiremt onset,cessation and growing length

		Annual Rainfall		Kiremt Rainfall		Belg Rainfall		Kiremt Onset		Kiremt Cessation		Kiremt Growing Length	
	Station	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV
North western stations	Agibe	696.1	0.2	629.3	0.2	56.5	0.6	171.2	0.1	265.2	0.1	94.0	0.2
	Shire	1017.6	0.2	856.3	0.1	86.7	0.6	162.4	0.1	299.1	0.1	136.6	0.1
	Seleklaka	1023.6	0.3	883.9	0.3	89.1	0.9	170.1	0.1	276.1	0.1	106.0	0.2
	Humera	584.1	0.2	556.6	0.2	39.0	0.6	171.3	0.1	287.8	0.1	115.6	0.1
Northern Stations	Aksum	760.2	0.2	609.5	0.3	98.6	0.8	173.7	0.1	288.6	0.1	114.9	0.2
	Adwa	836.5	0.2	686.9	0.2	105.4	0.7	172.9	0.1	289.9	0.1	117.0	0.2
	Abiadi	1129.8	0.4	1025.3	0.5	84.0	0.5	168.3	0.1	270.5	0.1	102.2	0.2
Northeastern stations	Adigrat	602.4	0.3	357.9	0.3	181.1	0.6	188.6	0.1	253.7	0.1	65.1	0.3
	Edagahamus	673.5	0.4	421.7	0.4	206.5	0.6	185.5	0.2	258.8	0.1	73.3	0.3
	Wukro	599.1	0.3	491.2	0.3	95.4	0.7	190.0	0.1	252.7	0.1	62.7	0.3
	Hawzen	548.6	0.3	433.5	0.3	84.8	0.6	187.8	0.1	259.1	0.1	71.3	0.3
	Mekelle(AB)	603.2	0.3	489.9	0.3	98.6	0.6	189.8	0.1	267.5	0.1	77.7	0.3
South Western stations	Debark	1034.6	0.2	839.9	0.2	126.6	0.5	159.8	0.1	305.9	0.1	145.8	0.2
	Ambagiorgis	1003.2	0.2	786.8	0.2	145.9	0.5	166.4	0.1	283.7	0.1	117.2	0.2
	Gonder	1099.3	0.2	851.2	0.2	144.1	0.4	162.2	0.1	324.8	0.1	162.5	0.2
	Enfiranz	1015.0	0.2	860.3	0.2	79.4	0.7	165.3	0.1	299.9	0.1	134.7	0.2
Southern Stations	Lalibela	853.7	0.1	656.7	0.2	143.2	0.5	182.4	0.1	290.8	0.1	108.4	0.2
	AgereGenet	1500.8	0.2	1156.3	0.3	211.7	0.5	171.8	0.1	298.1	0.1	126.3	0.2
	Nifas Mewicha	1036.5	0.2	774.5	0.2	191.3	0.4	178.2	0.3	306.7	0.1	128.5	0.2
Southeastern stations	Maichew	784.6	0.2	479.8	0.3	188.8	0.6	186.3	0.1	300.6	0.1	114.3	0.2
	Korem	966.0	0.2	598.7	0.3	216.9	0.5	187.9	0.1	300.8	0.1	112.8	0.3
	Adigudom	524.6	0.4	456.1	0.5	58.4	0.7	197.9	0.1	255.6	0.1	57.8	0.2
	sekota	590.2	0.2	508.5	0.2	58.9	0.4	186.8	0.1	260.4	0.1	73.6	0.1

Table 3. The best fitting model generated for Kiremt onset, cessation and growing length for the entire river basin

Index Name	Model	Nugget	sill	Range
Kiremt onset	Spherical	33.800	151.010	239804.400
Kiremt cessation	Spherical	107.09	480.28	240333.300
Kiremt Growing Length	Spherical	161.65	957.94	240333.300

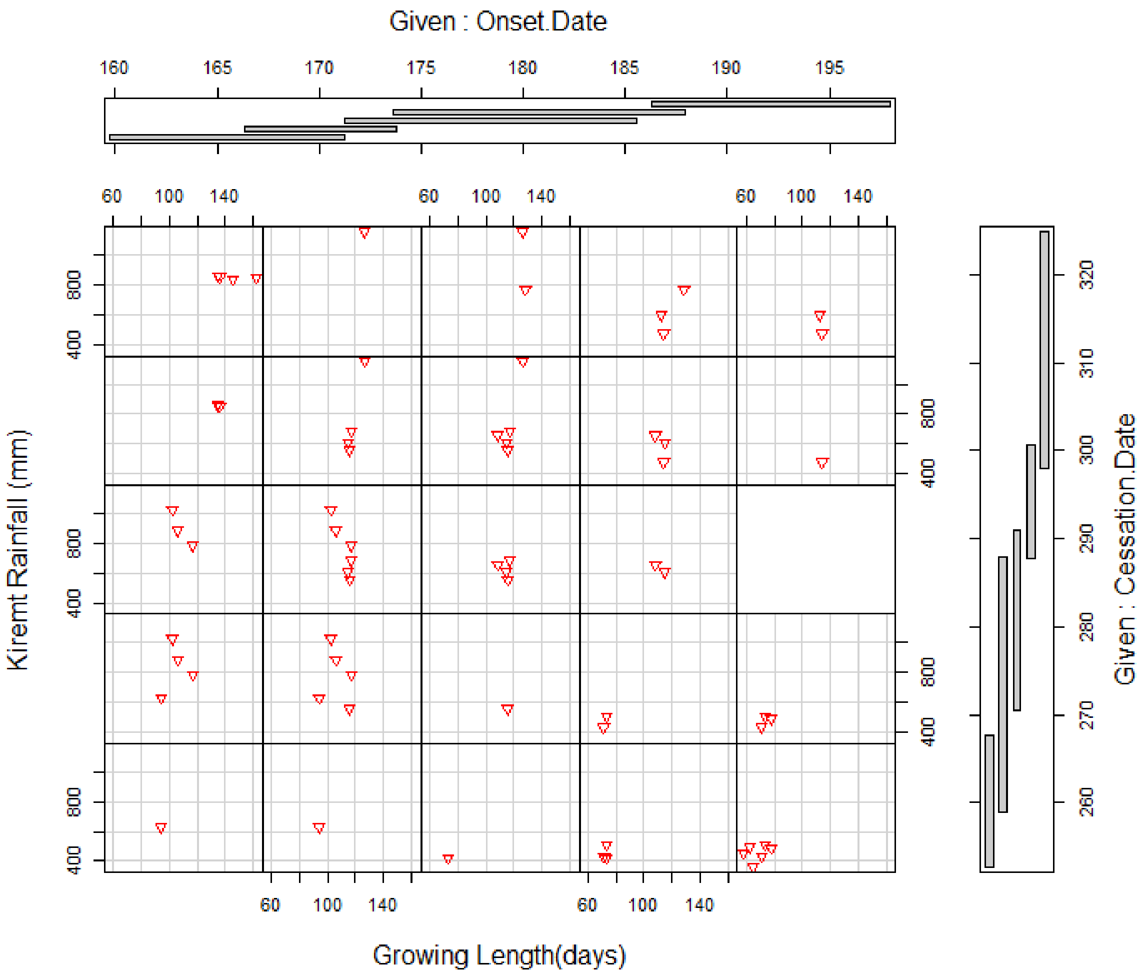

Figure 7. The relationship among Kiremt rainfall, Onset, Cessation and Growing Length

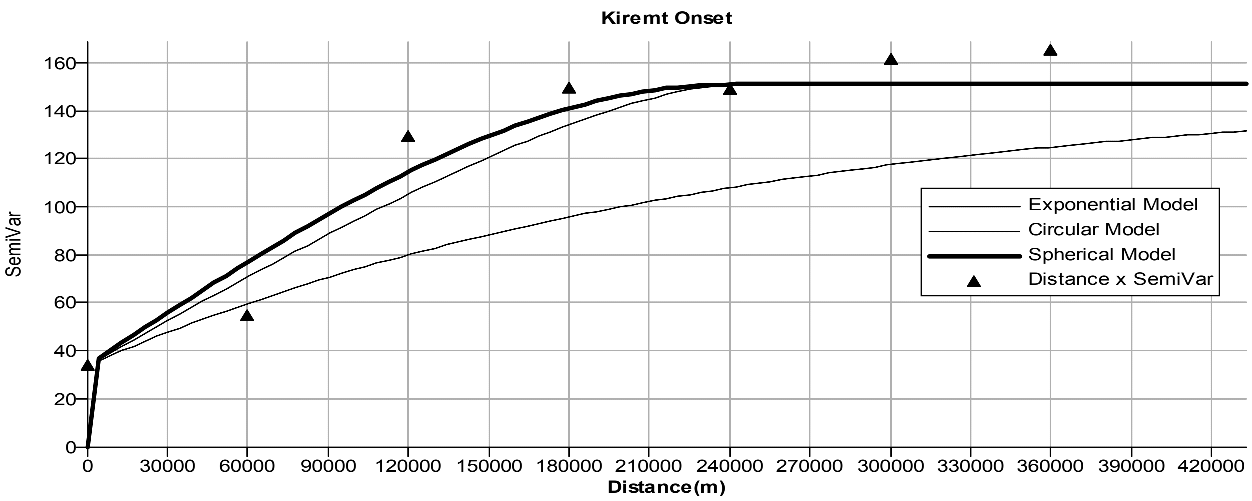

Figure 8. Spherical semi variogram model fitted to Kiremt onset data set

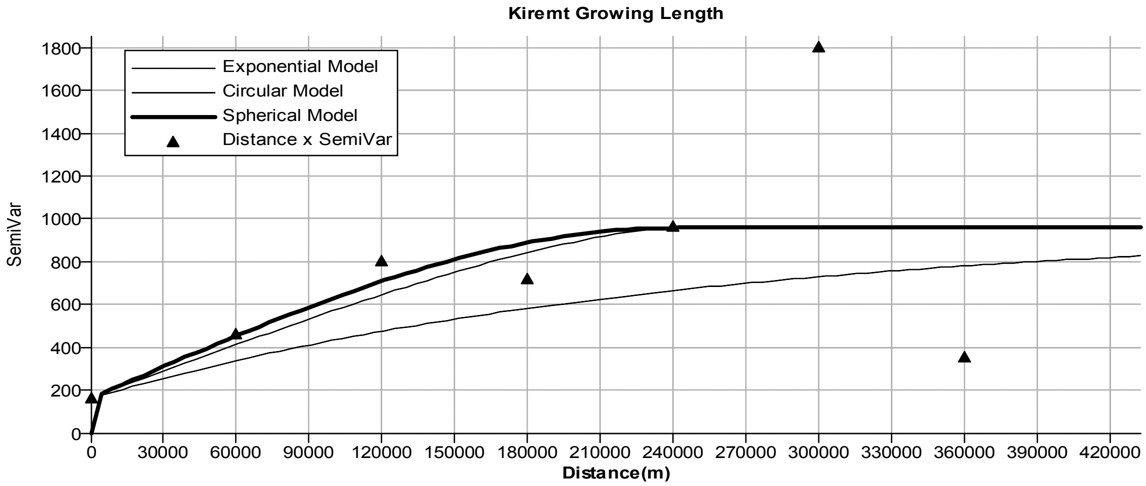

Figure 9. Spherical semi variogram model fitted to Kiremt cessation data set

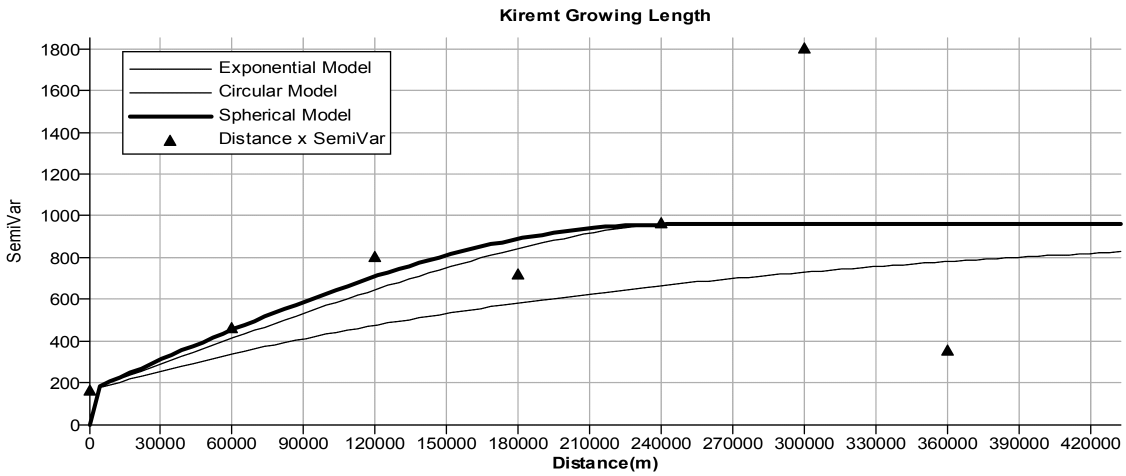

Figure 10. Spherical semi variogram model fitted to Kiremt growing length data set

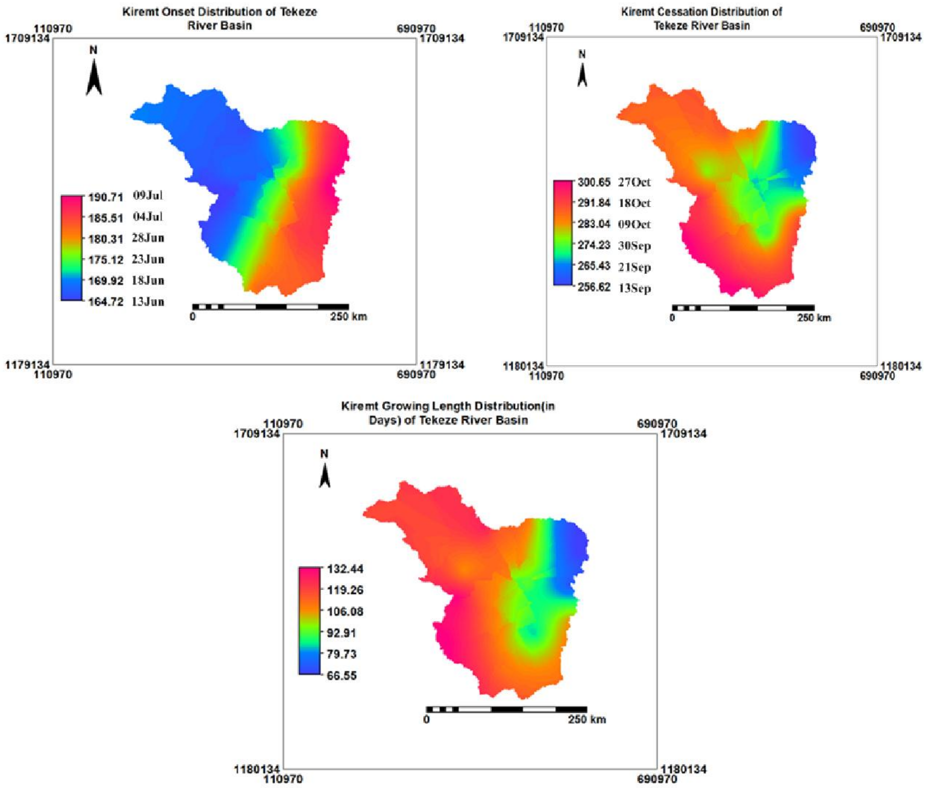

Figure 11. Spatial distribution of Kiremt onset, cessation and growing length over Tekeze river basin

Higher nugget value means high spatial variability of the variable less than the sampling interval. Due to this kiremt growing length show high spatial variability in distance less than the sampling interval in the basin followed by kiremt cessation. The different range values of the models in KOCGL show existence of spatial variability until its value in the basin and beyond it no existence of spatial dependence of the variables in the basin. Higher range value of a variable indicates the existence of the spatial dependence of the variable of the stations separated by higher distance. Due to this KOCGL show approximately the same spatial dependence in higher distances. The sill is the value of the variogram model attains at range. The higher the sill value of a variable, the steep becomes the model and the more rapidly changes the variable in space. But here it is better not to compare the KOCGL by their sill values because of different units they have and collected in different periods. The units of kiremt onset and cessation are in dates which are in different periods but the unit of kiremt growing length is in days. Since the KOCGL are fitted to the same spherical semi variogram, it can be compared how the variables change in the catchment by looking the steepness of the spherical variogram models. Therefore, as the spherical model of kiremt onset is steeper than kiremt cessation, the kiremt onset varies more rapidly in the catchment than the kiremt cessation especially in the east part of the river basin.

•Spatial distribution estimates of KOCGL estimates over the river basin

The KOCGL figures with their error figures of the Tekeze river basin are obtained by interpolation using their fitted models by ordinary kirging. The figures of KOCGL indicate the spatial distribution estimates over the entire basin using the 23 stations as shown in figure 11. The error figures of the KOCGL indicate the standard error of estimation of the KOCGL by the ordinary kirging as shown in figure 12. As indicated on the figures of Kiremt onset and kiremt cessation, the kiremt onset varies from about 13-June (164.72) in the west part of the basin to about 09-July (190.71) in the east part of the basin. In general kiremt onset begins early in the west and is distributed slowly to central and east part of the basin. The kiremt cessation varies from about 27-October (300.65) in the south and west parts of the basin to about 13-September (256.62) in the northeast part of the basin.

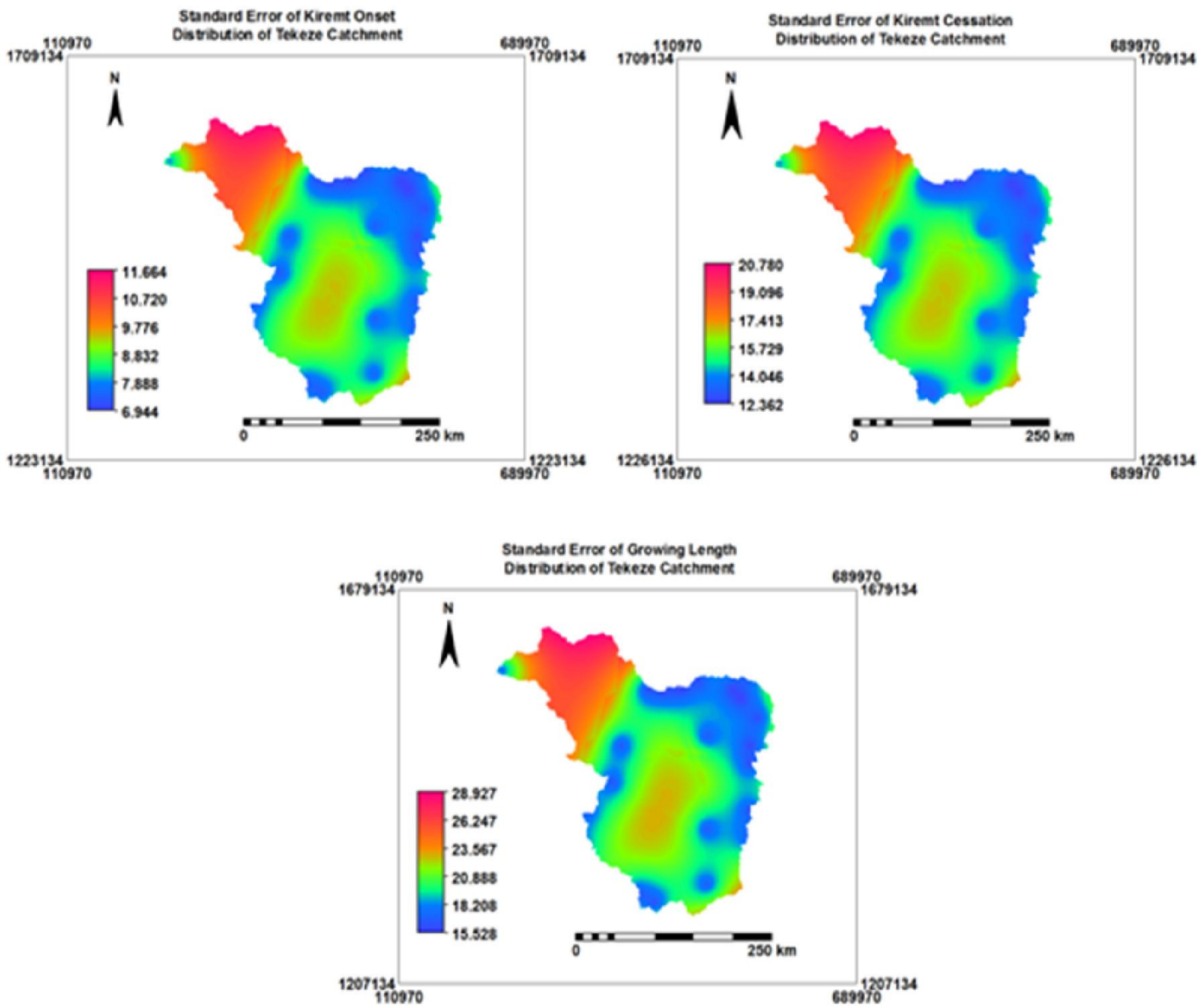

Figure 12. Standard error of spatial distribution of Kiremt onset, cessation and growing length over Tekeze river basin

The kiremt growing length (in days) which is the difference between kiremt cessation (end of kiremt season) and Kiremt onset (start of kiremt season) varies from about 106-132 days in south and west part of the basin to about 66-79 days in the northeast part of the basin. The reason that the kiremt growing length is high in the south and west part of the basin than the northeast is there is early kiremt onset and late kiremt cessation on the areas but kiremt growing length is lower in the northeast part indicates late kiremt onset and early kiremt cessation on the area. From the error figures of KOCGL it can be stated that higher standard error of the maps indicates that the sources of spare stations in the area than the other areas. These standard errors of estimations help for decision making in the areas. As indicated in the interpretation of variogram models of KOCGL, it is clearly seen from the figures of the KOCGL distributions that the Kiremt onset varies more rapidly in space than that of the Kiremt cessation in the river basin.

Conclusion and Recommendation

The main findings of the study are summarized below. Kiremt onset (start of main rainy season) begins earlier in the west part of the Tekeze river basin and is distributed slowly to central and east parts of the basin. Kiremt cessation (end of the main rainy season) is late in the south and west part of the river basin than the other parts. Kiremt growing length which is the difference between Kiremt cessation and kiremt onset is high over south and west part of the basin and low over northeast part of the basin. Higher growing length over south part of the basin is due to late kiremt cessation over the area and high growing length over the west part of the basin is due to early kiremt onset and late kiremt cessation over the area. The reason of low kiremt growing length in the northeast part of the basin is due to late kiremt onset and early kiremt cessation over the area. The year-to-year variability of kiremt onset and cessation over the basin is low. Very high temporal variability of growing length is found over northeast part of the river basin. The spatial variability of kiremt onset is higher than the spatial variability of kiremt cessation especially in the east part of the river basin. The results, figures developed here can be very useful for meteorological, hydrological and agricultural management activities at the Tekeze river basin. Especially the information on temporal and spatial variability of onset, cessation and growing length, are needed by the farmers on the river basin for deciding on crop types, varieties and dates for land preparations, planting and harvesting and for planning of civil and water resources projects. As in this study only 23 meteorological stations having different time periods were used, it also very important to consider world meteorological standard distributions of the stations in the basin with the same time period of data which comprise evapotranspiration ,a soil water holding capacity and other upper air observations so that the result can be improved. Again the interpolation technique used in the study of the spatial variability was ordinary kirging but it is very important to do evaluation of interpolation techniques like simple kirging, co-kirging and others with ordinary kirging and choosing the best interpolation technique in the basin can improve the results.

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