Spatial and Temporal Variability of Rainfall at Seasonal and Annual Time Scales at Tekeze River Basin, Ethiopia

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Abstract
Understanding climate variability using surface observed climatic parameters like rainfall at watershed spatial scale is a great input in decision making for practitioners in agriculture planning, water resources projects, rainfall-runoff modeling activities ,environmental impact assessment and civil works. This study examines the spatio-temporal variability of seasonal and annual rainfall totals over Tekeze river basin in Ethiopia. The indices were used over the basin based on data available from 28 meteorological stations having variable record length spanning from 1992-2009 for most of the stations. The data were subjected to main quality tests of outliers and homogeneity tests. Temporal variability was analyzed by coefficient of variability and spatial distribution and variability was investigated using ordinary kirging interpolation technique. The result showed: The annual and kiremt (June to September) season rainfall distribution are highest at the southwest part of the river basin and decrease to other directions. South and northeast part of the basin receive highest amount of Belg (February to May) season rainfall. The temporal variability of Belg rainfall is much higher than the kiremt rainfall. The spatial variability of annual and kiremt rainfall is higher than the spatial variability of Belg rainfall.
Keywords: Seasonal Rainfall, Annual Rainfall, Temporal variability, spatial variability

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.(Novtny 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 researches have been conducted to understand rainfall variability using the existing stations in the country. The previous researches on the rainfall variability have been done on different spatial and temporal scales. Examples: Osman and Sauerborn (2002) studied the 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. The above previous studies, with contradicting conclusions, did not study the rainfall variability at spatial scale and used little number of stations for their studies.

This study will focus and examine both the spatial and temporal variability of seasonal and annual rainfall totals at the Tekeze river basin using 28 meteorological stations.

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 Fig.1. 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 63,109.1km^2 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

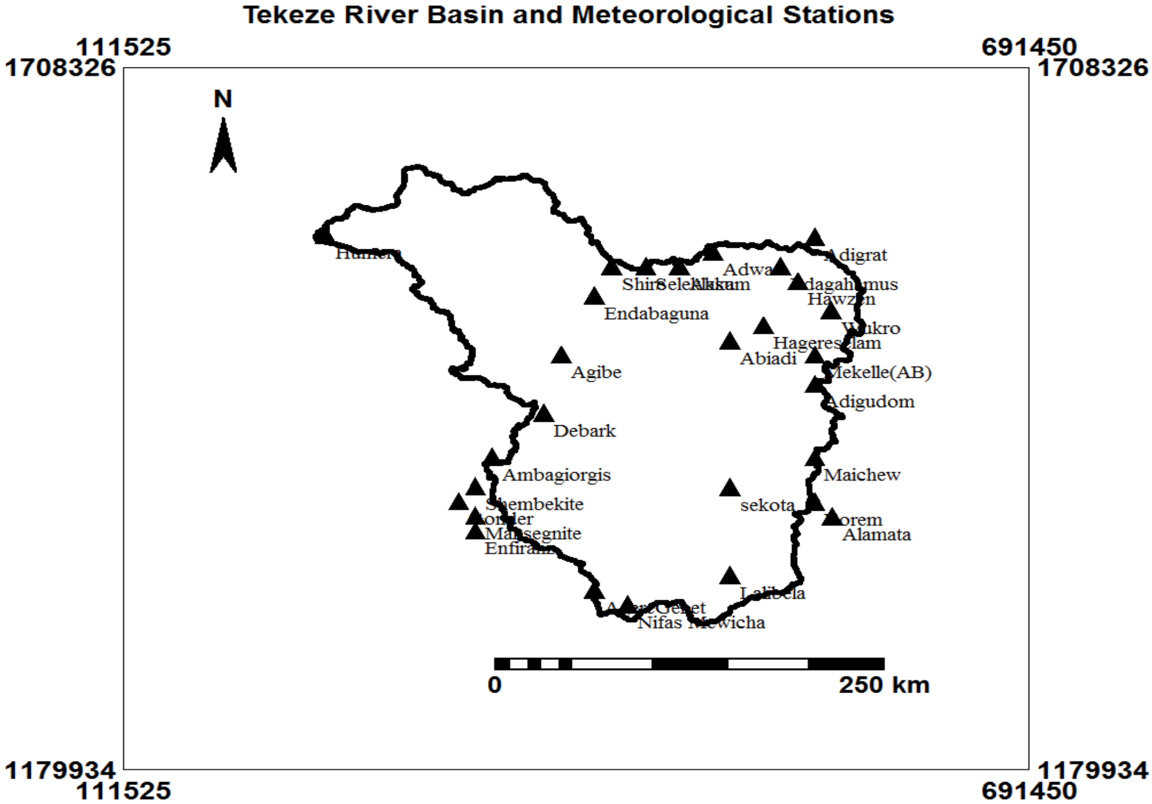

Fig 1. Study area with its meteorological stations

Methodology

In order to examine the spatial and temporal variability of rainfall in the Tekeze river basin, the study approach is summarized as follows and details are presented in the subsections in this chapter. A Digital Elevation Model (DEM), which is 90meter by 90 meter 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 is 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 can represent the basin, quality control for the daily data of each station have been done. Assessment for quality of the data of each station has been 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 temporal and spatial variability of daily rainfall over the basin has been done. The Figure 2 below shows the flow chart of the methodology

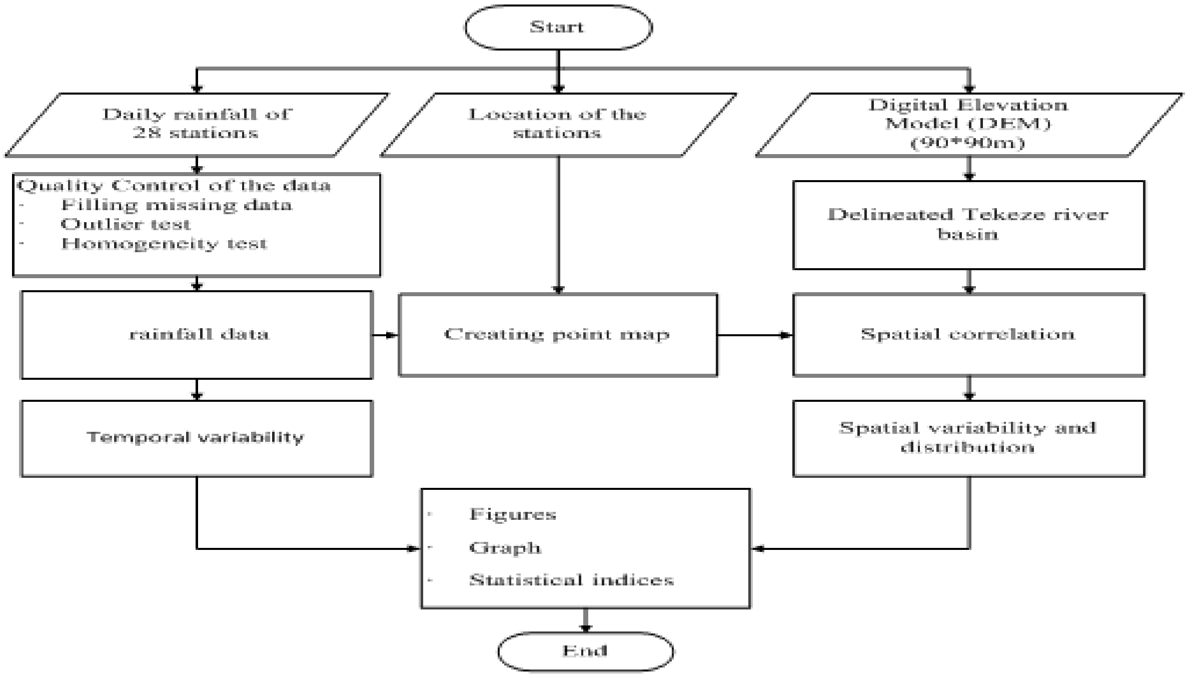

Fig.2 flow chart of methodology

Result and Discussion

Temporal variability of annual, Kiremt(June to September) and Belg(February to May) rainfall over Tekeze river basin

The annual rainfall variability of the 28 stations over Tekeze river basin appears within the coefficient variability (CV) range of 0.2 to 0.3. some stations in northern, northeastern and southeastern stations such as Abiadi, Edagahamus and Adigudem showing very high annual rainfall variability with a coefficient of variability of 0.4 and low annual rainfall variability is exhibited in the southern station of Lalibela with coefficient of variability of 0.1. The kiremt rainfall variability over Tekeze catchment exhibit a coefficient of variability of 0.2 to 0.3 except northern, and northeastern and southeastern stations of Abiadi, Edagahamus and Adigudem showing very high kiremt rainfall variability with CV of 0.5, 0.4 and 0.5 respectively. The Belg rainfall variability of the 28 stations over the basin is very high with (CV>0.4). In general the year-to-year Belg rainfall variability over the stations of Tekeze river basin is very high compared to the year-to-year variability of annual and kiremt rainfall of the stations.

Annual, kiremt and Belg Rainfall (AKBR) spatial variability over Tekeze river basin

The three variogram models of annual, kiremt and Belg mean rainfall shown in Figure 3 to 5 show a progressive decrease of spatial autocorrelation (equivalently an increase of semi-variance) until some distance in annual, kiremt and Belg rainfall in the stations in the basin. The annual mean rainfall decrease its spatial dependence in circular manner in the basin but the kiremt and Belg mean rainfall decrease their spatial dependence spherically in the basin. Even though the variogram models fitted to the variogram models show a common characteristics of decreasing spatial dependence with distance in the variables in the basin, the way they lose their spatial dependence with distance in the basin of the three variables is different because of fitted to different variogram models with different model parameters (nugget, sill and range).The annual, kiremt and Belg mean rainfall (AKBR) show a nugget effect in their variogram models. These nugget values of the models show two important things in the river 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 AKBR 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. Higher nugget value means high spatial variability of the variable less than the sampling interval. Due to this annual mean rainfall show high spatial variability in distance less than the sampling interval in the basin followed by kiremt mean rainfall. The different range values of the models in AKBR 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 annual mean rainfall have higher spatial dependence in more stations followed by kiremt mean rainfall. 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. Because of this the annual and kiremt mean rainfall change more rapidly in the river basin than the Belg mean rainfall does.

Spatial distribution estimates of AKBR estimates over the river basin

The AKBR maps of the Tekeze river basin are obtained by interpolation using their fitted models by ordinary kirging. The maps of AKBR as shown in Figure 6 indicate the spatial distribution estimates over the entire basin using the 28 stations.. As indicated on the figures of annual mean rainfall and kiremt mean rainfall, the annual mean rainfall varies from 1223.58mm in the southwest part of the basin to 588.23mm in far northwest and east part of the basin and the kiremt mean rainfall varies from 956.87mm in the southwest part of the basin to 425.73 in the east part of the basin. In general annual and kiremt mean rainfall decreases as one go from southwest to other directions in the basin. The Belg mean rainfall varies from about 167.26mm in the south and northeast of the basin to about 66mm in west and central part of the basin. Lower Belg mean rainfalls are found in the west and some part of the central than the other parts in the basin. As indicated in the interpretation of variogram models of AKBR, it is clearly seen from the maps of the AKBR distributions that the annual mean rainfall and kiremt mean rainfall varies more rapidly in space than that of the Belg mean rainfall in the river basin.

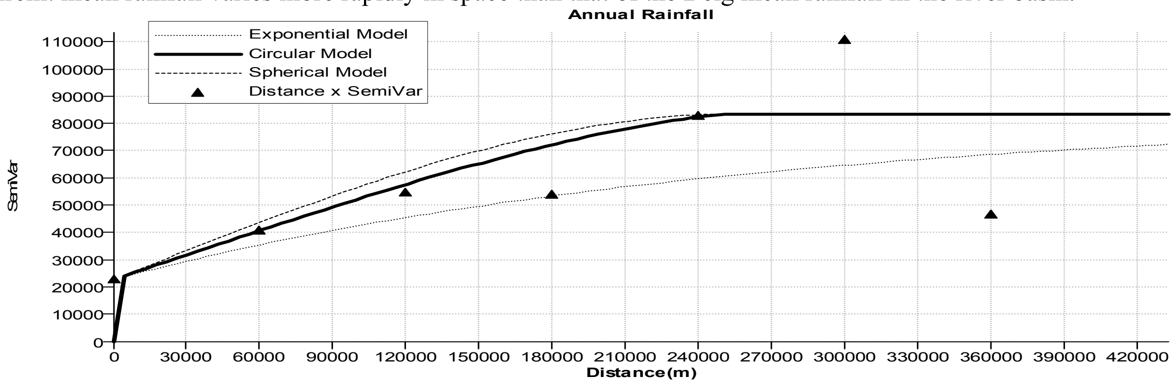

Figure 3: circular semi variogram model fitted to annual total rainfall data set

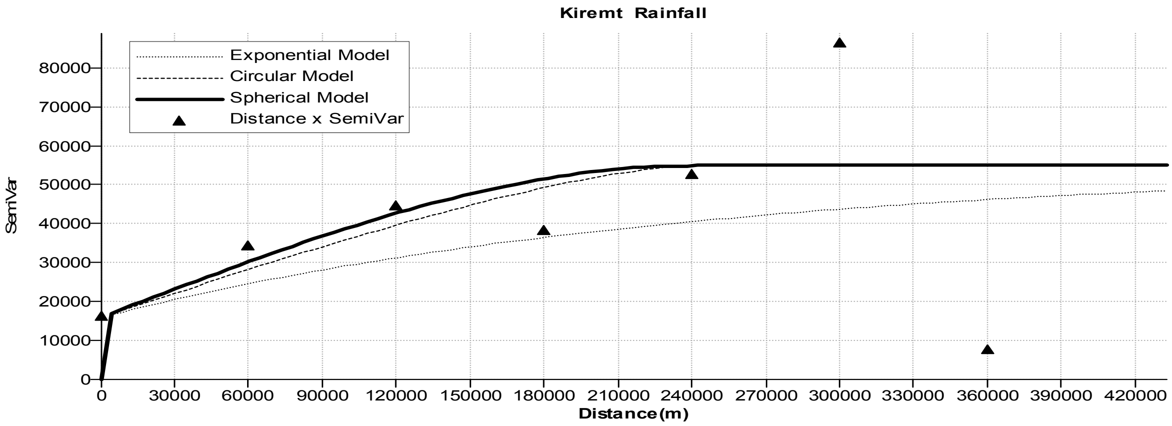

Figure 4: Spherical model fitted to kiremt total rainfall datastes

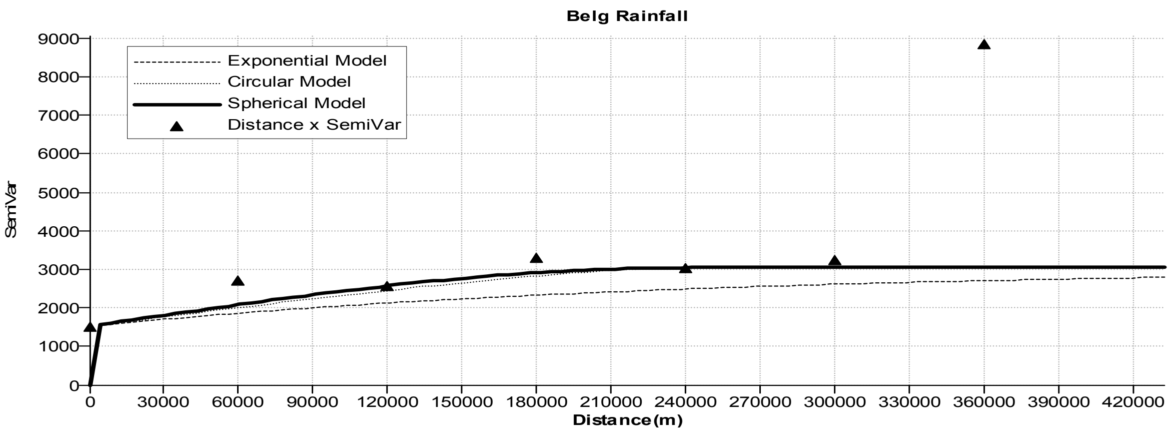

Figure 5: Spherical model fitted to kiremt total rainfall datastes

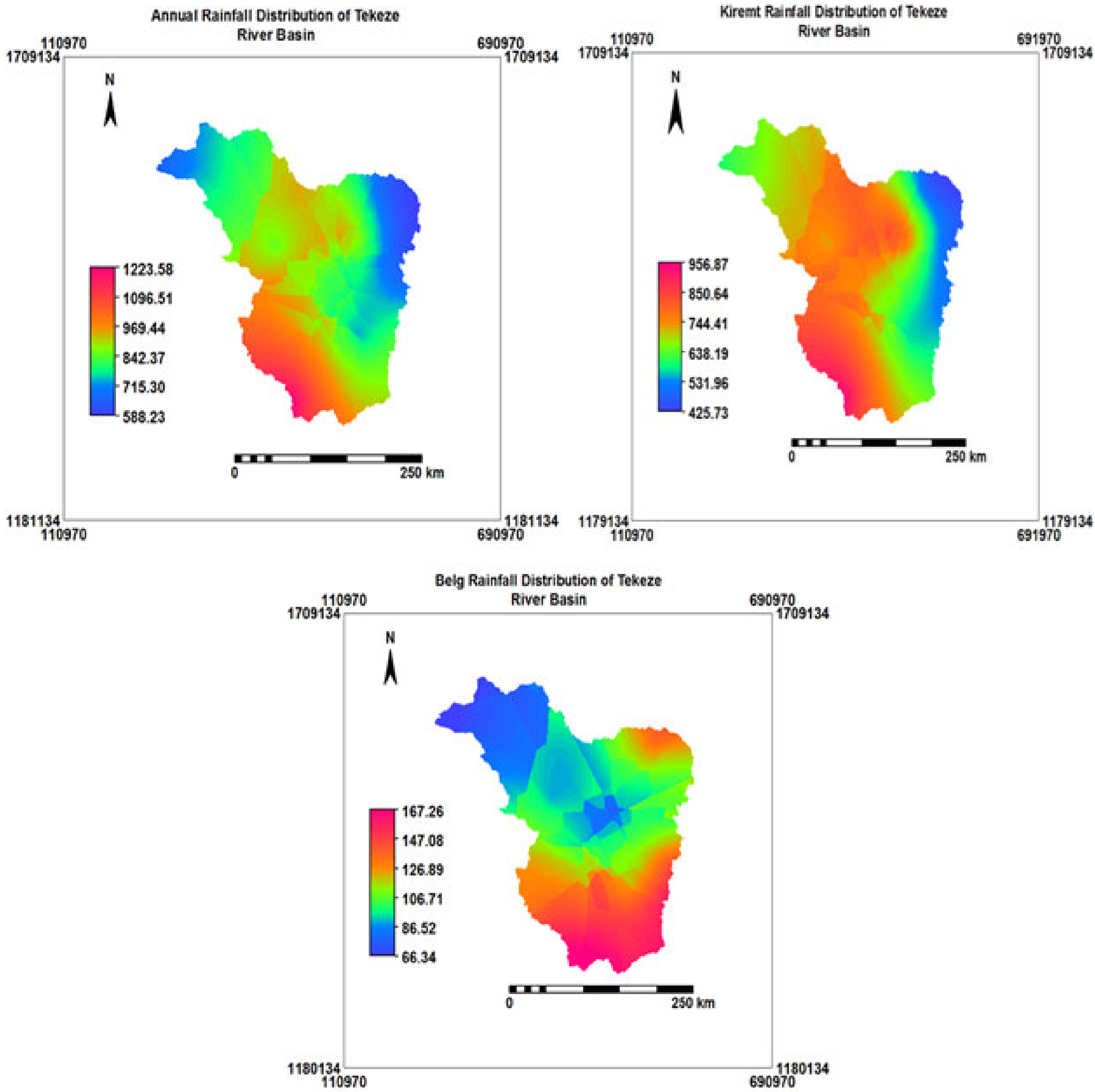

Fig : Spatial distribution of annual, kiremt and Belg rainfall over Tekeze River Basin

CONCLUSTION

Annual and kiremt rainfall distributions are highest at the southwest part of the Tekeze river basin and decrease progressively from southwest to other parts of the river basin. South and northeast parts of the river basin receive highest Belg rainfall than the other parts of the basin. The year-to-year variability of annual and kiremt rainfall of the 28 stations over the river basin is high. The year-to- year variability of Belg rainfall is much higher than the temporal variability of Kiremt rainfall over the river basin. The spatial variability of annual and kiremt rainfall is higher than the spatial variability of Belg rainfall over the river basin. That is to say annual and kiremt rainfall change more rapidly over the river basin than Belg rainfall. Annual rainfall has higher spatial dependence in the river basin followed by Kiremt rainfall.

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