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CLIMATE CHANGE AND EXTREME RAINFALL VARIABILITY IN PARTS OF NORTH-WESTERN NIGERIA

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Abstract
Rainfall variability on long and short-term scales were analyzed for North-Western Nigeria comprising Sokoto, Kebbi, and Zamfara States to ascertain the pattern of rainfall in the zone. The statistics adopted for the study shows a variation in the mean, the standard deviation and the coefficient of variability in the rainfall values. The analysis shows a fluctuation in both the inter-annual and intral-annual rainfall in the region. The study also reveals that the drought of 1970s and 1980s despite their severity has little or no influence on the climate of the region as the long-term mean rainfall higher than the short-term mean and indication that the region is getting wetter with the long-term mean annual rainfall in the zone increasing by 12 percent over the last four decades. Although it cannot be said if the shift is permanent or temporary. Possible options for stabilizing the region's climate are advanced.

Keywords: Cessation dates, Intra-annual, Inter-annual, Onset dates, Rainfall regime, Climate change

Introduction

North Western Nigeria is a significant portion of the Sudano-Sahelian Ecological Zone of Nigeria and climatic variation in this zone is no longer news. The zone is characterized of recurring droughts and flood episodes since the 1970s. The region has witnessed a lot of devastating droughts most especially that of the 1972/1973 and 1984/85 numerous dust storms and uncountable floods with 1980s and 2000 being the worst of them all (Ekpoh, 2010) This occurrence have made the climate of the zone unpredictable to an extent that people begin to wonder what has actually happened to the climate of the zone.

The persistent drought of 1970s and 1980s have been attributed to the prevalence of a stagnated anti-cyclonic circulation of the tropical atmosphere over areas that normally should be exposed to the rising arm of the tropical Hadley cell circulation by mid-summer.(Adefolalu, 1986; Babatolu, 1998; Dami, 2008 and Ojoye, 2012). These conditions are themselves related to the tropical component of the general circulation system. The tropical circulation patterns are particularly influenced by heat inputs from such sources as warm oceans surfaces acting through latent heat released in deep cumulus convection (Lockwood, 1998). These heat differentials influenced the rainfall pattern over West Africa in general and the North-Western Nigeria in particular causing annual variations in rainfall pattern with a marked tele-connection with distant locations (Dami, 2008).

The drought episode in the region was attributed to the late start of rainy season and early cessation of the rains resulting in drastic reduction in the length of the rainy season. A number of studies within the Sudano- Sahelian region have shown a significant trend towards false onset, late or delayed onset and early cessation (Dami, 2008 and Ojoye, 2012).

In addition, long-term rainfall analysis for the area has observed frequent appearances of false onset, as well as a trend towards a pronounced decrease in rainfall amounts (Ekpoh, 2007). Rainfall variability is a major characteristic of the Sudano- Sahelian parts of Nigeria, the last 5 decades since 1950 have witnessed dramatic reductions in mean annual rainfall throughout the region (Ojoye, 2012). According to the Intergovernmental panel on climate change, a rainfall decrease of 29-49 percent has been observed in the 1968-1997 period compared to the 1931-1960 baseline period within the SSEZ (IPCC, 2001). Also, a study conducted in Senegal showed a significant trend towards earlier cessation dates of the summer rains over a 43 year period from 1950 to 1992, with abrupt shift occurring around 1970 (Camberlin and Diop, 2003). Other studies conducted in this region have also noted a trend towards delayed onset and early cessation, resulting in a shorter rainy season. (Houndenon and Hernadez, 1998; Traore et. al, 2000).

Statement of the Problem

Drought is a condition of extreme but short climatic variation which results in insufficient rainfall to meet the socio-economic demands of a region in terms of water supply for domestic agricultural uses, industrial uses and ecosystem. The frequent drought in the region is usually attributed to the southward shifting of the Inter-tropical convergence zone (ITCZ). This rather simplistic explanation has been rejected because it failed to explain many important characteristics of rainfall such as late onset or early cessation (Nicholson, 1989, 1993).

Other studies have even suggested that the build up in atmospheric dust, exacerbated by anthropogenic factors such as fire-wood exploitation, bush burning and poor farming practices, as well as, frequent sand storms which causes changes in surface albedo may be responsible for large scale climatic alterations in the Sahel (Ekpoh, 2007).

However, modulation of the African Monsoon by regional and global scale patterns of sea surface temperature (SST) provides the best explanation for variation in Sahelian rainfall on multi-year to decadal time scales. Relationships between SST patterns and Sahelian rainfall are well established from statistically based Climatological analyses and have been used with some success in seasonal rainfall forecasts in the region (Folland et al, 1986; Ward et.al., 1993). Since the late 1960s, the SSEZ drought has tele-connections with El-Nino Southern Oscillation (ENSO), a phenomenon that is associated with periodic fluctuation in the intensity of the inter-tropical atmospheric and oceanic circulation that is usually coincident with an anomalous warming of the Eastern tropical Pacific Ocean (Akonga, 2001; Ekpoh and Ekpeyong, 2010).

Causes of Drought in the West African Sahel

Recent work by Giannini et. al., (2003) further identified SST as the principal driver of Sahelian rainfall variability, which they modeled successfully for the period 1930-2000, using a model that also represent the land-atmosphere interaction, via moisture feedbacks.

Available evidence on the nature of rainfall variability in Northern Nigeria suggests that a single overall mean periodicity is not observed rather, rainfall is primarily characterized by a multiple, non-symmetric cycle of anomalies with varying magnitudes. The cycles vary from 3 to 5 years in some locations, and from 10, 20, and 30 to 40 years in others (Ojoye, 2012).

Today, there is sufficient evidence of rising global temperature due to the emission of greenhouse gases. The increased global temperature can trigger large scale climatic disturbances which can have effect on the climate of the zone. (Ojoye, 2012). In spite of this, no satisfactory evidence has been given for the drought of the SSEZ but scientists have concluded that this may be unconnected with large scale patterns of the atmospheric circulation.

The Study Area

The study area is North-Western Nigeria, encompassing the three states of Sokoto, Kebbi and Zamfara (Figure 1.0). The area is found between latitude 10^0N and 13^058^1N; and longitudes 4^08^1E and 6^054^1E. It covers a land area of approximately 62,000km^2. It lies to the North-West of Nigeria and shares its boundaries with Niger Republic to the North, Katsina State to the East, Niger State to the South-east, Kwara state to the South and Benin Republic to the west.

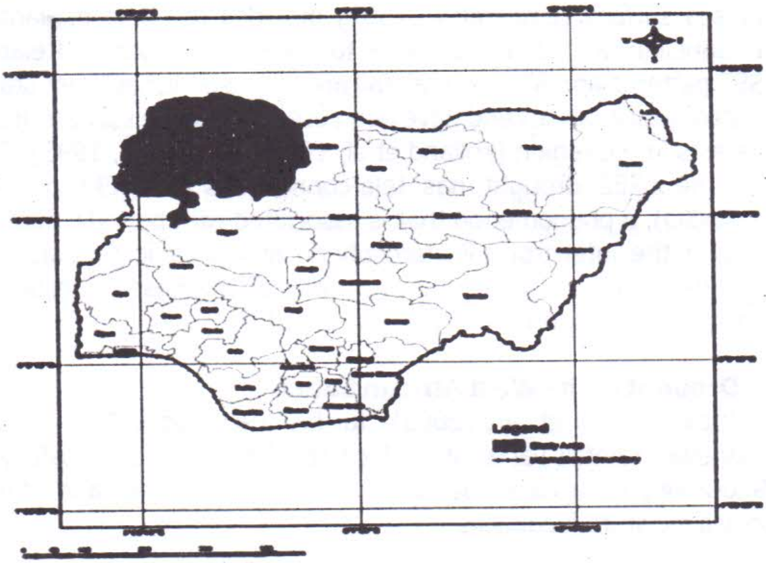

Figure 1: The study area

Like the rest of West Africa, the climate of the region is controlled largely by the two dominant air masses affecting the sub-region. These are the dry, dusty, tropical continental (cT) air mass which originates from the Sahara Desert, and the warm, tropical maritime, (mT) air mass (which originates from the Atlantic Ocean). The influence of both air masses on the region is determined largely by the migration of the ITCZ. The interplay of these two air masses gives rise to two distinct seasons within the sub-region. The wet season is associated with the tropical maritime air mass, while the dry season is a product of the tropical continental air mass. The influence and intensity of wet season decreases from the West African Coast northwards. Therefore, precipitation in the whole sub region of West Africa largely depends on thunderstorm activity which occurs along disturbance lines called "line squalls" and, about 80 percent of the total annual rainfall for most places is associated with line squall activities which are prevalent between June and September (Ojoye, 2012).

The region experiences a short rainy period and a long dry season. The rainy season starts about mid-May in the southern fringes of the study area and cessation at about middle to late September in the northern districts, and early October in the southern districts. The dry season, on average, lasts between seven and eight months. With an annual average temperature of 38.3°C, Sokoto is one of the hottest cities in Nigeria with maximum daytime temperature having between 35°C and 40°C which makes this dry environment quite unbearable. The warmest months are February, March and April when daytime temperatures exceed 45°C.

Methodology

To gain an insight into the nature of climatic variability within the climate system, it is necessary to study its components in a systematic way. For instance, records of rainfall, temperature, humidity, winds, clouds, pressure or sunshine will typically consist of a complex mixture of variations. For this study, rainfall variations was analyzed because researches have shown that in Northern part of Nigeria, rainfall is the most variable parameter out of all climatic parameters (Kowal and Knabe, 1972, Kowal and Kassam, 1978, Adefolalu, 1986, Mortimore and Adams, 2001, Odekunle et. al., 2007, Dami, 2008 and Ojoye, 2012).

Rainfall was analyzed in terms of changes in the Statistical distribution. The mean which represents the overall expectations of "normal" rainfall is denoted by the symbol X. In precipitation analysis, the mean can only provide a preliminary guide to the characteristics of a location's overall precipitation regime. Ekpoh, (2010) notes that the mean is the measure generally used to represent the 'normal' rainfall condition of a place , consequently, annual totals are often converted into running means; the advantage of running means is in their ability to smooth the most extreme irregularities, making it easier to detect underlying patterns. The Standard deviation (δ) describes the dispersion of rainfall from the mean value. The most frequently used measure of relative dispersion is the coefficient of variation (CV). This is calculated by dividing the standard deviation by the mean and multiplies the result by 100 and is given by

$$\frac{CV \times 100}{x} \quad \text{- - - - - - - - -} \quad 1.0$$

Where:

CV= coefficient of variation, δ = standard deviation, X = mean

For this study, it is assumed that annual rainfall has a normal distribution about the mean (X) and Variance (δ). Long-term variation in rainfall arises because of changes in either the mean or the standard deviation or both. Climate change under this scenario could be discussed according to the mean and standard deviation.

i. When the mean rainfall changes and the standard deviation remains the same. Under this condition, the tolerable range of rainfall may not change immediately since this is a mild form of climate change.
ii. The second type of climate change consider a situation where there is a change in standard deviation and the mean rainfall remain the same. If

the changes results in the standard deviation becoming larger, then there would be increased risk from both deficient as well as excessive rainfall.

iii. In the third type of climate change both the mean and the standard deviation changes. This was reported to be more severe type of climate change which can cause serious disruptions of economic activities, (Ekpoh, 2010)

From the climate change model outlined above and in order to examine the types of climate variation that have occurred within the period under consideration, rainfall data for 52 years (1958-2010) was divided into three periods viz: long term (1958-2010), the mid-term (1958-1988) and short term (2000-2010) according to Ekpoh, (2010), and analyzed using the mean, the standard deviation and the coefficient of variability.

Results and Discussion

The temporal variation in the rainfall of the study area were presented on a long-term, medium-term and a short-term basis from 1958 to 20010 and the results were as presented in Table 1.0 below

Table 1.0: Temporal rainfall variation in the North-West Zone of Nigeria for different climatic eras

Period	Mean	Std Dev.	C.V (%)
a. Long- Term (1958-2010)	672.99	176.76	26.26
b. Middle-Term(1958-1988)	648.88	183.82	28.33
c. Short –Term (2000-2010)	741.21	136.29	18.39

Table 1.0 shows the mean, the standard deviation and the coefficient of variability for long-term, medium-term and the short-term rainfall regimes. From Table 1.0, the mean annual rainfall for the period 1958 to 2010(long-term) was 672.99, with a standard deviation of 176.76 and a coefficient of variation 26.26%. The mean annual rainfall for the period 1958-1988 (medium-term) was 648.88 mm, with a standard deviation of 183.82, and coefficient of variation of 28.33%. In the same vein, the mean annual rainfall for the period 2000-2010 (short-term) was 741.21, with a standard deviation of 136.29, and a coefficient of variability of 18.39%. A comparison of the short-term annual rainfall characteristics with the long-term data shows a rise of about 9.19% (68.13mm) in the mean annual rainfall, and 22.9% in the standard deviation. In Climatological sense, any climatic variation that involves a shift in both the mean and standard deviation is a serious climatic condition (Fukui, 1979 and Ekpoh, 2010).

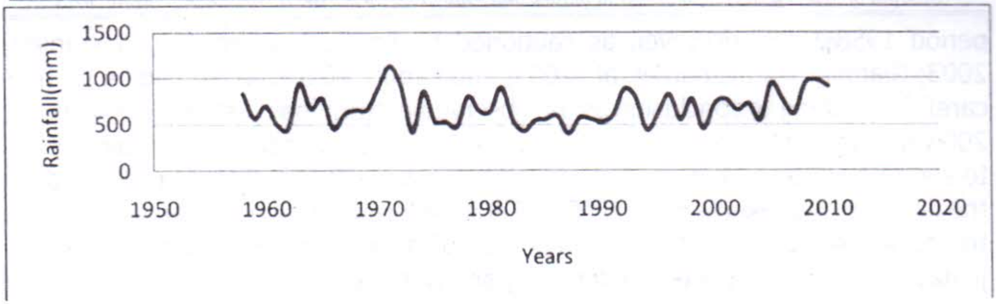

Figure 3: Time series of annual rainfall (1958-2010)

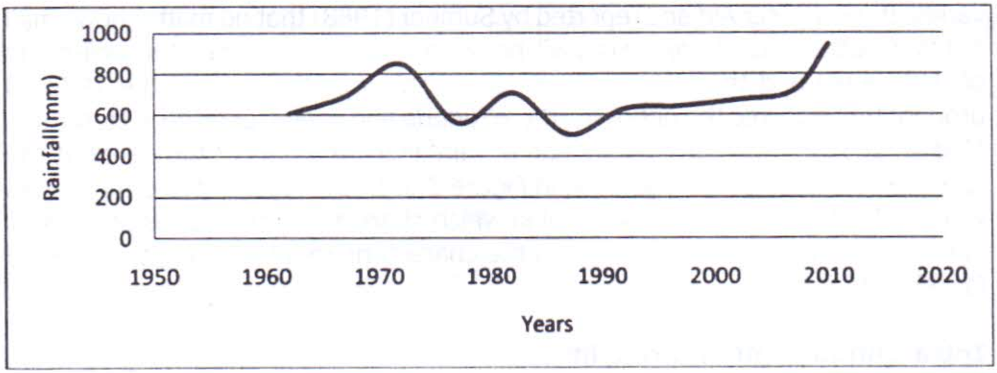

Figure 4: 5-Year running means for rainfall

A careful scrutiny of Figures 3 and 4 reveals two distinct climatic eras which are represented in Table 1 as middle and short-terms. A comparison of these two periods shows that the mean annual rainfall for the period 2000-2010 was 9.2% (68.22mm) higher than the mean rainfall for the period (1958-1988). The standard deviation also declined from 176.76 in the 1958-1988 periods to 136.29 in the 2000-2010 periods. Additionally, the coefficient of variability decreased slightly from 26.26% in the 1958-1988 periods to 18.39 % during the 2000-2010 periods.

From the foregoing, the results indicate that, among the three periods, the 1958-1988 periods showed the greatest tendency towards a dry trend, with a mean rainfall of only 672.99mm. Although the standard deviation was slightly higher, the coefficient of variability was higher during this period. All these indicate that the climate of the region has undergone serious alterations in its underlying characteristics to the extent that a new mean and a new standard deviation were established. This confirms the onset of climate change in the region during the period 1958-1988. However, as cautioned by eminent scientists (Winstanley, 2003; Giannini, Saravanan et. al., 2003; and Ekpoh, 2010), we should be slightly careful in rushing to conclusion as the observed pattern may just be a swing in the 200 year cycle of the region. Moreover, current flood episodes in the region seem to suggest a return of even wetter conditions, a result that was corroborated by the findings of Odekunle et.al, (2007). Thus the 'drama' that has been unfolding in the region since the last 40 years is that of a highly unpredictable climate, a juxtaposition of unexpected extreme dry and wet years.

Inter-annual rainfall variability

Inter-annual rainfall variation is the broadest time –scale over which precipitation varies .It was observed and reported by Sumner,(1988) that no matter how small or big the observed difference is it will have a devastating effect on the well-being of the people and the community at large. This was the case of the 1972/73 drought that affected the entire Northern Nigeria and is well reported in literatures (Ojoye, 2012). The yearly fluctuation of rainfall for the entire study area at the specified time-scale was displayed in Figure 3.0. In the Figure, two climatic eras were distinct; less than normal rainfall which characterize the 1970s and 1980s and above normal rainfall which was the characteristics of the long term period (1958-2010).

Intra-annual rainfall variability

It is an undisputed fact that the Northern Nigeria receives the least amount of rainfall in Nigeria because of its hinterland location (Ojoye, 2012).

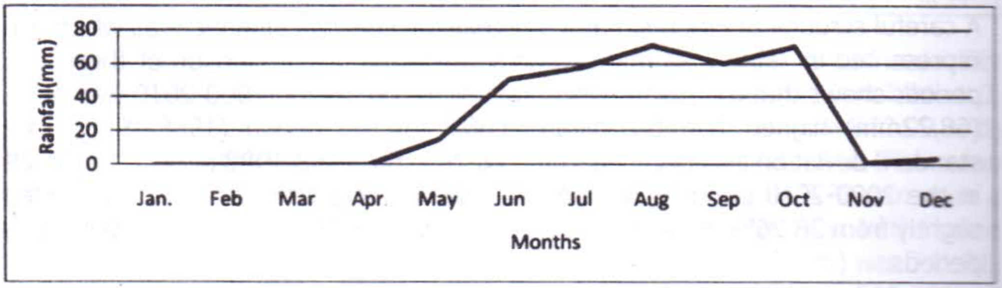

Figure 5: Mean monthly rainfall distribution

Figure 5.0 shows the mean monthly rainfall distribution for Sokoto for the period 1958 to 2010. From the Figure, rainfall in Sokoto should normally start from April and end by October. July is the month with maximum rainfall and the rainfall pattern is that of a single maximum. In water resources planning and management, the region has an effective five months of rainfall from April to September, for the recharge of surface and sub-surface reservoirs.

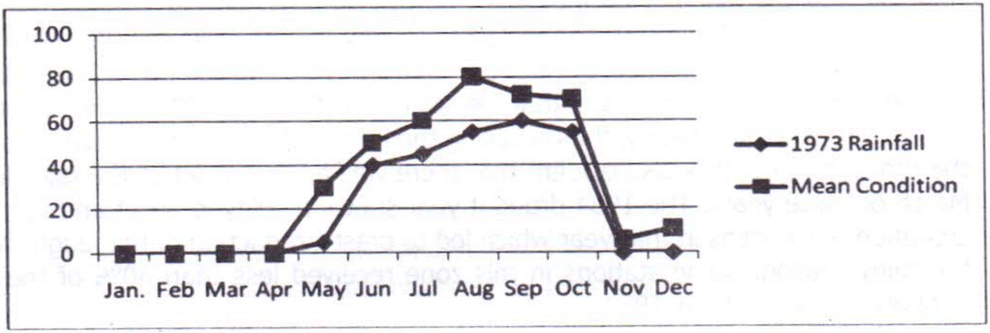

Figure 6: Comparison of 1973 rainfall (drought year) with mean condition

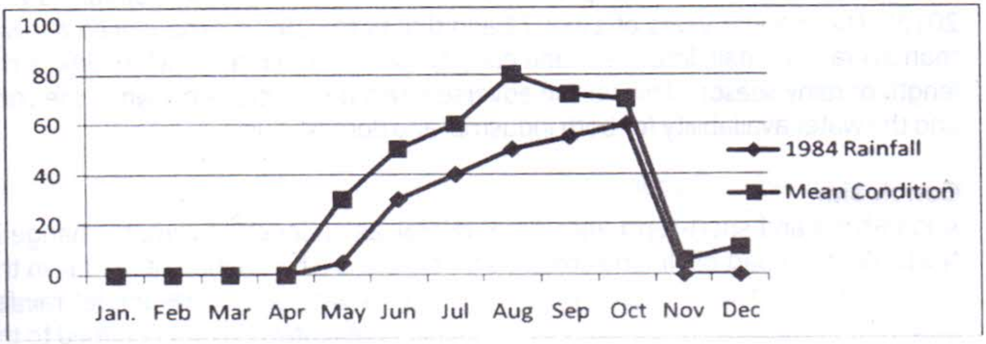

Figure 7: Comparison of 1984 rainfall (drought year) with mean condition

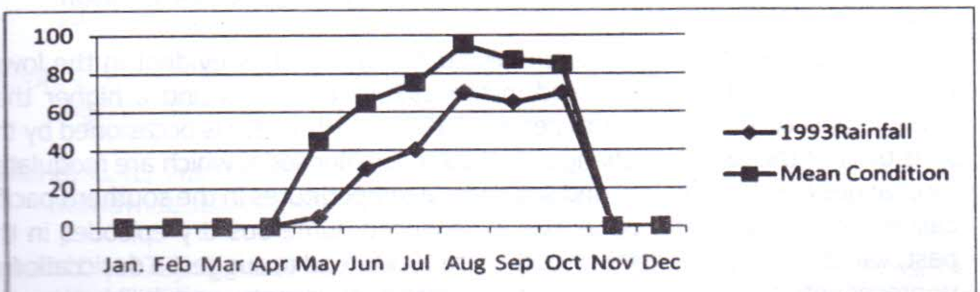

Figure 8: Comparison of 1993 rainfall (drought year) with mean condition

Figures 6-8 show the pattern of rainfall during the drought years in comparison with the monthly rainfall distribution for Sokoto. A close look at the diagrams shows that the pattern for 1972 and 1973 are very similar while that of 1984 is different from Figures 6 and 8, besides the total annual rainfall being far less than the long-term mean, it is evident that the rainfall in 1972 and 1993 in the region started late and ended early, thus reducing the length of the growing season for the drought years. It is also evident that there was a false onset of the rains in March of those years. The 1984 drought year shows a delayed onset and early cessation of the rains in that year which led to drastic reduction of the length of the rainy season. Some stations in this zone received less than 40% of their annual average rainfall in 1984.

As observed earlier, the mean annual rainfall since the late 1970s up to 1980s has decreased over 12% in comparison with the long-term mean rainfall (1958-2010). The drought years of 1972/73 and that of the 1980s experienced a lower than average rainfall, late onset and early cessation of rainfall which shortens the length of rainy season. This has an adverse effect on the crops grown in the zone and the water availability for both industrial and domestic use.

Conclusion

A long-term and short-term analysis of rainfall as an index of climate change in North-Western part of Nigeria confirms that there is a fluctuation of rainfall in the region. This fluctuation has affected the inter-annual and intra-annual rainfall patterns. The fluctuations in the inter-annual rainfall totals are not confined to the mean state conditions but also affect the standard deviation and coefficient of variation. With respect to intra-annual rainfall, the study has also shown that rainfall between 1958 to 2010 has fluctuated enormously not only in terms of total receipts, but also in onset dates, cessation dates and length of rainy season.

The zone is characterize with unpredicted rainfall which is evident in the lower than average rainfall experienced in the 1970s and 1980s and a higher than average observed on a log-term period of 1958-2010. These is occasioned by the sensitivity of the region to changes in the African Monsoon, which are modulated by changes in solar radiation and sea surface temperatures in the southern pacific called El-Nino. While the Sahel has experienced numerous dry episodes in the past, variations in the climate since the late 1960s tend to suggest a desiccation of unprecedented proportion within the context of climate variability over the historical period in north-western Nigeria. Although the changing regime in rainfall in the region has been sustained for a longer period of time now but it is impossible to confirm if the shift is not just another cycle in the long history of the region.

The rainfall characteristics of the zone suggest the following as part of the measures that could be taken to reduce the frequent flood episodes in the region:

(i) The planting of trees where desertification has taken place

(ii) Transfer of water from region where there is a high yield in rivers to areas where there are low yield to reduce sea level rise. Such transfer should be carried out through pipelines to avoid excessive loss through evapotranspiration and seepage which are usually associated with canalization.

These suggestions, if implemented will impact positively on the regional weather and climate, improve the hydrological regime and stabilize the ecosystem.

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