Space-time-frequency analysis of rainfall, runoff and temperature in the Casamance River basin, southern Senegal, West Africa

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Abstract

Using long-term data on rainfall and annual runoff, an investigation was made of the spatial and temporal variability of rainfall and runoff in the Casamance River basin located in southern Senegal, West Africa. A 5-year moving average was employed to identify trends in the data. Monthly and annual rainfall tends to have been decreasing, and the annual maximum temperature rising from around the mid-1960s. In addition, there has been a decreasing rainfall gradient from the coast to the interior. The analysis also showed a simultaneous runoff decline as a result of the rainfall decline. Available data on rainfall, temperature, and surface runoff from two upstream stations were used to develop a procedure for estimating runoff from the annual surplus values of precipitation minus reference evaporation. The resulting equations accounted for 74% to 77% of the variation in runoff. Spatial and temporal distribution of rainfall and runoff affects salinity migration inland and data are, therefore, useful for salinity management in the Casamance River basin.

Introduction

Rainfall and runoff deficits have been observed in the Sahelian countries since 1968, and drought has, consequently, persisted throughout this region of the African continent. This situation has led to design and implementation of many water management projects to protect agriculture from adverse climate change. For instance, the South Zone Water Management Project (SZWMP) is among the many projects which have undertaken construction of many hydraulic structures, such as anti-salt and retention dikes, to control water quantity and quality throughout the Casamance River valley and to reclaim saline soils. The main objective of this project, co-founded by USAID and the Senegalese Government, is to increase rice production by using improved water management techniques in the Ziguinchor and Kolda regions of southern Senegal. The total area to be reclaimed and protected is approximately 15 000 ha of unsalted and salted soils across 60 valleys in the Kolda and Ziguinchor regions. The successful implementation of the project requires a knowledge of the space, time, and frequency characteristics of rainfall and runoff.

This study is a part of the SZWMP's programme which began in 1991 by Louis Berger International, Inc. and Louisiana State University Agricultural Center in collaboration with Senegalese technicians. It empirically investigates the spatial and temporal distribution of rainfall in the Casamance River basin in Senegal, and determines whether rainfall has declined and temperature has increased as a result of climate change. Decline in rainfall and runoff on one hand and increase in evaporation due to increase in temperature on the other hand constitute two of the determinants for the degree of salinity intrusion in the Casamance River basin.

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Casamance River basin

Senegal, the most western country in Africa, is located between 12°30' N to 16° 30' N and 11°30' W to 17°30' W, covers an area of 196 722 km^2, and has a 600 km Atlantic coastline. It is bordered by Guinea Bissau and Guinea Conakry on the south, by Mali on the east, and by Mauritania, across the Senegal River, on the north. The Casamance River basin, as shown in Fig. 1, is entirely located in Senegalese territory, and has an area of 20 150 km^2. Its geographic co-ordinates are 12^{o}30' to 13^{o}21' latitude north and 14^{o}17' to 16^{o}47' longitude west. These co-ordinates show that the longitudinal extension (270 km from west to east) is greater than the latitudinal extension (100 km from north to south). The hydrological behaviour of the basin is influenced by the combination of climate, topography, hydrography and wave propagation from the sea (saline water intrusion). In the eastern part of Senegal, most of the territory is up to 100 m above mean sea level (amsl). Thus, Senegal is located between semi-arid and humid inter-tropical regions of the African continent.

Climate

The climate of the Casamance River basin is characterised by large precipitation variability from north to south ranging between 100 mm and 1 800 mm during summer, and high temperatures throughout the year (Thiam and Singh, 1997). There are three major atmospheric influences: the Acores anticyclones that bring maritime winds, named Alize, on the coast; the Saharan high depression responsible for the hot and dry winds of the dry season, named Harmattan; and the Saint-Helen anticyclones that are responsible for rainfall. The Inter-Tropical Convergence Zone (ITCZ) follows the movement of the sun and separates these two latter air masses.

From January to March the ITCZ is located south of Senegal, and from April it moves north, covers all the country around July to August, and moves southward with the sun. The length of the rainy season varies from five and half months in the south-east to