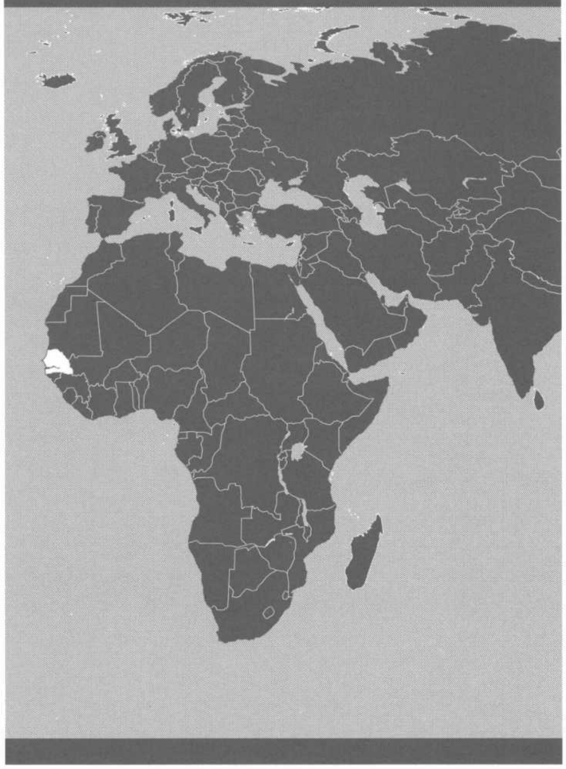
Senegal



Earth observation and GIS-based flood monitoring in the Senegal River Estuary and Valley

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SYMPOSIUM NOTES

The Senegal River basin

The Senegal River basin is located in West Africa and occupies an area of roughly 300 000 km^2. The entire basin, including the upstream catchments is drained by the 1700 km long Senegal River and its tributaries. The area of the river basin accounts for about 1.6% of the African continent and lies within the territory of four different countries: Guinea, Mali, Mauritania and Senegal (Figure 1).

Hundreds of thousands of people live along the Senegal river which rises in the Fouta Djallon mountains of Guinea and flows north towards the edge of the Sahara desert before swinging west to empty into the Atlantic Ocean. Its water is used irrigate large areas of rice, sugar cane, maize and tomatoes as well as grazing land for livestock. The basin is divided into three distinct regions: the upper basin which lies in the mountains of Mali and Guinea, the middle valley which forms the 500 km long borderline between Senegal and Mauritania, and the delta in the lower valley where the Senegal River discharge into the Atlantic Ocean.

The flow rate of the river is determined mainly by the rainfall in the upper basin. The high-water season lasts from July to October; the low-water season, with a steady decrease in volume, begins in November and lasts until May or June. The high-water season peaks at the end of August or beginning of September and quickly ends during October.

Another important feature of the Senegal River prior to the construction of its two dams was the inter-annual irregularity in its flow volume. For a long time this inter-annual flood irregularity posed a major problem for the valley, as it decreased the potential for guaranteed agricultural production in this narrow geographic area. The arable land area that could effectively be farmed after the flood could vary between 15,000 ha and 150,000 ha, depending on the magnitude and duration of the flood. Exceptionally high water levels caused widespread devastation in 1890, 1906, 1950, 1994, 1999 and 2003.

The particularly low water level during the dry season resulted in a deep intrusion of the ocean's salted waters into the riverbed. During the 1970s a saltwater wedge penetrated more than 200 km upstream of Saint-Louis. To address the problems associated with the significant inter-annual variability in rainfall and water flow of the Senegal River, three of the four main bordering countries (Mali, Mauritania, and Senegal) entered into a treaty to form the Senegal River Authority, the Organisation pour la Mise en Valeur du Fleuve Sénégal (OMVS), and related organizational structures in 1972.

The tasks of the OMVS were to attain the goal of food self-sufficiency for the Senegal River Basin inhabitants; reduce the economic vulnerability of the organization's member states to climatic fluctuations as well as to external factors; accelerate the economic development of member states; conserve ecosystem balance in the sub-region, particularly in the basin; and secure and improve the incomes of basin inhabitants. To accomplish these goals the OMVS was charged with constructing and managing a regional infrastructure consisting of two major dams. The first to be completed (in 1986) was the Diama dam, located 27 km upstream from the city of

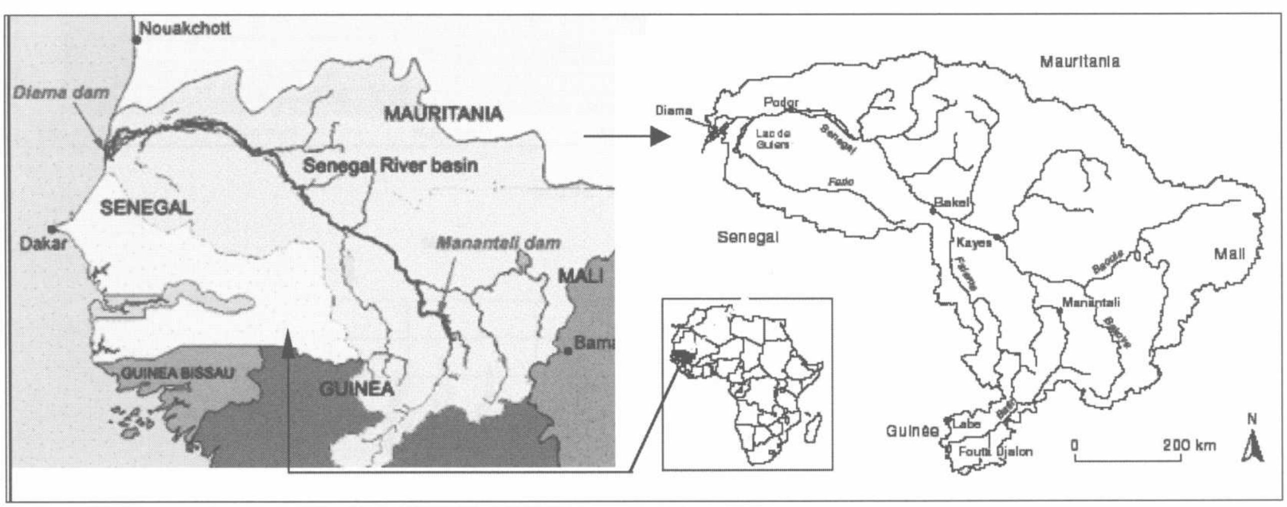

Figure 1: The Senegal River basin

St Louis (Senegal). It was built to stop the dry-season intrusion of sea water along the river bed which, during the drought years, would penetrate over 100 km inland. The second is the storage dam at Manantali in Mali (completed in 1990) on the Bafing, the main tributary of the river, which supplies approximately 50% of the annual flow. The reservoir is theoretically capable of stocking 11 billion m3 of the strongly seasonal rainfall on the Fouta Djalon Mountains in Guinea. The water can then be gradually released over a longer period than the natural flood. The two dams should provide enough water to achieve the following development objectives: irrigate 375 000 hectares of former floodplain, especially for rice production; produce hydropower (800 Gwh per year); make the river navigable all year round between Saint Louis at the river mouth and Ambibédi in Mali.

Water level and discharge measurements in the estuary

Discharge information from Diama dam is available from July 1986 to now. As shown below, releases from the barrage occur each year from approximately July through to December. At other times of the year there is no flow through the barrage.

Over the measurement period the data shows variations in both mean sea level and tidal range. Subsequent analysis of the data is presented, which displays tidal range both at St Louis (from the measured data) and the ocean (from tidal predictions) and mean water level at St Louis. The water level measurements from Diama Barrage are also shown. Note that as these measurements are only daily recordings, tidal range cannot be extracted.

When water levels exceed 1.2 m above MSL flooding occurs in Saint-Louis. According to the measurements at Saint-Louis, this has occurred nine times since 1964. Since the barrage was constructed in 1985, this has only occurred three times. The discharges from the barrage from 1985 onwards are also shown below. Note that the peak discharge greater than 3000 m^3/s recorded in 1987 is considered to be incorrect, and should be approximately 1500 m^3/s (Gilif, 2002).

OBJECTIVES OF THIS PROJECT

In 1999, the western part of Africa experienced higher precipitation rates, resulting in higher river discharge in the Senegal River and its tributaries and thus larger inundations in the river valley and delta than seen during the last 30 years. Several villages and irrigation infrastructures were destroyed. People had to abandon their houses and rice field crops were lost. Further downstream, Saint-Louis, the former capital of Senegal, experienced large damages due to inundation of areas built up during the dryer years in the 80s. Floods risk reduction is related to poverty in the sense that floods consequences

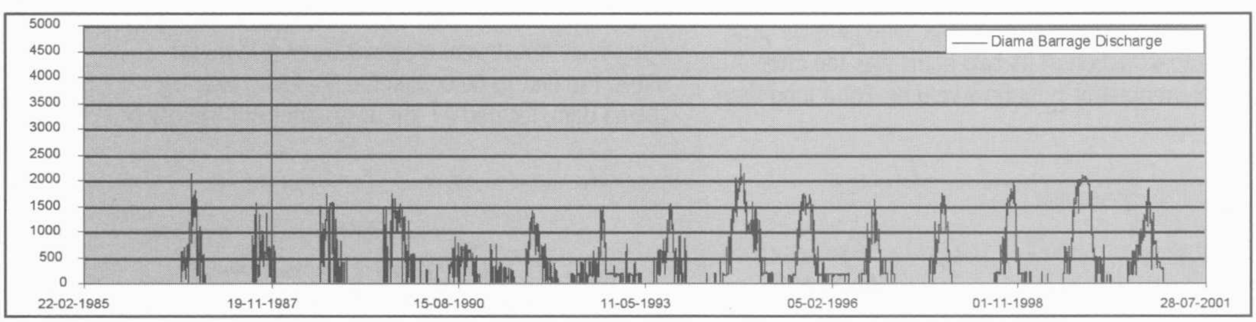

Figure 2: Time Series of Discharge, Diama Barrage (1986-2003)

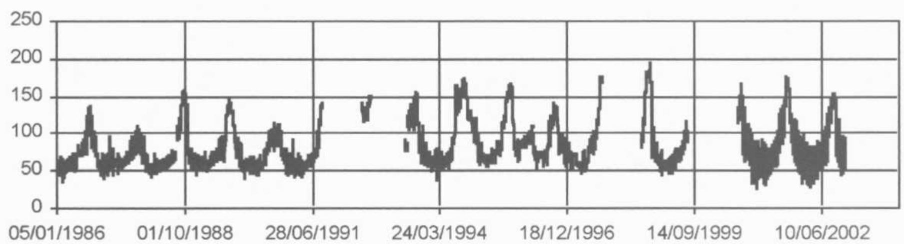

Figure 3: Water level at Saint-Louis 1986-2002

(removal of population, housing problem, health problem, lost crops, etc.) reinforce poverty; thus reducing flood risk will inevitably cut down the rate of poverty.

Therefore, local and regional decision-makers need management tools and materials for flood monitoring. The ultimate objective of this project is to develop new tools base on satellite images for flood monitoring and forecast in the Senegal River valley and estuary that can be used on regional, national and local level by relevant authorities to improve water management and to reduce impacts of extreme events like floods.

Accurate mapping of the areal extent and duration of the yearly flood of the Senegal River is desirable in order to monitor hazards on people, irrigated agriculture, buildings and infrastructure and also to assess the potential for the traditional flood recession agriculture. Furthermore it has been highlighted the necessity to have precise Land Cover Maps as a means to assess flood damage but also as a way of modelling the hydrological functioning to better characterise the watershed in the Senegal River valley and estuary.

METHODOLOGY

Data and image acquisition

Data acquisition was an important stage of this project. Several missions were carried out in the estuary and the lower valley because flood monitoring in the Senegal River valley and estuary require a large number of data sets. The most critical data include atmospheric weather data, soil physical data, current and historical land-use data for a general description of land cover and land-use management around the town of Saint-Louis.

Date	Mode	Season	Observations
13-10-1998	XS 4	Rainy	high floods
23-10-1999	XS 4	Rainy	high floods
31-10-2001	XS 4	Rainy	low floods
16-01-2002	Panchromatic	Dry	no floods

Table 1 : Satellite data

The SPOT 4 (1999, 2001, 2002) and SPOT 5 (2002) images were acquired near the University of Dakar in collaboration with University of Marne la Vallée (France). The SPOT Xi image of October 13, 1998 is recovered to the GILIF[1] project developed in 2002 on the Senegal river by the DGPRE[2], (UNEP) but belongs to former UTIS[3] center. The available satellite data are listed in Table 1.

This kind of approach based on satellite images has previously been used by Sandholt and al., (2000) in the lower valley around the city of Podor. This pilot study focused on different Landsat images in combination with data from other sensors like AVHRR and radar data from ERS.

Pre-processing

Geometric correction

The SPOT data were preprocessed for data extraction and geometric correction. The images we use in this study were not directly georefenced and at the beginning they have deformations and must be stood up to be put to the better orientation in conformity with the geographic reality, in a plan of projection. All images have been geometrically rectified to UTM Zone 28 North. Because of the differences in spatial scale and thus areal coverage for the images, different areal coverages are available in each case, so direct comparisons are only possible in regions with overlap

The Ground Control Points (GCP) we have chosen at the beginning with the Japanese International Cooperation Agency (JICA) maps (1/50 000), had not known conclusive results because the RMS often was being enough raised. The precision of those measures was not satisfied. The choice was being particularly focussed on remarkable points, as intersections of roads, trees, angles of fields, etc.

In order to correct these ground control points and to have a better precision in the choice of GCPs, we carried out a mission to complete the points with the GPS. This solution has permitted to obtain a precision of 5 m. These points thus made it possible to rectify the images with a high degree of accuracy.

Data fusion

In this case of images fusion, we have searched to combine judiciously the spatial information of high resolution panchromatic image of January 16, 2001

[1] Gestion Intégrée du Littoral et du Bassin Fluvial

[2] Direction de la Gestion et de la Planification des Ressources en Eau

[3] Unité de Traitement de l'Imagerie Satellitaire