USE OF SATTELITE IMAGE TO MAP FLOOD EXTENSION AROUND THE CITY OF SAINT LOUIS IN THE SENEGAL RIVER ESTUARY.

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ABSTRACT

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. Hundreds of thousands of people live along the Senegal river which rises in the Fouta Djalon mountains of Guinea and flows north towards the edge of the Sahara desert before swinging west to empty into the Atlantic Ocean (Codata, 2002). 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 80's. 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.

Keywords

Senegal River, Floods, Remote sensing, GIS, Saint-Louis

INTRODUCTION

The traditional method of satellite data combination and the gathering of important information made possible to produce a Geographical Information System to monitor floods in the lower estuary of the Senegal River valley (Sandholt, I., Fog, B. & Fensholt, R., 2001). This technical approach is a powerful tool for combining important information for a better comprehension of the floods and the characterization of surface qualities on the estuary. By a multi-temporal approach, we established the qualitative and quantitative impact of floods on the various geographical objects, a detailed cartography of the land use, the surfaces flooded in 1998 and 1999. The study undertaken to St Louis made possible to consider surfaces flooded in 1999 and to understand the width of these floods compared to those of 1998. The constitution of a tool of decision-making aid makes possible to have information relating to the limits reached by the flood, the surface of flooded surfaces and to detect the more exposed zones (the most reached) in order to establish a hierarchical map according to the percentage of exposure to the risk of the geographical objects touched by the floods (populations), road infrastructures and tracks, medical and social infrastructures, perimeters of cultures (agriculture), etc.

1. CONTEXTE OF THE 1999'S FLOODS

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 80's.

The relevance of the study has been accentuated by extensive flooding in 1999, when the greatest river flow in 30 years was reported. Because of exceptionally high rainfall in Fouta-Djalon in the rainy season of 1999, peak flow at Bakel reached 4440 m^3 /s (IRD [1], 2001).

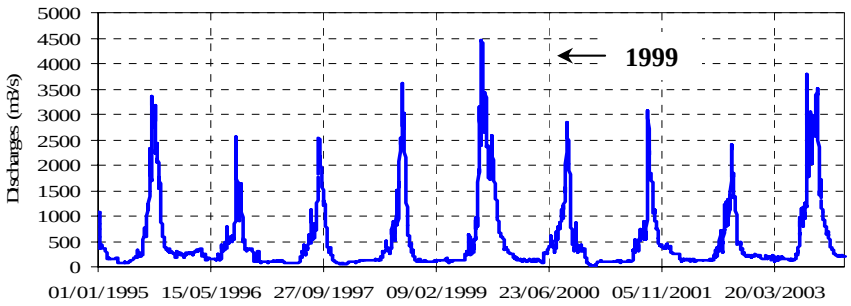


Figure 1: Time Series of Discharge at Bakel (1995-2004)

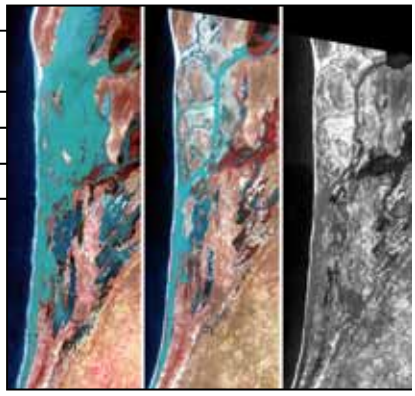
When water levels exceed 1.2 m above MSL, flooding occurs in Saint-Louis (Gilif [2], 2002). According to the measurements at Saint-Louis, this has occurred nine times since 1964. Since the barrage was constructed in 1985, this has only occurred three times.

2. SPOT IMAGE DATA

The SPOT 4 images (1999, 2001 and 2002) were acquired near a project developed by University of Dakar in collaboration with University of Marne la Vallée (France).

Tableau 1: Available image for this study

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



images

3. VIEW OF FLOOD EXTENSION IN THE ESTUARY

The 1999's satellite image (figure) shows that the floods were unusual for both its depth and duration. Unlike the normal floods, which cover large parts of the valley for several days or weeks during August to September, the floods in 1999 lasted until mid-October in many areas, killing people and destroying roads, houses, crops, and other assets.

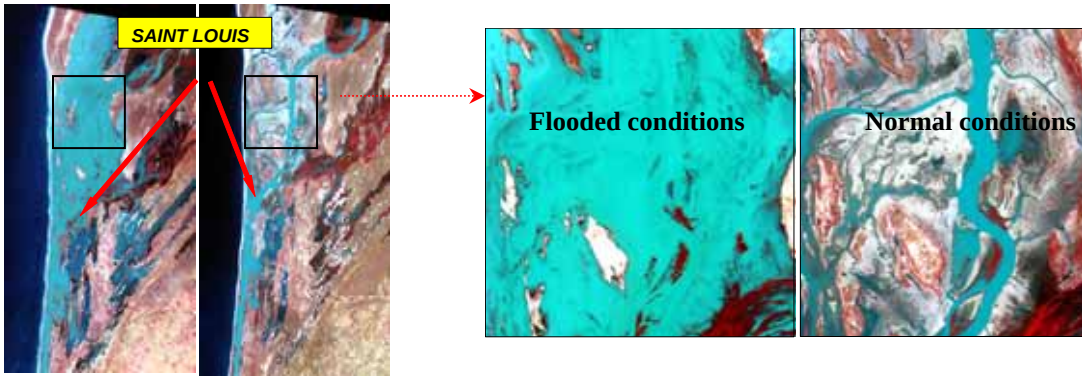


Figure 3: Satellite Imagery of Senegal River Lower Estuary, Flood conditions in October 1999 (left) and no flood conditions in October 2001 (right)

The floods devastated a very important surface. Its impacts was severe because of the high levels of vulnerability and low levels of resilience of the population, the lack of adequate physical protection infrastructure and changing flooding patterns due to environmental change and the impact of the dam's structures. Man-made factors contributed to the seriousness of the event. The increasing occupation of floodplains around the city of Saint Louis in the estuary, competing and conflicting developmental demands in the lower valley have exacerbated the impacts of floods on society (Dia, 2004). Even though the floods are obviously a fact of nature, their impacts on local resident depend to large scale on the resident behaviour.

Figure 4: A view of flooded area in Saint-Louis in 1999

4. METHODOLOGY OF FLOOD MAP EXTRACTION

This kind of approach based on satellite images has previously been used by Sandholt and al., (2003) 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.

4.1 Geometric correction

The SPOT images used 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 the 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 coverage are available in each case, so direct comparisons are possible in regions with overlap.

4.2 Image fusion

In this case of images fusion, we have searched to combine judiciously the spatial information of high resolution panchromatic image of 16 January, 2001 (10 m of resolution), with the multispectral SPOT images of 23, October, 1999 and of 31October, 2002 (20 m of resolution). This permits to obtain an image richer simultaneously in spatial and spectral information. The fusion is most certainly an important manipulation to realize in the case of such a study, but we realise that the panchromatic image brings noise on the Spot XS image and this information is very difficult to analyse in the classification process.

4.3 The Classification process

A standard supervised maximum likelihood classification was carried out using the ENVI image processing system. A total of five spectrally different classes are identified corresponding to spectral variability in the image. Differences on water reflectance are caused by turbidity and water depth and presence of varying amounts of green vegetation. Training and test areas were defined using field observations and delimitation carried out from a visual interpretation of SPOT images.

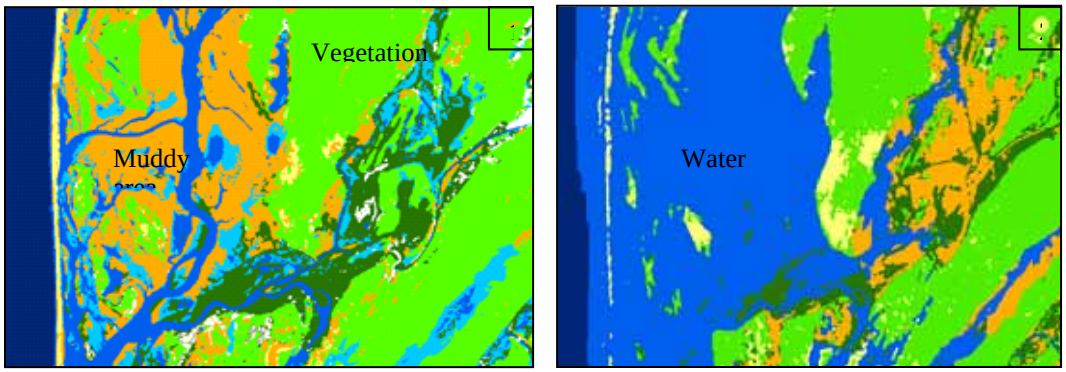


Figure 5: The classification results (1. Normal situation in 2001, 2. Flood situation in 1999)

5. CARTOGRAPHY OF FLOOD EXTENSION IN THE ESTUARY

The cartography of flooded area in the Senegal River estuary, permitted to isolate the different zones affected in October 1999. It is a multi-temporal approach which consists in comparing water surfaces around the city of Saint-Louis between the flooded period (SPOT 23/10/1999) and the normal period (SPOT 31/10/2001). The river bed largely overflowed and all the regions in the north of the town of Saint-Louis were considerably flooded.

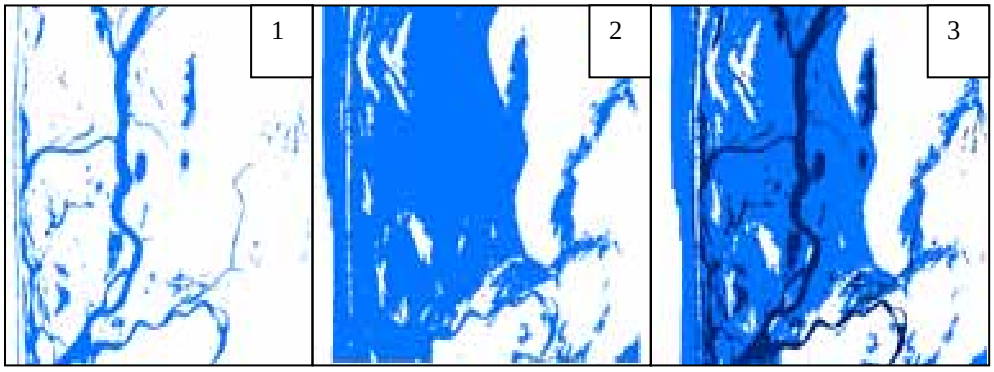


Figure 5: Flood extension in 1999

(1. Normal situation in 2001**. 2.** Flood situation in 1999**, 3.** Comparison of the 2 period

The flood map herein referred to is a map that graphically provides information on the extension of inundation in an easy-to-understand format. The goal is to show the high level of vulnerability of many areas around the city of Saint-Louis to those in charge of disaster prevention and those in charge of rivers and hydrology at local and regional level. The flood hazard map is particularly handy for the planners and administrators for formulating remedial strategy. It also makes the process of resource allocation simple resulting in a smooth and effective implementation of the adopted flood management strategy.

Conclusion

This study allows us to carry out several fields works and to collect many information and data related to the floods and to carry out a Geographic Information System (GIS). The investigations gave an idea on the overall organisation of the study zone in particular on the occupation of the easily flooded area around the town of Saint-Louis and some villages and small towns in the lower valley. The investigations allowed by stepping of testimonies to define the limit of the extension of the past floods and to index the level of the various historical risings. In this study the issue of flood hazard mapping has been addressed from the perspective of different mapping scale in a GIS environment. The flood hazard map is particularly handy for the planners and administrators for formulating remedial strategy. It also makes the process of resource allocation simple resulting in a smooth and effective implementation of the adopted flood management strategy. The aim of this regional study is to broadly identify the high hazard area in the area around the city of Saint-Louis and in the lower estuary of the Senegal River valley. Our project eventually leads to identification of the higher hazard zone.

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[1] Institut de Recherche pour le Développement

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