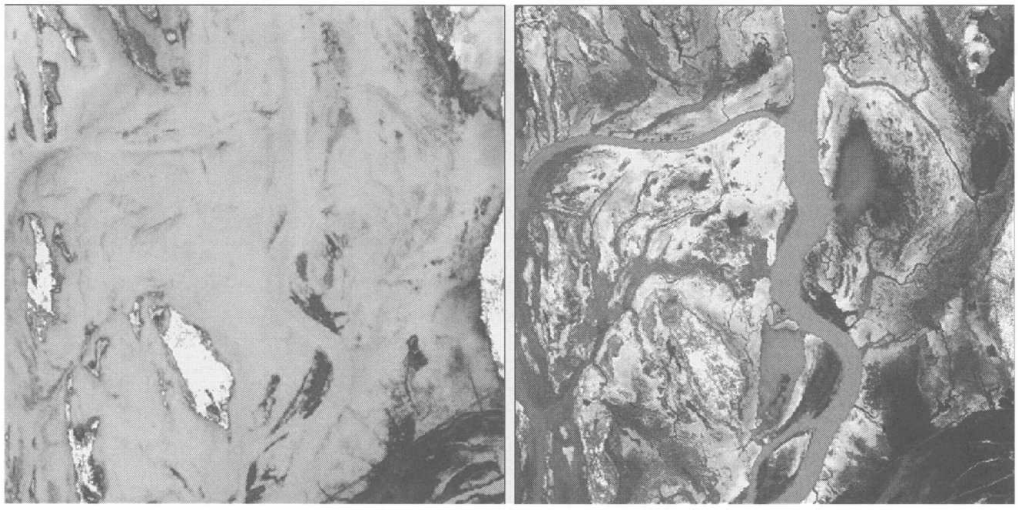


Figure 7b: Extract of spot 4 xs of 23/10/199 (left) and Spot 4 xs of 31/10/2001 (right).

One observes on these two extracts, the importance of the surfaces covered by the floods in October 1999. The principal bed of the river is largely overflowed and all the regions in the north of the town of Saint-Louis were considerably flooded (Figure. 8).

The floods devastated very important surfaces. With a comparison of these two satellite images (1999 and 2001), it appear that the different flooded surfaces have some difference. Slightly flooded surfaces account for 64.86% of flooded surfaces. Strongly flooded surfaces account for 21.52% of flooded surfaces and the other is the flooded and muddy surfaces (Table 3 and Figure 9).

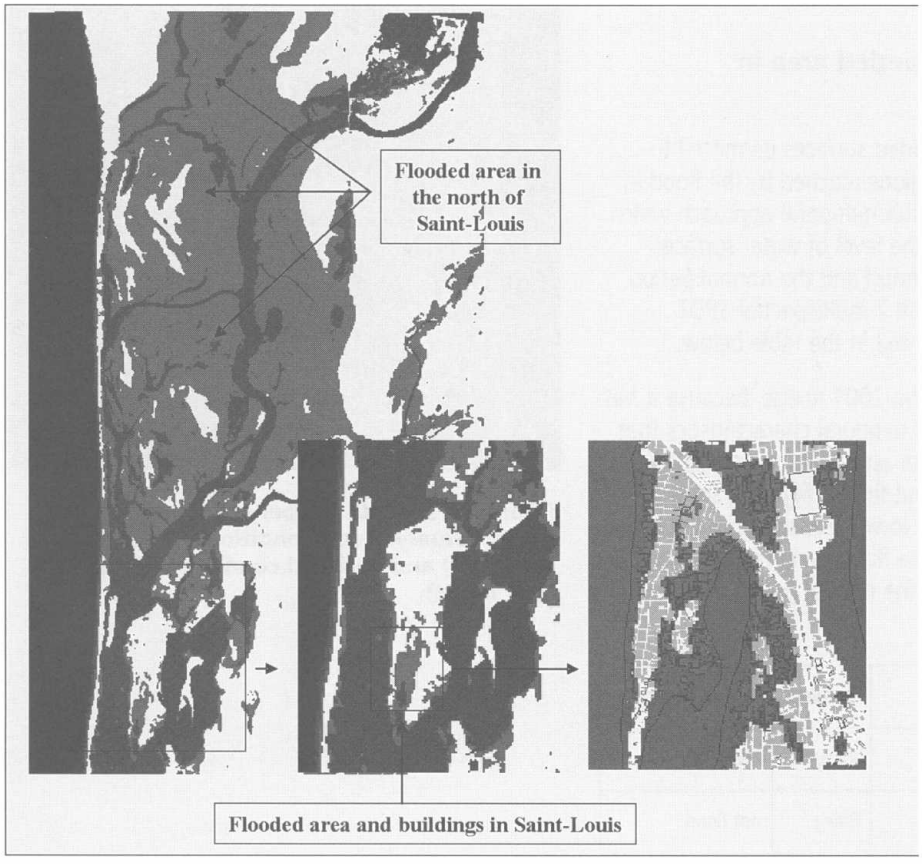
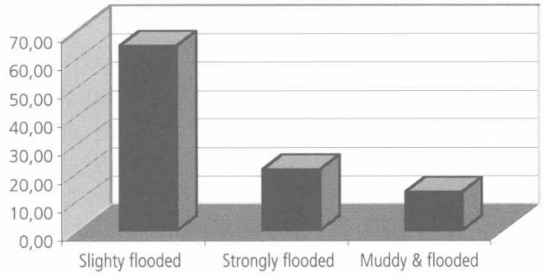


Figure 8: Flooded area in the region of Saint-Louis in October 1999

Types of objects	Number of objects	Min	Mean	Max	Summon	Standard deviation
Flooded surfaces (low)	1332	400	150759.16	28595200	200811200	1432383.37
Flooded surfaces (high)	2836	400	23493.37	3207600	66627200	136738.7
Flooded and muddy surfaces	2665	400	15821.84	1881600	42165200	67334.53

Table 3: Statistics of the surfaces flooded in October 1999, the surfaces are expressed in meters

Figure 9 : Flooded surfaces in 1999 (%)



These 3 layers of vectors were extracted automatically and exported with the Shape format to be integrated in the GIS (Figure 10a and 10b).

Figure 10a. Extract of the vector layers relating to the surfaces flooded in 199 in light blue, surfaces slightly flooded; in dark blue, strongly flooded surfaces; in red, flooded and muddy surfaces.

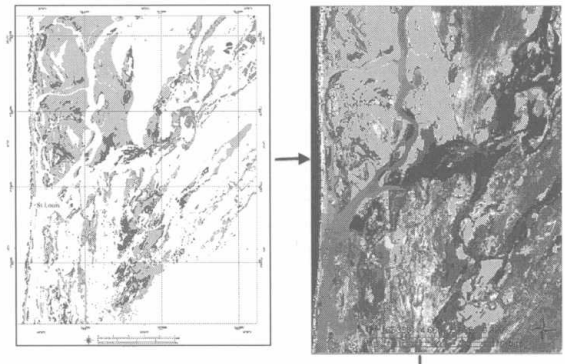


Figure 10b. Flooded surfaces in 1999 superimosed on image of fusion of Spot 4xs of 31/10/2001 and panchromatic of 16/01/2002. Scale 1/100 000

Water surfaces represent an important part of the total area considered. The total surface of water is 20.48% of the total surface of the area considered. Turbid water accounts for 16.93% of the total surface water.

Comparison of flood extension between 1998 and 1999

In October 1998 and 1999, important floods occurred in the area of Saint-Louis. Their respective extents were compared with satellite images by a multi-temporal approach. It arises that the floods were of 1999 were more important in term of surfaces flooded compared to those of 1998 (Table 4).

Year	No. of objects	Min	Mean	Max	Somme	Stand. Dev.
1998	510	400	41915.29	5104800	21376800	317499.44
1999	1062	400	86145.01	13822800	91486000	618155.77

Table 4: Statistics of the two SPOT images (1998–1999)

The 1999 floods have affected non flooded surfaces in 1998. The extent of flooded surfaces in 1999 represents 70,109 km^2 more ever than that of 1998.

THE DIGITAL ELEVATION MODEL

The relief of the area of St Louis is very low. The first peaks of altitude 10 to 15 m are located at several kilometers of the river. In the interior of the city the topography does not exceed 3m. The maps were delineated using topographic base maps with contour intervals of 10 feet, except in the city, where the contour intervals were five feet. The status of the topographic maps and the lack of high-resolution elevation data pose great difficulties. Availability and use of a DEM would expedite planning and development of land use for precision agriculture, drainage systems, land subdivision, utilities,

commercial and industrial districts, etc., and improve the quality of soils mapping.

The solution chosen to establish a DTM was to exploit the altimetric data provided in the form of point sides and level lines by JICA5 and SEGECOT maps. The precision of these altimetric data is unfortunately not easily measurable. Indeed, we don't know the reliability of the original data, neither the methods employed to obtain these data, and even less the geoids.

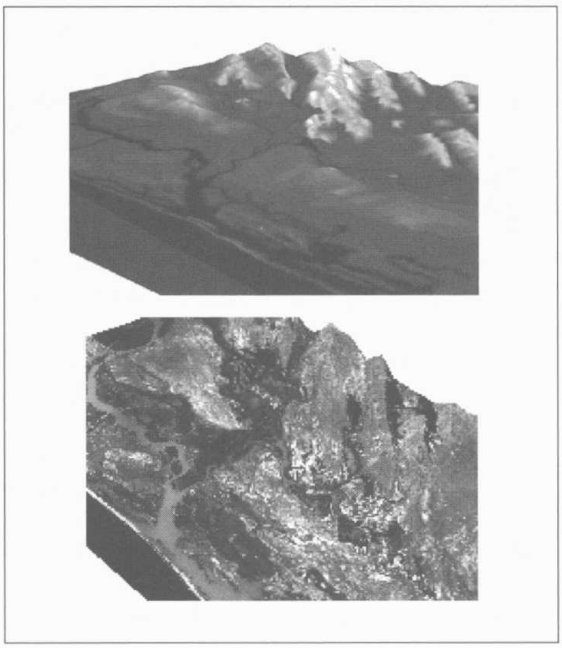


Figure 12a. DTM of the estuary area

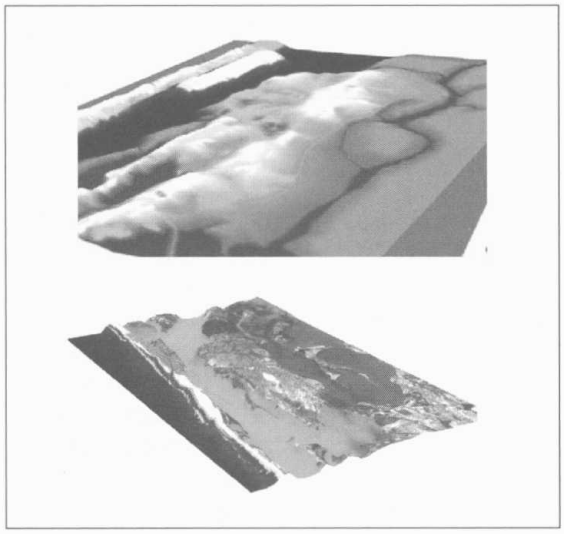


Figure 12b. DTM of the town of Saint-Louis

The traditional method of satellite data combination (Spot 4) and the gathering of important information made it possible to produce a Geographical Information System to monitor floods in the lower estuary of the Senegal River valley. Remote Sensing, DTM and GIS seem to be powerful tools for combining important information for a better comprehension of the floods and the characterization of surface qualities on the estuary.

We developed a Geographic Information System including approximately many layers of local and/or regional spatial data. We backdated relevant parameters such that the GIS is both uniformly formatted and historically accurate. With this GIS in place, we are able to assess the flood extension.

By a multi-temporal approach, we established the qualitative and quantitative impact of floods on the various geographical objects, a detailed cartography of the occupation of the ground, 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.

LESSONS LEARNED

African countries know unceasingly and almost each year dramatic natural disasters. It is the case in particular of Algeria (with repetitive earthquakes), Mozambique, Zimbabwe, and Senegal (which was struck by floods). Many of these disasters especially affected poor populations and had serious effects on the already fragile and unstable local economies. Their consequences are all the more serious as these affected populations do not have the means of being protected from such catastrophes and the States could not set up true policies or strategies of prevention or reduction of the natural disasters. The few rare strategies are often inappropriate and dedicated to the failure.

Disaster risk reduction and management approach is relatively new in concept as well as in practice. Although a few countries have adopted risk

management concepts and principles in disaster management, most countries, especially developing countries, remain unfamiliar with this approach. The prevailing practices, particularly in Africa, are more inclined towards managing response to disasters (which requires preparedness) than towards managing risks and the underlying conditions that lead to disasters (which requires, among others, risk assessment, vulnerability reduction, and capacity enhancement).

In the Senegal River valley and estuary for example, poor and socially disadvantaged groups are usually the most vulnerable and affected by floods These disasters, in turn, are a source of transient hardship and distress and a factor contributing to persistent poverty. Indeed, at the household level, poverty is the single most important factor determining vulnerability In Senegal, the prevalence of poverty is very high In 1994, the first Household Budget/Consumption Survey (ESAM-I)[4] made it possible to estimate the proportion of households below the poverty threshold (fixed at 2,400 calories per adult equivalent and per day) at 57.9 percent. On the basis of extrapolations made from the CWIQ[5] (2001) data, the percentage of households below the poverty threshold is about 53.9 percent, i.e. a slight drop compared with 1994, as a result certainly of the increase in per capita income over the period 1995-2001 However, these figures are well below the findings of the EPPS[6] (2001) according to which 65 percent of the households interviewed (same sample as the CWIQ) consider themselves poor and 23 percent even rate themselves as very poor. Moreover, 64 percent of the households declare that poverty has worsened over the past five years, a perception that is contrary to what is stated above. This apparent contradiction undoubtedly results from different criteria for assessing poverty.

Poverty in Senegal is located for a large part in the rural areas and more especially in the rural zones of the Center, South and Northeast. This concentration of poverty in rural areas is also confirmed by the EPPS (2001): in point of fact, in rural areas the incidence of poverty varies between 72 percent and 88 percent while in urban zones it ranges between 44 percent and 59 percent In both cases, the incidence of poverty remains high This situation is especially worsened by the floods which strike the rural populations. For example, the floods that swept through Senegal between 9-11 January 2002 led to the loss of 28 lives, with over 100,000 other affected. A damage assessment revealed that an estimated 105,471 head of livestock had perished and 13,993 homes here demolished. As much as 581 ha of crops were washed away. Approximately 1,537 tons of rice was also destroyed

The 1994, 1999 and 2003 floods in the basin were also unusual, for both their 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 Flood impacts have been severe in the zone 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.

Thus, to attenuate the impact of the natural disasters on the poor populations, it is important to undertake in-depth studies on the relation between disaster and poverty. Our project tries to tackle this question in the Senegal River basin by using space technology to map the floods extension and thus to identify area and populations which are touched or which are in danger. The establishment of this project provided a beginning of coordinated approach to a flood mitigation strategy for the Senegal estuary and lower valley. Since 1999, the local scientist community and local authorities try to made good progress in addressing the existing flood threats in the area.

The Government of Senegal, for instance, identifies floods in the Senegal River as one of the factors eroding the income of the poor populations via crisis-related expenditure and reductions in income earning capabilities. Furthermore, it recognizes that poverty alleviation cannot be achieved simply by increasing income, but instead requires a range of other measures, including the strengthening of local capacity to protect the poor against these floods.

In this case, recent catastrophic floods (2001 and 2003) all over the basin have raised new questions as to traditional approaches in dealing with such extreme events. The increasing occupation of floodplains around the city of Saint Louis in the

[4] Household Budget/Consumption Survey

[5] Core Welfare Indicators Questionnaire

[6] Household Survey on Perception of Poverty in Senegal

estuary, competing and conflicting developmental demands in the lower valley have exacerbated the impacts of floods on society and the environment. Furthermore, the concerns of human vulnerability and an environment that can be further mismanaged or abused, have focused attention to the need for more integrated, anticipatory, and far-reaching water policies and strategies. Understanding and responding to floods requires a comprehensive view of intervening environmental, social and economic factors. This calls for joint approaches by all relevant national agencies, as well as for the development of integrated support strategies by international agencies with expertise on the subject, as UNEP (United Nations Environment Programme) or UN/ISDR (International Strategy for Disaster Reduction).

The Senegalese Government should continue to give priority attention to its strategy for Disaster Reduction as a common platform for responding to the challenges presented by the increased incidence and scale of floods in the lower valley.

The analysis and lessons learned from prior experiences of floods help to define profiles of risk attached to people, activities and places that share attributes, in the face of particular potential sources of damage. Understanding risk relates to the ability to define what could happen in the future, given a range of possible alternatives. Assessing risks, based on vulnerability and hazard analysis, is a required step for the adoption of adequate and successful disaster reduction policies and measure in the Senegal River estuary.

The project allows us to carry out several fields works and to collect many information and data related to the floods and to carry out a 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.

This project meet a double aim, on the one hand to better include/understand the dynamic of the floods in the estuary, on the other hand to produce documents for early alarm in direction to the authorities and to place at their disposal tools of decision making. Its purpose was to provide a preliminary approach that can be used as a demonstration of the capabilities, applications and advantages of satellite images, and as a guide for future investigations. Remote Sensing technology has its special superiority and potentiality for flood monitoring and assessment, so it has been applied for this purpose in this project, especially for the disaster resulting from floods. A lot of scientific and practical achievements have been obtained in the study area. The information on inundated area and the variation of river channel was successfully obtained. In 1998 and 1999, by using the SPOT satellites images, the floods occur in the lower estuary of the Senegal River were investigated separately. After that, a lot of local experts recognized the importance of remote sensing image data for disaster risk reduction especially for the town of Saint-Louis in the lower valley and suggested to set-up the real time transmission system of airborne remote sensing for disaster monitoring with data providers.

This is a pilot study, and has not been subject to the rigorous calibration and validation exercise normally expected in a more advanced risk reduction assessment. This means that the results and findings should be considered as preliminary. Our project has thus the merit to apply such a step and to have satisfactory results. The GIS developed constitutes a tool of decision making aid for governmental and local authorities.

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