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Full Length Research Paper

Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal)

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Rapid development of urban centers in Africa is becoming a serious challenge for the coming decades with a wide range of foreseen social, economical and environmental implications. With the natural growth of the population, urban demography has been boosted by rural exodus triggered by serious droughts and increasing rural poverty. With the small resources available for an adequate urban management and the lack of efficient urban policy, Dakar capital of Senegal is characterized by an out of control urbanization process. Among the many impacts noted, flooding has appeared recently as a major threat for poor population leaving in the suburbs of Dakar. This study carried out at the outskirts of the town, in Yeumbeul District (17°24' North, 14°46' West), tries from rainfall variability, Digital Terrain Model and land cover change analysis since 1954 to track the interactions between natural and human causes of flooding occurring regularly since 1989. This integrated approach shows that the flooding process is not a mere climate variability related issue, it is tightly bound with poor urban management and occupation of irregular, unsuited land devoted to natural process. Satisfaction of housing needs was, for most poor rural dwellers, only possible through informal land markets, forcing them to settle in cheap yet risky lands. The recent extreme rainfall events reveal that most of these urban sprawls are located in flood prone areas. Environmental impacts of these flooded settlements have been examined. Serious flooding of 2005 has been a great momentum for the State and several other stakeholders to initiate various strategies that are discussed in this paper.

Key words: Flooding, rural migration, irregular settlements, Dakar, Senegal.

INTRODUCTION

The rapid urban growth

Urban development in Senegal is portrayed as an out of control process because of the very rapid development of the metropolis capital Dakar (Dubresson and Mbow, 2000; Seck, 1970; Mbow, 1992; Sakho and Soumah, 2000). The reasons of this are the rapid growth of population and settlements over time while a limited effort is made to better manage urban areas particularly in the outskirts of Dakar. The sharp increase in the urban population in Dakar is contrasted by the meagre growth of its economy. This has produced an urban infra-structure and level of services that has not kept up with the growth in demand.

In general terms, an unplanned urbanization process is linked with a rural exodus in Dakar that significantly increases the population of unplanned settlements since the seventies. The movement of rural dwellers during this period was triggered by extreme climate variability starting with the drought of the seventies (Goldsmith et al., 2004). The current picture of the present flow of rural

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resettlement is due to the eagerness of these migrants to financially enrich their lives by seeking employment in urban areas. Chain migration becomes a base on continuing population movement in Dakar when initial driving factors are vanished or mitigated.

The urban growth of Dakar is estimated to 7 - 8% per annum with only 2 - 3% due to natural growth. The number of populations of the whole agglomeration is 2.5 millions of persons representing 54% of the total urban effectives. Dakar covers only 550 km² with population density in suburbs passing 8000 habitants per km² (Enda, 1998; Soumah and Sakho, 2000). These figures are beyond the capacity of the State and local county possibilities to prevent undesirable effects of the uncontrolled urban growth. The environmental impacts and socio-economic implications become a high concern at various levels and stakeholders, while limited resources are available to manage the situation (Ndiaye, 1992). General statements agree on the development of urban sprawl as mainly associated to the extreme poverty conditions of rural areas that cause big migration in the capital with an extensive build up of non integrated habitations in unsuited lands in an atmosphere of winding streets, uncontrolled shantytowns of recycled materials from land fields or recuperated from other urban activities. The main particularity of the study area (Yeumbeul, in the north of Dakar), is the occupation of depressions which are normally occupied by streams and natural vegetation. The Human Development Index estimates that 47% of the Senegalese population lives in urban areas, and 25% of those urban zones are illegally occupied.

The land occupation problem

The development of under-integrated urban districts results in several ecological transformation from actions affecting quality of landscape and life standards (UICN/WWF, 2002). One of the most recent impacts of rapid land use change in Dakar has been the recurrent flooding in the irregular suburbs. Several serious flooding occurred in 1989, 1996, 2001 and 2005, but no sustainable solution has been taken for subsequent mitigation. In Yeumbeul where this study is carried out, flooding is triggered mostly by poor land management and is revealed by natural factors such as rainfall variability and near surface water table conditions. The combination of natural factors and human factors underpins complex interactions between ecological processes and the human shaped landscape in the suburbs of Dakar. These interactions results in a large spectrum of impacts with flooding as one of the most worrisome during the last decades. This complexity make it difficult to build theories or suggest conceptual models that fit in every policy sketch as most of these are very sectorial and not that prospective. Few of the several policy choices from various overall development plans such as the *Plans de Développement Urbain* (PDU) have not been applied as suggested because the numerous barriers. The barriers could be economical (budget), institutional (roles and responsibilities), social (lobbies) and time delay (when published the figures from which solutions have been proposed are over passed).

The urban sprawl development leads to a shift from natural land cover to a greatly reduced and highly fragmented landscape. The initial natural state is first affected by natural disturbances, then come through human threats and the end of the process is a particular fragmented urban pattern and an increased substitution of ecological functions with human functions (Alberti et al., 2006). This overview is particularly true for Dakar, which original colonial name was Cap Vert (The Green Cape) because of luxuriant natural vegetation associated with a typical azonal ecosystem called Niayes. The situation now shows the highly reduced natural function of Niayes to support human functions mainly housing needs.

This rapid changes in Dakar suburbs is triggered either by the action of slowly changing variables (population growth, rainfall progressive decline) and/or by relatively discrete chocks (periodic droughts, extreme rainfall events). The combination of slow acting variables and rapid yet strong chocks from extreme events are together the basis of various forms of population and landscape dynamics.

The livelihoods and poverty in urban extensions

The particularity of Yeumbeul is the low level of income of residents (Sané, 2003; Enda, 1998; Wade, 1997). This shows that, while migration is caused by poverty, the later becomes potentially a clear route towards poverty enforcement rather than a solution for a sustainable life. The satisfaction of the existence basic needs and the improvement of the living conditions are the main motives of the migration processes. In parallel, population pressure on land, due to serious reduction of soil fertility over years of extensive agriculture plays a role in the redistribution of the population in big towns. Sub-urban areas development in Dakar could be also seen as a result of an emerging living standards imposed by the weak performances of the underdeveloped countries economy and particularly to the non competitiveness of the agricultural sector. Urban megalopolis is an area where rural migrants can reproduce their social affinities and their group solidarity base on chain migration, while satisfying jobs requirements either formally or informally.

This process of poverty displacement from rural areas to urban areas explains that the lower income people are pushed to occupy sites with fewer amenities and greater environmental risks. This underpins various social, in-

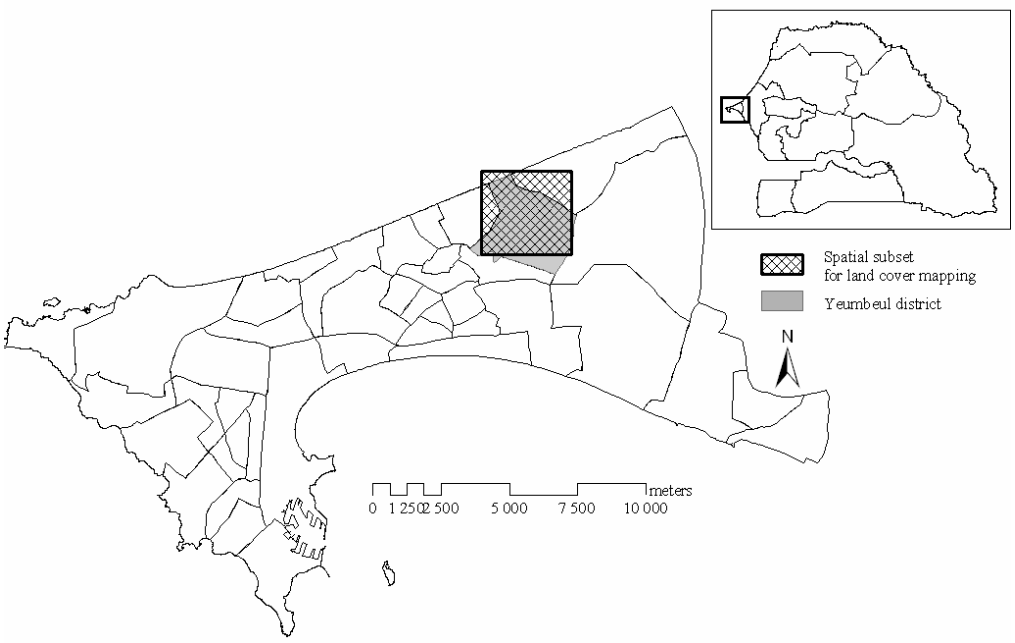

Figure 1. Location of the study site.

inequity, lobbying, progressive marketisation of housing of lands depending to amenities available and hazards proneness of the site (Alberti et al., 2006). When the government steps back on the housing business several real state companies come to the play with real liberal behavior with no place for poor citizens. This was a starting point of the daring attitude pushing people to settle in irregular sites that could be regularly flooded during the rainy season with several environmental/health consequences.

This paper is an attempt to track back the evolution of the suburb landscape and tries to analyze the main driving factors of flooding with their social and environmental consequences.

METHOD

The complexity of the issue developed in this paper required a combination of various tools to generate synthetic information related to causes, consequences and management of flooding. The method used spans mainly spatial techniques (land cover mapping, digital terrain model), field interviews (focus groups, individual interviews) and exploration of climate data and ancillary information related to urban development and management.

The analysis of flooding, in the Yeumbeul context, needs the development of a minimum conceptual framework that helps better understand the methods of this study. Flooding is understood in this study as water invasion in build up land in an urban context. To analyze such a process it would be a possibility to use conventional optical remote sensing or Radar data to trace the spatial extent of flooded houses. Both techniques in a city like Dakar are associated with a blurred perception of zones affected by flooding (Dia et al., 2006). The reasons are: i) flooding occur during the rainy season when it is extremely difficult to get a cloud free optical image; ii) Radar images in an urban context come with a lot of speckle that hinders a clear-cut image interpretation; iii) the building in the flooded areas hides the extent of water. Moreover, the scope of this paper is not to map flood extent but to generate spatial evidence that explain why flooding occur in an African city and how this has been managed locally.

Study area

Yeumbeul (17°24' North, 14°46' West), is located in the Department of Pikine at about 18 km from Dakar main center (Figure 1). The small Commune d'Arrondissement has 60,000 persons on a total surface of 9 km². The population density is very high (6600 habitants/km²) most of residents are migrants from the rural areas except the group of Lebou who are native of the original village (Wade, 1997; Enda, 1998).

The original Lebou village was continuously extended. During the drought from 1968 to 1984, several new settlements from immigrants (rural exodus) have been established. The most accessible land for housing was therefore the dried depressions. In parallel with the increasing immigration, the ethnicity becomes more diversified with incoming Diola, Serer, Pular and Mandinka in addition to the Wolof Lebou. These ethnic groups tend to conger-gate in specific location to maintain social affinities.

This new demographic situation bound with poverty was the basis of a rapid development of the informal sector with small trade, waste recycling, peri-urban gardening with subsistence and commercial crops in a progressively polluted or salted water table context and a rapid degradation of the physical environment.

Drinking water supply in Yeumbeul is very poor and household connected to the freshwater network are about 5% of the total (Diop, 2006). There is a drastic lack of sanitation system with waste water directly released in the rest of depressions (sludge traps) or individual pits. Inversely there are more than 55% of household connected with electric network (Diop, 2006). One single health

center and maternity home is established.

Yeumbeul is in some extent a dormitory district because of its high number of labors operating in other sites of Dakar agglomeration (waste recyclers in landfills, labor in fabrics, guardians in companies, small business in the streets of Dakar, etc.).

The physical context of Yeumbeul shows low altitudes (< 12 m), sandy dune soils on hills and clay/vertisol soils in depressions where the static water table level varies from 1 to 4 m. Natural vegetation is dominated on sandy soils by Sahel-Soudanian species (*Faidherbia albida*, *Acacia sp.*) and depression by Guinean plants (*Elaeis guineensis, Cocos nucifera, Ficus sp.*)

Land cover mapping

Using GIS tools and spatial data, land cover maps of the study area has been made. The Land cover classes' discrimination was based on a visual interpretation of images covering the study area in different dates: aerial photographs of 1954 and 1978 and Quickbird image of 2003. The visual interpretation of the aerial photographs was based on an interpretation key driven from image patterns and thematic meaning of dominant classes. Dominant land cover classes (water, humid zones, houses, gardening/agriculture, natural vegetation, tenure reserved by the Sate, dunes and plantations) are considered in the mapping classes. Translation of the interpretation key on the Quickbird image was simple and straightforward because of the ease associated to the reading of spatial pattern in this high resolution image.

The choice of mapping dates is bound with the following rational: the 1954 date is to picture the situation before the independencies when the region was not that populated and when the traditional housing system dominated the study area. The 1978 date shows the situation following the drought of the seventies and the 2003 date is a proxy of the actual situation. Trends of surface on various cover type have been analyzed based on surface comparison.

Validation of mapping results was based on field observations and historical profile made with elder persons of the area and old topographical maps showing some previous landscape characteristics.

The land cover dynamics analysis has been supplemented with a delineation of flood prone areas using a Digital Terrain Model (DTM). This DTM has been driven from the USGS SRTM (Shuttle Radar Terrain Model) in 90 m resolution. A superimposition of GIS layers from the National Mapping Service (*Direction des Travaux Géographiques et Cartographiques*) was made to see the extent of low lands occupation. This flood risk assessment using a DTM was based on direct GPS data collection on flood prone areas that was used for the subsequent raster DTM segmentation. In addition, the Quickbird image has been used to delineate the houses occupying depressions and already subjected to a very high risk of flooding.

Data and information collection

To gather information on most important driving factors of land cover change and its relation to flooding, some simple interview guides have been implemented. Focus group and individual interviews have been carried out to collect qualitative data on causes of flooding, impacts of land occupation, history of land occupation, constraints of depressions occupations. The interviews have been directed to various stakeholders including: women associations, elder persons, youth associations, flooded house owners and technical sectors such as health, town hall technical services, the state local administration and urban managers. The information collected was analyzed using a matrix to organize most recurrent information and citations that sustain arguments of the various ideas related to main questions of the interview guides. In addition, secondary data exploration has been made for health issue, policy and strategies for a better management in the outskirts of Dakar to avoid flooding. The results of this information collection have been qualitatively analyzed to get the mainstream arguments on the local perception of flooding and evaluate initiatives taken by various stakeholders.

RESULTS

Land cover dynamic in Yeumbeul

The land cover change map is based to main cover types that are relevant for flooding analysis; these are namely houses, agriculture, water and humid areas. The Figures 2 shows from 1954 to 2003 a rapid development of settlements while any other covers including humid zones, empty space occupied by natural vegetation or agricultural areas have been seriously reduced. Progressively, the housing progressed towards the fringes of humid zones and via a filling up process (accretion or polderization), local population managed to "gain lands" in *non aedificandi* areas. Later the heavy rainfalls reveal these areas as part to the stream network.

As shown in Table 1 the surface of house outrage any other cover type in the study area. While in 1954 natural vegetation was the dominant land cover type, the 1978 picture shows a competition between houses and agriculture (peri-urban gardening development), and lately in 2003 no place for either extensive agriculture, or natural vegetation. From vegetation dominated lands, we ends with housing dominated land (Figure 2). Quantitative figures of the land occupation are given in Figure 3 and Table 1.

This information is important when addressing the flooding issue because it shows that the water did not come to houses, the houses went to where water was supposed to flow. Most of the populations settled in Yeumbeul are originally farmers from the *Lebou* ethnic group who settled for market gardening and fishing activities. Before serious drought affected the area, there were several humid zones in the area (*Tiourour, Ouarouaye, Youi, Reumbeut, Ganar, Yawax* and *Ndianax*) with very productive soils that was a big opportunities for counter season agriculture (Figure 2). Lately, this peri urban agriculture was an important activity both of the natives and for poor migrants ho had better market access and good production factors (water, fertilizers). Before the drought the migration rate was very low in the area and the dominant group of *Lebou* was settled on a top dune site with no flooding risk (map of 1954, Figure 2).

With the severe drought of the seventies, most of these fields where abandoned, leaving large empty lands that become in a short run a big housing potential for poor citizens. During that period, important immigration flux resulted in a land demand so important than almost every new comer had better deal to occupy the empty lands of former fields, than trying complex and expensive land te-

Table 1. Surface evolution of the different land covers types.

Land cover type	1954		1978		2003	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Coastal dunes	78,55	7,84	1,00	0,10	1,81	0,18
Houses	46,77	4,67	224,52	**22,38**	548,52	**54,71**
Agriculture	136,61	13,66	316,16	**31,52**	183,8	18,33
Vegetation on dunes	456,23	**45,48**	227,28	1,50	14,97	1,49
Vegetation on niayes	94,51	9,42	52,20	3,79	38,87	3,88
Water	69,53	6,93	22,30	2,22	32,76	3,27
Humid zones	67,56	6,74	122,41	12,20	37,81	3,77
Bare soil	39,96	3,99	14,16	7,70	77,17	7,70
Plantations	12,99	1,30	23,19	6,68	66,96	6,68

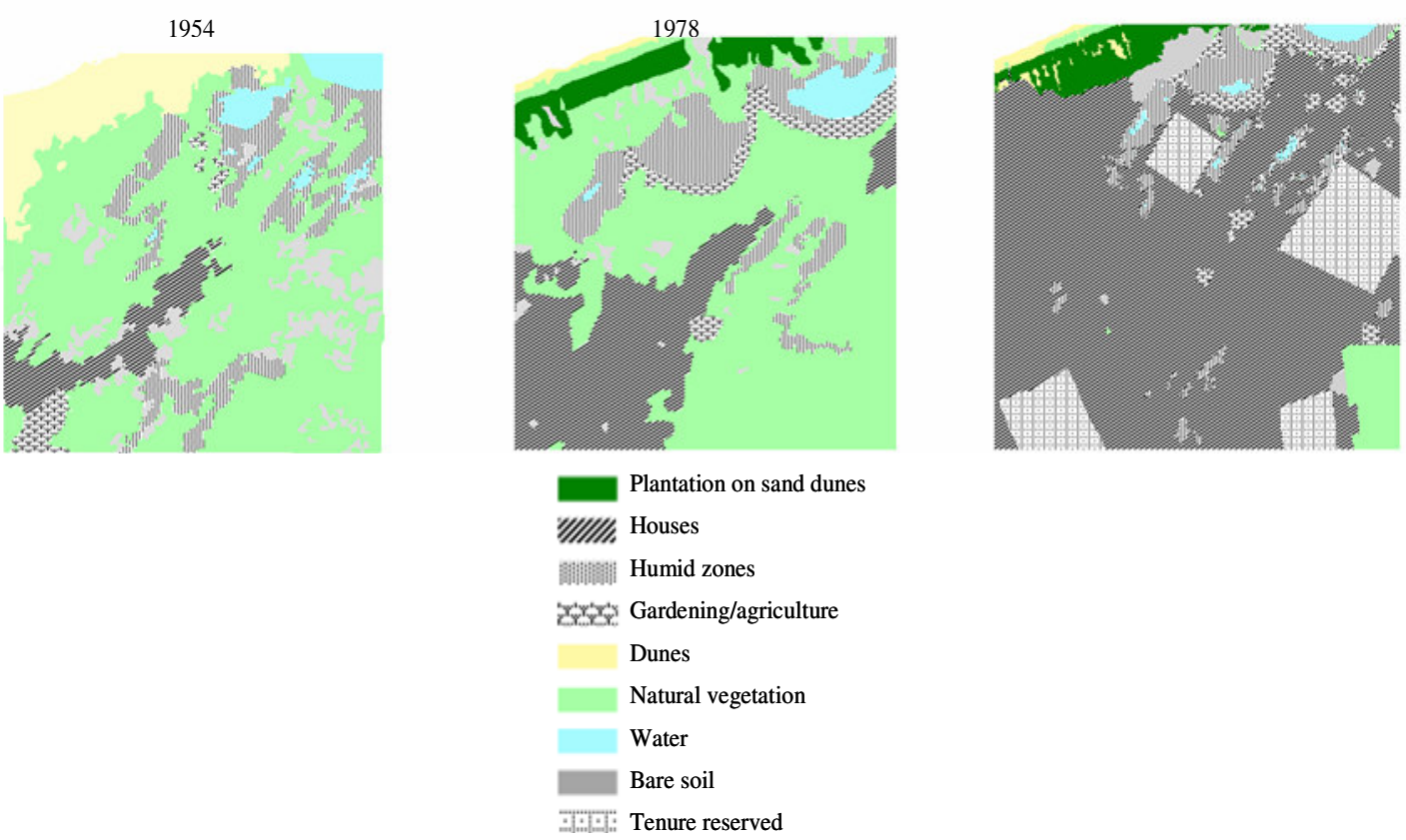

Figure 2. Yeumbeul housing extension from 1954, 1978, and 2003

nure processes.

The land occupation was therefore based on 'irregular' land access because rural immigrants did not have any propriety rights on the land and there was no authority that prevented this occupation. The result is a non organized land occupation with temporary shelter first and a continuous upgrade of the house depending on how successful are the activities of the family in getting important income they could invest in better housing. In any case, the occupation of depressions kept a positive strong trend that played an important role in the flood risk exposed to resident.

Causes of suburbs flooding

There are three major causes of flooding in Yeumbeul:

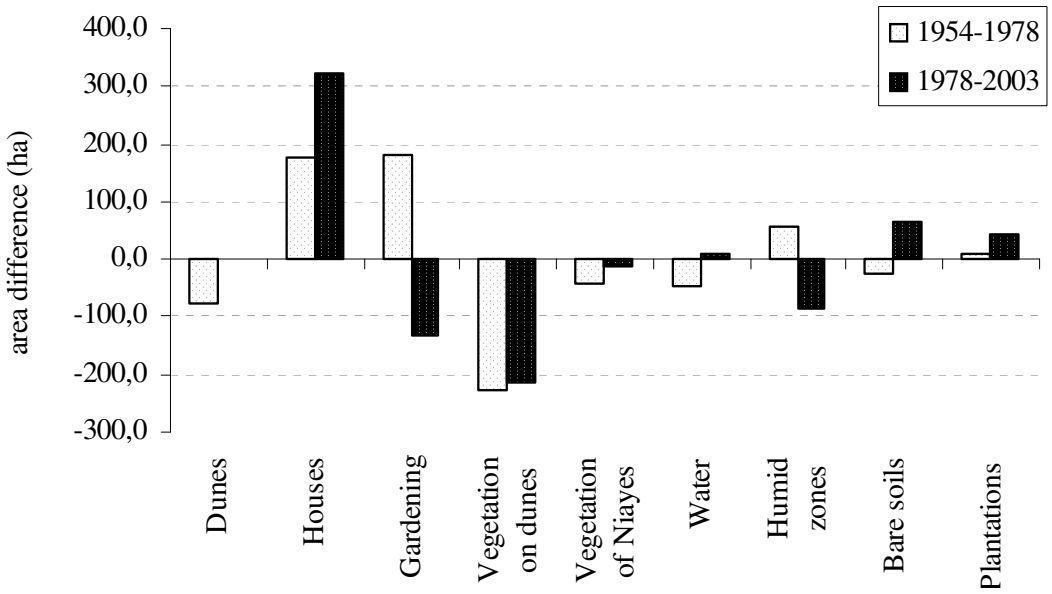

Figure 3. Positive and negative evolution of various land cover types.

the natural causes, the human causes and external factors. These causes are very difficult to isolate in an integrative or systemic analysis that aims at giving the general picture of flooding. Therefore, the highlights given for each of the causes are a synthesis of overall aspects explaining the severity of the flooding issue in the study area. The possible interactions between human cause and natural factors are shown in Figure 4.

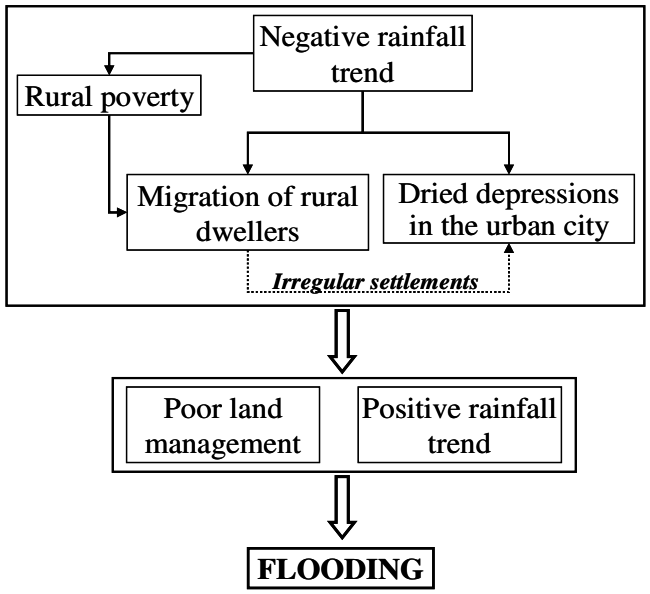

Figure 4. Conceptual model of flooding in Yeumbeul (Dakar-Senegal).

Natural causes

The natural factors are twofold: the topography and the rainfall variability. Large parts in Yeumbeul are characterrized depressions called Niayes (Figure 8). The risk of flooding occurs in sites below 5 m high which are 40% of Yeumbeul settlements sites. The water table is near surface in these depressions (< 1 - 2 m). The high altitudes are about 10 - 15 m on sand dunes where the original village was built. The fact of setting houses in normally flooded depression is one aspects of the vulnerability of these settlements.

Another natural factor is the extreme climate variability which is associated to several important processes impacting on the flood issue. One aspect of climate variability is extreme droughts during which the depressions in Dakar get dry and become a possible housing site for most of the poor migrants from rural yet unproductive lands. As rainfall variability usually takes reverse trends, the good rainfall years are associated with rapid water saturation of occupied depressions causing serious flooding (Figure 4). Climatic variability plays an important role in the way it stimulates the mobility of rural population towards Dakar. Regressive evolution of rainfall in Senegal since the seventies (Figure 5) is considered as one of the most significant trigger of migration among other possible responses to climate variability. Statistical analysis of rainfall trends shows the rapid drop of rainfall in the seventies that tends to continue with few back trends. In general several deficit periods occur since the seventies punctuated by good rainfall years (Figure 6).

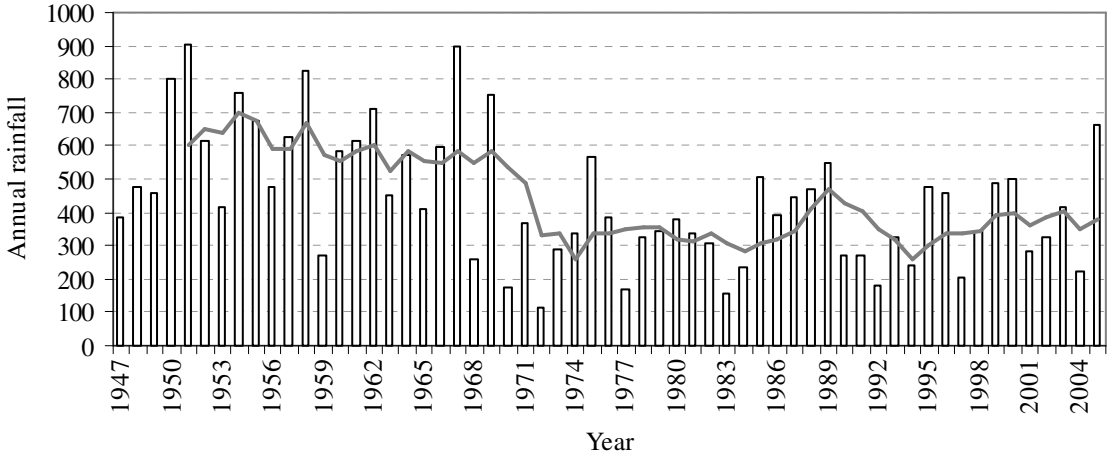

Figure 5. Long term rainfall variation (In Dakar Yoff: 14°44'N/17°30'W) showing the rapid drop of annual rains from the seventies.

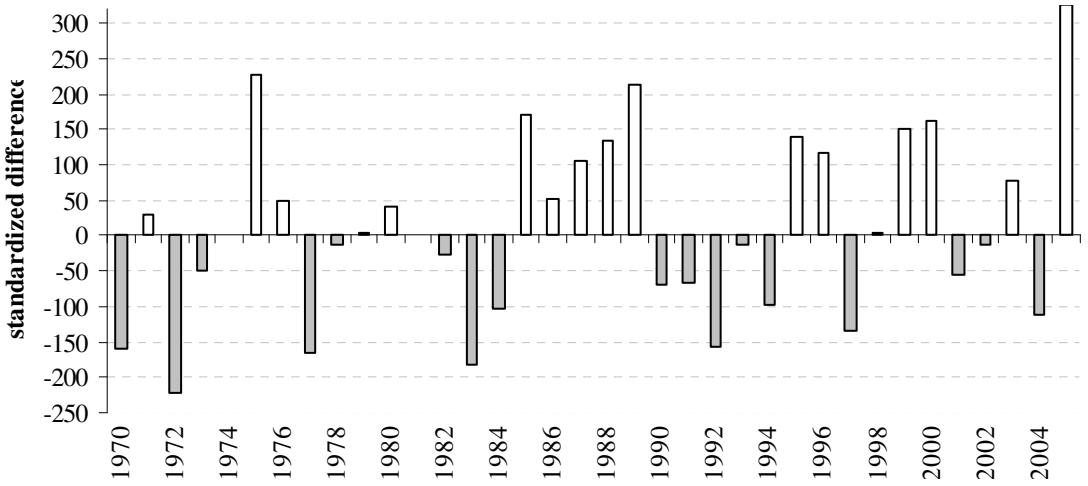

Figure 6. Positive and negative evolution of rainfall in Dakar-Yof

Results of these successive droughts are starvation in rural area, bad crop production, heavy mortality of herds, deeper poverty conditions, low resources and income, overpopulation, etc. All these being push factors with a lot of candidates to migration mainly in Dakar.

The periodic droughts are interrupted by some humid sequences as shown by Figure 6. The most important humid years are (1975 - 1976; 1985 - 1989; 2003 and 2005).

The flooding occurrence is according to Sakho (2006) not due to total rainfall alone it is also associated to quantity of rain water in a small span of time. Some illustrations are the flooding of 1989 and 2005. The former occur in 550 mm/year and the later under 662 mm/year; none of these total rainfall was the highest registered in Dakar during the past. The years 1950, 1951, 1958 and 1967 had all a total rainfall exceeding 800 mm/year. The most related rainfall parameter to flooding is the rainfall sequences during the pick season in august (Table 2). These heavy rains in a short time are the main cause of flooding in relation to the installation of settlements in depressions. The total rainfall acts as a cause of saturation of the water table whilst the distribution of rains over a short time is kick off factor of water accumulation in occupied depressions. The absence of housing in depressions from 1950 to 1968 explains why flooding during this period was with no direct negative impact on population.

On another hand, during the very dry years, the salty water from the ocean invaded the water table (saline intrusion) and renders the market gardening (peri-urban agriculture) not widely possible, so these lands had not

Table 2. Rainfall sequences during the month of august in Dakar for two flood occurrence years (1989 and 2005).

Year	Rainfall sequences
1989	1st-2nd august : 61,7 mm (in 2 days) 11th-16th august : 75 mm (6 days) 24th-26th august : 202.1 mm (3days)
2005	16th-17th august : 87.4 mm (2 days) 19th-22nd august : 184.5 mm (4 days with a pick in the 21st) 28th-31st august : 55.2 mm (4 days)

Source: Sakho (2006).

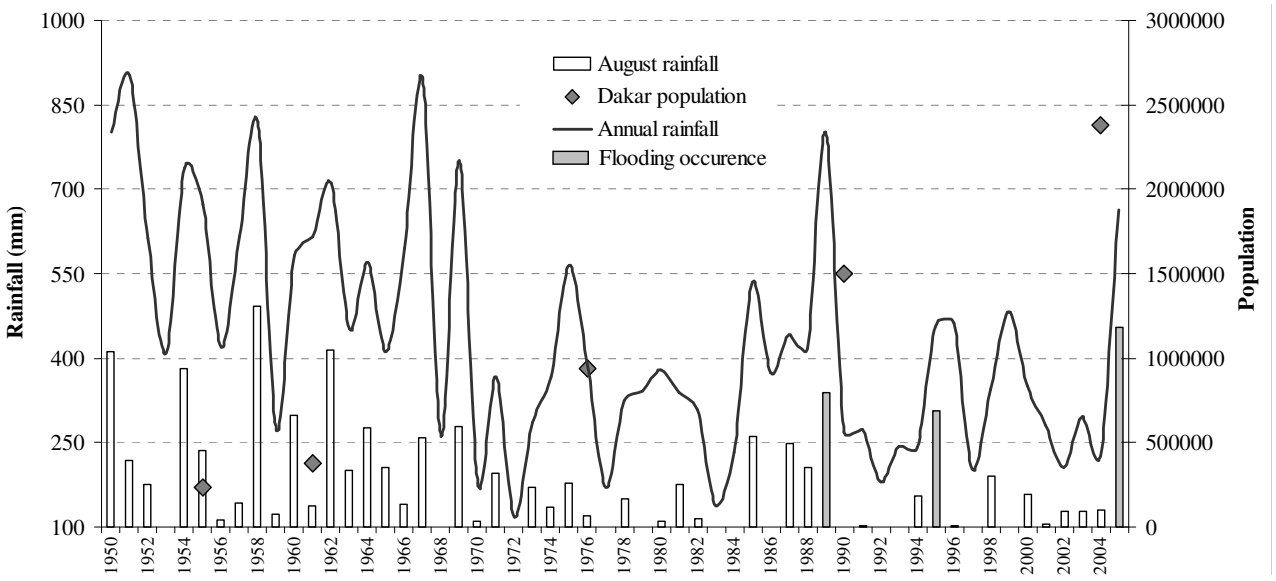

Figure 7. Rainfall variability and rapid housing trends in Yeumbeul.

other value than hosting houses of poor migrants.

Human causes

The human factors that can be cited in the flooding occurrence are numerous and can be complex local triggers or external macro issues. The first important factor is the outstanding migration from rural areas following the drought of the seventies. The vulnerable rural population dependant to rainfall for production was forced to migration in urban town for a gloomy hope a source of income (Goldsmith et al., 2004). The land available to satisfy extended needs of new houses construction is the abandoned lands near water stream. The land acquisition system is the informal pathways which are easier (from person to person) and correspond to the rural way of tenure disposal. For a symbolic amount of money, with no administrative requirements, rural migrants gained lands for housing in non planed areas previously dedicated for natural process or agriculture. This situation did not reveal any risk until the rainfall comes back. The come back of the rainfall shows not only that the water finds its original track occupied by migrants but shows that there is no space left for rainwater infiltration (surface compaction by housing) leading to a strong runoff which favors rapid flooding situations. Indication of flood proneness of these depressions is according to interviewees the proximity of the water table (< 2m). This did not alert the new settlers who defend not having “any alternative” revealing their deep fatalistic attitude.

Moreover, with the infrastructure development, a network of roads and buildings was made inside the water streams without any drainage system. The hydrosystem was therefore totally disturbed. According to some technical services this situation is due to lot of new low points created, no through-flow planed and a lot of water stagnation generated. Facing the solid waste evacuation problem, people release their wastes in depressions making

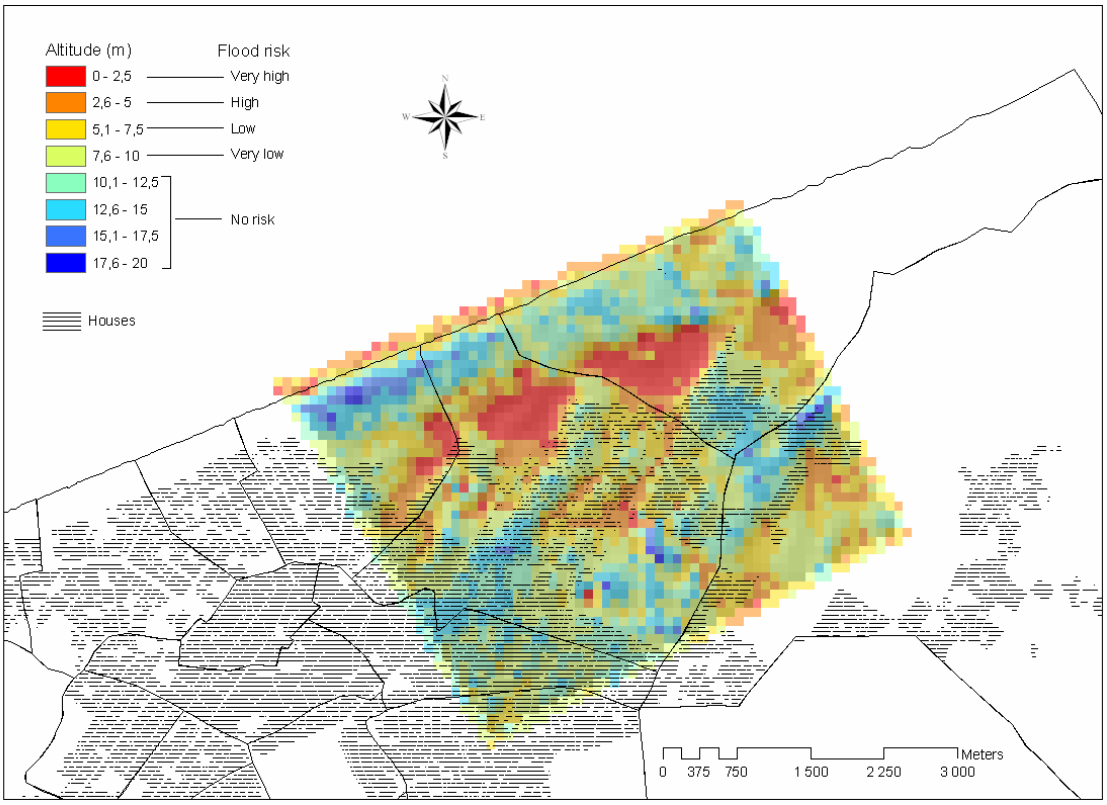

Figure 8. Flood prone areas derived from a DTM (SRTM, 90 m resolution) and the urban structure of Yeumbeul.

Table 3. Water borne diseases consulted in the Health centre at Ainoumadi SOTRAC (Yeumbeul).

Diseases	% of patients
Malaria	46.3
Verminosis	9
Dermatitis	8.1
Dysentery	7.2
Diarrhea	4.0
Total	74.5

them less receptive to water with a serious clogging process. Most of the depressions have more than 3 m filled up from their original bottom level. On attempt by doing so is to recover some spare land for possible housing. The possibilities for these depressions to contain water become very shallow. In addition, with the water table pollution (nitrate more than 200 mg/l), the water company stops using the water table in Thiaroye for drinking water as the WHO standard is 50 mg/l (Baldé, 2006). Since then, the water table rises up and become very close to the surface. It requires not much rains to have the area completely saturated and flooded. Figure 7 shows the interaction between climate variability and the evolution of the surface of settlements in the study area.

This Figure 7 shows that flooding cannot be explained by the mere climate variability, which just reveals it. The most important factor is the human factors with the poor management of land and the occupation of depressions (Figures 8 and 9). A Quickbird view of a portion of the study area shows houses which are located in flood prone areas (Figure 9).

Finally, another human dimension factor is the lack of a strong group dynamic to address the flooding issue. The social links are very strong when it comes to other issues such as cultural events, politics or religion. Individual solution are most foreseen, when the city mayors tries to raise awareness and bring prompt solutions to the problem (Figure 9)

External factors

The drought appears to be the strongest factor of this urban sprawl development leading to flooding. At the same time with the rainfall decline, the international market for peanut showed clear reduction of the export peanut price. The per capita agricultural production index (base year 1989 – 1991, 3-year average) has decreased

Figure 9. Quickbird view of a portion of the study area (2003)

by almost 50% (Goldsmith et al., 2004). The price at producers become not competitive compared to other job opportunities in urban areas. At some extent being a waste recycler is more benefic than trying to produce cash crops with little income mainly when rainfall decline, soil poverty increases and land become scarce. The new overpopulated situation associated with the international market trends was big push factor for rural exodus in cities.

The international crisis during the seventies was also the oil crisis with the energy issue absorbing most of the state resources leaving rural population with no subsidies or subsequent help to get out of the drought impacts. Lately occurs the Structural Adjustment Plan “suggested” by the World Bank to help the third world to pay back their dept. This created a situation where the State could not support any more the agriculture and the rural areas become lonely facing big survival challenges. Other connected factors render the situation more difficult to handle, these are the low increase in the economy, inflation, devaluation, budgetary deficit, low salaries, and high poverty rate of the total population. All these factors were triggers pushing rural people towards urban areas to generate a back cash flow (remittances) from urban to rural.

Some consequences of flooding in Yeumbeul

The most immediate and apparent impact of flooding as a consequence of the rapid urban development is the ecological disequilibrium. Dakar has been seen as the Green Cap (Cap Vert) because of the Niayes, it is now becoming the Grey Cap (Cap Gris) with substitution of natural ecosystems with buildings. The water stagnation with no runoff caused several ecological problems such as eutrophication, development of weeds such *Typha australis*, mosquito reproduction, and nest of several water born diseases. The survey showed that malaria is the most serious diseases affecting people the year round. As there is no sanitation or waste collection system, the remaining parts of the depressions become the land field and deposits sites of any wastes from household. Individual septic tanks are made in houses, but the low water table hinders any deep digging of the ground. Unfortunately, with the lack of running water a significant part of local water needs are satisfied using the polluted water table (Diop, 2006). Field information revealed also that local population has a negative perception of the quality of the ground water, but with no other alternative they argue using this water for cleaning purposes. From direct observation we notice some cases of consumption

of this water with a nitrate concentration ranging from 142.4 to 576.8 mg/l (Baldé, 2007) while the WHO fix the maximum concentration acceptable to 50 mg/l.

The consequence of all these aspects is the permanent contact between population and extremely polluted water with several health impacts. Water born diseases are dominant in Yeumbeul and the Table 3 depicts the situation in Ainoumadi-SOTRAC (a sub district of Yeumbeul) where the main medical interventions at the health center are water borne diseases (74.5%) (Table 3).

Very recently, local population mentioned that some emerging or re-emerging cases of cholera and typhus have been signaled since the last couple of years (2004 - 2005) as a raising health issue in these areas.

Field surveys showed another risk of house collapses associated to the occupation of these depressions, because of permanent ground humidity and the salt effect. It has been noted several house abandonment because of the lack of sustainable solutions against permanent humidity and basement decay of not strong houses built at best with small quantities of cement and most often with recuperated raw materials. The survey showed that a significant proportion of the houses are occupied by renters, the riche owners are living in decent, not risky areas. These owners do not generally invest in these low prices rented house, and are mostly motivated by the maximum profit. Therefore no long term sustainable efforts are invested in the houses, accept when the house belongs to the occupant. This general attitude explains in a large proportion the image of ruin of the area.

In a social perspective, the flooding generated several problems associated with the displacement during 2005 of a large number of households (climate variability refugees). More than 800 houses were flooded. The National Emergency Plan (Organization Régionale des Secours: ORSEC) came into play to rapidly raise some tents to shelter the victims. Several tents sites were built with peculiar name: Gannaar, Bujumbura, Sahara, etc. The naming of the sites by population mirrors the hard conditions of living, even when the government afforded food and medicines for a short period the first couple of months. Social affinities were broken and a lot of families tried to rent houses elsewhere rather than blurring their dignity in the tents. Others preferred to deal with the water and remains in their house. Education of most children was disturbed, because of distance and accessibility, but also acceptation and psychology of parents willing to find a solution against the flooding rather dealing with children education. Insecurity increases in these areas, with abandoned house becoming the target of robbers and hackers. In addition, the non standard electric connection system highest the electrocution risk (buried cables, almost falling electric mast). These social consequences are very well perceived by victims who try to improve their organizational skills to better set up strategies and rapid solution to their living conditions. Nevertheless, the survey showed a certain fear from local population because of the army controlling most of the tent sites.

The economic losses from the flooding have not been estimated, but for sure one can understand that the destruction of hundreds of houses and a lot of goods wiped out with runoff occasioned big investment loss. It has been very frequent to meet desperate people ho have to reconstitute decades of extreme efforts to set back a shelter for their family. In addition, some of the places flooded was working places (workshops, shops, small restaurants, fields, poultries, etc.) and became non functional after flooding, hindering income generation for some population. The recovering effort during the flooding aftermath was also very costly both for the State, NGOs and international donors. The main problem raised by local population is related to efficiency of the use of the budget by local decision makers. Some aspects of bad funding handling have been given during the survey. This situation underlines the requirements to improve public services for emergency situation when it comes to it.

Evaluation of strategies developed for flooding aftermath

The Senegalese government has taken some actions to move people out of irregular settlements. Soon after the flooding, many of the families living in depressed areas were relocated to tents where water and other basic necessities were provided by the government. This was the first phase of the Plan Jaxaay, a campaign to eradicate irregular settlements by providing alternative housing in predefined, government subsidized zones. Plan Jaxaay's leitmotiv is "one family, one roof" (MAHR/SA, 2006), an ambitious goal that seems unattainable due to the government's unwillingness to usher people out of their tents and into permanent housing (ISE, 2006).

The government presented several measures to encourage both developers and families to follow the new plan. First, the government has pledged to give free plots of land to developers and to exempt builders from import taxes on building materials that are to be used to relocate families from flood zones. And secondly, the government is offering a 33% subsidy on the purchase price of the finished houses for families who meet income eligibility requirements. This means that the new houses, which are projected to be valued at € 9,000 and € 7,000, will cost only € 6,000 and € 4,500, respectively. The mortgages on these houses can be paid off over ten years (MAHR/SA, 2006). Plan Jaxaay is far from perfect. Even with government subsidies, the proposed houses will be too expensive for most Senegalese families (ISE, 2006). Furthermore, no land has yet been donated to developers; instead, the government prefers to sell land to

Table 4. State versus population initiatives to overcome flooding.

State	Population	Structural measures	WFC	LOC	FOP
Subsidized houses (social house)		X		X	
Water collection during flood event	Water evacuation from houses		X		X
Canals and improved sanitation	Stream deviation	X	X		
Permanent pumping stations		X	X		
District restructurings		X		X	
Dikes and walls against flooding	Small water barriers	X	X		X
	Small bridges for mobility	X	X		
Inter-communality promotion	Community aid				X
Roads raising (higher that average terrain altitude)	House filling after building			X	
Emergency lodging (tents, schools)	Temporal house abandonment			X	X

WFC: Water flow control; LOC: Land occupation control; FOP: Flood aftermath operations

to wealthier people who can pay for it. The government has stopped funding the relocation settlements but that has not stopped people from continuing to live there. Tent villages were meant to provide only temporary shelter; however, many families show no interest in quitting now that they have relatively safe and inexpensive places to live.

In parallel, individual solutions have been developed by victims to minimize flood impact. Most of these individual strategies are short term and provisory options trying to orient water flow far from houses. Table 4 shows both State and populations initiatives to overcome floods in Yeumbeul (Table 4).

It appears in the table that there is heavy long term structural investments required to overcome floods and emphasis is given more on water flow control for flood reduction than on sustainable management of land occupation which appears as the real roots of flood occurrence.

DISCUSSION AND CONCLUSION

Several flood events occurred in Dakar this last decade. These floods are associated with several natural and human factors. The rainfall variability and extreme events have been pointed as the main factors, but we defended in this paper that the human factors and triggers are the strongest. One reason is that the come back of rains does not yet exceeds the level of rainfall 50 years ago and there was no flooding. Therefore, the development of urban sprawl in unsuited lands with no overall development plans explains the frequency of these floods in a wide extent. The extreme rains reveal the many problems of urban management, not only flooding but also sanitation system, services, accessibility, amenities and life quality and the socio-economy of the area. All these issues together raise several environmental and social-economic impacts. They require also a more comprehensive policy that satisfy the integration and cross sectorial requirement in a systemic way of management. We have to ban short time interventions on emergency situation for a longer term planning and policy implementtation. Moreover, these elements reveal the strong relationship between changing climatic conditions and changing socioeconomic conditions in Yeumbeul. This could be a good reason why the state should take into account these connections in the policy making and governance machinery.

Senegalese Government has made a democratic choice to decentralize several aspects of environmental management since 1996 (Law n° 96-06, Local Collectivities Code). Although laws have been established to decentralize government participation in urban development, land use remains a centralize responsibility for the Senegalese government. Nevertheless, the development of a community consciousness regarding environmental and housing concerns, participation in planing and collaboration between enterprise and administration should ensure the sustainability of urban development projects within resettlement.

In that context, an effort should be made at the State level to avoid new settlements in non suited lands (Vernières, 1973) and minimize the Government policy contradictions such as its opposition to the informal settlements, but provide them with telephone lines and water; both of which are necessities, but end up sending mixed messages (Diop, 2006; ISE, 2006).

On another hand, the flooding in Dakar shows institutional and administrative problems depicting a non clear

decision making boundary between various State decision platforms. In some extent that is the local mayor who is responsible, the later defending not having required means to face flooding. At the State level, at least six departments are connected with the flooding issue: the Ministère de l'Urbanisme, the Ministère de l'Environnement, the Ministère de l'Aménagement du Territoire, the Ministère de l'Intérieur, the Ministère de l'Hydraulique, and the Ministère de la Prévention. Coordination problems foster the Government to create a National Agency to tackle these physical and social aspects of flooding. Responsibilities of this National Agency are now dispatched to several Ministries, which is step back to coordination problems.

All these problems showed that the flooding as other environmental issues is not addressed in global terms and there is none such integrated policy to cover various aspects of the problem (Mbow, 1992; Ndiaye, 1992). In addition populations are not associated in the pathways definition to overcome the problem. One example is the Jaxaay Houses (meant social help of poor persons affected by flooding) did not take into account the resource capacity of incumbents.

Individual solution to face flooding spins various problems associated to the quality of equipment and materials used to minimize water flow. Sometime unhealthy materials such as organic component (rest of woods) or solid wastes are easier to access to fill up low points (ISE, 2005, 2006). The best soil for land filling is sand and is expensive to acquire (15 m^3 cost € 62) and out of reach of poor persons. In another hand when people manage to fill their house, then the building becomes too low and they need to raise the house up a bit more and this is another expense. A declaration of one resident gives a clear impression of the situation "In Yeumbeul, The persons do no grow (they do not get richer), but the houses grow (the houses are permanently fixed against total collapse)". Moreover, since there is no good sanitation system, the local population are investing a lot of money to fix the pits or pay for waste water evacuation (10 m^3 cost € 46). In extreme case they release the waste water in the streets during the night with several impacts in their own health. The final situation is a big amount of money invested, with always high possibility to get the water back because the area habited are located in flood prone areas. House abandonment follows usually with some psychological impact when leaving a certain social environment.

Analysis of some initiatives to prevent or mitigate floods has to be reconsidered as suggested below:

1. It is not useful pumping a fully saturate water table to avoid flooding, since the water keeps coming from the ground water table.
2. Emergency lodging suppose that better alternatives are found rapidly which is not the case, the tents and occupied schools etc., becomes big humanitarian issues (health promiscuity, violence, psychological impacts, education of children,…).
3. Rapidly built dikes or walls could not be enough in face of other big flood events. The resistance of these should have been studied before.
4. The rain water collection system should have been accompanied by a good sanitation program; otherwise local population will continue connecting irregular pipes with household west water. This blocks sooner or later the pumping equipment and higher the maintenance costs of the stations.

Holistic approach is therefore necessary; with preemptive, anticipatory policies in order to not only avoid irregular settlements, but to better manage environmental crisis such as flooding. To make this achievement some aspects should be considered such as:

- Creating incentives for people to move out of flooded areas (better transportation, supply drinkable water, electricity, telephone lines in with social advantages for those who prefer to set their house in suited areas);
- Road improvements for better transportation – there will not be a need to create informal settlements around places of work.
- Reduce the rural exodus – bolster agriculture, improve rural living and economic conditions.
- Create other economic centers, other than Dakar.

Any effort tending to liberate the remaining natural landscape of Dakar (the Niayes), will be great achievement towards a sustainable city with green spaces pre-eminently absent in Dakar environment (Pasdune, 1994).

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