PREPARING TO MANAGE

Natural Hazards AND Climate Change Risks

IN DAKAR, SÉNÉGAL

LA BANQUE MONDIALE

GeoVille Group

Institut Africain de Gestion Urbaine

A Spatial and Institutional Approach

Pilot Study Report

Hyoung Gun Wang, Marisela Montoliu-Munoz,
the Geoville Group and Ndèye Fatou D. Gueye

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The findings, interpretations, and conclusions expressed in this report can, nevertheless, only be attributed to the authors, and do not necessarily represent the views of the World Bank, it Executive Directors, or the countries they represent.

ACRONYMS AND ABBREVIATIONS

ADM	The Municipal Development Agency
AOF	Afrique Occidentale Française (French West Africa)
CAPC	The Auxiliary Committee of Civil Protection
CEP	Coastal Erosion Potential
CIP	Coastal Inundation Potential
CRED	Center of Research on the Epidemiology of Disasters
CRPC	The Regional Committee of Civil Protection
CSE	Centre of Ecological Monitoring
CSPC	The High Commission of Civil Protection
DASSE	Direction of Social, Health and Educative Affairs (Direction des Affaires Sociales Sanitaires et Educatives)
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DPC	The Division of Civil Protection
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DST	Technical Services
FEU, SDN	The Finance, Economics and Urban Development Department, The Sustainable Development Network
GFDRR	The Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information Systems
GNSP	Fire Department staff (Groupement National des Sapeurs Pompiers)
IAGU	African Urban Management Institute
IPCC	The Intergovernmental Panel on Climate Change
MSL	Mean Sea Level Rise
NGO	Non-Governmental Organization
ORSEC	Organization des Secours (the National Emergency Organization Plan)
PDAS	Master Plan for Urban Planning and Preservation of the Niayes and the Green Zones of Senegal
PDU	Urban Master Plan
PDUD	Urban Mobility Plan for the Agglomeration of Dakar
PRDI	The Regional Integrated Development Plan
PRSP	Poverty Reduction Strategy Paper
RFP	Relative Flood Potential

SAR	African Oil Refinery Company
SPOT	Satellite Pour l'Observation de la Terre
SRAT	Regional Land-Use Planning
SRTM	The Shuttle Radar Topography Mission
UN/ISDR	The United Nations International Strategy for Disaster Reduction
UNDP	The United Nations Development Programme

EXECUTIVE SUMMARY

Introduction

1. This report describes a pilot study of natural risk hazards in the peri-urban extension areas of the Dakar Metropolitan Area, Senegal.[1] The area subject of this study stretches across 550 square kilometres, covering less than 1% of the national territory, but housing about 50% of Senegal's urban population**.** Much of the rapid population growth of the Dakar Metropolitan Area is taking place beyond the boundaries of the Department of Dakar (the city center), in peri-urban areas that combine two disquieting features: they present significant vulnerability to some natural hazards, and they have unclear administrative and governance arrangements, often being out of the direct oversight of established urban and rural local governments. Situations like this are not unusual in developing countries, and call for more systematic attention to hazard risk management in peri-urban areas, including a better understanding and awareness of the nature of the hazards that they face as well as of the institutional capacities and measures that would be necessary to manage them better.

2. The objective of this pilot study is, therefore, two-pronged. First, the study intends to propose a new methodology for quick assessment of natural hazard risks at a metropolitan-region scale, using new tools of spatial analysis based on geographic information systems (GIS) data. Second, the study aims to apply the principles and diagnostic questionnaire of the Climate Change City Primer developed by the East Asia Region of the World Bank to get a comprehensive view of the institutional framework for climate change-related hazard risk management existing in the city at this time. Bringing the spatial and the institutional analyses together, the study proposes and starts to develop a number of dissemination and awareness-raising tools that can help to inform different stakeholders about the general parameters of the natural hazard risks facing the Dakar Metropolitan Area. The pilot study concludes with a broad action plan for Dakar, to ramp up disaster management practices, as motivation for a stakeholder debate to define subsequently a set of specific and viable actions.

Natural Hazards in the Dakar Metropolitan Area

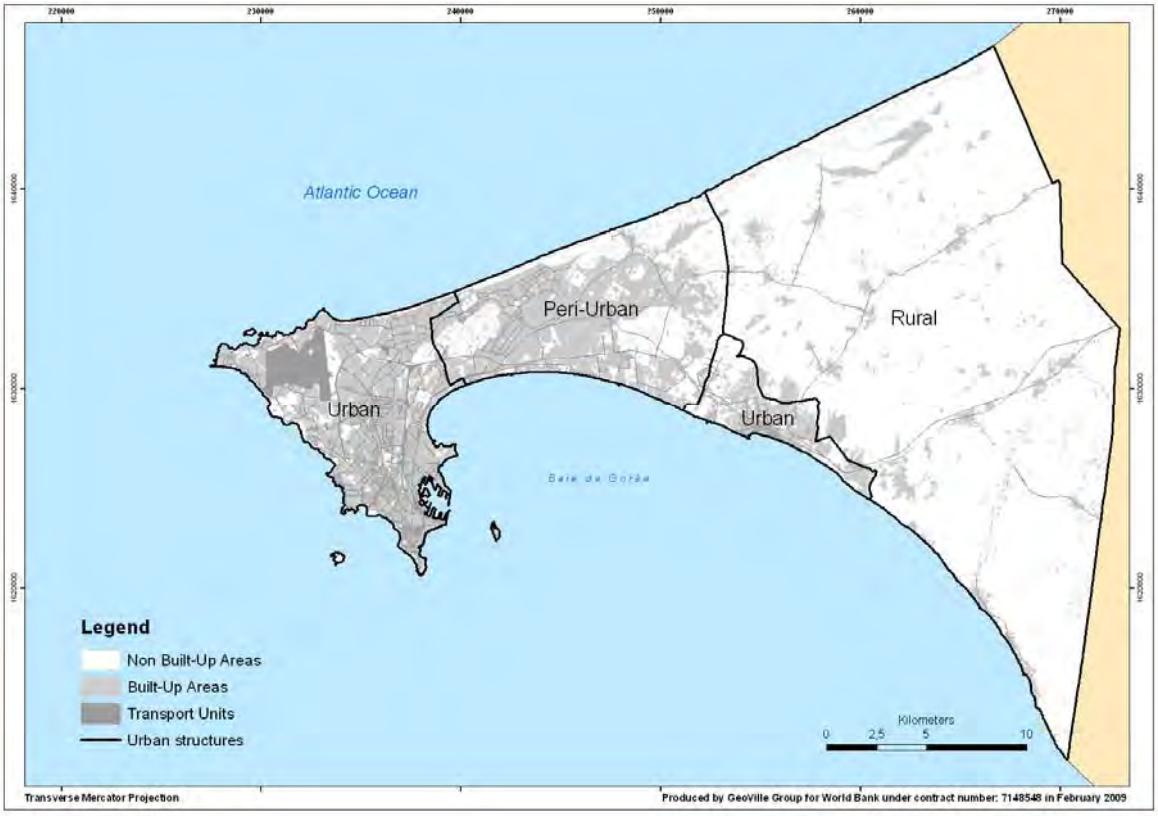
3. The pilot study focuses sharply on three types of natural disaster hazards affecting the Dakar Metropolitan Area and its surrounding regions: flooding, coastal erosion, and sea level rise. Flooding is one of the most severe hazards threatening Senegal, and in recent decades it has become a frequent and enduring reality. Senegal is also one of the African countries that suffer most from coastal erosion. In addition, the phenomenon of sea level rise – although less imminent and visible today – is attracting increasing attention as part of the ongoing discussion of the impact of climate change in coastal areas. These three types of natural hazard risks coincide in the Dakar Metropolitan Area, located in a low-lying, peninsula-like territory with a long coastal line. The area concentrates significant social, economic and political assets that are vulnerable to these hazards. These three types of hazards were chosen as focus of this pilot study because of their relevance and, especially in the case of flooding and coastal erosion, their current prevalence and impact in the area under study. The extension of the study to other types of natural hazards – e.g. land subsidence, also present in the area – was limited by the time and resources available for this pilot study.

[1] The Dakar metropolitan area is also called the region of Dakar (la région de Dakar).

Peri-Urban Expansion Areas

4. The definition of peri-urban areas varies across countries and can sometimes be a source of confusion. This study started by defining the broad geographic scope of the analysis, which covers an area of 550 square kilometers including and around the city center of Dakar, and stretching the Departments of Dakar, Guediawaye, Pikine, and Rufisque (see map below). Using a combination of quantitative measurements (distance to city center, population density) and qualitative observations and know-how from local experts, the study classified the communes in this broad area into three segments: Urban (Dakar center, and communes with high density of urban economic and industrial activity), Rural (communes conventionally classified as "rural" according to Senegal administrative system), and Peri-Urban (communes lying in-between, exhibiting mixed land uses and relatively lower densities than the urban communes.).

Figure 1: The Classification of Urban, Peri-Urban, and Rural areas in the Dakar Metropolitan Area

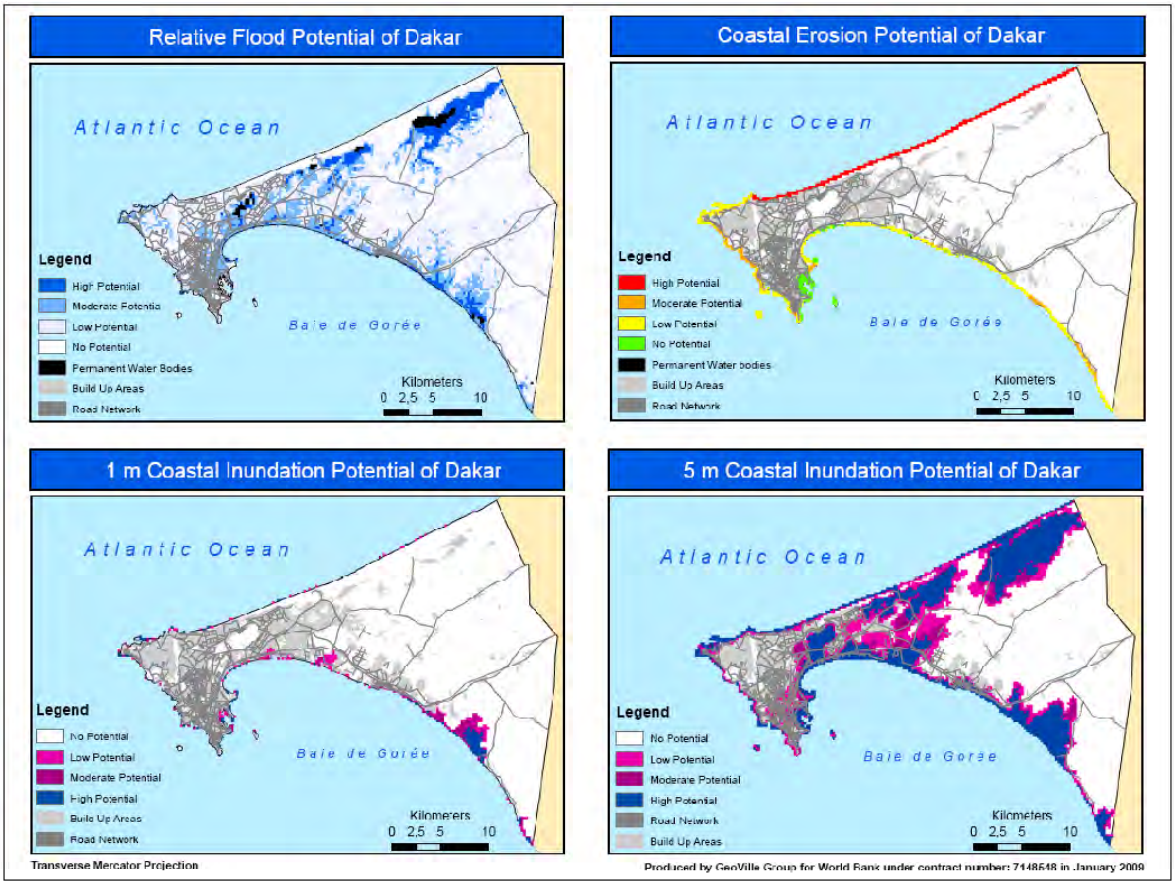


Spatial analysis

5. The spatial analysis combines results from hazard mapping (see maps below) with population maps, land price data, and land cover information in order to derive the exposure of different variables in different locations to the three selected natural hazards. The scale of the spatial analysis is regional/metropolitan, a level of detail that is relevant for the

awareness-raising and institutional engagement purposes intended here. Extensions to this analysis, not covered at the current pilot stage, may include (a) consideration of other natural hazards; (b) more thorough evaluation of the potential economic impact of natural hazards, taking into account direct and indirect damages; and (c) additional analysis of more detailed geographic information systems (GIS) data, cadastres, and first-hand ground-truthing, to ascertain detailed risks faced by specific populations and built areas in the broad areas indicated here as under risk.

Figure 2: Hazard Mapping of the Dakar Metropolitan Area



6. Spatial analysis helps to discern the spatial relationship between the natural hazard potentials and the exposed variables, i.e. population, land use units, and economic assets. Specifically, it generates statistical results and maps containing the following information:

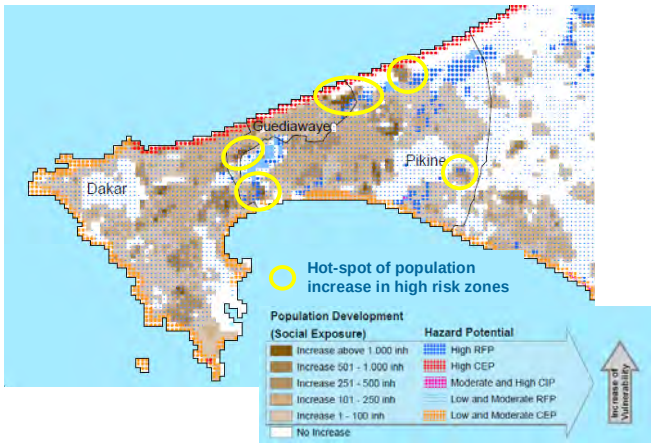
- *Potential hotspots and risk areas* illustrating type and degree of vulnerability for the different risk categories and scales of risk defined previously,
- *Built-up areas exposed to risk:* general characterization of the urban land use (i.e. residential, industrial/commercial, etc.) including type of vulnerability, and
- *Non-built-up areas exposed to risk:* general characterization of the land use, topography, and soil, including type of vulnerability.

7. Spatial analysis shows that land cover in the area under study has changed significantly in the past twenty years – the surface of urbanized areas has increased by over 25% in the period, about 1% per year. Population growth over the period between 1988 and

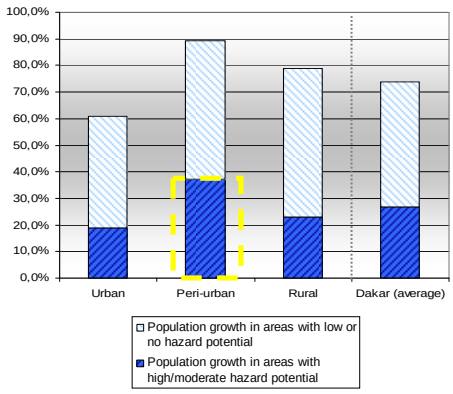
2008 took place to a significant extent in areas that are prone to a moderate or high hazard potential. In particular, peri-urban areas have the highest percentage of population growth in hazard prone areas. In communes that are defined as peri-urban, almost 40% of new population has settled in areas with significant hazard potential from inland flooding, coastal erosion, or sea level rise. This rate is twice as high that of urban (19%) and rural communes (23%) in the area under study.

Figure 3: Hotspots of Social Exposure with High Population Growth and High Hazard Potentials VS Population Growth (1988 – 2008) in Areas with Hazard Potentials

Hotspots of Social Exposure with High Population Growth and High Hazard Potentials



Population Growth (1988 – 2008) in Areas with Hazard Potentials



8. A broad calculation of the exposure and vulnerability of economic assets in the area under study was inferred from the spatial analysis of land price values. Using this method, the study estimated that the Dakar Metropolitan Area represents a total land value of $44 billion. Out of this total value, over $2 billion or 5% is exposed to high natural hazard potentials. Given the imperfect functioning of land markets in Dakar, this is only a very rough approximation to the exposure of economic assets to natural hazards. Further extensions of this work should refine the methodology for the calculation of economic risks due to natural hazards. Nevertheless, these early estimates indicate the importance of appropriate planning to mitigate the city's economic vulnerability to these risks.

Hotspot characterization and assessment of institutional capacity

9. A survey developed by the World Bank's East Asia Region (the City Typology and Risk Characterization Matrix, or simply the "Primer" Questionnaire) was adjusted to the needs of this analysis and conducted to collect information on the Dakar Metropolitan Area's human and built environment characteristics, potential impacts of natural hazards and climate change risks, and local-level disaster management institutional capacity. The survey analysis reviewed (i) general information on four administrative Departments of the Dakar Metropolitan Area: Dakar, Guédiawaye, Pikine, and Rufisque, (ii) governance structure related to disaster risk management, (iii) urban planning and land use regulations, and (iv) other factors such as political and economic impacts of disasters, climate change preparedness, disaster response system, and peri-urban areas.

10. The survey found that the implementation framework for disaster risk management (DRM) is ambiguous and complex at the local level, even though Senegal has been actively pursuing Disaster Risk Reduction (DRR) strategies at the national and regional levels. For example, in the case of flooding hazard, the local mayor is often responsible for disaster response but has very little influence on mitigation as those policies are often determined at the national level. Local governments lack adequate funding for infrastructure investments and service delivery, and face the challenge of skills shortage and lack of technical capacity to deal with complex issues like climate variability risks. Furthermore, planning instruments like land use planning, which has the ability to influence the urban-rural footprint, remains under the influence of the national government.

Using Lessons Learned to Assist Awareness-Raising

11. ***Guiding principles: Hyogo Framework for Action.*** The Hyogo Framework for Action is adopted as guiding principle for designing the recommendations from the current study. The Hyogo Framework is a global blueprint for disaster risk management implementation during the decade 2005-2015, adopted by the Member States of the United Nations. It underscores: (i) the need for a more pro-active approach to informing, motivating and involving people in all aspects of disaster risk reduction in their own local communities; and (ii) the scarcity of budget resources allocated to risk reduction objectives, as compared to the significant potential to better exploit existing resources and established practices for more effective disaster risk reduction. Consistent with these principles, the recommendations emerging from this study include measures that improve awareness of disaster risks, as well as a frank assessment of institutional resources and capacity for disaster management and prevention in the Dakar Metropolitan Area (see summary table below).

12. ***Informing, motivating, and involving people in their own local communities.*** The most immediate recommendation from this pilot study is to develop a general awareness campaign – which has already started with the process of validation and dissemination of the findings of the study. Local agencies and local communities should play a pivotal role in disaster management practices, and develop demand for improved land use planning and disaster response. In turn, empowered local communities and agencies can play a key role in identifying areas and structures under risk, and monitoring and evaluating the implementation of the measures. Alignment with the Hyogo Framework requires a consultative and participatory process that ensures sustainability and ownership of the measures proposed.

13. ***Strengthening local institutional capacity and coordination.*** The study also reveals failures of capacity, accountability and coordination among local agencies and between them and agencies at other administrative levels. These are issues that require further examination and discussion among the relevant stakeholders. This study limits itself to pointing to some of the key institutional capacity and coordination issues identified. It suggests some that may be on the critical path for progress and deserve special attention, such as the identification and empowerment of an institutional champion for disaster risk management and prevention at the metropolitan level, and the development of a local database on hazards and the training of local agency staff to use it effectively.

14. ***Policy reforms and investments for improved hazard resilience and preparedness at the local level.*** Beyond the immediate findings and recommendations of this study, stakeholders in Dakar need to consider what substantive policy and investment measures may be considered over time. Ultimately, policy reforms that influence behavior to promote better risk management and investments that strengthen resilience at the local level would be

needed to improve the situation of Dakar and its peri-urban expansion areas. The findings of this study suggest the importance to focus on better local land use planning and management, and infrastructure, and the last segment in the table below summarizes possible measures to be considered. This study does not make specific recommendations in these areas, however, as this would require a more detailed analysis. Selection of viable choices would also depend importantly on stakeholder consultation.

Avenue for engagement	***Action plan***
General Awareness Campaign (Already initiated in the context of this pilot study)	• Organize local knowledge and information dissemination activities, targeting local public agencies and local communities, on the seriousness of the natural hazards and climate change impacts on their own lives, with focus on the behaviors that the population can control and improve on. • Arrange collaboration and joint activities with various local agencies, academic and research institutions, non-profit organizations (NGOs) to pursue these campaigns of sensitization.

Strengthening Local Institutional Capacity and Inter-agency Coordination	• Identify viable and well-recognized institutional champion at the Metropolitan Level.
	• Initiate discussion at the highest political level for institutional strengthening and coordination and reforms:
	  • Initial focus: (a) development of early warning and quick-response system, paying attention to currently under-served peri-urban areas; and (b) improve local organization and capacity to enforce urban zoning and regulations to reduce vulnerability to natural hazards, with special focus on currently under-served and fast-growing peri-urban areas.
	  • Medium-term focus: (a) adequate resourcing of key agencies; (b) policy reform; and (c) reallocation of public expenditure and investment to local disaster risk mitigation and prevention. (See further below.)
	• Develop a spatial database for local disaster management in the Dakar Metropolitan Area, and ensure broad access and hands-on training for local agency staff.
	• Promote local communities' engagement and participation in disaster prevention measures.

Policy Reform and Investment	• Improve local land use planning and management: (a) improvement of land property right assignment and enforcement, with special focus on peri-urban areas; and (b) consultative development of metropolitan development plan, including identification of disaster hotspots and corridors for urban expansion, and potential land acquisition plans to support urban growth corridors.

	• Strengthening resource base for local authorities, including through proposed betterment taxes that take advantage of improved land management plans and corridor development. • Invest in climate- and disaster-proofing infrastructure and housing stock: retrofitting existing infrastructure and housing in hazard-prone areas; improving infrastructure planning and monitor quality of investments.

Replication of the Pilot Study

15. This study was intended as a pilot to test new methodologies, and identify how the approach could be enhanced in case of replication. Interest in replicating the approach exists for other African cities, as well as for a selection of Asian cities. This pilot study may also provide the foundation for the development of a city vulnerability index to be applied to a large number of cities. In replications of this study, it is proposed that the following enhancements be considered:

- Consideration of a broader range of natural hazards, beyond the three included in this study.
- Progress toward a more robust definition of peri-urban areas.
- More detailed and better documented analysis of the economic impact of hazards.
- More detailed discussion of the methodology for population density imputation, possibly considering different relationships between building density and population density, depending on whether the area is formal or informal.
- Addition of information (layering) on major infrastructure (roads, electricity, sanitation).
- Utilization of more detailed GIS data sources, such as those captured in cadastres, to inform the more detailed economic and population analysis suggested above.

16. These extensions of the current pilot study may lead to slight increases in the cost of undertaking the study in the initial replications, until the methodology is refined and standardized.

1. Introduction

17. The Dakar Metropolitan Area (or the Region of Dakar) represents less than 1% of the national territory, but shelters 25% of its total population and 50% of its urban population. Since it was the capital city of the French West Africa (AOF), Dakar has been a hub; its strategic position was instrumental in its cultural and political leadership. Moreover, its economic, cultural, and political leadership was associated with touristic and military assets derived from a favorable geographical context.

18. The Dakar Metropolitan Area has become a sprawling conurbation. This evolution was made possible by the dynamism and natural growth of its population, its role as a main exchange point, and its role as host area for migrants. With the excessive concentration of population in a small portion of space, Dakar agglomeration is a real "Human Anthill". The rapid urbanization of the region remains uncontrolled resulting in huge problems in terms of meeting the basic needs in housing, land, mobility, life environment, and urban poverty.

19. The urban structure is marked by imbalances and lack of integration as a result of ineffective land management and lack of strategic planning at the local and regional levels. The Government's urban investments are mostly concentrated in the city center (the Department of Dakar) at the expense of the peri-urban areas – labor supplying areas where half of the total population of the region lives. Yet this social and infrastructural disparity promotes the spillover of migration from the city center, its peri-urban areas, and its close hinterlands resulting in degradation of the life environment.

20. Dakar's housing and land markets face a number of interrelated challenges in terms of access and affordability; it has become increasingly hard to meet the rapidly increasing demand for these goods within the city's perimeter, in the context of price inflation and land speculation. As a consequence, the suburbanization of the region has accelerated, creating new problems – for instance, those associated with property rights and management: ownership is often unclear or uncertified in peri-urban areas. As underscored by World Development Report 2009: Reshaping Economic Geography (World Bank, 2008a), well-functioning land markets are essential to facilitate the movement of the population toward economic opportunity, as well as the evolution of land uses from lower to higher value or, more importantly, the allocation of land to the most efficient uses.

21. The current territorial and administrative organization of the Dakar Metropolitan Area is complex, with interlocking of various forms of governance (Region, Department, Arrondissement, Commune, Rural communities). At the larger, regional level, the "Region" is headed by the governor (appointed), followed by the "Department," headed by the Prefect (appointed). At the local level, there are three types of distinct territorial or administrative units: the "Arrondissement" is headed by the Sous-prefect (appointed), the "Communes" by the Mayor (elected), and the "Rural Communities" by the President of rural community (elected).

22. This institutional complexity and ambiguity generates a fragmentation of local policies and power conflict at various levels (administrative and institutional). In addition, the weight of the national and regional governments can often undermine local authorities and local public action. With the ongoing decentralization reform, administrative authorities and decentralized public services are in fact losing weight. The relationships between local authorities and the national and regional administrations are not very well defined, mixing autonomy, assistance, and supervision. The excessive "agencization" of the Government

activities and key projects results in higher density and more complex government structure, with new ad-hoc agencies carrying out the missions the ministries are expected to take.

23. The Dakar Metropolitan Area is characterized by a lack of dialogue between the administration services, the administration and local authorities, and between the local authorities. The populations, the civil society, and the private sector are only weakly involved in urban management.

24. Dakar has been a hub of cultural and political leadership and the destination of large rural-urban migrations since the 1960s. Recent satellite imagery reveals contiguous expansion of urban built-up areas over the decades, with a large proportion of the urban growth occurring in the peri-urban areas (outer suburbs) of the city center. As the Dakar Metropolitan Area experiences rapid urban expansion, it faces increased vulnerability to natural hazards and climate change risks.

25. Overlaid on top of this confluence of political and demographic factors, the natural hazard risks faced by the Dakar Metropolitan Area make for a truly complex picture in terms of ensuring safe livelihoods and an enabling environment for economic productivity. In order to meet those challenges and to manage rapid urbanization in the areas likely to be hit by natural hazards or undergo climate change impacts, the knowledge and response capacity of the local authorities need to be significantly improved.

26. The World Bank's Spatial and Local Development Team (FEU, SDN) and the World Bank-housed Global Facility for Disaster Response and Recovery (GFDRR), in collaboration with colleagues from the World Bank Senegal Country Office, have launched an innovative pilot study. The main objectives of this study are two pronged:

27. First, it develops a new generic methodology combining spatial and institutional analyses at reasonable costs, which would serve a standard assessment template ready to replicate to other cities and other countries. This will benefit global disaster management practitioners and communities.

28. Second, it provides action plans for Dakar, Senegal to ramp up disaster management practices. We aim at providing an overarching strategic framework in bottom-up and sensitization perspectives, rather than a list of extensive top-down directions and micro-management recommendations. We believe the latter is counter-productive, unsustainable, and inconsistent with our guiding principle: informing, motivating, and involving people in all aspects of disaster risk reduction in their own local communities. This element will benefit directly local communities in the Dakar Metropolitan Area as well as Senegal governments in general.

29. In this regard, this study (i) develops state-of-the-art spatial analysis tools to spatially evaluate natural hazard and climate change risks, and (ii) addresses the critical knowledge and capacity gaps of local governments in dealing with rapid peri-urban expansion into areas that may face vulnerability to natural hazards, including those risks associated with climate variability. Three pillars of activities are being implemented sequentially.

Activity 1: Spatial Analysis of Natural Hazard and Climate Change Risks and Hotspot Characterization in Peri-Urban Expansion Areas of Dakar, Senegal

30. Activity 1 develops a methodology for the generation of hazard and vulnerability maps for the Dakar Metropolitan Area. Three types of hazards are selected for detailed spatial analysis: Flooding (inland flooding of depressions), Coastal Erosion, and Sea Level Rise. The

occurrence of flooding within the area of Dakar has recently been increasing for climatic and anthropogenic reasons, and constitutes a major threat especially for newer settlements in unsuited low-lying terrain. Coastal erosion as a more steadily acting, but very hazardous process in the area is included in the detailed analysis along with scenarios of sea level rise.

31. Satellite imagery at different time points (1988, 1999, and 2008) and hazards information from various sources are collected, geo-processed, and integrated for the thematic map generation. These maps include land use profiles, geology, hydrology, single and multi natural hazard maps (flooding, coastal erosion and sea level rise scenarios). Spatial analysis combines all these information, and produces hazard risk profiles in the Dakar Metropolitan Area. The concepts and methods follow best-known standards and scientific approaches.

Activity 2: Hotspot Characterization and Assessment of the Institutional Capacities at the Local Level

32. Activity 2 implements a local field survey for the hotspot characterization of the four departments in the Dakar Metropolitan Area: Dakar, Pikine, Guédiawaye and Rufisque, and identifies the inter-relationship between governance structure, urban-rural characteristics, disaster risks and climate change preparedness. The survey also examines the institutional capacity at the local level. The activity combines survey results and assesses gaps in the prevention and mitigation capacity of local governments with respect to the particular risks that they face as their cities expand beyond their current jurisdictions.

Activity 3: Action Plans to Ramp up Natural Hazard and Climate Change Risk Management Practices in Dakar, Senegal

33. Activity 3 proposes action plans of Dakar to ramp up natural hazard and climate change risk management practices. The guidelines and action plans draw on the findings of Activities 1 and 2 and the international consensuses on best-practice exercises.

34. The guiding principle is “more pro-active approach to informing, motivating, and involving people in their own local communities,” as articulated in the Hyogo Framework for Action 2005-2015. Local agencies and local communities should play a pivotal role in disaster management practices, and correspondingly empowered to ramp up disaster management practices. The empowerment should follow four venues of engagements.

- First, local agencies and local communities should be better informed. Construction of a spatial database for local disaster management and sensitization is highly recommended.
- Second, local agencies and local communities should be provided more resources and administrative support (from national and regional governments) to implement and enforce disaster-mitigating land-use regulations effectively.
- Third, disaster management in peri-urban expansion areas, which are often politically and economically neglected, should be addressed in long-term inclusive local development perspectives.

- Fourth, Sensitization activities to wake up public awareness on natural hazards and climate change risks are a key trigger for more sustainable and inclusive disaster management.

2. Natural Disasters in Dakar, Senegal

35. Flooding is one of the most severe hazards threatening Dakar, and in the last years it has become a frequent and enduring reality. The underlying causes are complex and involve not only the recent increase of rainfalls, but in particular the whole socio-economic process of an out-of-control urban sprawl. The consequences are devastating: "Three months since 183,000 people in Dakar were affected by severe floods resulting from torrential rains, many houses and schools are still floating in water."[2]

36. Moreover, Senegal is one of the countries that suffer most from coastal erosion: "Currents sweep away the sand from Rufisque's coast and deposit it further south. The beach is slowly being hollowed out and the shore is receding. Abdoulaye Ndiayhe, an old fisherman who offers his services as guide, insists that more than 100 meters once separated the sea from a house whose ruins are now being lapped by the waves."[3]

37. Around Dakar, the maritime domain is crowed with hotels -- already operating or in construction – buildings touching the sea which may result in rock slides and tidal waves. There are various causes of coastal erosion, whether they are natural or entropic. But global warming generated by greenhouse gas may increase sea level. Coastal erosion can therefore be regarded as a phenomenon in progress. Surveys on the impacts of climate change in the Senegalese coastal areas (Denis et al. 1995; Niang-Diop et al. in press) show that the increase of the sea level can result in floods in the lower coastal areas and increased salinization of lands and of surface and ground waters.

38. In the Cap-Vert Peninsula, coastal erosion is felt in both beaches and rocky shores. The main identified erosion areas include: the area of Camberene-Yoff, the West and East ledges of Dakar, and the bay of Hann. It is worth mentioning the Mbeubeuss quarries which show serious signs of erosion. Coastal erosion is particularly felt in the area of Rufisque-Bargny with the narrowing of the beach of Rufisque, particularly along the center of the city, resulting, in the sectors of Merina and Thiawlene, in overhanging buildings and stripped roads.[4]

39. The rocky sector of the tip of the Cap-Vert Peninsula is an unstable area. Based on the observation of the Madeleines, Fall et al. (1996) proposed annual rates between 0.8 and 1.4 m for the loamy cliffs of the Hospital reaching 4m at the volcanic tuffs of the Pasteur beach. For all the West and East ledges, Diop (2000) indicates that between 1980 and 1997 the annual gradual disappearance rate of the littoral is 0.45 and 2.7m. The most affected sector being the Madeleine and the Rebeuss beach.

40. Thus, the below shown pictures are only small glimpses of the extent of the hazards that are threatening and afflicting the Dakar Metropolitan Area. The flood map shown in Figure 3 gives an impression of the dimension of the 2008 flooding. Both, flooding and coastal erosion, are to a large part caused by human behavior and are exacerbated by Climate Change.

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[2] http://www.planuk.org/wherewework/westafrica/senegal/floodsindakar/.

[3] http://portal.unesco.org/en/ev.php-URL_ID=30499&URL_DO=DO_PRINTPAGE&URL_SECTION=201.html

[4] Rapport sur l'état de l'environnement au Sénégal. Edition 2005. Centre de Suivi Ecologique.

Figure 4: Flooding and Coastal Erosion Threaten Life and Resources of Dakar

Upper left: A desperate impression of the recent flood

http://www.solarpanel.co.za/global-warming.htm

Upper right: September 2008 in Dakar

http://wow.gm/africa/senegal/dakar/article/2008/9/10/senegal-flooding-spreads-as-rains-continue

Lower left: Senegal: Coastal Zones at the Mercy of the Waves

http://portal.unesco.org/en/ev.php-URL_ID=30499&URL_DO=DO_PRINTPAGE&URL_SECTION=201.html

Box 1: Natural Hazard and Disaster Risk Overview for Dakar

Overview (Source: **http://ww2.unhabitat.org/programmes/uef/cities/summary/dakar.htm**[5]

Dakar, the political and economic capital of Senegal, has a metropolitan population of over 1.8 million; thus, it concentrates 22% of the country's population on 0.1% of its land. The metropolitan region enjoys a temperate coastal climate. It is located on a peninsula that can be divided into three zones: a) an eastern section of volcanic outflow, sands and a large plateau; b) a central region of dunes and depressions; and c) a western section of undulating hills and plateaus.

[5] UN-Habitat (no date given): Identifying Geographic and Thematic Environmental Issues through Consultation. http://ww2.unhabitat.org/programmes/uef/cities/summary/dakar.htm

Economy

(Source: **http://ww2.unhabitat.org/programmes/uef/cities/summary/dakar.htm**

Economically, Dakar generates 68% of Senegal's GDP and its workers account for 66% of the national wage bill. 80% of the country's industries are located in the metropolitan region. In resource use, Dakar consumes three-quarters of Senegal's piped water and 40% of its charcoal. The unemployment rate is 30% and 40% of the active work force is employed in the informal sector. About 13% of the population is estimated to be living below the country's poverty line.

Settlement Structures

(Source: **http://ww2.unhabitat.org/programmes/uef/cities/summary/dakar.htm**

Spatially, urban development is characterized by a preponderance of informal settlements with limited access and poor transportation, and inadequate infrastructure and services. Two of every three newly-established households in the metropolitan region are sub-standard. Unplanned settlements have made it difficult to gain access to and to connect neighborhoods, and have put additional strain on the existing transportation network. Low-income districts tend to be the most underserved; for example, in the central city 61% of households have piped water but this figure drops to 16% in the poor district of Rufisque.

Hazards

(Source: **http://ww2.unhabitat.org/programmes/uef/cities/summary/dakar.htm**

Problems of environmental health - malaria, gastrointestinal diseases and upper respiratory tract infections are prevalent in Dakar's poorer neighborhoods and are linked with poor sanitation and waste management.

Water pollution - Dakar's most important aquifer is located close to the surface, making it vulnerable to malfunctioning sanitary systems and other domestic wastewater. The risk of bacteriological contamination is greatest for those who draw water from those who draw water from the aquifer's 5000 unregulated wells.

Natural risks - the city is exposed to frequent and constant natural risks. Flooding, though infrequent, can be devastating. The last major flood affected 10,000 families; it is estimated that the next major flood will cause nearly $9 million worth of damage. Damage from coastal erosion is a more constant risk.

Industrial risks - Dakar's citizens have experienced a series of fatal industrial accidents. These are linked to poor workplace safety, proximity of industrial activities and residential areas, a low level of public information, and lack of enforcement of safety measures and other rules.

Recent climatic developments and implications for Dakar

(Source: http://findarticles.com/p/articles/mi_go2454/is_/ai_n29342505)

Senegal benefits from a Sudano-Guinean climate and thus from more favorable ecological conditions in the southern part of its territory. Furthermore, the temperate climate of the Atlantic seaboard has played an important role in the establishment of most of its major cities. The resulting imbalances between North and South, East and West, both eco-geographically and with respect to economic potential, significantly influence the **internal mobility of the population**. Reflecting these factors, Senegal's current population of almost

11 million is distributed very unevenly across the country's total area of 196 722.

Changing climatic conditions have stimulated this mobility and contributed to reinforcing the role of urbanization. Indeed, like most West African nations, particularly those of the Sahelian region, Senegal has experienced a **complete upheaval in its climatic norms since the mid-1960s**, when a long period (1950-67) of surplus rainfall caused the rapid growth of the overall population and an augmentation of rural population density.

Jean Leborgne points to three distinct periods of rainfall deficit (1970-3, 1976-7, 1983-4) punctuating the long period of drought in the Sahelian region between 1970 and 1990. The climate in Senegal is regulated by a rainy season of 3-4 months and a dry season of 8-9 months, and the natural world proves extremely vulnerable to climatic variations (Michel 1990). Because the Senegalese economy is based principally on agriculture (peanuts, millet, sorghum, rice, cotton, manioc, sugar cane and niebe), **the chronic drought since the 1970s has had a traumatic effect**.

The crisis of the economic motor that is agriculture inspired a **massive migration toward the cities** and increasingly to foreign countries.

The capital, **Dakar, has been the principal destination for the rural exodus** and the principal site for observing the most pertinent problems caused by this migration and accelerated urbanization. The development of Dakar has manifested itself by a rapid spatial expansion, resulting from intrinsic demographic dynamism (natural increase) and migratory influx from regions of the interior (net immigration). The Dakar agglomeration, with a population now estimated at some 4 million, thus constitutes the most important site of socialization and invention of Senegalese society.

As a result of the enduring internal migration, Senegal's population was already over 48% urban in 2001, one of the highest levels of urbanization in mainland sub-Saharan Africa. **Over 76% of this urban population lived in areas classified as slums**, which were growing at over 4% p.a. (UN-HABITAT 2006, 188).

The **degradation of marine ecosystem** conditions through climatic change and other factors has left Senegalese fishermen, especially the youngest age cohorts, destitute and thus drives them toward massive emigration to Spain on traditional fishing boats, as now regularly featured in international news reports. This dramatic phenomenon sees thousands of immigrants searching for a better life through suicidal voyages from the Senegalese coastline.

(Highlighted text by author of this study)

Box 2: Natural Hazards in the Dakar Metropolitan Area

Hazard Type and Hazard characteristics	Information, maps, and data provided by various sources	References
Flooding Local occurrence in depressions Human factors are very important factors of flooding Recent increase due to increased rainfall Flooding closely linked to the geological setting of the area	Scientific paper on the relationship between Urban sprawl and flooding at Yeumbeul suburb. In depth analysis of the natural, human and external causes of flooding. "The most important factor is the human factors with the poor management of land and the occupation of depressions".	Mbow, C., Diop, A., Diaw, A.T., Niang, (2008)[6]
	Scientific paper on Problems associated with flooding in Dakar, western Senegal: influence of geological setting and town management "The increase of both flooding in some districts and the environmental damage that is taking place year by year are closely linked to the geological setting of the area, notably the topography and geomorphologic processes. These factors are so important that decision makers must take full account of them when considering any new proposals for development".	Lo' P.G., Diop, M.B.[7]
	"The last major flood affected 10,000 families; it is estimated that the next major flood will cause nearly $9 million worth of damage"	UN-Habitat[8]
	Flood map of Western Africa from Sept. 30, 2008	ReliefWeb[9]
	Aug.Sept. 2005 Heaviest rains in Dakar in two decades. Worst affected were Pikine and Guediawaye shanty towns outside Dakar. Worst floods in 20 years in Senegal's suburbs. "reconstruction required after the floods would cost some 45 billion CFA francs"	Dartmouth Flood Observatory [10]

[6] Mbow, C., Diop, A., Diaw, A.T., Niang (2008): Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal). African Journal of Environmental Science and Technology Vol. 2 (4), pp. 075-088 http://www.academicjournals.org/AJEST/PDF/pdf%202008/April/Mbow%20et%20al.pdf

[7] Lo' P.G., Diop, M.B. (2000): Problems associated with flooding in Dakar, western Senegal: influence of geological setting and town management. Bull. Eng. Geol. Env. 58, p 145-149.

[8] UN-Habitat (no date given): Identifying Geographic and Thematic Environmental Issues through Consultation. http://ww2.unhabitat.org/programmes/uef/cities/summary/dakar.htm

[9] ReliefWeb: Floods in Western Africa (as of 30 Sep 2008). http://www.reliefweb.int/rw/rwb.nsf/db900SID/LPAA-7JZBJQ?OpenDocument&rc=1&cc=sen

[10] Dartmouth Flood Observatory, Global Active Archive of Large Flood Events. http://www.dartmouth.edu/%7Efloods/Archives/2008.xml

Hazard Type and Hazard characteristics	Information, maps, and data provided by various sources	References
	Floods reported for Dakar: 2008, 2007 (2003, 2002, 2000)	GLIDE Disaster Data Base[11]
	"Thousands have been affected by flooding in more than 40 neighborhoods across Senegal, including 21 Dakar suburbs according to the Senegalese fire rescue services. AFP has reported at least one drowning". "Dakar neighborhoods affected include Pikine, Guédiawaye, Thiaroye and Diamaguène, according to Mayé Konate, spokesman the National Association of Firefighters". But Youcef Ait Chellouche, disaster management coordinator at the IFRC, warns the problems are only beginning. "We need to be ready for potential epidemics – like cholera – to break out as the water starts to subside. We are closely monitoring this situation." "Flooding worsened a cholera epidemic already underway in Dakar in 2005, which eventually infected more than 23,000 people".	SENEGAL: Flooding spreads as rains continue[12]
	"The two districts are Guédiawaye and Pikine, both of which are in coastal wetland zones. Particularly affected is the neighborhood of Wakhinane Nimzatt, which means "dig and drink" in the local language Wolof". "Building on wetlands exacerbates the flood situation", said Sysall. "These wetlands are not viable for construction." The rural exodus to Dakar has contributed greatly to the flood problem, as newcomers build houses illegally, but the government is planning a tougher stance.	SENEGAL: Thousands displaced from their Dakar homes[13]
Coastal Erosion	"Analysis of the results shows that the slides were influenced by the geotechnical properties of the soil, the	Fall, M., Azzam, R.,

[11] GLIDE Disaster Data Base, http://www.glidenumber.net/glide/public/search/search.jsp
[12] SENEGAL: Flooding spreads as rains continue. http://wow.gm/africa/senegal/dakar/article/2008/9/10/senegal-flooding-spreads-as-rains-continue
[13] SENEGAL: Thousands displaced from their Dakar homes. http://wow.gm/africa/senegal/dakar/article/2008/10/7/senegal-thousands-displaced-from-their-dakar-homes

Hazard Type and Hazard characteristics	Information, maps, and data provided by various sources	References
Permanent process Cliff retreat rates up to 2m p.a. Human factors contribute, e.g. via sand extraction	weathering, the hydrogeological situation, and the erosion by waves". "It was demonstrated that the tuff cliffs retreated 10 to 60 m between 1953 and 1981. This agrees with the poor geotechnical properties of the volcanic tuffs. The recession of the loam cliffs in this period is 10 to 20 m. The basalt cliffs show the lowest recession because of their high strength".	Noubactep, C.[14]
	"The village is facing a serious coastal erosion problem; the outer row of fisher folk houses has already been destroyed by the sea and thus abandoned by the population. Assistance from specialists in coastal dynamics/processes is an urgent requirement".	UNESCO-Dakar Office[15]
	"Like many other coastal cities in West Africa, Dakar is prone to several coastal hazards. The most serious among these hazards is coastal erosion". "The effect of nature is through two modes of strong and constant swells and the action of tidal waves during rough-sea seasons. The contribution of human beings is due to a cumulative effect of poor city planning and overpopulation". "This concentration of people led to a construction boom, and then, to excessive sand extraction from beaches and dunes".	Sane, M., Yamagishi, H.[16]
Drought Major hazard of the area when regarded at a continental scale. Drought is an	Droughts are a common meteorological phenomenon in the Sahel zone, and are caused by recurring, large-scale shifts in the general global circulation. They may be aggravated by climate change, or climate variability may further increase with climate change. Droughts decrease agricultural yields and led in the past decades to the tremendous migrations of people to Dakar	Mbow, C., Diop, A., Diaw, A.T., Niang, .. (2008)[17]

[14] Fall, M., Azzam, R., Noubactep, C. (2006): A multi-method approach to study the stability of natural slopes and landslide susceptibility mapping. Engineering Geology 82 241– 263. http://cat.inist.fr/?aModele=afficheN&cpsidt=17446593

[15] UNESCO-Dakar Office: Socio-cultural survey of the Yoff coastal community, Senegal: conserving biological and cultural diversity. http://www.unesco.org/csi/act/dakar/projec4e.htm

[16] Sane, M., Yamagishi, H. (2004): Coastal Erosion in Dakar, Western Senegal, Journal of the Japan Society of Engineering Geology, Vol. 44; No. 6; p. 360-366. http://sciencelinks.jp/j-east/article/200407/000020040704A0134339.php (abstract)

[17] Mbow, C., Diop, A., Diaw, A.T., Niang (2008): Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal). African Journal of Environmental Science and Technology Vol. 2 (4), pp. 075-088 http://www.academicjournals.org/AJEST/PDF/pdf%202008/April/Mbow%20et%20al.pdf

Hazard Type and Hazard characteristics	Information, maps, and data provided by various sources	References
indirect driver for severe other hazards (e.g. flooding) in the Dakar Metropolitan Area.	and other urban areas. Thus, droughts lead indirectly to the problems and hazards within the Dakar Metropolitan Area itself.	
Earthquakes	The earthquake potential is low in Dakar according to the Nathan data base of Munich Re, though not totally absent.	Munich Re, Nathan[18]
Tornado	There is a medium probability of tornados according to Munich Re, on a four-point scale ranging from low over medium to high and very high.	Munich Re, Nathan
Hail Storm	The Hailstorm probability is low (from low – medium – high) according to Munich Re.	Munich Re, Nathan

41. At the environmental level, despite the efforts made, pollution is prevailing in the bays surrounding Dakar such as the Bay of Hann. The other major environmental concern remains air pollution which derives from public transportation, old cars, and cement factories. The gradual colonization and degradation of the "Niayes" and other sensitive ecological areas may turn out to be the worst ecological disaster.[19] The environmental problems cannot be addressed without mentioning the "Mbeubeuss" dump, an environmental disaster-in-the-making, surrounded by human settlements and agricultural lands.

[18] NATHAN Data Base by Munich Re, http://mrnathan.munichre.com/

[19] "Niayes" means lowlands between parallel sand dunes. The "Grande Niayes" is located between Dakar and Pikine. The water table is near the ground surface (ie located under the superficial sand zone).

3. Conceptual framework for hazard, risk, and vulnerability

3.1 Definitions

42. There is a variety of definitions of hazards, risk, vulnerability, and related terms, as listed in Thywissen (2006). The definitions and understanding of these terms reflect the attitude towards the underlying causes and factors of risk and, at the same time, influence concepts and strategies of disaster management. As Thywissen points out, there has been a shift from regarding disasters as extreme events caused by natural forces, to viewing them as manifestations of unresolved (human) development problems.

Hazards

43. Among the many definitions of *'Hazard'*, the one of the United Nations International Strategy for Disaster Reduction (UN/ISDR) is frequently found in the relevant literature and is taken here as a standard definition:

> A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability. (UN/ISDR, 2004).

44. This study is confined to *Natural* Hazards. Nevertheless, their assessment includes the consideration of anthropogenic factors, as these may aggravate the natural factors and in some cases even turn hazardous situations into actual disasters. This applies for instance to the flooding events in Dakar. In other cases, anthropogenic factors trigger extreme natural events, which would otherwise not materialize and remain hazards- potential events.

Hazard versus Event, Disaster and Risk

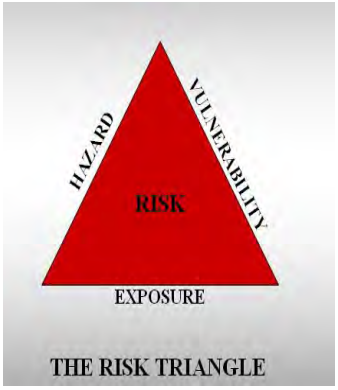
45. While *Hazards* have been and may be differently defined in different contexts, it should be stressed that the term *'Hazard'* needs to be differentiated from *'Event', 'Disaster'* and *'Risk'*. Shortly, Hazards are no events, but only potential harmful events, whereas a Disaster is the impact of a hazard that has materialized to an event, on a community, human assets and/or natural resources.

46. *Risk,* according to an UNDP definition is "The probability of harmful consequences, or expected loss of lives, people injured, property, livelihoods, economic activity disrupted (or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions. Risk is conventionally expressed by the equation (UNDP, 2004).

Risk = Hazard × Vulnerability.

47. Another concept that is widely applied in disaster research is risk being composed of the three components *Hazard, Exposure,* and *Vulnerability* (Schneiderbauer and Ehrlich in Birkmann 2006) illustrated with the Risk Triangle by Crichton (1999).

Figure 5: Risk Triangle, Crichton 1999



48. The risk concept presented in Figure 5 is based on a separation of the impact of hazard events into exposure and vulnerability.

49. *Exposure* refers to the quantity of the exposed elements: "Elements at risk, an inventory of those people or artifacts that are exposed to a hazard." (UNDP, 2004). One may add environmental/natural assets to the list of potentially exposed items, although these are more difficult or often impossible to quantify.

50. *Vulnerability* refers to "The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (UN/ISDR, 2004).

51. While several definitions of vulnerability integrate or equate exposure and vulnerability (see Thywissen 2006), the authors of this study believe that the separation of the two terms makes definitely sense. Exposure in the above cited definition can be measured or estimated by studies such as this or similar approaches. Vulnerability, on the other hand, is a very complex and often in many respects intangible property that cannot be directly measured and hardly be quantified in absolute terms. Yet, the decrease of vulnerability (and the increase of coping capacities and resilience) has moved in the focus of disaster management strategies and superseded the mainly technical prevention or mitigation of disasters. In this respect the development of Vulnerability Indicators is of importance.

52. Figure 6 presents a third concept of risk. Here a longer-term perspective is explicitly taken, by adding the resilience of a system to the factors that determine the size of the risk.

Figure 6:: Risk as a Function of Hazard, Vulnerability, Exposure, and Resilience[20]

53. To understand the logic behind this concept, a short digression is made to the terms Coping Capacity and Resilience following Thywissen (2006), who puts all these disaster related terms and their manifold definitions in a logical and coherent synthesis. According to Thywissen,

- *Coping capacity* encompasses those strategies and measures that act directly upon damage during the event by alleviating or containing the impact or by bringing about efficient relief, as well as those adaptive strategies that modify behavior or activities in order to circumvent or avoid damaging effects.
- *Resilience* is all of these things, plus the capability to remain functional during an event and to completely recover from it. So resilience includes coping capacity but at the same time goes beyond it.

54. Thywissen (2006, p.38) points out: "If the extent of the damage or harm is defined also by the duration of the adverse effects and by its repercussions on people's poverty, economy, or awareness, then vulnerability has to include coping capacity and resilience".

Analogy to illustrate the Risk Concept

55. For a better understanding, let's take the following analogy: A hundred persons are exposed to the same bacteria *(Hazard)* during the same time period let's say in a train compartment. Thus, the *Exposure* of these 100 people is identical. But yet they may not be infected by the bacteria to the same degree – some persons may stay healthy, the other ones may get infections depending on their individual degree of *susceptibility (or Vulnerability).* In addition, some of the infected people may stay ill for two weeks, some others only for 3 days, or similar, depending on their *Resilience.*

56. However, *Vulnerability* can in certain instances depend on the degree of *exposure*. (In the above analogy that might be the case if the people in the compartment are exposed to the bacteria over an extremely long time span, so that almost nobody can resist). In addition, *Vulnerability* and *Resilience* are interrelated as they partly depend on the same factors, but overall they include also many different factors.

[20] Thywissen (2006)

3.2 Risk Factors and Related Information Sources

57. A comprehensive risk profile for a specific region and time frame would under the above definition of risk include the items listed in Table 1. Here, not all of these items are requested, and only for a part of them can information be derived in the frame of this study. The respective items are highlighted in yellow. Thus, Table 1 illustrates the relation between a more comprehensive Risk assessment and the elements that are provided in this study.

Table 1: Components and Factors of *RISK* and Related Information Sources and Assessment Results

Risk Components and Definitions used here	**Factors of the Risk Components**	**Information Sources (indicative examples)**	**Resulting Information (generic type, examples)**
Hazard *A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation* (UN/ISDR, 2004)	Location	Single hazard factor maps (e.g., DEM, geology, soil sealing)	Spatial differentiation of single and multi-hazard factors
	Intensity	Superposition of single and multi-hazard factors	Spatial distribution of relative hazard intensity
	Frequency	E.g., climate data, disaster data bases, etc.	Statistics, Assessments
	Probability	Long term data series Scientific assessments, Monitoring of Current Trends	Damage-frequency relationship, Return period
Vulnerability *The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards* (UN/ISDR, 2004)	Physical factors and processes	E.g., Climate data to show recurring adverse or deteriorating climate conditions and consequences	Statistics, Maps, Assessment
	Social factors and processes	Social data, e.g., education Demographic developments	Statistics, Maps, Assessment E.g., Maps of recent urban expansion
	Economic factors and processes	E.g., Individual Income data Financial Situation of the public sector Adverse Economic Trends	Statistics, Maps, Assessment
	Environmental factors and processes	E.g., Maps of very sensitive elements, habitats, etc.; Monitoring of Habitat degradation	E.g., coral reef maps, Statistics on climate-sensitive resources
Exposure *Elements at risk, an inventory of those*	Exposed people	Land Use Maps, census data	Distribution of residential areas and population

people, artifacts, and environmental resources that are exposed to a hazard. (UNDP, 2004) "environmental resources" added by author	Exposed property	Land use maps	Distribution of residential and other built-up areas
	Exposed livelihood	Land use maps	Distribution of agricultural, industrial, commercial etc. activities
	Exposed environment	Land cover maps	Land cover types
Resilience *Includes coping capacity and the capability to remain functional during an event and to completely recover from it.* According to Thywissen (2006)	Direct relief	Information about external assistance and relief needed and provided through humanitarian organizations during or following hazard events	Assessment, statistics
	Adaptive strategies that modify behavior	Review of political developments, educational measures; Information about technical, social and economic conditions and developments, etc.	E.g., Maps of hazardous zones for land development that are to be avoided
	Prevention measures	Information about planned and concrete measures under way	E.g., maps showing dams, sewers, protection against erosion; Hazard-proof buildings, etc.
	Capability to remain functional during an event and to completely recover from it	Monitoring and documentation of reconstruction, protection, prevention and early warning measures, and of socio-economic factors	Descriptions, assessments, maps of those measures; Time series of socio-economic data covering the period before and after the hazard event

Note: The contents highlighted in yellow are covered by this study.

3.3 Hazard types

58. Hazards are often grouped into three main categories according to their causes (Schneiderbauer and Ehrlich in Birkmann (ed.) 2006):

- natural,
- technological, and
- anthropogenic or social causes.

59. The allocation of a hazard to one cause may be difficult, as hazards may have interrelated causes, and frequently one hazard is triggered by another.

60. Table 2 contains an overview of natural hazards and combined natural/anthropogenic hazard types. Four types of hazard events (tropical cyclones, earthquakes, floods and droughts) were responsible for 94 percent of the deaths triggered by natural disasters between 1980 and 2000 worldwide (UNDP, 2004). Many of these so-called natural hazards have also anthropogenic causes or may be triggered by human factors. Only a few hazards are purely natural.

Table 2: Types of Natural Hazards, Potential Anthropogenic Causes and Relations to Other Hazards

Natural and combined natural/anthropogenic Hazards	**Hazard Types**	**Potential Anthropogenic factors or triggers**	**Major relations to other hazards**
Geological Hazards	Earthquake		Tsunamis, fire
	Volcanic eruption		Land slides
	Land Slide and Mud flow	Soil destabilization as a result of deforestation, agricultural, technical, or leisure activities	
	Subsidence	Excessive extraction of water or other substances	Flooding
	Coastal erosion	Extraction of sand or other materials	Flooding
Hydrologic Hazards	Flood	Soil sealing, especially rapid urbanization Canal contamination River regulations	Epidemic, famine
	Snow and ice avalanche	Leisure or technical activities Deforestation	
	Tsunami		May be caused by earth quake
	Storm surges	Potential increase with climate change	Flooding, coastal erosion

Natural and combined natural/anthropogenic Hazards	Hazard Types	Potential Anthropogenic factors or triggers	Major relations to other hazards
Atmospheric Hazards	Meteorological Drought	Soil degradation in combination with dry meteorological conditions may lead to edaphic droughts	Famine Subsequent severe soil erosion
	Tropical cyclone	Potential increase with climate change	Flooding
	Tornado	Potential increase with climate change	
	Hail storm	Potential increase with climate change	
	Heat wave	Potential increase with climate change	
Wildfire Hazards		Carelessness; Intended fires running out of control Criminal actions	
Biospherical Hazards	Epidemic	Lacking education Poor sanitation and waste management	
	Famine	Complex socio-economic-natural reasons, mainly related to poverty besides natural conditions and armed conflicts	May cause or trigger human actions that in turn increase the probability of further hazards

3.4 Hazards and Climate Change

61. “The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events, especially where rapid urbanization is occurring.” (IPCC, 2007). This statement of the 4th IPCC Assessment Report fully applies to the Dakar Metropolitan Area. Natural hazards cannot be regarded separately from climate change and its variability. It is widely known that the number and severity of natural disasters has increased during the past decades.

62. Climate change is interrelated with natural hazards in several ways. In this context, it is important to look at an area in a greater spatial context. While sea level rise is the most direct and prominent climate-change related threat for low lying coastal cities, deteriorating climatic conditions in the wider surroundings of those cities will in many places increase human migration into the cities and thus accelerate the already rapid urbanization. Unmanaged urban growth aggravates or even triggers natural hazard events, as urban expansion tends to occur in hazard-prone peri-urban areas which attract poor people with a cheaper land price. At the same time, climate change and its variability weaken the resilience capabilities of those cities.

4. Spatial Analysis

4.1 Overview and the Definition of Peri-Urban Areas

63. This section aims at providing the conceptual and methodological basis for the generation of hazard and vulnerability maps for Dakar, Senegal. While all types of "natural" hazards relevant for the area are considered, a selection of the following hazards for a detailed spatial analysis was made: Flooding (inland flooding of depressions), Coastal Erosion, and Sea Level Rise. Local subsidence over time was not considered in this study. The occurrence of flooding within the Dakar Metropolitan Area has recently been increasing for climatic and anthropogenic reasons, and constitutes a major threat especially for newer settlements in unsuited low-lying terrain. Coastal erosion as a more steadily acting, but very hazardous process in the area was included in the detailed analysis along with scenarios of sea level rise.

64. The generation of all map inputs needed for the risk analysis are described in detail. These maps include land use at three different points of time (1988, 1999, and 2008), Digital Elevation Model (DEM) based data layers, geology, hydrology, single-hazard maps (flooding, coastal erosion and sea level rise scenarios), and a multi-hazard map integrating all three hazards analyzed.

65. The Spatial Analysis combines the hazard mapping results with population maps, land price data, and land cover information in order to derive the exposure of these items to the hazards. As an important intermediate step, the population data from the census are disaggregated to the much finer level of 250 meter grid cells using housing density data derived from the satellite data.

66. The scale of the spatial analysis is regional, a level of detail that is relevant for the awareness-raising and institutional engagement purposes intended here. Extensions to this analysis, not covered at the current pilot stage, may include (a) consideration of other natural hazards; (b) more thorough evaluation of economic impacts of hazards taking into account direct and indirect damages; and (c) additional analysis of more detailed geographic information systems (GIS) data, cadastres, and first-hand ground-truthing, to ascertain detailed risks faced by specific populations and built areas in the broad areas indicated here as under risk.

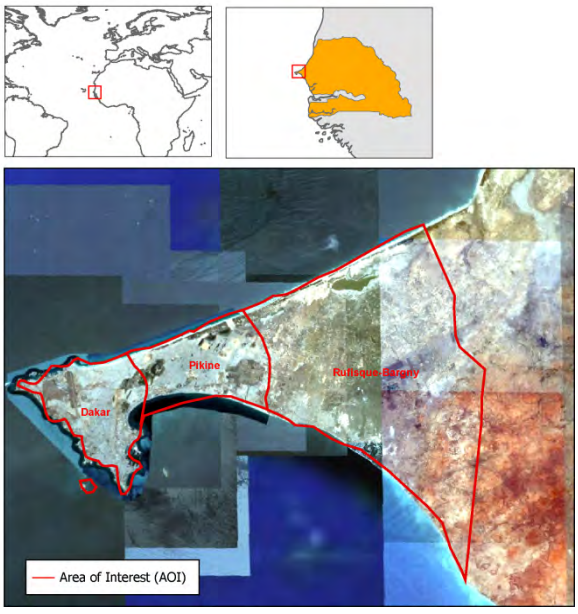
Box 3: Justification for Selection of Specific Natural Hazards

According to the historical data (see previous chapter) available for the Dakar Metropolitan Area and surroundings, flooding, coastal erosion and drought are identified as the most frequent, prevalent and significant natural hazards. While inland flooding and coastal erosion are direct risks to urban development in Dakar, the natural risk of drought must be viewed in wider geographic perspective. In Senegal, drought is documented to be a driver of migration to Dakar, but cannot be regarded as direct hazard to urban development within the Dakar Metropolitan Area. Sea level rise has been selected as it is the most pertinent climate-change related natural risk for the coastal city of Dakar.

Study area

67. The Area of Interest covers a surface of approximately 582 square kilometers. It is shown in the map and satellite images below:

Figure 7: The Dakar Metropolitan Area, Covering the Departments of Dakar, Guédiawaye, Pikine, and Rufisque[21]



[21] Sources: (2008) Africa's Urbanization for Development: Understanding Africa's Urban Challenges and Opportunities Built-up area in 2008 (white line), as observed from aerial photography—Authors' manual analysis. Administrative area (blue line)—maplibrary.com. ground imagery—GoogleEarth & embedded sources.

Peri-urban areas

68. There is no consensus on a definition of peri-urban (urban fringe) areas. Peri-urban areas have been defined in a qualitative way, for instance, as a zone of transition in land-use lying between the continuously built up urban and suburban areas of a central city (Pryor, 1968); a transition zone between fully urbanized land in cities and areas in predominantly agricultural use (Rakodi, 1998); or an area subject to urban expansion on the edge of cities and environmentally fragile urban area which is unstable and unfit for occupation (World Bank, 2007). Buxton et al. (2006) considered proximity to primary metropolitan areas and to their physical structure and form, especially types of land use.

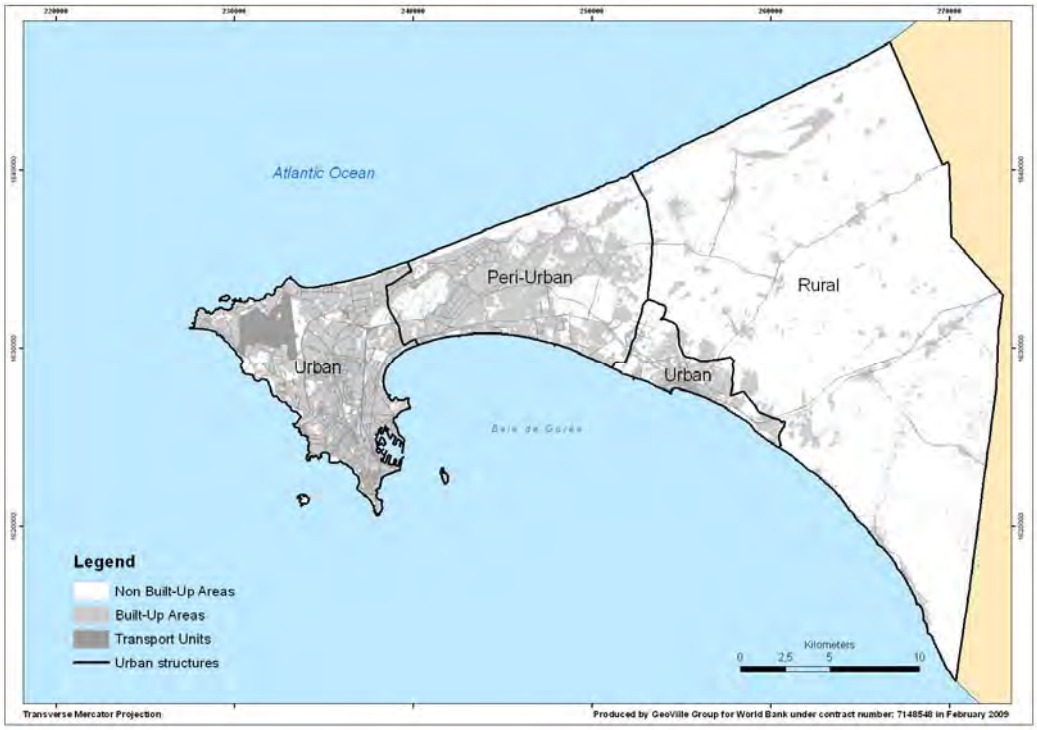
69. In addition, there have been attempts to define peri-urban areas quantitatively, for example in terms of the contiguous territory to a central place having a density of at least 1,000 persons per square mile (US Census Bureau).[22] However, there is a general agreement that peri-urban areas cannot be defined uniformly only by one measure. As Webster (2002) notes, contiguous built up (peri-urban) areas sometimes extend as far as 150 km from the core city – or, in the case of Chinese cities, as far as 300km.

70. This study adopts an eclectic peri-urban definition, combining quantitative and qualitative local information and taking into consideration know-how of local experts. The communes in the Dakar Metropolitan Area are classified into 3 subdivisions: (i) Urban areas, including communes in the Department of Dakar (the city center) and four communes (Rufisque, Bargny, Diamniadio and Sébikotane) and three joint districts (Rufisque Ouest, Rufisque Nord and Rufisque Est) in the Department of Rufisque, which are in general, areas with strong urban and industrial economic activities; (ii) Rural areas, including two large communes in the Department of Rufisque defined locally as "Rural Communes," Sangalkam, and Yène; and (iii) Peri-urban areas, which are the areas lying in between these other types of areas, including mixed land use and relatively lower densities (Figure 8).[23]

[22] US Census Bureau 1995 at: http://www.census.gov/population/censusdata/urdef.txt.

[23] Specifically, Urban areas include Biscuiterie, Cambérène, Dieuppeul-Derklé, Fann-Point E-Amitié, Gorée, Grand Yoff, Grand-Dakar, Gueule Tapée-Fass-Colobane, Hann-Bel Air, HLM, Médina, Mermoz-Sacré Cœur, Ngor, Ouakam, Parcelles Assainies, Patte d'Oie, Plateau, Sicap Liberté, and Yoff (the Department of Dakar); Bargny, Rufisque Est, Rufisque Nord, and Rufisque Ouest communes (the Department of Rufisque). Rural areas are Sangalkam, and Yène rural communities (the Department of Rufisque). Finally, Peri-urban areas cover Golf Sud, Ndiarème Limoulaye, Sam Notaire, and Wakhinane Nimzatt (the Department of Guédiawaye); Dalifort, Diamaguène Sicap Mbao, Djidah-Thiaroye Kaw, Guinaw Rail Nord, Guinaw Rail Sud, Keur Massar, Malika, Mbao, Pikine Est, Pikine Nord, Pikine Ouest, Thiaroye Gare, Thiaroye Sur Mer, Tivaouane Diaksao, Yeumbeul Nord, and Yeumbeul Sud communes (the Department of Pikine).

Figure 8: The Classification of Urban, Peri-Urban, and Rural areas in the Dakar Metropolitan Area



Some remarks on the limitations of the study

71. It can be seen that this study compiles and spatially analyses many components of hazard (or disaster) risks, especially with regard to the spatial distribution and interaction of major risk factors. On the other hand, the study is limited in the following respect: With the available input information only the spatial distribution of relative hazard potentials can be estimated. The absolute damage-frequency relationship and probabilities and their spatial differentiation cannot be derived. So for instance absolute inundation levels and probabilities cannot be determined, and it is not possible with a *remote* study to infer concrete figures about coastal erosion. Likewise, the projected flooded areas in connection with the assumed seal level rise scenarios are the result of simplifying assumptions (the only possible in such a study), and do by no means mean that the flooded area will actually be of that extension.

72. With regard to vulnerability and exposure, mainly exposure-related information can be derived. Vulnerability, as argued below, cannot be measured directly, but only inferred with the help of indicators. In the context of this study we derive spatial indicators of vulnerability from hot spots of exposure, assuming that extreme concentrations of exposure will lead to locally increased vulnerability.

73. Finally, for this study no information on protection and prevention measures that may be taken or planned by local authorities are known and included.

4.2 Map Generation

74. The map generation described in this chapter comprises

- Land use and land use change for two periods (1988-1999, 1999-2008)

- Single hazard factor maps
- Single hazard potential maps, and
- Multi-hazard potential maps.

75. In Table 3, an overview is provided about these maps, including input data used, methods, map contents, and references for their production.

Table 3: Overview of the Produced Maps

Map Type	Input Data	Approach	Contents	References
Land Use and Land use Change Maps				
Land use and land use change	Optical satellite data	Image Co-registration Visual Image interpretation Change analysis Topology checks and validation	Current detailed land use (2008) and Land use changes 1999 – 2008 and 1988 – 1999 Legend: 13 and 7 classes, respectively	Modified CORINE land cover legend
Single Hazard Factor Maps				
Corrected and adapted Digital Elevation Model (DEM)	Hybrid (based on X and C Band) SRTM (Shuttle Radar Topography Mission)	DEM correction based on imposed drainage condition; Adaptation of seashore level to high resolution satellite imagery	Hydrologically correct, depression-less DEM	ANUDEM program by Michael Hutchinson[24]
DEM derivate: Slope	Corrected DEM	Average maximum technique	Slope in degrees	Burrough and McDonell[25]
DEM derivate:	Corrected DEM	State of the Art	Aspect in	ArcGIS

[24] Hutchinson, M. F. (1993): Development of a continent-wide DEM with applications to terrain and climate analysis. In Environmental Modeling with GIS, ed. M. F. Goodchild et al., 392–399. New York: Oxford University Press.

[25] Burrough, P. A., McDonell, R.A. (1998): Principles of Geographical Information Systems (Oxford University Press, New York), p. 190.

Aspect		GIS software	degrees: 0° = N, 180° = S	software
DEM derivate: Flow direction	Corrected DEM	Derivation of steepest descent (or maximum drop) among eight directions	Eight direction flow model; Flow direction in degrees	Jensen and Dominingue[26]
DEM derivate: Flow accumulation	Corrected DEM	Flow derived as accumulated weight of all cells flowing into each downslope cell in the output raster	Flow accumulation expressed as no. of cells contributing to the accumulated water at a given location	Jensen and Dominingue
DEM derivate: Watersheds	Corrected DEM		Catchment areas	ARC GIS software
Geology	Detailed Map by Lo and Diop (1:25.000), and Geologic map 1:200.000	Digitizing and merging the two input maps	Geological map with 11 geologic units	Lo and Diop[27]; Centre de Suivi Ecologique (CSE, http://www.cse.sn/)
Rocky Cliffs	Topographic Map 1 :50.000 (1983)	Visual map interpretation and delineation of respective features	Map containing coastal stretches with rocky cliffs	Institute Geographique National France (IGN, http://www.ign.fr/)
Soil Sealing	2008 Land use map derived in this study	Map re-coding	Binary map containing sealed and non-sealed surfaces	
Hydrologic Features	Topographic Map 1 :50.000	Visual map interpretation and delineation	Map containing: Wetlands/Ponds	Institute Geographique National France

[26] Jenson S. K., Domingue, J.O. (1988): Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. Photogrammetric Engineering and Remote Sensing 54 (11): 1593-1600.

[27] Lo, P.G., Diop, M.B. (2000): Problems associated with flooding in Dakar, western Senegal: influence of geological setting and town management. Bull. Eng. Geol. Env. 58, p 145-149.

(without permanent water bodies)	(1983)	of respective features	; Temporary flooded; Temporary water channels	(IGN, http://www.ign.fr/)
Permanent water bodies	Topographic Map 1 :50.000 (1983) High resolution Satellite data 2008	Visual map interpretation and delineation of respective features, merging features from both sources	Map containing: Permanent water surfaces; Permanent water channels	Institute Geographique National France (IGN, http://www.ign.fr/)
Single Hazard Potential Maps				
Flood Potential Map	DEM and derivates ; Geological Map ; Soil Sealing Map Hydrological features	Re-classification of all map input layers using five-point scales and additive merging	Map of Relative Flood Potential: five levels from no risk to very high plus permanent water bodies	Lo and Diop; Mbow et al.[28]
Coastal Erosion Potential	Geological Map ; Aspect of the coast facing the predominant wave impact; Slope of the coast	Re-classification of all map input layers using five-point scales and additive merging	Map of Relative Coastal Erosion: five levels from no risk to very high	Fall et al.[29]
Coastal Inundation Potential	DEM	Connectivity analysis for 2 seal levels rise scenarios	Map of flooded areas in different sea level rise scenarios	Poulter and Halpin[30]

[28] Mbow, C., Diop, A., Diaw, A.T., Niang, .. (2008): Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal). African Journal of Environmental Science and Technology Vol. 2 (4), pp. 075-088 http://www.academicjournals.org/AJEST/PDF/pdf%202008/April/Mbow%20et%20al.pdf.

[29] M.Fall, R.azzam,C.Noubactep. 2006. A multi-method approach to study the stability of natural slopes and landslide susceptibility mapping. Engineering Geology 82: 241-263.

[30] Poulter, B., Halpin, P.N. (2007): Raster Modelling of Coastal Flooding from Sea-Level Rise. Int. Journal of Geographical Information Science, Vol. 22, No.2, p. 167-182.

Multi - Hazard Potential Maps				
Multi Hazard Potential	Relative Flood Potential Coastal Erosion Potential Coastal Inundation Potential	Re-classification of all map input layers and merging	Map of showing potential for natural hazards in Dakar	Khatsu and v.Westen[31]

4.2.1 Land Use Mapping

76. These base maps should include urban areas and rural communes, show built-up and non-built up areas, and highlight areas and direction of observed rapid urban expansion based on comparison of time series data.

77. The objective of "map generation" is to generate multi-temporal base GIS maps of the Dakar Metropolitan Area from satellite imagery, depicting built-up areas, the nature of major infrastructure and areas with rapid urban expansion as well as non-built up areas such as agriculture and forests. The project should generate comparable information as input to diagnostics for urban extent and peri-urban expansion in the Dakar Metropolitan Area. GIS maps should show the status and development of land cover/use within the area for three points in time, i.e. 1988, 1999, and 2008. In order to create multi-temporal base GIS maps for the Dakar Metropolitan Area three different acquisition dates within the last 3 decades were considered.

Table 4: Available Multi-temporal Satellite Scenes

Acquisition Date	Sensor	Resolution
2008-09-08 / 2007-09-26	SPOT 5	2.5m
1999-11-04 / 1999-11-11	Landsat ETM	15 m (resolution merge)
1988-03-10	Landsat TM	30m

Base mapping 2008

78. Mapping started with the most recent satellite data with the highest spatial resolution (SPOT satellite image 2008 with 2.5 meter resolution). Technical procedures are based on automated object-based classification to detect specific land cover elements, complemented by GIS-based post-processing and visual image interpretation to add additional land cover/use classes that need detailed on-screen investigation and verification. Additional

[31] Khatsu, P., v.Westen, C.J, (2005): Urban multi-hazard risk analysis using GIS and Remote Sensing: A case study from Kohima Town, Nagaland, India, ACRS Proceedings, p9.
. http://www.aars-crs.org/acrs/proceeding/ACRS2005/Papers/URM1-2.pdf

sources for identification were scanned topographic maps and information extracted from online-sources (webmaps).

79. The current nomenclature of 13 thematic classes represents the maximum information content that can be realistically derived from SPOT satellite imagery. For subsequent mapping of land use changes an aggregated land use nomenclature was used to allow for reliable detection and recognition of land use changes using Landsat imagery.

Figure 9: Detailed Land Use Map of Dakar, 2008

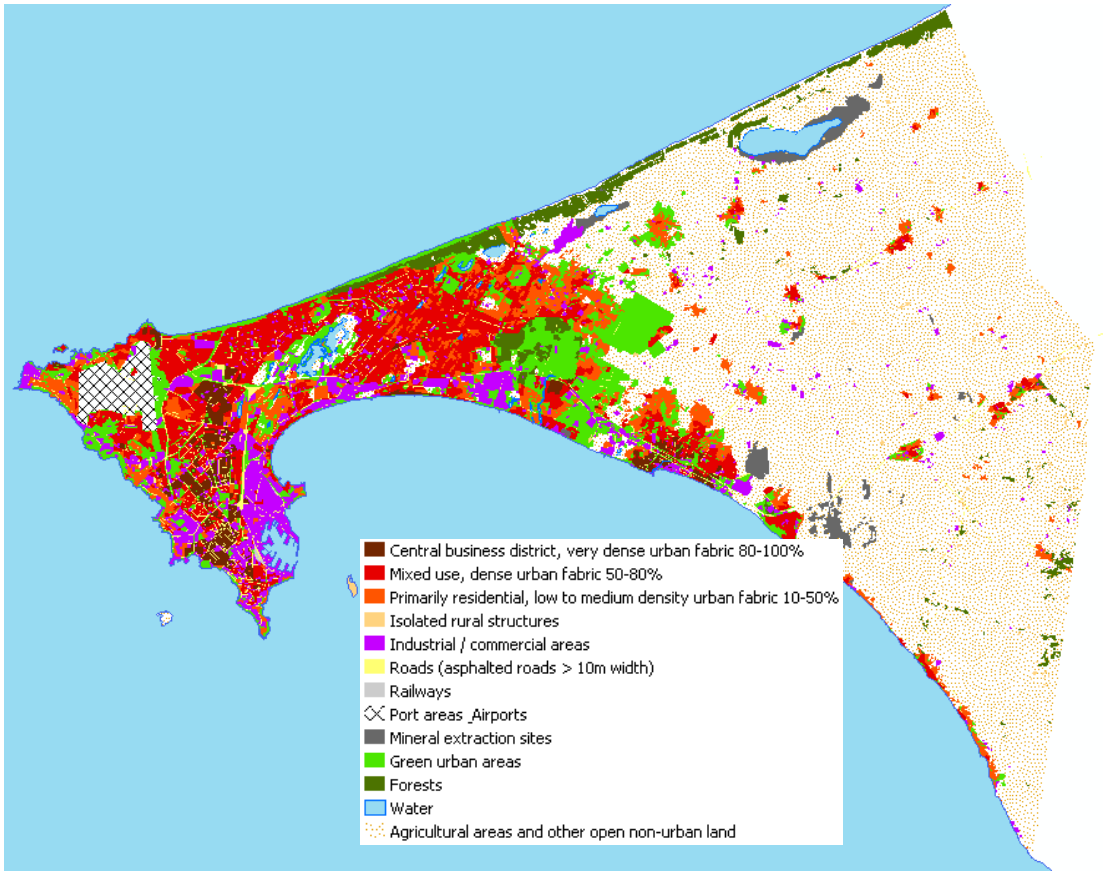
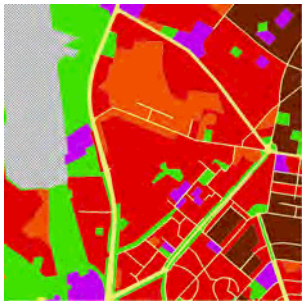


Figure 10: Comparison of Detailed and Aggregated Land Use Map for Year 2008

Detailed Land use classification 2008 (13 classes)	Aggregated Land use classification 2008 (7 classes)
	
Central business district, very dense urban fabric 80-100% Mixed use, dense urban fabric 50-80% Primarily residential, low to medium density urban fabric 10-50% Isolated rural structures Industrial / commercial areas Roads (asphalted roads > 10m width) Railways Port areas & Airports Mineral extraction sites Green urban areas Forests Water Agricultural areas and other open non-urban land	Residential areas Non-residential urban areas Transport units Green urban areas Forest Water Agricultural areas and other open non-urban land

Base mapping 1988 and 1999 and changes

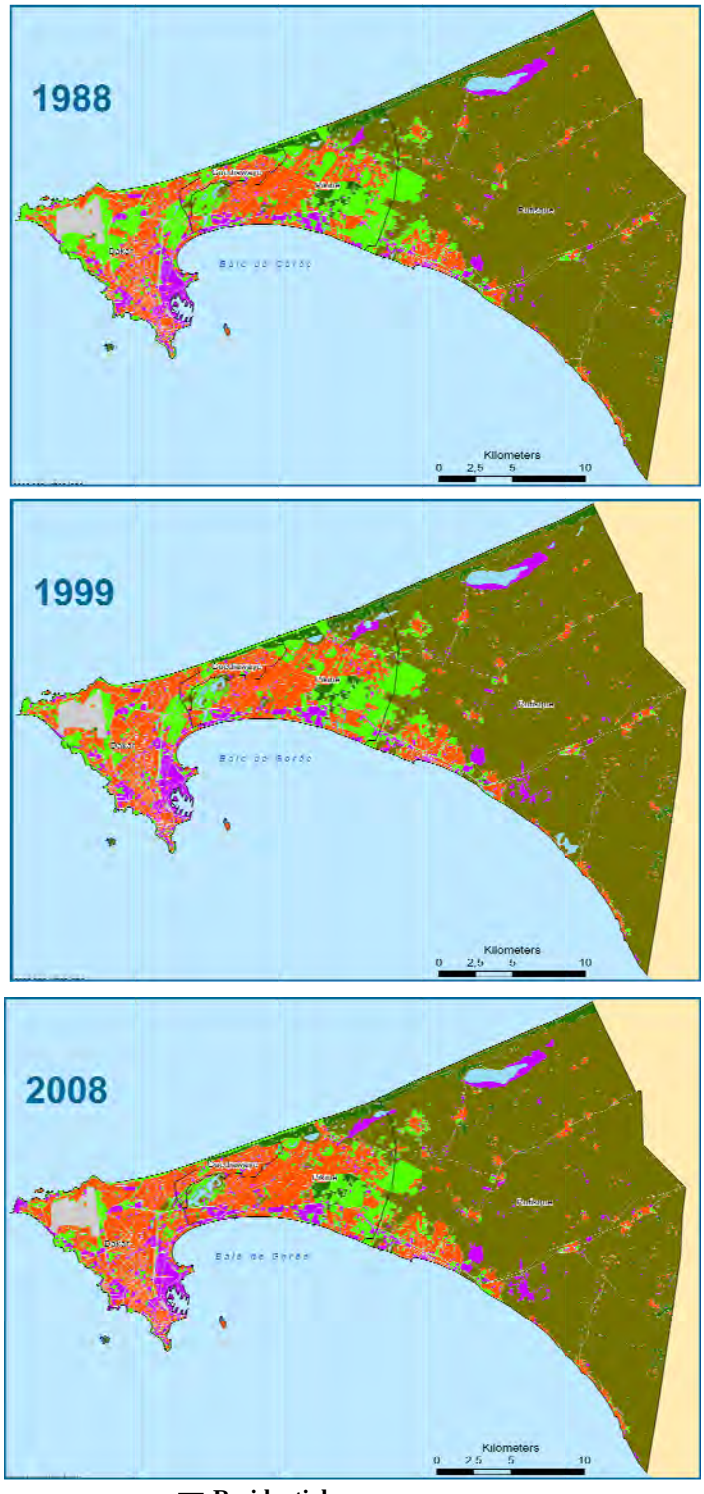
80. Mapping of the historical land use for the reference dates 1988 and 1999 was done by using lower resolution Landsat imagery (15m merged image for 1999, 30m image for 1988). Methods used comprise automated land cover derivation and visual interpretation.

Table 5: List of Thematic Classes for land use change mapping

Common classed land cover/use maps 1988, 1999 and 2008		**Additional classed only for land cover/use map 2008**
Urban areas	Residential areas	Central business district, very dense urban fabric 80-100%
		Mixed use, dense urban fabric 50-80%

Common classed land cover/use maps 1988, 1999 and 2008		**Additional classed only for land cover/use map 2008**
		Primarily residential, low to medium density urban fabric 10-50%
		Isolated rural structures
	Non-residential urban areas	Industrial / commercial areas (incl. water supply infrastructure, sea walls and flood defenses)
		Mineral extraction sites
	Transport units	Roads (> 10m width)
		Railways
		Port areas & Airports
	Green urban areas	
Non-urban areas	Forests	
	Water	
	Agricultural areas and other open non-urban land	

Figure 11: Land Use Changes, 1988, 1999, and 2008



4.2.2 Hazard Potential Maps

Single Hazard potential maps

81. The purpose of the single hazard factor maps is to provide the necessary input data layers for a spatial representation of the natural hazards in Dakar. As also human factors contribute to these hazards, they are also contained in this map array (i.e. soil sealing). For each hazard type we classified the available input parameter for risk potential according to peer reviewed published scientific literature of related studies in the area and merged the appropriate parameters using best practice knowledge and GIS techniques. The input parameters, spatial analysis and results are described for each natural hazard hereafter. Input data maps are also shown in Annex.

82. In order to facilitate analysis for the Dakar Metropolitan Area and to accommodate the different resolutions and accuracies of the input data in the final multi hazard map, the single hazard risk potential grids were aggregated to 250 x 250 meter cells using a nearest neighborhood method. Comparability of all hazard potential maps is ensured by using a homogeneous classification scheme for each hazard map as shown in the following table:

Table 6: Key for classifying and reporting relative natural hazard potentials at aggregated resolution (250 meter)

	High
	Moderate
	Low
	No risk

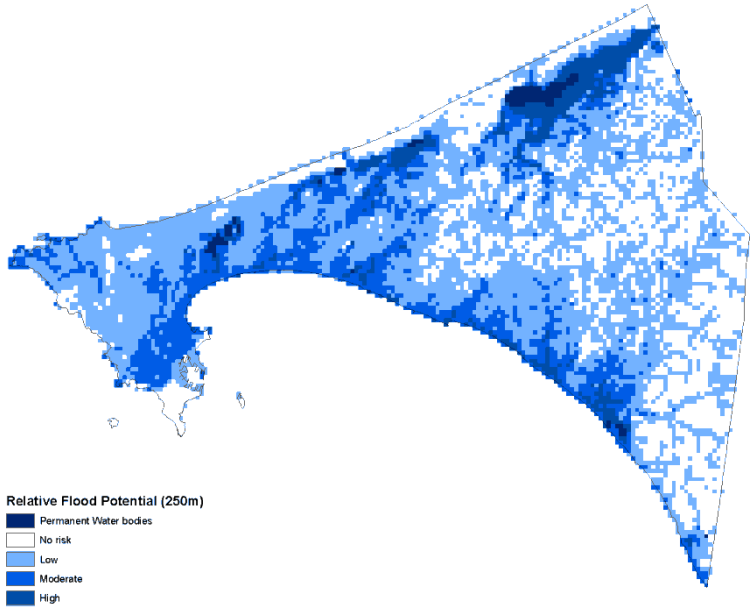
Relative Flood Potential (RFP)

83. To derive a relative flood potential map of Dakar all factors were considered that were in past studies identified to be significant and/or relevant parameters contributing to flooding by rain and for which a data layer was available. These are:

- Elevation (from absolute, depressionless DEM)
- Geology as an indicator for the permeability of the ground
- Degree of soil sealing
- Slopes of the topography
- Degree of potential flow accumulation
- Hydrological features
- Permanent water bodies

84. Each parameter was reclassified for relative flood potential according to the studies by Lo and Diop (2000) and Mbow et al.(2008), and to best practice knowledge by our scientific experts.

Figure 12: Relative Flood Potential Layer for Dakar, Senegal Aggregated to 250m Cells.



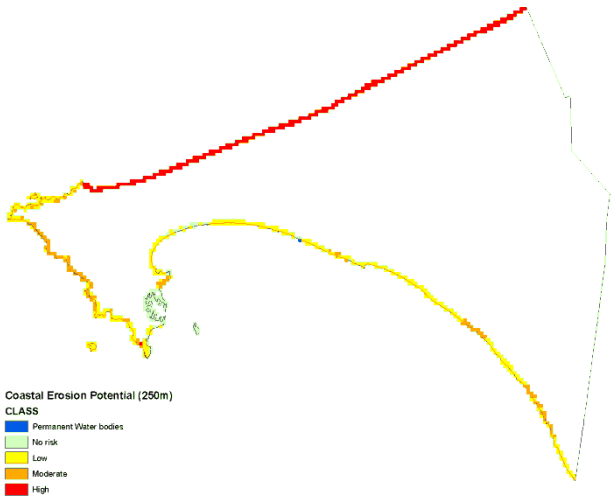
Coastal Erosion Potential (CEP)

85. In order to derive a coastal erosion potential map of Dakar, Senegal, all factors were incorporated that were in past studies identified to be significant and/or relevant parameters contributing to coastal erosion and for which a data was readily available in an adequate resolution. These are:

- Geology as an indicator for the stability of the coast
- Aspect of the coast facing the pre-dominant wave impact
- Slope of the coast
- Information on the direction of pre-dominant wave impact, based on Satellite Radar data and obtained through the database of http://www.surfline.com.

86. Each parameter was re-classified for coastal erosion potential based on the studies by Fall et al. (2006) and according to best-practice knowledge by our scientific experts.

Figure 13: Coastal Erosion Potential Layer for Dakar, Senegal Aggregated to 250m Cells.



Sea Level Rise

87. Two scenarios were assumed: A mean sea level rise (MSL) of 1m and a mean sea level rise of 5m. These two scenarios are not considered to be likely in the short term, but representing them in the maps of the city can give stakeholders and policy makers a sense of the magnitude of extreme climate change impact. The projection of the sea level rise was based on the DEM.

88. Sea level rise can be expected to cause coastal erosion and inundations. During that time an unforeseeable sequence of coastal erosion, protection measures and actual inundation will occur, which will vary depending on various conditions, especially topography, geology and human factors. Meteorological factors during the period of sea level rise, such as storm frequency, can also not be projected.

89. For the technical approach a comprehensive study of Poulter and Halpin (2007) has been consulted, which shows the high variability of resulting flood extents when using varying horizontal DEM resolutions and different assumptions made on hydrological connectivity.

Figure 14: 1m Coastal Inundation Potential for Dakar, Senegal Aggregated to 250m Cells

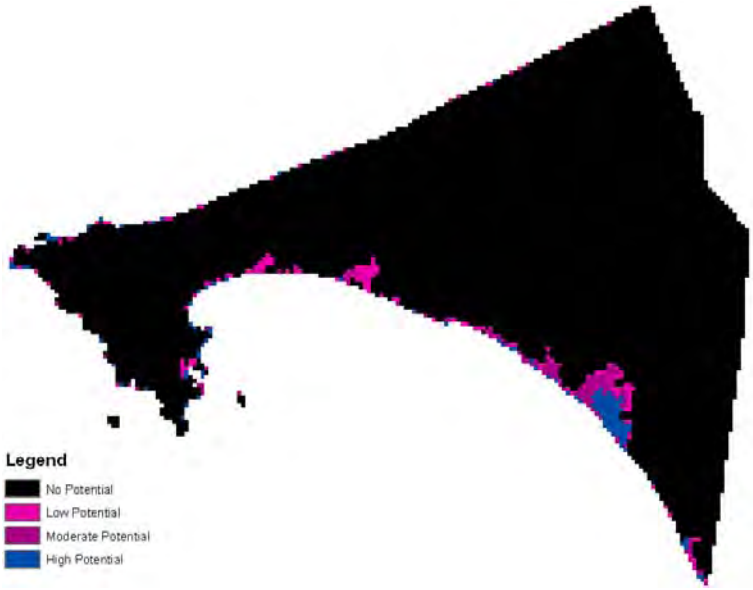
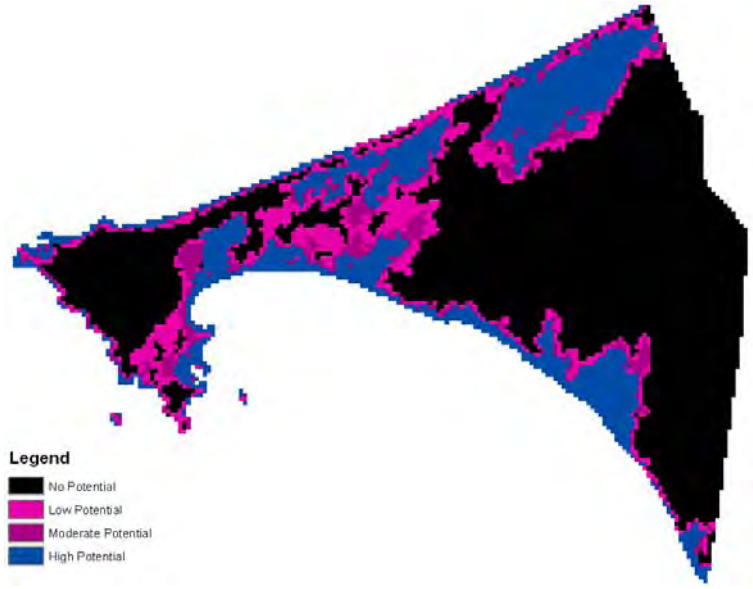


Figure 15: 5m Coastal Inundation Potential for Dakar, Senegal Aggregated to 250m Cells



Multi hazard potential map

90. The single hazard potential maps aggregated to 250m grid level were merged with the objective to obtain a map that reflects both, the type and the potential of all three analyzed natural hazards for a given location (250x250m cell). In order to achieve this, the single hazards and their potential were combined to a new set of hazard potentials that includes possible combinations of several hazards, single hazards, where only one hazard type occurs, and areas with no hazard potential.

91. For multi-hazard maps, this is a standard approach (see for example Khatsu and v.Westen, 2005), even though different variants of the approach may be applied.

The three single hazards

- Relative Flood Potential (RFP)
- Coastal Erosion Potential (CEP), and
- Coastal Inundation Potential (CIP)

92. Were combined to a multi-hazard map containing both, the hazard types and their potential. However, due to the complexity of the map, not all original degrees of the hazard potentials could be maintained. Consequently, an aggregation of the hazard potential to the following two levels was applied:

1) Low and moderate potential of the respective hazard (aggregating the low and moderate potential)

2) High Potential of the respective hazard (remained the same as in the single hazard maps).

93. One exception from this scheme was made for the RFP as a single risk, as the aggregation of low and moderate RFP would result in a very large, undifferentiated aggregated class. For this reason, moderate and low RFP are depicted as individual classes.

94. As a result, the hazard classes listed in Table 7 were derived for the multi-hazard map. Figure 16 shows the resulting multi-hazard map with the classes listed in Table 7. Figure 17 shows another representation of the multi-hazard potential, where the single hazards are juxta-positioned instead of overlaid.

Table 7: Classes Contained in the Multi-Hazard Map

Hazard Classes derived for the multi-hazard map	**Original Hazard Potential in Single Hazard Map (possible alternatives)**
No Potential	No Potential of any single hazard
Low and Moderate CIP/CEP	CIP low or moderate, CEP low or moderate
Low and Moderate CIP/RFP	CIP low or moderate, RFP low or moderate
Low RFP	RFP low, others no potential
Moderate RFP	RFP moderate, others no potential
Low and Moderate CEP	CEP low or moderate, others no potential
Low and Moderate CIP	CIP low or moderate, others no potential
High CIP/CEP	CIP high, CEP high
	CIP high, CEP moderate or low
	CIP moderate or low, CEP high

Hazard Classes derived for the multi-hazard map	Original Hazard Potential in Single Hazard Map (possible alternatives)
High CIP/RFP	CIP high, RFP high
	CIP high, RFP moderate or low
	CIP moderate or low, RFP high
High RFP	RFP high, others no potential
High CEP	CEP high, others no potential
High CIP	CIP high, others no potential

Figure 16: Multi-Hazard Potential in Dakar, Senegal, Including Relative Flood Potential, Coastal Erosion and 1m Coastal Inundation Potential Scenarios

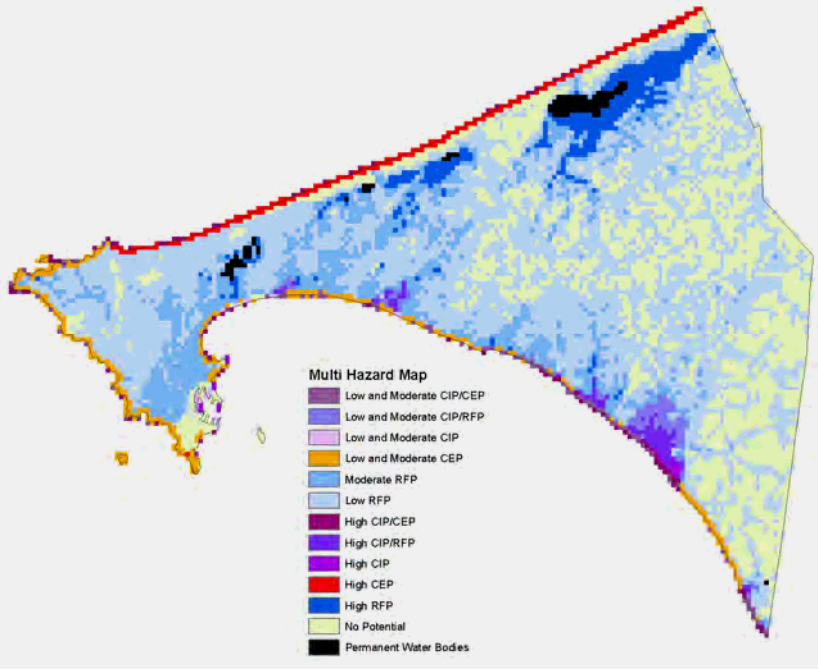
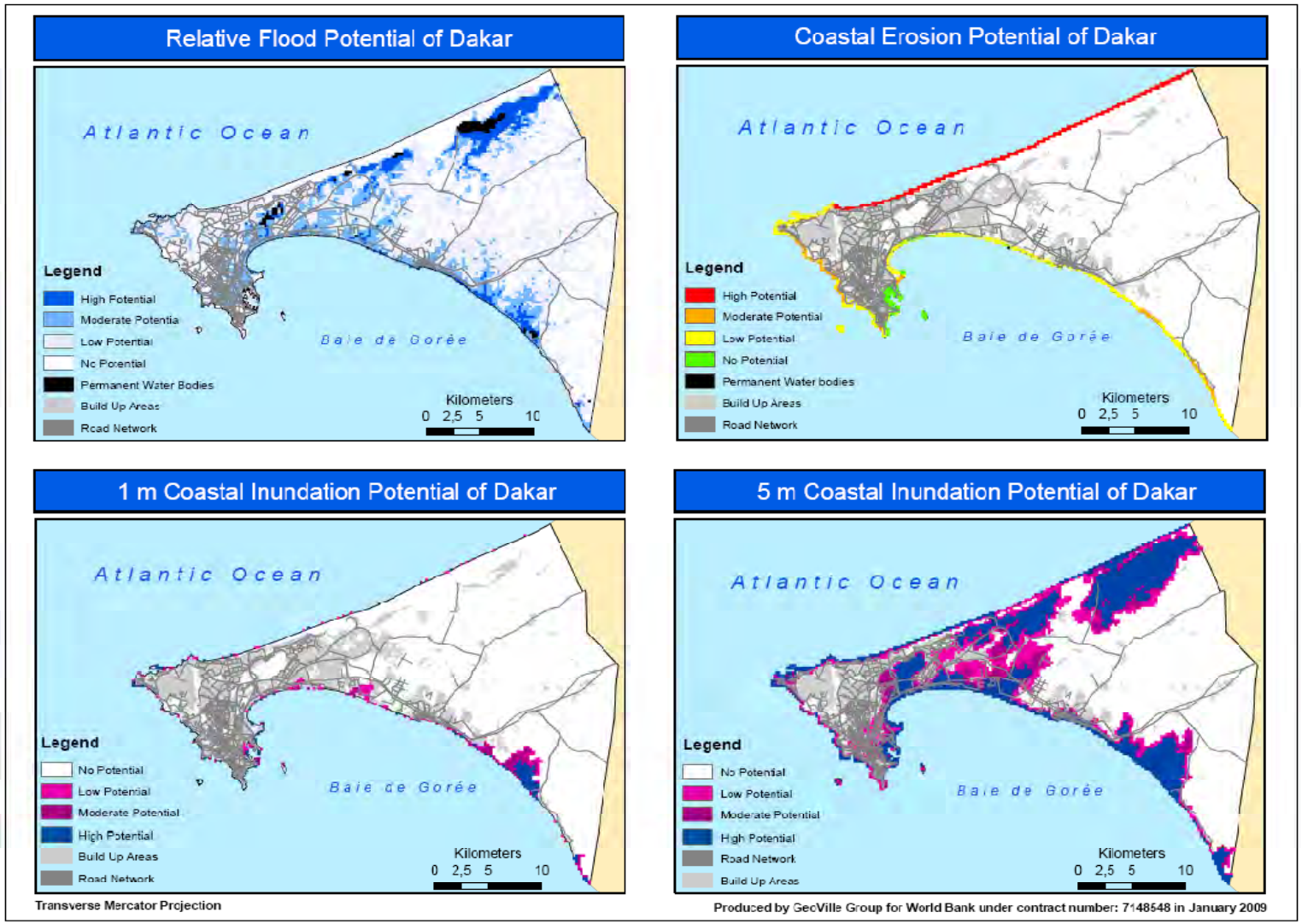


Figure 17: Multi-Hazard Potential in Separate Maps



4.3 Spatial Analysis

4.3.1 Methodology

4.3.1.1 Overview

95. The objective of "Spatial Analysis" is to obtain information about the spatial relationship between the natural hazard potentials and the exposed "items", i.e. population, land use units, and economic assets. For this purpose, different spatial analyses were to be performed, generating statistical results and maps containing the following information:

- Potential hotspots and risk areas illustrating type and degree of vulnerability for the different risk categories and scales of risk defined previously (Task 1)
- Built-up areas exposed to risk: general characterization of the urban land use (i.e. residential, industrial/commercial, etc.) including type of vulnerability (Task 2)
- Non-built-up areas exposed to risk: general characterization of the land use, topography, and soil, including type of vulnerability (Task 3).

96. As an outcome of the theoretical part of this project and of the common clarification, instead of the term "vulnerability" the term "exposure" should be used in this context for the following reason: What we measure with remote sensing and auxiliary information in such a project is the kind and quantity of items, which are exposed to potential hazard events. We cannot infer conclusions about their vulnerability without further information. Such information would for instance include institutional capacities at different administrative levels, state of the infrastructure(s), public income and expenses, educational level, etc. This type of "vulnerability analysis" however is not covered in this study.

97. Instead, we relate the spatial distribution of the hazard potentials to different quantities and types of exposed items, i.e., people, land prices, and land use. Vulnerability is thus not directly derived, but a relative spatial increase of vulnerability is indicated in the map legends as a result of a concentration of exposed items and hazard potentials (see Figure 20). This follows the logic that a higher vulnerability of exposed items can be expected at locations where spatial concentrations (hot spots) of both hazard potential and degree of exposure occur.

98. The objectives stated in the three above listed items were first translated into a list of map products that can be generated on the basis of the available input data and results generated so far (Table 8). The relation of these map products to the original, above listed tasks is indicated in the table (Task No., column 1).

99. Along with the maps, statistical analyses were performed, using MS Excel. In the following sections, the methodology and results of the produced statistics and the maps are presented, structured according to the three above listed project tasks.

Table 8: List of Maps Produced for Spatial Analysis

Task No.	Map Name	Map Contents	Approach
Social exposure and vulnerability			
1	Social exposure and vulnerability 2008	No. of residential people per hectare in 2008 within potential (multi)-hazard zones on a continuous scale	Disaggregation of residential population figures to 250 m grid cells on the basis of land use data and overlay with (multi)-hazard zones. The population figures are shown on a hectare basis.
1	Social exposure and vulnerability 1999	No. of residential people per hectare in 1999 within potential (multi)-hazard zones on a continuous scale	
1	Social exposure and vulnerability 1988	No. of residential people per hectare in 1988 within potential (multi)-hazard zones on a continuous scale	
1	Population development and vulnerability 1999 to 2008	Population development 1999 - 2008 in absolute numbers on a 250 m grid basis within (multi)-hazard zones on a continuous scale	Derivation of the population development on a 250m grid basis and overlay with (multi)-hazard zones
1	Population development and vulnerability 1988 to 1999	Population development 1988 - 1999 in absolute numbers on a 250 m grid basis within potential (multi)-hazard zones on a continuous scale	Derivation of population development on a 250m grid basis and overlay with hazard zones
Economic exposure and vulnerability			
1	Economic exposure and vulnerability 2008	Land price values in $ /sq km and potential (multi)-hazard zones	The land prices are on a sq km basis and were converted from the Senagalese Franc into U.S. dollars
Overall social and economic vulnerability			
1	Overall social and economic	Land prices and population density overlaid with potential	Based on a classification of the land prices and population density 6 combined classes for

	vulnerability 2008	(multi)-hazard zones	these two properties were built and overlaid with (multi)-hazard zones
Built-up Areas exposed to Hazards			
2	Built-up areas with (multi)-hazard potential 2008	Built-up land use classes in 2008 and potential (multi)-hazard zones	Overlay of built-up land use classes and (multi)-hazard zones; (multi)-hazard zones are only depicted within built-up areas
2	Built-up areas with (multi)-hazard potential 1999	Built-up land use classes in 1999 and potential (multi)-hazard zones	
2	Built-up areas with (multi)-hazard potential 1988	Built-up land use classes in 1988 and potential (multi)-hazard zones	
2	Share of industrial/ commercial/traffic areas and vulnerability 2008	Percentage of industrial/commercial/ traffic areas within 250 m grid cells overlaid by and (multi)-hazard zones	Derivation of percentage of these economically used areas within 250 m grid cells, shown together with (multi)-hazard zones (multi)-hazard zones are depicted for the total area
Non-built-up Areas exposed to Hazards			
3	Non built-up areas with (multi)-hazard potential 2008	Non built-up land use classes in 2008 and potential (multi)-hazard zones, soil types	Overlay of non built-up land use classes and (multi)-hazard zones together with soil types; (multi)-hazard zones are only depicted within non built-up areas
3	Non built-up areas with (multi)-hazard potential 1999	Non built-up land use classes in 1999 and potential (multi)-hazard zones, soil types	
3	Non built-up areas with (multi)-hazard potential 1988	Non built-up land use classes in 1988 and potential (multi)-hazard zones, soil types	

4.3.1.2 Generation of Input Data

100. For the generation of the input data of the Spatial Analysis, several data sources were used, which were partly generated in this project, and partly derived from respective source data. A list of the data sources and the derived input data for the Spatial Analysis is contained in Table 9. The table includes a short description of the data preparation and generation methods. A more detailed description of the population disaggregation is added following Table 9.

Table 9: Source Data, Preparation Methods, and Resulting Input Data for the Spatial Analysis

Source data	Vintage and Data source	Method of data preparation/generation	Resulting input for the Spatial Analysis
Satellite data from SPOT and LANDSAT satellites	Generated in this project	Automatic image classification and visual correction and refinement Visual change detection	Land cover data with 10m raster size 13 (detailed) and 7 (generalized) classes Share of industrial/ commercial/traffic areas
Hazard Potentials	Generated in this project	Various GIS intersection and modelling approaches Transformation in 250m raster data sets	Hazard potentials with 250m raster size
Demographic data from different administrative levels; Land cover data (generated in this project)	Land cover data (1988, 1999, 2008) generated in this project Demographic data (1988, 1998, 2005) from: Ministry of economy and finances of Senegal National agency for demography and statistics – Dakar	Population disaggregation modelling using in-house developed models The figures for 1999 and 2008 were extrapolated based on averaged population growth rates	Disaggregegated population data: Number of people per hectare, rasterized with 250 m grid resolution Population development between 1988 and 1999, and 1999 and 2008

Source data	Vintage and Data source	Method of data preparation/generation	Resulting input for the Spatial Analysis
Digital Elevation Model Hybrid X and C Band SRTM-Data, 30m (90m for gaps)	2000 DLR	Bilinear interpolation for smoothing, resampling; Filling gaps with 90m SRTM	Elevation data with 10m raster size
Topographic Maps Dakar, Bargny, Kayar 1:50.000	1983 National Geographic Institute of France	Extraction of permanent water bodies in combination with land cover maps	Permanent water bodies as depicted in the Spatial Analysis Maps
Soil map of Senegal 1:1.000.000	1965 Institute of research in Dakar (centre O.R.S.T.O.M)	Scanned, vectorized, translation of soil types, geographical coregistration, assignment of map colors	Digital soil map, used for cartographic overlay
Administrative boundaries, various levels	2008 National agency for demography and statistics - Dakar	Analogue borough boundaries were vectorized and partially corrected; Derivation of district boundaries	Digital administrative boundaries
Land Price Values	2008 Local consultation	Currency translation from Senegalese Franc to U.S. $	Land prices in U.S. $/sq km

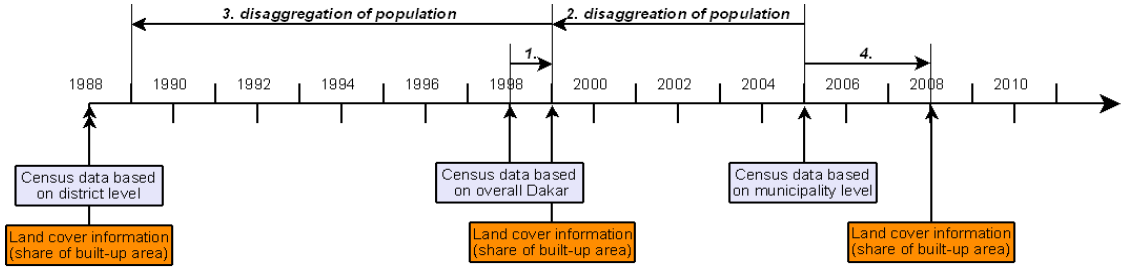
Derivation of the Disaggregated Population Data for 1988, 1999, and 2008

101. Information about the distribution of population within Dakar was essential to estimate the local social exposure to the hazards. The better the allocation of the population can be assessed, the better the exposure of the population to natural hazards can be estimated. Therefore it is of greatest interest to disaggregate the population from municipality or district level to a more detailed level such as 250 m grid cells.

102. For the study area census data was obtained for the years 1988, 1998 and 2005. While for 1988 the census data was available on district level, 1998 census data was only available for whole Dakar, and for 2005 census data was available on municipality level.[32]

103. To use the census data for the disaggregation procedure, which is based on the housing density (proportion of residential areas) derived from earth observation data, the census data has to be synchronized with the land cover data. Land cover data was derived from the satellite images that were available for 1988, 1999 and 2008.

Figure 18: Synchronizing Land-Cover/Use Data with the Census Data



104. The following steps were performed for synchronizing land cover data and the census data (see Figure 15):

- Extrapolation of overall Dakar population to 1999 based on population growth between 1988 and 1998.
- Disaggregation of population on commune level based on population of 1999 and change of residential build up area between 2005 and 1999
- Disaggregation of population on commune level based on population of 1988 and change of residential build up area between 1999 and 1988
- Extrapolation of population to 2008 on commune level based on population growth between 1999 and 2005.

105. The population information on municipality level serves as input for the population disaggregation to 250m grid cells. Applying housing density (proportion of residential areas) as a proxy for population density allows estimating the local population distribution. This approach can be formalized as follows:

$$Pdens = k * Hdens \qquad (1)$$

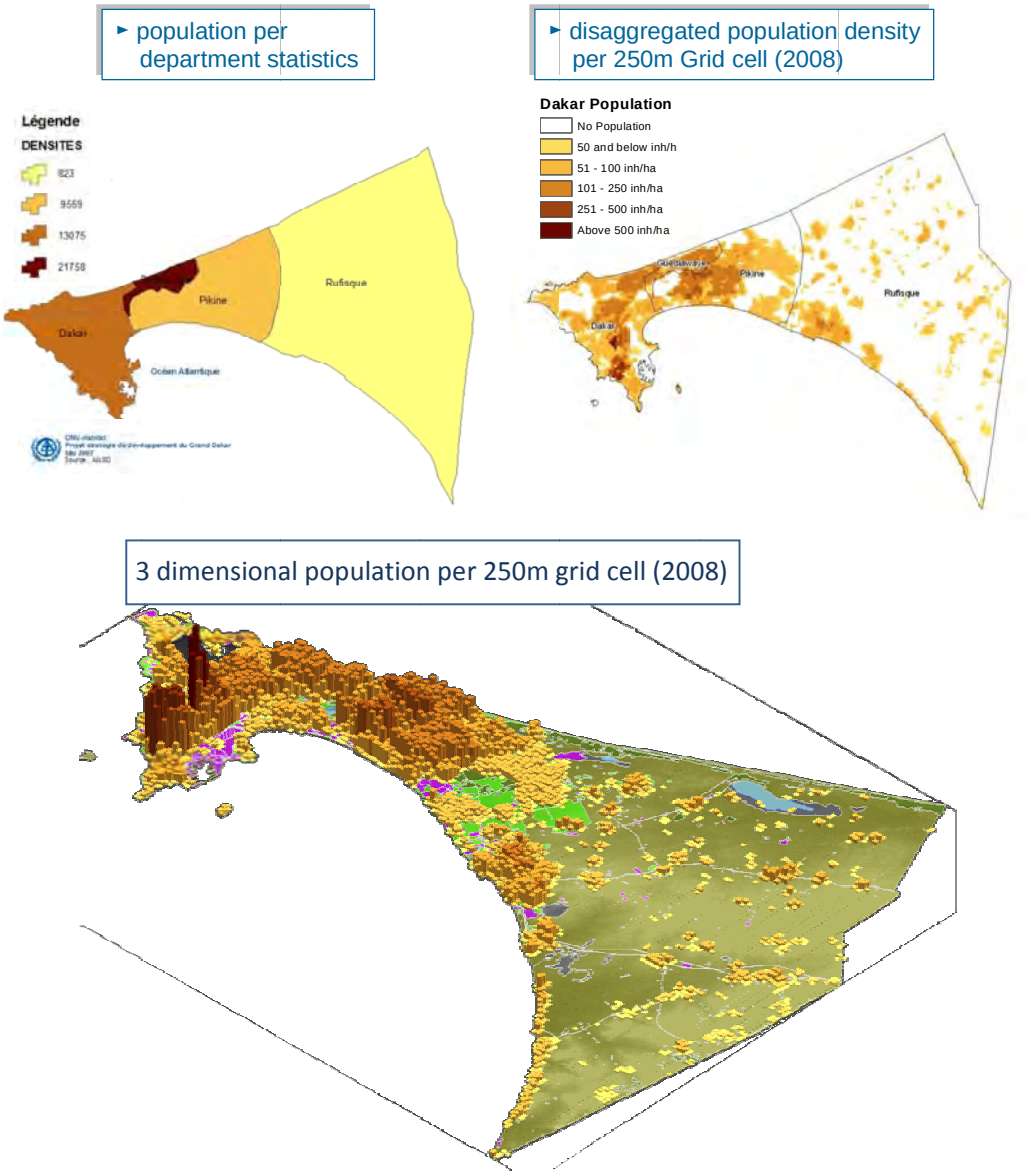
$$POP = \sum_i (A_i * k * Hdens_i) \qquad (2)$$

106. where Pdens and Hdens are the population and housing density respectively, POP is the total population of the municipality and Ai corresponds to the area of the housing density i. The factor k, representing the relationship between population and housing density, can be derived by solving equation (2). The local population density is then calculated from equation (1). The following assumptions were made when applying this approach: (i) the population density is

[32] Agence Nationale de la Statistique et de la Demographie

proportional to housing density, (ii) no population occurs outside housing areas, and (iii) dependency between population and housing density is constant within a region.

Figure 19: Comparison of Census-Based (Department) [33] and Spatially Disaggregated Population Distribution



107. Figure 16 shows the effect of the disaggregation. After the disaggregation, uninhabited areas are separated from inhabited areas, and within the latter the population density is shown. This gives a significantly "sharper" image of the actual distribution of the resident population.

[33] Source : UN-Habitat (2007), Stratégie de développement urbain du Grand-Dakar. Diagnostic Territorial, Rapport Consolidé.

4.3.1.3 Mapping and statistical analysis

108. The Spatial Analysis Maps are raster based maps with a general raster size of 250m. This is the reference grid size used for the derivation of the hazard potential, the disaggregation of the population and for the derivation of the share of the industrial/ commercial/traffic areas shown in one of the maps covering. Exempted from the 250m raster size is the representation of the land cover classes, properties of the non-built-up areas (soil types, DEM), traffic lines, and district boundaries. These items are depicted in 10m resolution.

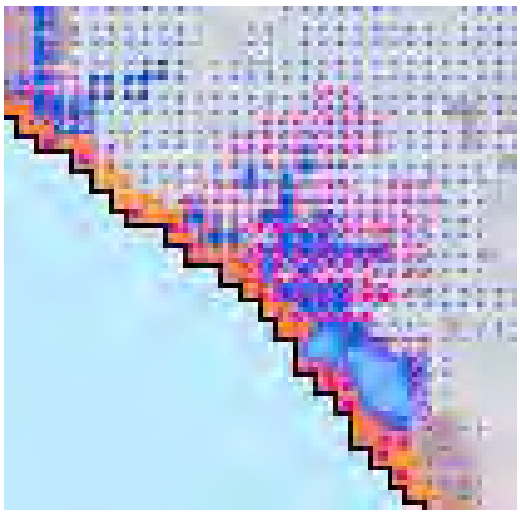
109. For the maps showing the spatial analysis results, the hazards potentials were generalized for cartographic simplicity. High Potential zones were kept separately, while Moderate and Low Potential zones were combined, which resulted in a total of six Hazard Potential zones (Figure 17).[34]

Figure 20: Hazard Potential Zoning Applied to the Satistical Analysis Maps

110. Cartographic overlay techniques using dots of different colors and size were used for the superposition of the exposed items and the hazard potentials (see Figure 18). The dot grids were shifted to each other in order to enable the representation of co-occurring hazard potentials.

[34] For the Coastal Inundation Potential in the Spatial Analysis, only the 1m Sea Level Rise scenario was used. The latter comprises possible coastal inundations to over 3 to 4 meters, because spring-tides and storm waves have to be accounted for. A sea level rise of 1m is expected to occur within more than half a century to over three centuries (current estimates move towards the shorter end).
The 5m sea level rise scenario was not included in the Spatial Analysis. This would go far beyond the temporal applicability of the other map parameters; further on there is complete uncertainty as to what time period may be needed for a 5m rise.

Figure 21: Detail of Hazard map



Note: see Figure 20 for Legend

111. The statistical analysis was performed using MS Excel. All three Hazard Potentials, i.e. High – Moderate – Low where used separately for the analysis, while for the cartographic presentation Low and Moderate Hazard Potentials where combined. The statistics were derived separately for the following three spatial units: (i) Urban areas, (ii) Peri-urban areas, and (iii) Rural areas. The subdivision classification is based on the consultation with local experts (Figure 8).

4.3.2 Spatial Analysis Results

4.3.2.1 Land Cover Changes

112. The land cover changes are not part of the spatial analysis, but they are shown here in order to highlight the massive urban development that has taken place during the observed time period. Table 10 provides an overview about the major land cover changes between 1988 and 2008. In the last column the changes are indicated in percent of the land cover 1988: both residential and other urban areas have increased by over 25% each, meaning they grow at a rate of more than one percent per year. They grew mainly at the expense of green and other non-built-up urban areas, and to some extent agricultural areas. Forest areas experienced little change.

Table 10: Land Cover 1988 and 2008 and Land Cover Changes

Thematic classes		Area in km²		Change in km²	Change in %
		1988	2008	1988 - 2008	1988 - 2008
	Residential areas	81.58	102.04	+ 20.46	+ 25.1
	Non residential urban areas*	29.91	38.07	+ 8.16	+ 27.3
	Transport units	15.17	15.49	+ 0.32	+ 2.2
	Green & other non-built-up	73.16	47.87	- 25.29	- 34.6
	Forests	15.98	15.99	+ 0.1	+ 0.1
	Water	4.88	6.37	+ 1.49	+ 30.6
	Agricultural and other open	362.22	356.13	- 6.09	- 1.7

* Comprises all industrial/commercial areas including water supply infrastructure, construction & mineral extraction sites.

113. The development of built-up areas within the areas defined in this study as Urban, Peri-urban and Rural is shown in Figure 22. The highest relative growth in built-up area has occurred in the area defined as Rural, and the lowest in the Urban area. That means the Rural built-up land is developing most dynamically – although from a small initial base – while, in absolute terms, the Urban areas accommodate the largest growth of built-up areas. The current situation is shown in Figure 23: The Urban area has 77%, the Peri-urban area 55%, and the Rural Area 6% built-up land.

Figure 22: Development of the Built-up Area, 1988, 1999, and 2008

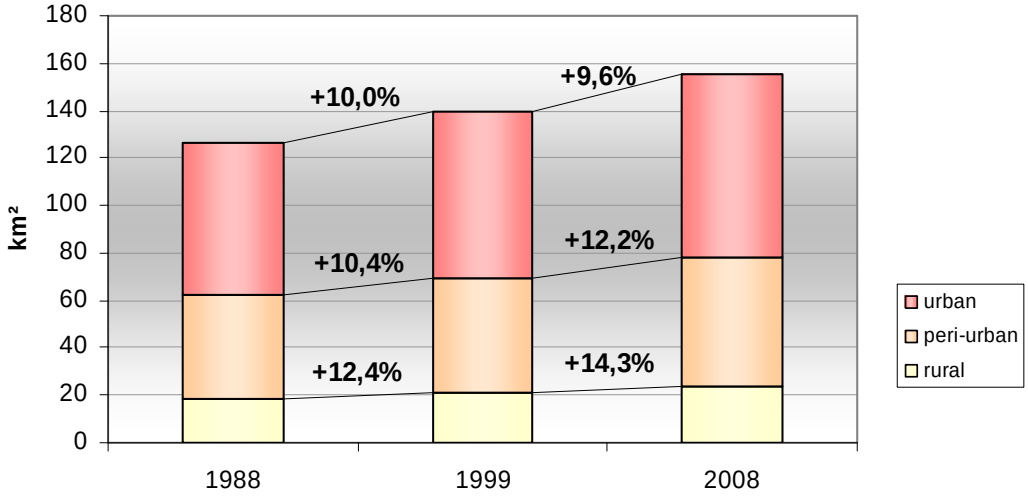
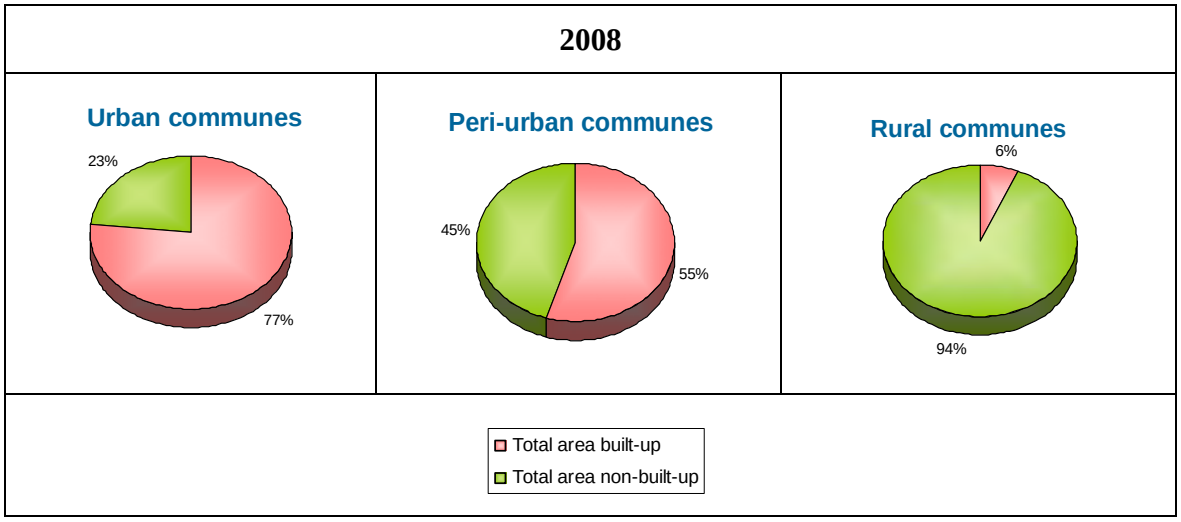


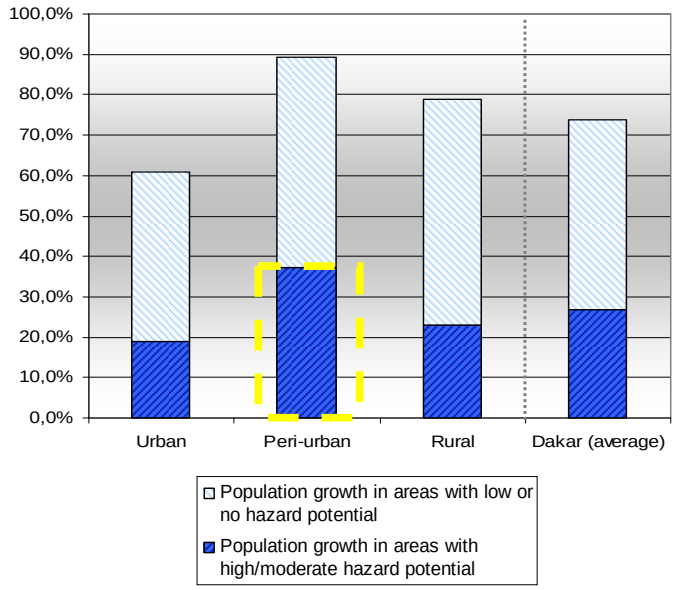
Figure 23: Total Share of Built-up Areas within Urban, Peri-urban, and Rural Communes in 2008



4.3.2.2 Social Exposure and Vulnerability

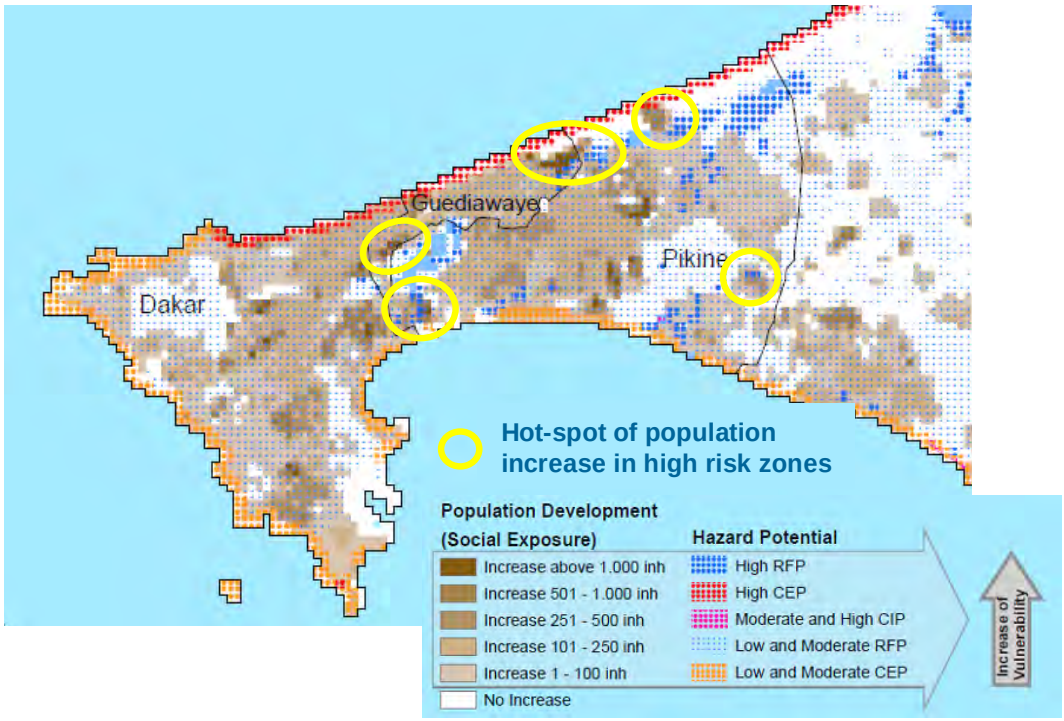
114. This section examines the relation between the population growth during the time period 1988/1999/2008 and the areas experiencing hazards of inland flooding (RFP = Relative Flood Potential), Coastal Erosion (CEP), and Coastal inundation Potential (CIP). As highlighted in Figure 24, much of the population growth that happened in this period took place in areas that are exposed to a moderate or high hazard potential – and the Peri-urban zone has the highest percentage of population growth in hazard prone areas. In Dakar's Peri-urban communes, almost 40% of new population has settled in areas with significant hazard potential from inland flooding, coastal erosion, or sea level rise. This rate is twice as high compared to urban (19%) and rural communes (23%) in the Dakar Metropolitan Area.

Figure 24: Population Growth 1988 - 2008 in Areas with Different Hazard Potentials



115. Still another representation of the social exposure and vulnerability is shown in Figure 25, where the yellow ellipses mark areas with a high population growth 1999 – 2008 and high hazard potentials.

Figure 25: Hot Spots of Social Exposure Given by High Population Growth between 1999 and 2008 and High Hazards Potentials



4.3.2.3 Economic Exposure and Vulnerability

116. The links between economic exposure and vulnerability are based on information on land price values collected through local consultation. Land prices are expressed in U.S. $ per square km (Figure 26). The figures reveal that the Dakar Metropolitan Area represents a total land value of 44 billion USD, and that 4.9% of this land value, i.e. 2.15 billion USD, is exposed to high hazard potentials.

117. Further, Table 11 shows the land values exposed to high hazard potentials differentiated according to Urban/Peri-urban/Rural zone, and to hazard type: while in the Urban area, the largest exposure is to Coastal Erosion, in the Peri-urban and the Rural Areas the major hazard threatening land values is Inland Flooding.

Figure 26: Economic Exposure to Hazards Expressed by Land Price Values (US$ per sq km)

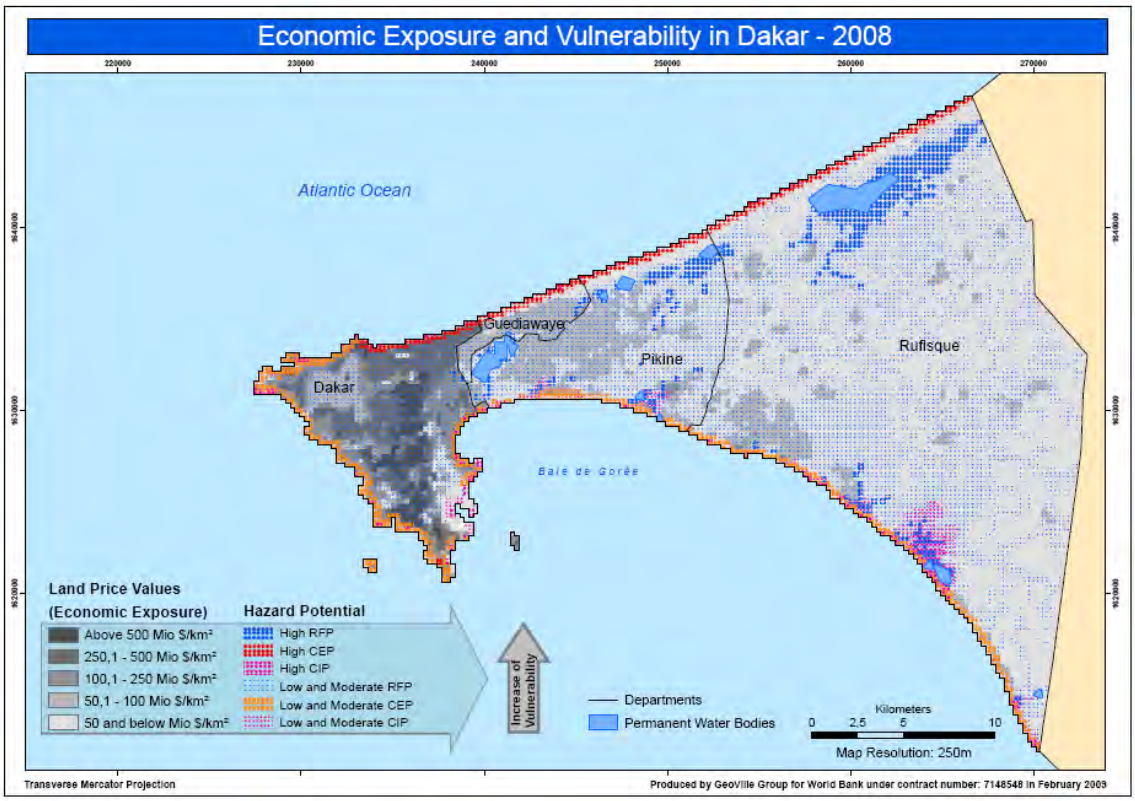


Table 11: Land Price Value Exposed to High Hazard Potentials (million US$)

Hazard type	Urban	Peri-urban	Rural	The Dakar Metropolitan Area (total)
Inland Flooding	134	291	751	1,176
Coastal Erosion	501	115	97	257
Coastal Inundation	73	2	181	714
TOTAL	709	408	1,030	2,147

4.3.2.4 Built-up Areas exposed to Hazards

118. An example of Spatial Analysis output is shown in Figure 27. The hazard potentials are only overlaid on built-up areas, therefore the pattern of hazard potential present in the other maps is interrupted here.

119. This map type shows what kind of built-up land use classes are exposed to hazards, and the type and degree of hazard potential. In the detailed (upper) part of Figure 24 there is a widespread low to moderate inland flooding hazard potential within the respective area, and that areas under high hazard potential for inland flooding seem to be limited in extent. Likewise, in this area there is a low to moderate coastal erosion potential threatening the southern coastal region.

120. Thus, this type or similar maps could be used as the basis for infrastructure planning such as sewage disposal, or engineering measures to locally decrease hazard potentials. As a sort of economically relevant built-up land exposed to hazards, a further map type was generated within this category: It shows the kind and degrees of hazard potentials, and the amount of Industrial/Commercial/Traffic areas exposed to them (Figure 28). Again, a detail is extracted in the upper part of this figure. The map shows that areas containing large shares of economically relevant land cover classes are prone to at least a low to moderate inland flooding or coastal erosion hazard.

Figure 27: Built-up Area in 2008 Threatened by Hazards, with Detail Shown in the Upper Part

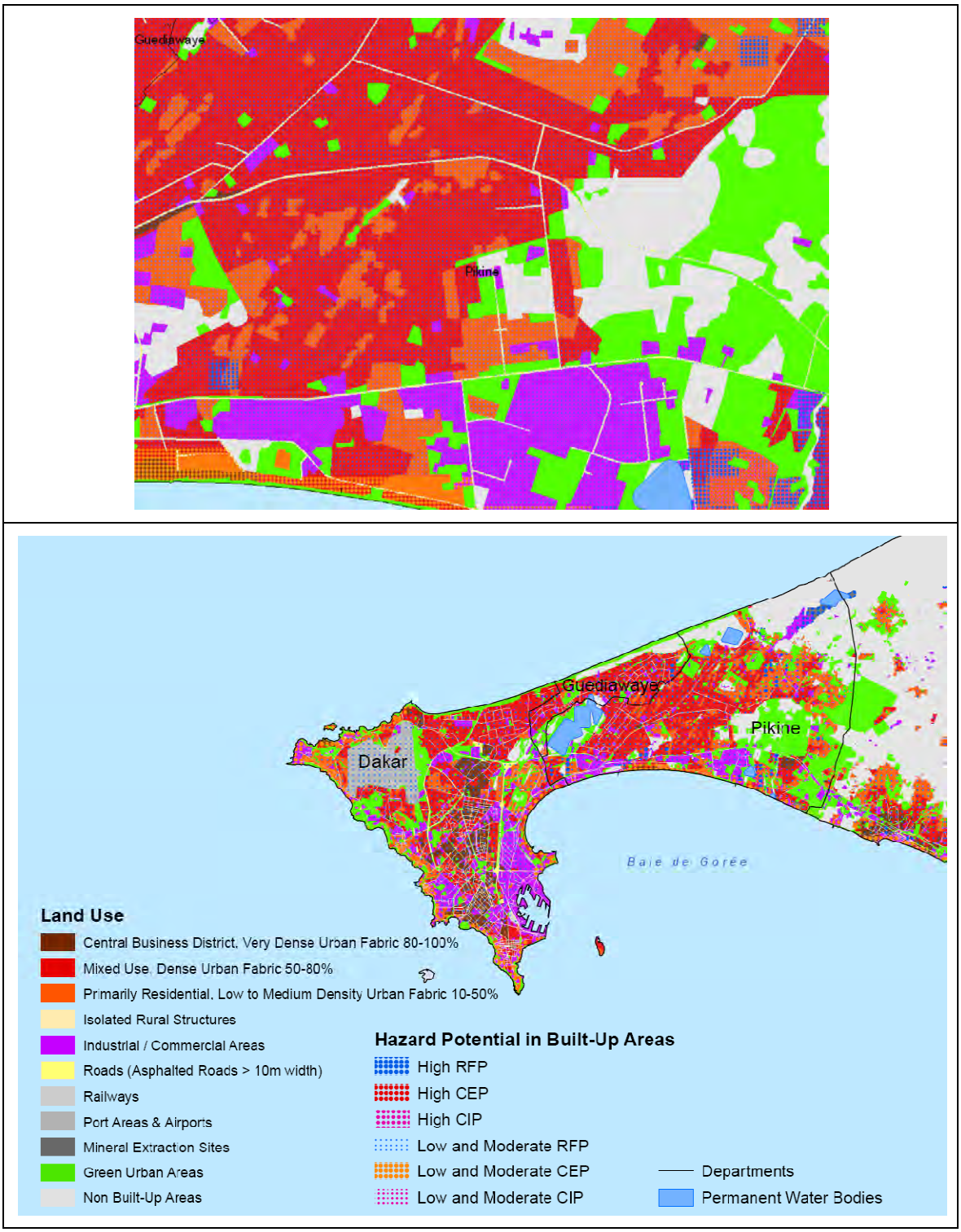
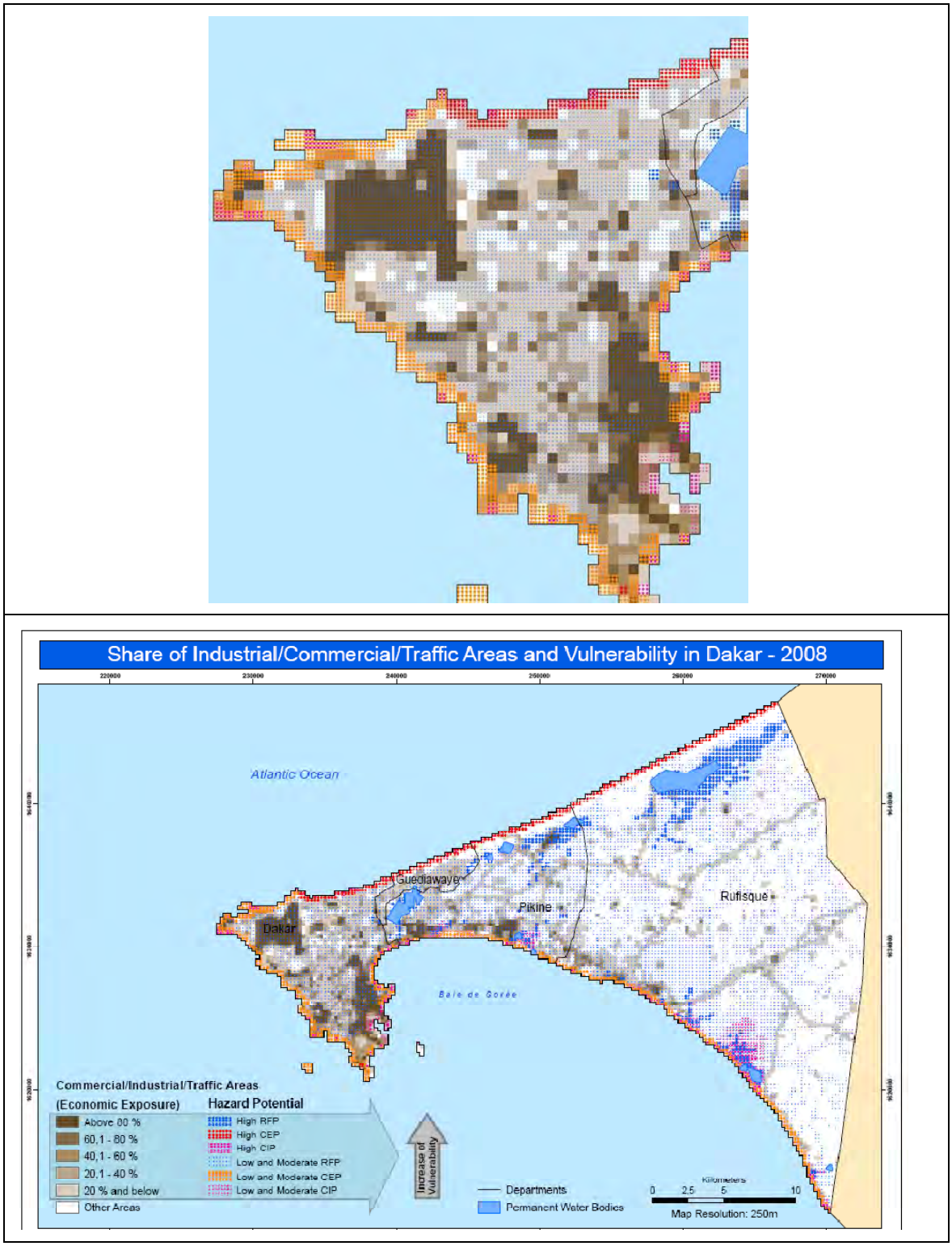


Figure 28: Share of Industrial/Commercial/Traffic Areas and Exposure to Hazards in 2008



4.3.2.5 Non-built-up Areas exposed to Hazards

121. The final type of Spatial Analysis was applied to investigate hazard potentials in non-built-up areas. The result for 2008 is shown in Figure 29. Especially in the enlarged upper part of the figure, low elevation areas (depressions) can be recognized, which are obviously more prone to flooding than surrounding areas with larger slopes. This type of map can potentially be used for advising municipal administrations in the question of land use zoning. Areas with high hazard potential, for instance, should not be assigned as building zones.

122. The scope of this study does not allow for detailed area or structural assessments, but it provides the basis for planning more *in-depth research*, including in-situ work to develop land use zoning maps. Figure 30 shows the percentage of non-built-up areas in the Urban, Peri-urban, and Rural communes that are exposed to high hazard potentials.

Figure 29: Non-built-up Areas 2008 Exposed to High Hazard Potentials

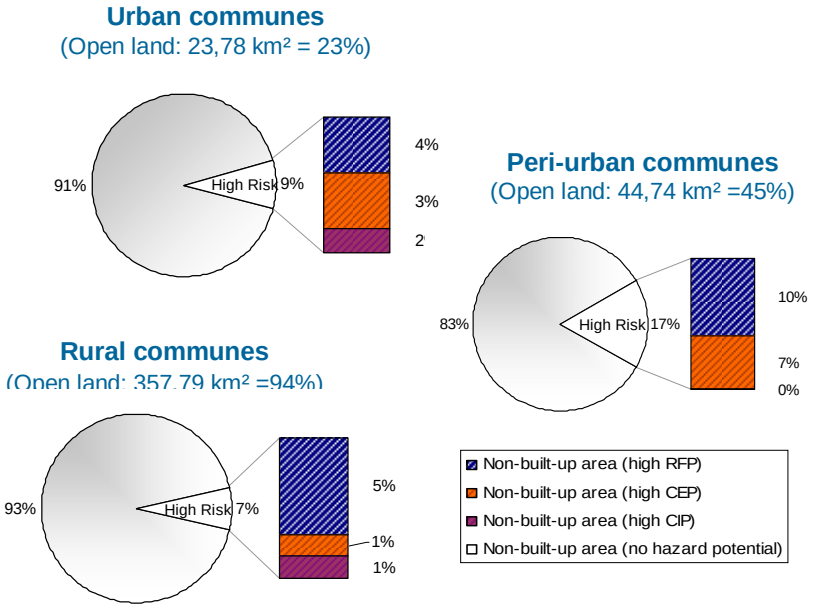
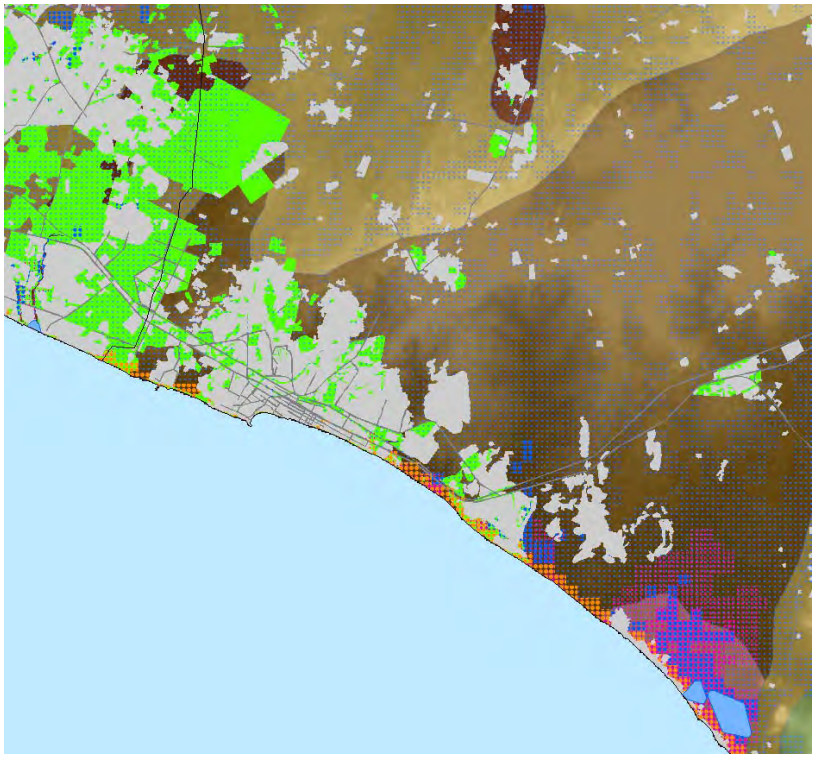
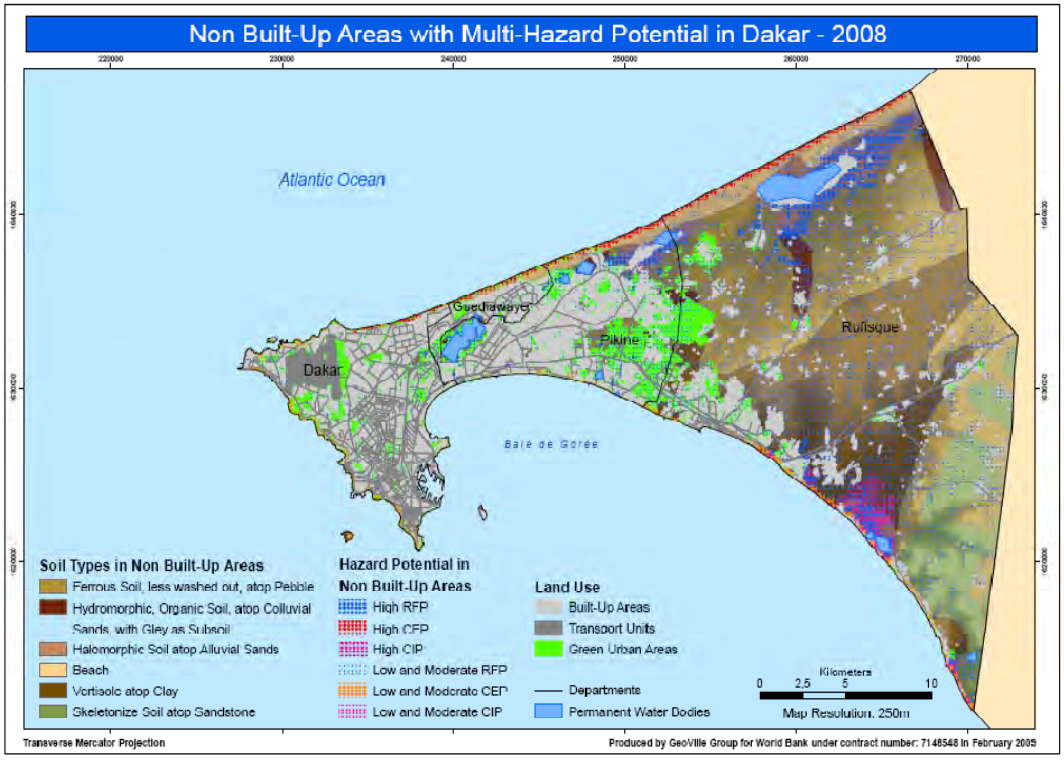


Figure 30: Hazard Potentials in Non-built-up Areas





5. Hotspot Characterization and Assessment of Institutional Capacity

5.1 Overview

123. Senegal has been actively pursuing a Disaster Risk Reduction (DRR) strategy at the national and regional levels as part of its Poverty Reduction Strategy (PRS) process (IMF 2007). The strategy, which was developed as part of the Africa Regional Strategy for Disaster Risk Reduction, has initiated several programs at the national level, including the establishment of flood and disaster management committee under the coordination of the Ministry of the Interior. The Ministry of the Interior is also responsible for the plan of the national disaster relief organization (ORSEC). Furthermore, a special flood management plan, also known as the JAXAAY plan, has been established with a view to increasing the effectiveness of the services provided in flood prone areas. However, the implementation framework for disaster risk management (DRM) is ambiguous, complex, and unclear at the local level.

124. For example, in the case of flooding, the local mayor is often responsible for disaster response but has very little influence on mitigation, as those policies are often determined at the national level. In Senegal, six Departments at the national level are in charge of flooding issues: 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 (Mbow et al., 2008). The coordination mechanism is weak among the ministries, which in turn weakens coordination at the local level further.

125. Even though Senegal has devolved extensive responsibilities to local governments as part of its decentralization process, local governments lack adequate funding for infrastructure investments and service delivery. They also confront skills shortages in general; the lack of technical capacity is even more poignant in relation to dealing with complex issues like climate variability risks. Furthermore, planning instruments like land use planning, which has the ability to influence the urban-rural footprint, remains pretty much under the control of the central government. Ex-ante disaster risk management (DRM) measures like land-use and infrastructure planning that can reduce exposure of natural hazard risks at the local level are essential in a fast-growing city like Dakar.

5.2 The "Primer" Survey (the City Typology and Risk Characterization Matrix)

126. In order to assess DRM institutional capacity at the local level, a specially designed survey was implemented, namely the City Typology and Risk Characterization Matrix, or simply the Primer Questionnaire (World Bank, 2008b). The assessment exercise, developed by the World Bank, identifies the city's human and built environment characteristics, and potential impacts of natural hazards and climate change risks.[35]

127. The Primer Questionnaire is designed to give an overview of all important issues and activities that could affect the city, and should be completed by a range of city stakeholders. It is

[35] The assessment will also identify (i) local government prerogatives and authorities that would allow them to take action in dealing with potential climate change impacts and natural hazards, and (ii) main vulnerable and at-risk areas. This knowledge provides valuable information in order to define priority actions that move (or "cool down") the city from becoming a "Hot Spot."

divided into 11 categories of attributes (A through K) in four main areas. We extend the Questionnaire by adding additional modules of (i) Vulnerability assessment for different consequences of climate change, (ii) Preparedness and response to different natural hazards in peri-urban expansion areas, (iii) Institutional framework, and (iv) Peri-urban areas.

Table 12: City Typology and Risk Characterization Matrix

City description	
Category A	the geographical location of the city
Category B	the size and main characteristics of the city area and population
Category C	governance structure and hazard management
Category D	the responsibilities for disaster risk management and climate change management
Category E	the financial resource of the city
Category F	the city's built environment.
Political and economic impacts	
Category G	the political impact of a disaster affecting some cities
Category H	the impact of disasters on the most relevant urban economic activities of the city
Natural hazards	
Category I	the threat of natural hazards
Category J	the disaster response system and existence of a city's emergency response plan
Climate change impacts	
Category K	climate change impact

128. The survey collected local DRM information from four administrative Departments of the Dakar Metropolitan Area: Dakar, Guédiawaye, Pikine, and Rufisque. It was implemented in December 2008 using the questionnaire in the Annex. The questionnaire is divided into three modules: 1) Definition of hotspots; 2) The institutional framework; and 3) The peri-urban areas.

A local consultant, with help of two professionals, conducted the survey. A range of decentralized authorities were interviewed, including Préfets, city authorities (Mayors, Deputy Mayors) technicians from the cities of Dakar, Guédiawaye, Pikine, and Rufisque, urban planners, land use specialists, financial experts, and hotel managers.

5.3 The survey results

5.3.1 General data on the Departments

129. The Dakar Metropolitan Area (the Region of Dakar) stretches only about 550 square kilometres or 0.28% of the total national territory, but is the highest population density area with 4,122 inhabitants per square kilometer. However, its population is unevenly distributed with 22,108 inhabitants per square km in the department of Guédiawaye and 842 inhabitants per square km in Rufisque.[36] Given the fact that Rufisque is the least populated department and its rural characteristics, it has the largest land stocks particularly in the rural communities of Yène and Sangalkam.

130. The Dakar Metropolitan Area has a population of 2,167,893 inhabitants distributed as follows: Department of Dakar: 871,038; Guédiawaye: 259,972; Pikine: 767,046; and Rufisque: 269,737 inhabitants.[37] According to the same source, the annual population growth rates in 2002-2006 in the four departments are respectively: 2.96%; 2.9%, 3.9%; and 3.32% for Dakar, Guédiawaye, Pikine, and Rufisque. The department of Guédiawaye is the smallest one (12.9 sq/km and has the highest population density (22,108 inhabitants per square km), followed by Dakar with a population density of 13,366 inhabitants per square km living on 78.5 sq/km, Pikine (9,777 inhabitants per sq/km on 86.8 sq/km land, and Rufisque which is the largest department (371.8 sq/km) with the lowest density (842 inhabitants per sq/km).

131. Squatter settlements, which are defined as housing occupation in areas which have not been plotted out based on urban planning rules, is very common in the cities of developing countries. Statistics are not reliable, as shanty towns, slums, irregular housing, squatter settlements, and traditional villages integrated in the city tend to be confused. Some specialists assume that 30% of the Senegalese urban population, which is around 1,300,000 inhabitants, is living in squatter settlements. The largest concentration of squatter settlements in Senegal is in the Pikine-Guédiawaye area with a population of 600,000 inhabitants (Diagne, 2002), which in our definition of this study can be classified as peri-urban areas.

[36] Source : Situation économique et sociale de la région de Dakar-année 2006, ANSD, Service Régional de la Statistique et de la Démographe de Dakar (SRSD), October 2007.

[37] Source : Situation économique et sociale de la région de Dakar-année 2006, ANSD, Service Régional de la Statistique et de la Démographe de Dakar (SRSD), October 2007.

Table 13: Population in Authorized and Non-authorized Human Settlements in the Dakar Metropolitan Area[38]

	Region	%	Dakar	%	Pikine	%	Rufisque	%
Housing (regular, Buildings, Villas)	4674.1	62.28	2952	89.05	1482.3	42.95	239.96	32.5
%	100		63.15		31.71		5.14	
Squatter (Spontaneous)	1633.1	21.76	98.32	2.98	1464.2	42.42	70.58	9.57
%	100		6.02		89.65		4.33	
Village Type	1196.7	15.96	264.36	7.97	504.74	14.63	427.63	57.93
%	100		22.09		42.17		35.74	
TOTAL	7504	100	3314.7	100	3451.1	100	738.17	100

Source : enquête ménages CAUS- PDU de Dakar 2025

132. Given the percentage of the floating population[39], the department of Dakar has the lowest rate (2.98%). The highest rates are in Guédiawaye, Pikine, and Rufisque. There is data variability for Guédiawaye, because our calculations based on the results of the latest population census carried out in 2002 give 37.5% whereas the environmental profile of Guédiawaye (IAGU, 2005) gives 70%. As far as Rufisque is concerned, the city Mayor gave the figure of 22.95%. For Pikine the rate is 64.2% (Audit Urbain de Dakar, 1999).

5.3.2 Governance Structure Related to Disaster Risk Management

Current Disaster Risk Management System

133. Traditionally, the hazard and disaster management is assured through 2 types of mechanisms: The High Commission of Civil Protection (CSPC), which have subdivisions at regional and departmental levels, and the Division of Civil Protection (DPC).

134. The High Commission of Civil Protection (CSPC) is a special consultation body in the domain of civil defence, established by the Government for risk prevention. The Commission is chaired by the Minister of Interior and is represented at administrative level by the regional and auxiliary commissions of civil protection and it includes representatives of Presidence,

[38] Enquête ménages CAUS-PDU de Dakar 2025

[39] Floating population includes all people living in irregular zones, spontaneous occupations (in zones that have not been parcelled), and traditional villages. Our own calculation (for Guédiawaye) was made as follows: population of the irregular quarters (Medina Gounas and Wakhinane Nimzat) / Total department population × 100.

Primature, Parliament, sectoral ministries, local authorities, the private sector, and civil society organizations, etc. (Decree n° 99 – 158 du 22 février 1999).

135. The Division of Civil Protection (DPC) is responsible in time of peace or war for protecting people, facilities, resources, and public and private properties. It heads various departments of civil protection at all levels and can use the Fire Department staff (GNSP). DPC manages the permanent secretariat of the High Commission of Civil Protection (CSPC) and it includes:

- Department of Surveys and Civil Defense Operations ;
- Administrative and Financial Division;
- The Permanent Secretariat of the High Commission of Civil Protection ; and
- The Training and Refresher Training Centre for Civil Protection of Dakar.

136. Its mission in terms of prevention consists of:

- Developing draft texts on civil protection ;
- Organizing in partnership with Regional and Auxiliary Commissions of Civil Protection and Inter-Ministry Technical Committees, prevention visits in public settlements, classified facilities, high buildings, and other buildings at risk;
- Ensuring follow-up of reports from prevention visits;
- Providing security recommendations for construction projects of public settlements, classified facilities and high buildings. The recommendations are made prior to delivering a construction authorization ; and
- Training, informing, and sensitizing on hazard prevention.

137. In terms of disaster management, its mission consists of:

- Developing relief plans, for example the ORSEC Plan ;
- Providing recommendations on Individual Intervention Plans (P.P.I.) and Internal Operational Plans (P.O.I.);
- Developing regional resource files that can be mobilized when the ORSEC Plan is triggered. The Division of Civil Protection heads the ORSEC National Resource Management Committee;
- Securing the file of the civil protection back-up units; and
- Developing focussed hazard management programmes: rehabilitation and establishment of fire hose systems, lightning rods, etc.

138. The hierarchical structure between these civil protection structures is descending: at the top level we have the High Commission of Civil Protection (CSPC), then the Regional Committee of Civil Protection (CRPC) and the Auxiliary Committee of Civil Protection (CAPC). The Division of Civil Protection (DPC) plays a role of connecting those three organizations because it is coordinating all the means of the Plan ORSEC.

139. The functional relations between these civil protection organizations can be resumed as follow: in case of disaster occurring in Rufisque, for example, the Prefect, with regard to the extent of the disaster, initiates the ORSEC Plan at departmental level via the CAPC that (s)he is heading. However, before the starting of the departmental ORSEC Plan, a localising, identification and mobilisation of means must be done by the Prefect. If the disaster is beyond the capacities of the CAPC, or if it spreads to the other departments of the region, the Governor takes the matter in charge, under the instruction of the DPC. This latter DPC plays a role between the CRPC, the CAPC and the CSPC, of which it assures the permanent secretariat. If the disaster spreads too many regions, the DPC asks to the Ministry of Interior, via the CSPC to start the National ORSEC Plan. However, the Prefects and Governors are often surpassed because the means censing and update at departmental and regional levels are still not correctly done.

The institutional framework includes also:

- The National Flooding Prevention and Control Unit (CNPLI) chaired by the Minister of Interior (Decree n°2004-1153 du 18 août 2004 modifiant le décret n°2003-685 du 13 novembre 2003) ;
- The Steering Committee of Risk Prevention and Hazard Management within the framework of the Charter signed in September 2002 by the Minister of Interior and the Chair of the National Employer Council (CNP), which is one of the most representative employer organizations in Senegal;
- The Steering Committee of the Memorandum of Understanding on prevention of drowning in authorized beaches signed in March 2004 by the Minister of Interior and the Chair of the Association of Mayors in Senegal; and
- The National Platform for disasters risks reduction.

140. The mechanism also includes the National Commission of Sustainable Development (CNDD), the National Meteorological Centre of Yoff, the Centre of Ecological Monitoring (CSE), the Ministry of Environment, Nature Protection, Water Storage Ponds, and Artificial Lakes, and recently the Disasters Risks Reduction Network of members of Parliament. Moreover, following consultations organized with the stakeholders involved, and within the aforementioned commissions, the Government defined the following:

- A national action plan on risk prevention aiming at mainstreaming policies and programmes within the framework of a sustainable development strategy ; and
- A short and medium term national programme of prevention and protection of vulnerable areas (2004-2007). The programme includes (i) building dykes against water swelling in vulnerable areas, (ii) building channels and pumping stations, (iii) developing of retention ponds, and (iv) transferring population from flooding prone sites to suitable sites.

141. Finally, between July and December 2004, the Government organized a consultation meeting with a group of Senegalese and international experts supported by ILO to define an industrial hazard control system. The system includes the following:

- Establishment of a national industrial hazards control unit;
- Consolidation of an industrial hazards legal and regulatory framework;

- Creation of a National Research Institute on major industrial hazards;
- Capacity building on major industrial hazards control;
- Definition of an industrial hazards management plan; and
- Organization of a promotion campaign for the project with the stakeholders.

142. In the aforementioned multi-sector programmes, steps have been made to encourage prioritization of risk prevention in economic and social development plans, sustainable development programmes, poverty alleviation programmes, and national UN Millennium Development Goals implementation plans.

143. A number of academic and research institutions are working on disasters and climate change. Some of them are:

- The Institute of Environment Science (ISE) in the Faculty of Science and Techniques of Cheikh Anta Diop University of Dakar (UCAD);
- The Laboratory of Atmospheric Physics in UCAD Faculty of Science and Techniques;
- The Centre for Ecological Monitoring (CSE);
- The Regional Centre for Improvement of Adaptation to Drought (CERAAS/ISRA);
- Adaptation to Climate Change in Africa (ACCA) of the International Development Research Centre (IDRC);
- Institute of Earth Sciences (IST) ;
- The National Meteorology Division ;
- African Urban Management Institute (IAGU) ;
- ENDA;
- GREEN Senegal (Environment Research and Survey Group) ; and
- The Federation of Senegalese NGOs (FONGS).

144. About the territorial administration, the Government is represented at departmental level by the Prefect who is appointed for an undetermined term. The city authority is the Mayor who has a five year term. In general, the municipalities do not have a division in charge of risk management. For Pikine, there is the “Direction des Affaires Sociales, Sanitaires et Educatives” (DASSE), which is responsible for public assistance to the population. DASSE has three equipped ambulances and fifty relief workers as a result of Italian cooperation. For Rufisque, there is a Security Commission within the Mayor’s Office in addition to the technical services in charge of prevention and compliance visits. The Secretariat is sheltered by the Fire Department.

145. In all the cities there is the Environment Department. At regional level there exists the Environment and Classified Settlements Division and the Regional Environment Service. In Guédiawaye and Pikine, there is within the Prefecture a department in charge of environment management headed by the sanitation services.

Financial Resources of the Cities of the Dakar Metropolitan Area

146. Revenues (47.4 billion CFA) as well as expenditures (47.3 billion CFA) of the Dakar Metropolitan Area are significant, but they represent only 2% of the regional GDP. The budget of the City of Dakar rose from 2 billion CFA in 1985 to 10 billion CFA in 1996, 24 billion in 2004, 26 billion in 2005, and over 28 billion in 2006, making 50% of the budgets of local authorities in the agglomeration. This shows a clear financial imbalance between the local authorities in the Dakar Metropolitan Area. The distribution of the expenditures confirms the predominance of operational expenditures over investment expenditures with respectively 59% and 41% (Source: CDS, IAGU, 2008).

147. The revenues are 94% recurring revenues whereas an important part of the expenditures (68%) are devoted to functioning, leaving some for investment. However, compared with the regional wealth, the levies at local levels are very low (2%) against 13% for the Government levies. But this situation is more due to the nature of taxes levied in each entity rather than to performance of local authorities. (Source: CDS, IAGU, 2008).

148. The survey shows the total budget of the administrative departments is 36.73 billion for Dakar, 841.21 million for Guédiawaye, 8.85 billion for Pikine, and 6.33 billion for Rufisque as of 2008. The budgets mainly include local taxes and levies (around 90%) for all the departments. Subsidies from central government remain minimal, less than 2%. The funds from internal and international markets are not often specified.

Climate Change Management and Hazard Management at Administrative Department Level

149. The hazards related to climate variability and human action are increasing. The concentration of population in large agglomerations, their settlement in risky areas, and the development of economic activities in some sites, result in the population vulnerability to disasters and major hazards.

150. Senegal has experienced several disasters including the explosion of an ammonia tank in 1992 in the SONACOS factory in Dakar, the crumbling of buildings (old buildings and even building under construction, in some cases as a result of non compliance with the construction standards), flooding in some areas (lack of channels, works and structures undersizing against the cities' demographic evolution). The accidents resulted in heavy human and property losses. The advent of such hazards showed the urgency of having proper knowledge of the nature of those hazards which threaten the populations, their location, and the resources needed.

151. In an effort to face natural disasters and those generated by human action, the Government authorities have adopted since 1993 the ORSEC Plan, which aims at coordinating relief operations in times of disaster. Within the framework of the hazard prevention effort, the Government established in 1993 a High Commission and Regional and Auxiliary Commissions of Civil Protection. Moreover, Commissions for specific disaster management were also established, such as the National Commission of Flooding Prevention and Control.

152. The activities implemented by those Commissions and the identification of risks carried out in October 2002 by the Division of Civil Protection in partnership with administrative authorities helped define the areas where risks are likely to take place at the expense of the populations, the nature of the risks, and the preventive measures to take. It is necessary to visualize in the maps all those data in order to help the authorities have a readable risk database

and existing resources to cope with it, take appropriate action, and strengthen intervention and disaster management resources. This study provides practical spatial database and action plans to support the initiatives.

153. As far as disaster risk management at department level is concerned, the responsibilities are clearly defined consistently with the terms of reference of the Division of Civil Protection both at depopulated and decentralized levels. However, in terms of climate change management, given its technical aspect, the Prefect refers to the Regional Department of the Environment and Classified Settlements. For the specific case of Rufisque, the Water and Forestry Department is very active. The authorities in charge of the contracts for the services are: the Prefect, the cities and communes Mayors, and the Chairs of rural communities (specific case of Rufisque).

5.3.3 Urban Planning and Land Use Regulations

154. With regards to the issue of urban planning, there are many planning documents which are partial and hardly integrated in the regional space. In other words, the (technical and regulatory) instruments which could help own urban development are yet to be implemented.

155. Urban Master Plans (PDU) are hardly implemented for proper spatial evolution in the region. The PDU is a reference document that aims to plan and program the development of an agglomeration in short and medium terms (10 to 20 years), taking into account the global objectives of the regional development. It specifies the socio-economic and demographic perspectives of the region and the agglomeration and determines the means and strategies to be implemented in order to reach a harmonious and sustainable development. From 1946 to 2001, there have been four urban Master Plans developed in 1946, 1961, 1967, and 2001. The latest Master Plan was developed in December 2006 (Dakar Horizon 2025), but it has not been validated yet for a lack of implementing order. As a matter of fact, its validation was postponed by the stakeholders until some data are updated. The data are updated but the implementing order remains to be signed.

156. The Urban Mobility Plan for the agglomeration of Dakar (PDUD) Horizon 2025 has been developed to address the critical problems of mobility in the Dakar Metropolitan Area and to reorganize the transport by promoting public transportation in Dakar. The PDUD, which dated back in September 2007 (it can be seen in the Division of Urban Planning in the Departmental Urban Service), is not forcibly taken into account in the construction of the major roadwork items which are often managed by specialized agencies. Guédiawaye as well as Pikine and Rufisque depends on PDUD. However, for Rufisque there is an accessible Subdivision Plan in the City Technical Services and in the Departmental Land and Estate Registry Services.

157. The Master Plan for Urban Planning and Preservation of the Niayes and the Green Zones of Dakar (PDAS) has not played its role yet, in terms of overall urban planning. The PDAS is a specific plan for the Niayes (depressions zones) and Green Zones at the level of the Dakar Metropolitan Area, and has been validated since 2004.

158. The Regional Land-Use Planning framework (SRAT) provides comprehensive guidelines which are not forcibly taken into account in the field. In fact, the SRAT is validated but the implementation does not really respect the prescriptions included in it. Finally, the actions planned in the Regional Integrated Development Plan (PRDI) finalized since 2004 are not implemented yet.

159. The survey finds that the percentage of population living in regular areas is 63% in Rufisque, 60% in Dakar, 35.8% in Pikine, and 30% in Guédiawaye. These data show the level of irregular settlements in the administrative departments. Guédiawaye and Pikine are the departments where a large majority of local people reside in irregular areas. The population density in the irregular areas of the department of Dakar is very high (375 inhabitants par square kilometer and around 200 inhabitants per sq/km in Rufisque. In Dakar, the population of the traditional and historic districts is around 100,000 inhabitants representing 11.5% of the total population of the administrative department, whereas for Rufisque, the population is less than 5% of the total department population.

160. With respect to the issue of the building code, Senegal has a Code of Urban Planning (Loi N° 88-05 du 20-06-1998) which regulates the construction standards and is being reviewed in an effort to integrate hazard aspects in building construction. This Code stipulates in Chapter 2, Article 69 that nobody can undertake a construction without authorization no matter what its nature is or carry out modifications in existing buildings in the Cities and in the agglomerations with over 5,000 inhabitants, and the other agglomerations defined by Decree, other agglomerations with important demographic growth, extension, and functions. This obligation is put upon public services and public service contractors, administrative departments and communes as well as private persons.

161. Construction authorization is delivered by the Ministry of Urban Planning and Housing, or by the Governor of the administrative region where the construction will take place, or by the Director in charge of urban planning in the conditions defined in the regulatory part of the Code. There is also the law (Loi N° 78-43 du 06 juillet 1978) which provides guidelines for architecture in Senegal. All the services of the Ministry of Urban Planning and Housing are in charge of their implementation. But at the city level, the DST (Technical Services) is involved.

162. The construction authorizations are instructed by the services of the Ministry of Urban Planning and Housing for the local collectivities. The request (comprising a number of documents) is addressed to the Mayor and the documents are transmitted to the urban planning service for registration and preliminary examination before its introduction in the approval circuit (Domains, Cadastre, Civil Protection, Division of Environment, etc.). Then the authorization ordinance is prepared and transmitted to the Mayor for signature and after signature, the documents are transmitted to the Prefect for approval before going back to the Urban Planning service which delivers it to the applicant. The duration of all this operation can be three months. In Rufisque, the DST has developed construction guidelines for the clay belt.

163. With regards to the level of compliance with the construction standards, in Dakar, Pikine, and Rufisque, there are no figures, because the compliance certificate is not demanded after completing their construction. For Guédiawaye, the percentage is estimated 10%.

164. As far as the vulnerability of the buildings to natural disasters is concerned, no data are available, but our sources have evaluated this aspect for the four administrative departments: for Dakar less than 5% of the buildings are highly vulnerable, for Guédiawaye and Pikine it is over 15%, and for Rufisque it is between 5 and 15%. For historic buildings, the percentage is everywhere less than 5% whereas for new formal constructions, the rate is under 1% for Dakar and Rufisque and over 5% for Guédiawaye and Pikine. However, as the estimates are not based on scientific quantitative analysis such as the spatial analysis of this study, those are only for reference.

5.3.4 Exposure of Political and Economic Assets to Disasters

165. Covering only 2.8% of the national territory, the Dakar Metropolitan Area hosts 75% of the country's economic activity. Dakar's GDP is worth around 2.724 billion CFA and represents 60% of wealth generated in the national territory. Its sector-based distribution shows the predominance of services with 69% of the GDP, far ahead the secondary and primary sectors. The revenues collected by local authorities on the wealth generated in the agglomeration remains poor despite the increasing growth of the budgets of communes and key local authorities of the Dakar Metropolitan Area. The national Government remains the main player of the economy in spite of a consolidated decentralization at institutional level.

166. We briefly discuss the locations of political and economic stakeholders and the size of economic values exposed to disaster risks.[40]

Exposure of Political Assets to Disasters

167. As the national capital city, a regional and departmental capital, Dakar shelters the political administration, 80% of Senegalese industries, and the majority of decision makers. Guédiawaye, Pikine, and Rufisque are departmental capitals with many decision makers as a result of its political and historical background. It is very likely that disasters influence political activity in urban as well as in peri-urban areas.

Exposure of Economic Assets to Disasters

168. The administrative departments covered by the survey are situated in the Dakar Metropolitan Area which shelters the major national economic activities. The departments of Dakar and Rufisque are at various levels the main economic activity centers at national and regional levels, unlike Guédiawaye and Pikine.

169. The Dakar Metropolitan Area accommodates over 46% of the Senegalese officials, 97% of the trade and transport sectors employees, 96% of the bank employees, 95% of industries and businesses, and 87% of permanent jobs[41]. Industries in Dakar include high risk industries such as hydrocarbon tanks in the Port, factories like SONACOS, and petrochemical industries.

170. In Rufisque, there is the largest cement plant in West Africa (SOCOCIM Industries), pharmaceutical industries like VALDAFRIQUE, an oil factory (SENARH), a mattress factory (SPI), the electric power plant of Cap des Biches which produces 22.2% of the total production of SENELEC (National Electricity Company) with 167 MW, and another power plant in Kounoune.

171. In Pikine, the industry represents 9,111 jobs, 8.1 % of the total jobs. Industrial activities are located in the industrial zone with SAR (Africa Oil Refinery), a woodwork plant (La Rochette), RHONE POULENC, and the Free Zone (SAFCAC, SENECOR, VENUS, etc.)

172. The sector of services is represented by trade (35 markets the most important of which are the fish market and the stockyard), and transportation is also an important service sector. The sector of finance is developed in the Department of Dakar, but it is not important in other

[40] This section is not intended to evaluate economic impacts of disasters systematically by taking into account direct and indirect damages. It is rather a broad description of the mass of economic activities exposed to disaster risks.

[41] Plan de développement de la région de Dakar, conseil Régional, 2004

administrative departments. In Dakar, the tourism sector is the most important with 22% of the national capacity and 233,643 arrivals in 2006.

5.3.5 Climate Change Preparedness

173. In general, the climate change impacts are unknown by the survey interviewees. As for the sectors vulnerable to climate change, in all the administrative departments covered by the survey, the following have experienced the effects of climate change:

- The built-up environment (the coast dwellers);
- The cultural and religious heritage (in Rufisque, the Mosque, the Church, and the central market are threatened by the sea);
- The local economy (trade, industry);
- Electric power production and distribution (Cap des Biches Power Plant in Rufisque);
- Access to healthcare;
- Land use (resulting in Rufisque in displaced population to new land plotting);
- Transportation (water taxi system planned for Rufisque to connect Dakar by the sea can be a solution to the transportation constraints);
- Recreation sites; and
- Tourism.

174. With regards to Dakar, the evaluation of climate change is based on surveys which were already carried out. As for Guédiawaye and Pikine, there has been no specific survey on climate change. However, the organizational, financial, and urban audits conducted by ADM and other surveys address the issue in general terms. As far as Rufisque is concerned, a perfunctory survey has been carried out with partners from the city of Nancy, France in addition to the alert made by the Chair of the Environment Commission of the Mayor's office since 2004. But none of the cities has a specific climate change strategy.

5.3.6 Disaster Response System

175. In terms of climate change related national policy, since 1994, Senegal has developed a national climate change strategy completed by a 1997 National Communication which is a report dealing with policies and projects to mitigate the climate change impacts in vulnerable areas, but also aiming at adapting agriculture to climate change. The second reference document is the National Action Plan Against Climate Change developed in a participatory way.

176. The Dakar Metropolitan Area is prone to disasters such as flooding and coastal erosion. There is a system to respond to these phenomena. There is the ORSEC Plan (Relief Organization Plan) for flooding. For coastal erosion, there is urban planning of the Millennium Port from the ledges of Dakar to Gorée Island, but all those interventions are made at national level as a result of Dakar position. In Rufisque, it seems that the system which includes the police, the

Gendarmerie, the Mayor's Office, and the Fire Department is still in stand-by but operating loosely.

177. At departmental level, there is a disaster response system that is a departmental commission coordinated by the Prefect and includes the technical services and the Fire Department which operates the Secretariat. There is also the ORSEC Plan triggered by the High Commission of Civil Protection (CSPC) which is in contact with the Governor who informs the Prefect and the latter contacting the Sous-prefects. Decentralized authorities (city mayors, commune and arrondissement mayors) and services and structures (technical services, the Fire Department, etc.) are involved in disaster management. The Police and the Gendarmerie are also involved in the disaster response system.

178. For the classified settlements (at risk) there are the Internal Operational Plans (POI) supported by the ORSEC Plan, depending on the scope of the disaster. But, altogether this mechanism lacks - suffers of an insufficiency of - resources and a prevention mechanism. The population civic commitment is usually called upon when relief interventions are organized.

179. However, this disaster response mechanism is not often tested and there are hardly any simulations. The legal arrangement has to be improved by identifying and locating resources for simulation exercises. The mechanism is not updated on a regular basis.

5.3.7 Peri-urban Areas

180. The institutions that exist in the urban communes are 19 arrondissement communes in the Department of Dakar, 3 arrondissement communes and 2 communes in the department of Rufisque. In the department of Rufisque, there are 2 rural communities. Rufisque is the only administrative department in the Dakar Metropolitan Area that includes in its local authorities two rural jurisdictions: Sangalkam and Yène. We classify as peri-urban communes five arrondissement communes in Guédiawaye and sixteen in Pikine.

181. In peri-urban communes, there is not a specific, formal and well organized disaster response system. However at departmental level, in addition of the fire department, there are punctual actions of arrondissement communes and also in case of disasters, there is, what we call, community dynamics that is a solidarity dash coming from associations, and individual citizens at the quarter level. Unfortunately, there is no formal interactions between communes and administrative departments on disaster management activities, even though communal authorities, often, use to ask help of some institutions (to have for example motor-pumps in case of flooding).

182. A number of public (or para-public) agencies are responsible for infrastructure investments. The public institutions are essentially the Government and Local Collectivities. The Para-public institutions are the Municipal Development Agency (ADM), Public Works and Employment Agency (AGETIP), Autonomous Agency of Roads Works (AATR Agence Autonome des Travaux Routiers), Programme of Construction and Rehabilitation of State Build Patrimony (PCRPE Programme de Construction et de Réhabilitation du Patrimoine Bâti de l'Etat), National Office of Sewage System in Senegal (ONAS Office National de l'Assainissement du Sénégal), and National Programme of Local Development (PNDL Programme National de Développement Local).

5.4 Knowledge and Capacity Gaps for disaster management and climate change impacts

183. The survey helped point out that apart from the interviewed technicians, most of the people interviewed, even though they are not aware of disaster risks which are threatening, can remember serious accidents such as the ammonia explosion in SONACOS factory in 1992, which claimed several casualties and important material damages, although they know nothing about climate change and its negative impacts on their life environment. Apart from their participation in seminars and other meetings dealing with climate change and other initiatives taken within the Rufisque Municipal Council which includes an Environment Commission steered by an expert, and in Pikine where a reflection has been initiated for three years, local authorities are not knowledgeable about the issue of the climate change impacts.

184. Policies addressing the natural hazards and climate change risks exist at the national level. Risk management mechanisms also exist, for instance, in risky industries. However, no mechanism is set up to deal with the impact of climate change, and local authorities are not prepared to face them either.

185. The capacity of institutions to face climate change was found to face limitations, but more in terms of resources and planning capacity than in terms of awareness:

- In general, technicians from the ministries involved in the climate change issues and those from organizations such as ADM (Municipal Development Agency), research institutes, universities and NGOs are well aware of the issue. In some institutions, actions are taken but much is yet to be done; and
- The issue of resources is often referred to, to explain the fact that almost nothing is done in terms of preparedness to climate change.

186. ADM is aware of the scope of natural disasters, which are a recurrent phenomenon in the country (flooding, coastal erosion, atmospheric pollution as a result of mobility conditions). ADM also developed, in partnership with the Division of Civil Protection, the Fire Department, and other consultants, training modules for capacity building of municipal technicians, territorial administration staff, elected representatives, and other policy makers. For the cities, in partnership with environment associations, ADM considers developing a sharing, exchange, and popularization framework on effective risk prevention.

187. As for SAR (African Oil Refinery Company), an operational risk control mechanism is in place. The risks and disasters are managed by the Control and Method Service under the supervision of the Safety and Environment Sections in compliance with the arrangements of the International Security Evaluation System. At internal level, the Chief on duty is responsible for it. When a problem arises, the Internal Operational Plan (POI) is triggered in relation to the Prefet, the Fire Department, the Gendarmerie, and the populations. This mechanism is being simulated on an annual basis. SAR has equipments for sea leaking with a floating dam which helps absorb the leaked wastes. This equipment is unique in West Africa and is stored with Dakar Port's Authority (PAD). It is also worth mentioning that SAR is involved in the ORSEC Plan. However, there is no mechanism to mitigate climate change impacts.

188. During the interviews conducted for this study, urban planners and land use specialists have confirmed that, in all the administrative departments, the risk zones are spotted by the

technical services, but there is a lack of specific structures in charge of hazards and disaster management and preparedness to facing climate change impacts. Municipal technicians point out the absence of a specific service devoted to hazards and disaster management at the commune level and of a preparedness mechanism to mitigate the climate change impacts.

6. Moving Forward: Lessons Learned and Action Plans to Ramp up Natural Hazard and Climate Change Risk Management Practices in Dakar, Senegal

189. The current pilot study focuses on applying spatial and institutional analysis at the regional/metropolitan scale to the identification of hazard risks facing the peri-urban expansion areas of Dakar. As a pilot for a broader work program on hazard risk management in peri-urban expansion areas, this study is helping in determining how the analytical methodologies can be improved, and what aspects of this analysis work best and can be most useful for awareness-raising and decision making. In addressing the specific problems of Dakar, the most appropriate use of this level of analysis is in awareness-raising itself. This pilot study can be and is being effectively used to improve overall awareness of governments at different levels and civil society stakeholders of the magnitude and nature of these exposures and vulnerabilities, to motivate further discussion, analysis and action. Next steps on both fronts – actions for Dakar and improvements and replication of the methodology – are discussed in this final section, against the broader backdrop of the Hyogo framework for action on disaster reduction.

6.1 Guiding principles: Hyogo Framework for Action

190. A recent global initiative to promote a strategic and systematic approach to reducing vulnerabilities and hazard risks is the Hyogo Framework for Action 2005-2015.[42] It was adopted at the World Conference on Disaster Reduction in January 2005 in Kobe, Hyogo, Japan. The Conference underscored the need for, and identified ways of, building the resilience of nations and communities to disasters.

191. The Hyogo Framework for Action draws on the conclusions from the review of the 1994 Yokohama Strategy[43], and underpins (i) more pro-active approach to informing, motivating and involving people in all aspects of disaster risk reduction in their own local communities, and (ii) the scarcity of resources allocated specifically from development budgets for the realization of risk reduction objectives while noting the significant potential to better exploit existing resources and established practices for more effective disaster risk reduction.

192. In order to achieve strategic goals, the Hyogo Framework for Action has selected five priorities for action. States, regional and international organizations and other actors concerned need to take into consideration the key activities under each of five priorities and implement them to their own circumstances and capacities.

[42] The scope of this Framework for Action encompasses disasters caused by hazards of natural origin and related environmental and technological hazards and risks. It thus reflects a holistic and multi-hazard approach to disaster risk management and the relationship, between them which can have a significant impact on social, economic, cultural and environmental systems, as stressed in the Yokohama Strategy (section I, part B, letter I, p. 8).

[43] The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action ("Yokohama Strategy") adopted in 1994, provides a landmark guidance on reducing disaster risks and the impacts of disasters.

Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.

193. Countries that develop policy, legislative and institutional frameworks for disaster risk reduction and that are able to develop and track progress through specific and measurable indicators have greater capacity to manage risks and to achieve widespread consensus for, engagement in and compliance with disaster risk reduction measures across all sectors of society. Key activities include (i) National institutional and legislative frameworks, (ii) Resources, and (iii) Community participation.

Identify, assess and monitor disaster risks and enhance early warning.

194. A starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of that knowledge. Key activities include (i) National and local risk assessments, (ii) Early warning, (iii) Capacity, and (iv) Regional and emerging risks.

Use knowledge, innovation and education to build a culture of safety and resilience at all levels.

195. Disasters can be substantially reduced if people are well informed and motivated towards a culture of disaster prevention and resilience, which in turn requires the collection, compilation and dissemination of relevant knowledge and information on hazards, vulnerabilities and capacities. Key activities include (i) Information management and exchange, (ii) Education and training, (iii) Research, and (iv) Public awareness.

Reduce the underlying risk factors.

196. Disaster risks related to changing social, economic, environmental conditions and land use, and the impact of hazards associated with geological events, weather, water, climate variability and climate change, are addressed in sector development planning and programs as well as in post-disaster situations. Key activities include (i) Environmental and natural resource management, (ii) Social and economic development practices, and (iii) Land-use planning and other technical measures.

Strengthen disaster preparedness for effective response at all levels.

197. At times of disaster, impacts and losses can be substantially reduced if authorities, individuals and communities in hazard-prone areas are well prepared and ready to act and are equipped with the knowledge and capacities for effective disaster management.

6.2 More pro-active approach to informing, motivating, and involving people in their own local communities

198. Following the Hyogo Framework for Action guidelines, local agencies and local communities should play a pivotal role in disaster management practices. They should be better informed and provided more resources to implement effective disaster management practices. National and regional governments legislate for various land-use regulations and mobilize physical and administrative resources for various ex-ante and ex-post disaster management activities. However, the actual implementation to prevent and mitigate natural hazard and climate

change risks including enforcement and supervision should be done by local agencies and local communities.

199. Consistent with these principles, the recommendations emerging from this study include measures that improve awareness of disaster risks, as well as a frank assessment of institutional resources and capacity for disaster management and prevention in the Dakar Metropolitan Area. We identify three avenues for engagement:

- First, informing, motivating, and involving people in their own local communities. .
- Second, strengthening local institutional capacity and coordination. .
- Third, policy reforms and investments for improved hazard resilience and preparedness at the local level. .

6.2.1 Informing, motivating, and involving people in their own local communities.

200. The most immediate recommendation from this pilot study is to develop a general awareness campaign – which has already started with the process of validation and dissemination of the findings of the study. Local agencies and local communities should play a pivotal role in disaster management practices, and develop demand for improved land use planning and disaster response. In turn, empowered local communities and agencies can play a key role in identifying areas and structures under risk, and monitoring and evaluating the implementation of the measures. Alignment with the Hyogo framework requires a consultative and participatory process that ensures sustainability and ownership of the measures proposed.

Action plan: General Awareness Campaign

201. (Already initiated in the context of this pilot study)

- Organize local knowledge and information dissemination activities, targeting local public agencies and local communities, on the seriousness of the natural hazards and climate change impacts on their own lives, with focus on the behaviors that the population can control and improve on.
- Arrange collaboration and joint activities with various local agencies, academic and research institutions, non-profit organizations (NGOs) to pursue these campaigns of sensitization.

6.2.2 Strengthening local institutional capacity and coordination.

202. The study also reveals failures of capacity, accountability and coordination among local agencies and between them and agencies at other administrative levels. These are issues that require further examination and discussion among the relevant stakeholders. This study limits itself to pointing to some of the key institutional capacity and coordination issues identified. It suggests some that may be on the critical path for progress and deserve special attention, such as the identification and empowerment of an institutional champion for disaster risk management and prevention at the metropolitan level, and the development of a local database on hazards and the training of local agency staff to use it effectively.

Action plan: Strengthening Local Institutional Capacity and Inter-agency Coordination

- Identify viable and well-recognized institutional champion at the Metropolitan Level.
- Initiate discussion at the highest political level for local institutional strengthening and coordination and reforms:
  - Initial focus: (a) development of early warning and quick-response system, paying attention to currently under-served peri-urban areas; and (b) improve local organization and capacity to enforce urban zoning and regulations to reduce vulnerability to natural hazards, with special focus on currently under-served and fast-growing peri-urban areas.
  - Medium-term focus: (a) adequate resourcing of key local agencies; (b) policy reform; and (c) reallocation of public expenditure and investment to local disaster risk mitigation and prevention. (See further below.)
- Develop a spatial database for local disaster management in the Dakar Metropolitan Area, and ensure broad access and hands-on training for local agency staff.
- Promote local communities' engagement and participation in disaster prevention measures.

6.2.3 Policy reforms and investments for improved hazard resilience and preparedness at the local level

203. Beyond the immediate findings and recommendations of this study, stakeholders in Dakar need to consider what substantive policy and investment measures may be considered over time. Ultimately, policy reforms that influence behavior to promote better risk management and investments that strengthen resilience at the local level would be needed to improve the situation of Dakar and its peri-urban expansion areas. The findings of this study suggest the importance to focus on better local land use planning and management, and infrastructure, and the last segment in the table below summarizes possible measures to be considered. This study does not make specific recommendations in these areas, however, as this would require a more detailed analysis. Selection of viable choices would also depend importantly on stakeholder consultation.

Action plan: Policy Reform and Investment

- Improve local land use planning and management: (a) improvement of land property right assignment and enforcement, with special focus on peri-urban areas; and (b) consultative development of metropolitan development plan, including identification of disaster hotspots and corridors for urban expansion, and potential land acquisition plans to support urban growth corridors.
- Strengthening resource base for local authorities, including through proposed betterment taxes that take advantage of improved land management plans and corridor development.

- Invest in climate- and disaster-proofing infrastructure and housing stock: retrofitting existing infrastructure and housing in hazard-prone areas; improving infrastructure planning and monitor quality of investments.

6.3 Replication of the Pilot Study

204. As mentioned earlier, this study was intended as a pilot to test new methodologies, and identify how the approach could be enhanced in case of replication in other cities and regions of the developing world. Interest in replicating the approach exists for other African cities, as well as for a selection of Asian cities. Also, this pilot study may also provide the foundation for the development of a city vulnerability index to be applied to a large number of cities. In replications of this study, it is proposed that the following enhancements be considered:

- Consideration of a broader range of natural hazards, beyond the three included in this study.
- More robust definition of peri-urban areas.
- More detailed and better documented analysis of the economic impact of hazards.
- More detailed discussion of the methodology for population density imputation, possibly considering different relationships between building density and population density, depending on whether the area is formal or informal.
- Addition of information (layering) of major infrastructure (roads, electricity, sanitation).
- Utilization of more detailed GIS data sources, such as those captured in cadastres, to inform the more detailed economic and population analysis suggested above.

205. These extensions of the current pilot study may lead to slight increases in the cost of undertaking the study, at least in the initial replications.

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The World Bank's Spatial and Local Development Team (FEU, SDN) and the Global Facility for Disaster Response and Recovery (GFDRR), in collaboration with colleagues from the World Bank Senegal Country Office, the Geoville Group and African Urban Management Institute (IAGU), have developed state-of-the-art spatial analysis tools to spatially evaluate natural hazard and climate change risks, and addresses the critical knowledge and capacity gaps of local governments.
The report proposes action plans to ramp up natural hazard and climate change risk management practices drawing on the findings of the study and the international consensuses on best-practice exercises.

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