Dakar in 2050: how do public policy decisions define a future of vulnerability to flooding?

Introduction

Over the past twenty years, Senegal's economic capital has experienced several flooding events with consequent human and material repercussions (Descroix 2018). During the 2009 rainy season, no fewer than 360,000 people were affected by flooding in Dakar's peri-urban areas, including 371 neighborhoods in Pikine and 27 in Guédiawaye. The extent of the damage was estimated at 48 billion F CFA (Gouvernement (République) du Sénégal 2010).

This type of extreme rainfall with dramatic consequences can be explained by several types of factor, the first of which relates to the intensity of rainfall, which has been steadily increasing in recent years (Chagnaud et al., 2022). Another factor that is often put forward is urbanization, although the very definition of what this polysemous term means is sometimes lacking. Very often, urbanization is reduced to its most commonly visible manifestation: the increase in housing. Particularly in the case of African cities such as Dakar, the focus is often on the housing of the poorest urban population, spontaneous, informal housing, described as anarchic and/or illegal, particularly by the political elites relayed by the media.

Referring to the particular conditions of creation and evolution of Dakar's suburbs (near and far), the latter often invoke anarchic and irregular occupation to justify the recurrence of flooding. However, public policies are also partly responsible for increasing vulnerability to flooding in Dakar ((Diongue 2014; Mbow, Diop, Diaw, Niang 2008):

- Letting people settle: lack of real vision, effective urban planning
- Urban planning that fails to consider the risk of flooding and, in particular, soil characteristics, etc.

Based on this observation, this article aims to demonstrate how the orientation of public policies can lead to very different forms of urban dynamics in Dakar, a city that is intrinsically vulnerable to flooding.

Material and method

Dakar, a naturally flood-prone city

Dakar, the economic capital of Senegal, is built on land that is naturally prone to flooding. This is due first and foremost to its topography, with several areas located at sea level, notably in the departments of Guédiawaye (3.5% of the territory located at altitudes <= 0 metre), Pikine and Rufisque, which each have 2.3% of the territory located at altitudes less than or equal to zero metres. This topography favors maritime ingress, resulting in the presence of several Niayes; stagnant, salty waters, and swampy areas distributed mainly in the latter departments. Secondly, the pedology of the Dakar peninsula shows a very dominant presence of hydromorphic soils (57% of the territory of the Dakar Region) (Figure 1). Hydromorphic soils are water-saturated soils identified as wetlands and therefore flood-prone land. They are permanently saturated by the water table, which rises by an average of 15 cm per year, and seasonally saturated by rainfall from July to September. Over 53% and 70% of the land in the departments of Pikine and Rufisque, respectively, is subject to flooding (Figure 1).

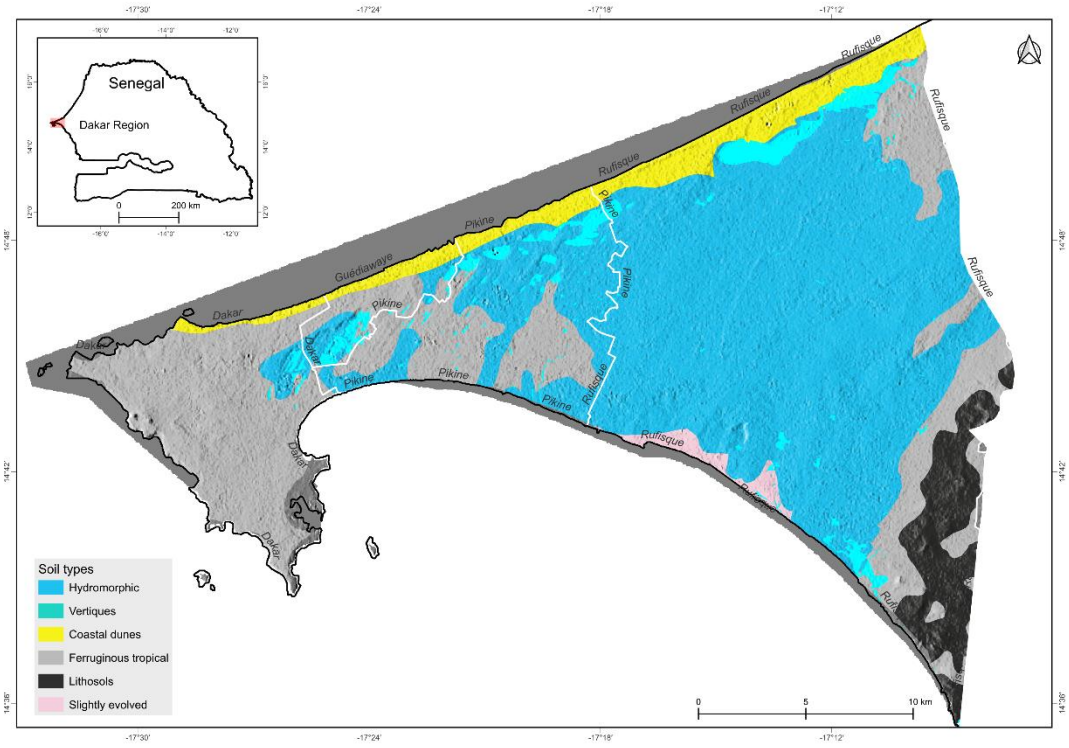

Figure 1 : Soil typology map of Dakar Region (data provided from the GEOSEN platform)

Land use and land cover mapping

Satellite image remote sensing techniques were used to map land cover/use in the Dakar region over 3 years; 2001, 2011 and 2021. Multispectral satellite images, Spot-4, Spot-5 and Sentinnel-2, were freely downloaded from the CNES Sport World Hertiage (https://regards.cnes.fr/) and ESA Copernicus (https://scihub.copernicus.eu/) platforms. These data underwent various pre-processing operations to correct geometric and atmospheric errors. All images were resampled to the same 10-meter pixel resolution.

In the processing phase, the eCognition software (https://geospatial.trimble.com/) was used to perform a supervised hierarchical classification using the object-oriented method as used by (Révillion, Attoumane, Herbreteau 2019) with Spot 5 images to produce a land use/occupation map of small islands in the Indian Ocean. However, only 5 land use classes were predefined: urban, bare soil, vegetation and water. The choice of these classes was guided by the field reconnaissance carried out prior to processing, but also by the intention to establish future scenarios for large-scale occupancy mapping.

In order to validate this land use mapping, 120 GPS points (i.e. 30 points per class) were collected in the field. A confusion matrix was established between the field observations and the satellite image classification, in order to calculate the overall accuracy and Cohen's Kappa index. These two indicators allow us to assess the map accuracy that would be acceptable with a kappa value > 75% (Foody 2002).

Prediction of land use and land cover scenarios to 2050

The Land Change Modeler (LCM) program of the TerrSet2020 software (Eastman 2020) was used to produce 3 scenarios of land cover and land use change in the Dakar Region by 2050. The prediction of change was carried out in three stages; the first was the analysis of historical changes in land use between 2001 and 2011, and also between 2011 and 2021, a step which enabled us to identify the dominant transitions in each decade. The second stage involved transition potential modelling, to identify the drivers of transition. Multi-Layer Perceptron (MLP) neural network was chosen as the model for estimating potential transitions. Distances to primary and secondary roads, altitudes, slopes, distance to Hann and Mbao forests and distance to wetlands were the factors integrated into the transition potential modeling phase. The final stage is the prediction of land use and land cover change from 2011 to 2021, a data set that has been validated by the pre-established data from the direct processing of satellite images. Following this validation, the three scenarios for 2050 starting from 2021 were established: the

first is a so-called natural prediction, as it only takes into account physical transition factors; the second is a so-called environmental prediction, as it imposes constraints on the non-change of forest areas, wetlands and the sand strip of Dakar's northern coastline; and finally, the last prediction imposes constraints on the non-change of urban growth limits defined in Dakar's Urban Master Plan (PDU) up to 2035. These zones include: risk zones (landslide zones due to steep slopes, flood zones and coastal submersion zones) and urbanization control zones reserved for the promotion of agriculture, and therefore restricted to urban development. This last prediction would then consider public policy choices to provide for sustainable Dakar urban development.

Results

Rapid change in the dynamics of Dakar's urban footprint 2001-2021

Over the past twenty years, the urban dynamics of the Dakar Region have seen a considerable increase in its urban footprint (urban area), rising from 17% in 2001 to 38% in 2021, representing an annual growth rate of 1.9% (Figure 2). This growth in the urban footprint has accelerated over the last decade (2.07%/year between 2011 and 2021 versus 1.83%/year between 2001 and 2011), leading to near-saturation of certain departments, notably Dakar (≈ 80% urban footprint coverage rate in 2021) and Rufisque (60% urban footprint coverage rate in 2021) (Figure 2). As a result, Rufisque (23% EU coverage rate in 2021) remains the only department where it is possible to conquer space for urbanization. It is therefore under enormous pressure, as evidenced by its annual urban land growth rate of ≈ 4%, i.e. twice the urban land growth of the entire Dakar region over the period 2011 – 2021 (Figure 2).

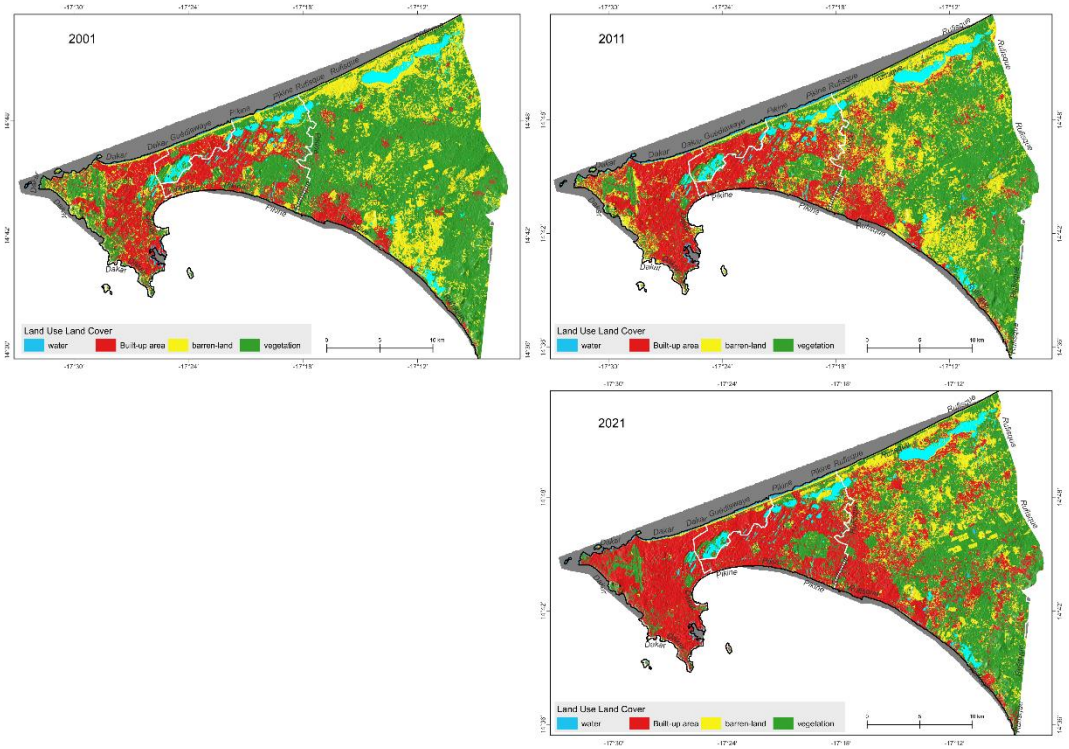

Figure 2 : Land use land cover maps for 2001, 2011 and 2021

Dynamics of Dakar's urban footprint to 2050, the influence of public policy choices

Projections of the growth of the Dakar Region's urban footprint to 2050 (Figure 3) have made it possible to appreciate the effects of urban development policy choices if they are applied within the planned timeframe. Indeed, the urban footprint coverage rate for the entire Dakar region in 2050 will be 52% with constraints versus 55% without constraints. With the constraints considered, this urban land coverage rate will drop significantly in the departments of Guédiawaye (-19%) and Pikine (-7%). Rufisque, despite its inability to escape urban and economic development, will nevertheless experience a drop in its annual urban growth rate (1.27% with constraints vs. 1.32% without), bearing in mind that it will be the only department to experience growth in excess of 1%/year. In concrete terms, the effects of considering urban growth constraints in future projections will be more visible spatially, with the preservation of green spaces in the Niaye of the Dakar Technopole and forests (Mabo, Hann

and filaos plantations), the maintenance of agricultural areas and the limitation of the expansion of the urban footprint on the northern coastal front and near marshy areas (Figure 3).

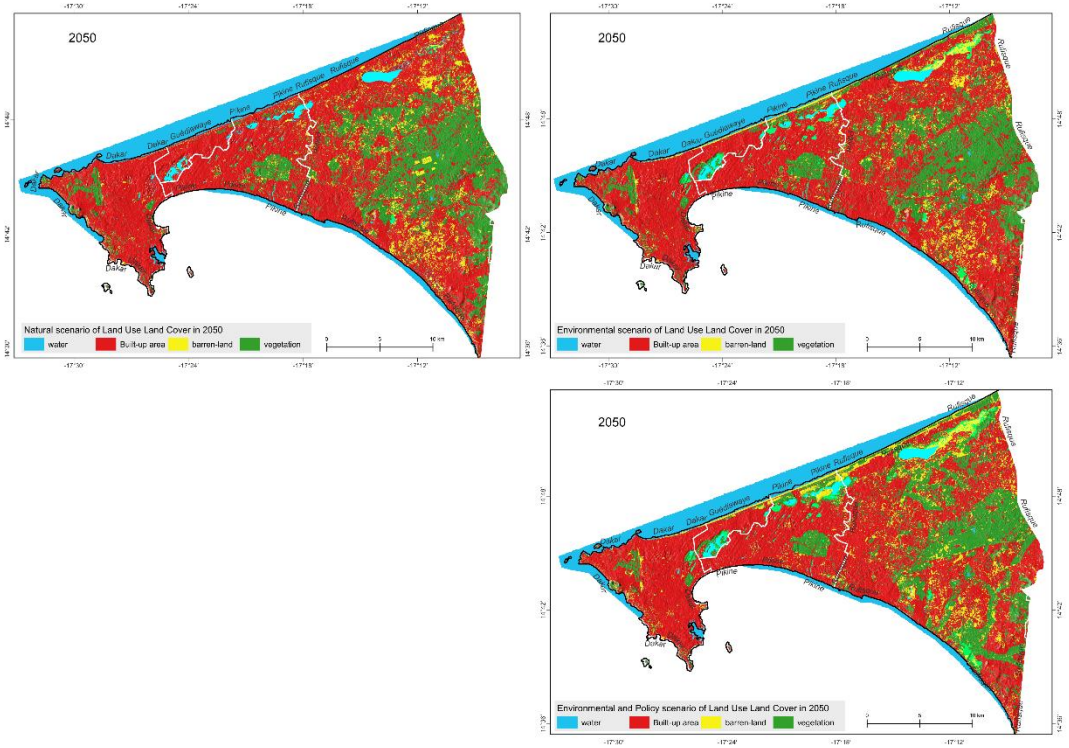

Figure 3 : Scenarios for changes in land use and land cover in 2050

Conclusion

By analyzing the history of land use from 2001 to 2021, this study has shown that the public policy choices made over the last ten years have had a considerable influence on accelerating the dynamics of the urban footprint in the Dakar region, and more specifically in the department of Rufisque. This urban footprint dynamic has accelerated the process of occupying land vulnerable to flooding, accentuating the vulnerability of the poorest populations whose socio-economic conditions enabling them to acquire secure land appear weak. Their fate then depends on the choices made by public planning policies, which may or may not consider the physical reality of vulnerability to flooding in the Dakar region. It is up to political decision-makers to plan a sustainable development that will reconcile the planning of economic and tourism development zones with the planning and development of safe territories to accommodate populations.

Reference

DESCROIX, Luc, 2018. *Processus et enjeux d'eau en Afrique de l'Ouest soudano-sahélienne*. Online. Archives contemporaines.

DIONGUE, Momar, 2014. Périphérie urbaine et risques d'inondation à Dakar (Sénégal): le cas de Yeumbeul Nord. *Eso Travaux et documents, Résumés des Travaux*. 2014. No. 37, p. 45–54.

EASTMAN, J. R., 2020. TerrSet 2020–Geospatial Monitoring and Modeling System Manual. *Clark Labs, Clark University: Worcester, MA, USA*. 2020.

FOODY, Giles M., 2002. Status of land cover classification accuracy assessment. *Remote Sensing of Environment*. 1 April 2002. Vol. 80, no. 1, p. 185–201. DOI 10.1016/S0034-4257(01)00295-4.

GOUVERNEMENT (RÉPUBLIQUE) DU SÉNÉGAL, 2010. *"Rapport d'évaluation des Besoins Post Catastrophe. Inondations urbaines à Dakar en 2009", Rapport préparé par le gouvernement de la République du Sénégal avec l'appui de la Banque Mondiale, du système des Nations Unies et de la Commission Européenne, Rapport final*. Online. Dakar.

MBOW, Cheikh, DIOP, Aminata, DIAW, A. T. and NIANG, Ch I., 2008. Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal). *African Journal of Environmental Science and Technology*. 2008. Vol. 2, no. 4, p. 075–088.

RÉVILLION, Christophe, ATTOUMANE, Artadji and HERBRETEAU, Vincent, 2019. Homisland-IO : Homogeneous land use/land cover over the Small Islands of the Indian Ocean. *Data*. 2019. Vol. 4, no. 2, p. 82. DOI 10.3390/data4020082.