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IMPACT OF LAND USE ON GROUNDWATER QUALITY IN THE THIAROYE UNSEWERED SUBURB (DAKAR SENEGAL): Remote Sensing and GIS approach

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Context and aim of the study

Contamination through septic tanks and effluents of the urban groundwater used by local population for agricultural practices and domestic consumption has led water authorities, stakeholders and researchers to develop strategies for water resource management. In this respect a multi-disciplinary approach which combines Remote Sensing, GIS, hydrogeological and sociological techniques focusing on water quality degradation and devastating urban floods were developed to provide material for future emergency planning and hazard mitigation in the densely populated area in the Dakar suburb.

Physical setting

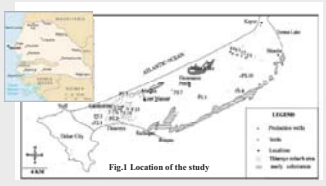


Fig.1 Location of the study

Research area is located in the Midwestern part of Senegal. It extends as a peninsula.

Geology of the area is registered on the general context of the senegalo-mauritanian basin (fig.2).

The main morphological feature are the eastern depression " Niayes" along the ocean façade.

The studied hydraulic system (fig.1) is located from Dakar to Kayar (300km^2). The shallow Thiaroye aquifer reservoir is composed of unconsolidated quaternary sand.

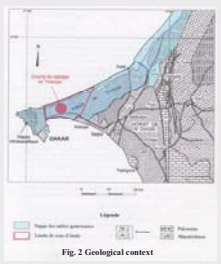
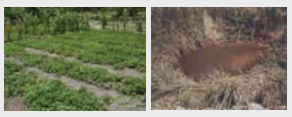


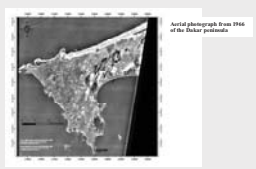
Fig. 2 Geological context


Niayes Zone "Local term used to designate interdune depression where agricultural practices are developed"



Material & Methods

In order to improve the water resource management in the area, long trend analytical stretching back to 1966 were considered to evaluate impact resulting from the rapid expansion of the region. Record on nitrogen, chloride, sulphate compounds were correlated with multi data land use and other thematic maps from aerial photography (1966), Thematic Mapper of Landsat (1972, 1988) and Spot 4 imagery (1995). For the present study Spot 5 images acquired on October 2006 are available in panchromatic with 2.5m pixel resolution and multispectral with 10m pixel resolution. With ERDAS 8.5 software the two images are combined to generate a high resolution image with 2.5m pixel resolution. Spatial information was acquired with different spatial resolution of 2.5m to 30m (Fig3-8). Data from aerial photographs and RS images have been interpreted using ARC GIS 9.2 to provide separate land use distribution for each time periods between 1966 and 2006.


Aerial photograph from 1966 of the Dakar peninsula

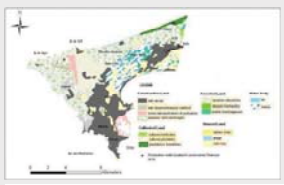


Fig.4 Land use / cover classification map of Dakar peninsula based on the analysis of aerial photograph for 1966


Fig.5 Spot 4 image of the study area acquired in 1995

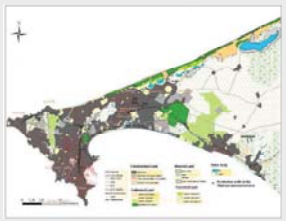


Fig.6 Land use / cover classification map of Dakar peninsula based on the analysis of spot 4 image for 1995

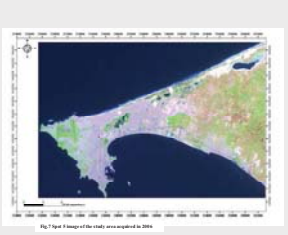


Fig.7 Spot 5 image of the study area acquired in 2006

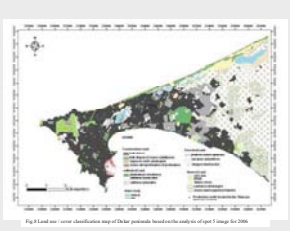


Fig.8 Land use / cover classification map of Dakar peninsula based on the analysis of spot 5 image for 2006

Results & Interpretation

Table 1: Land-use conversion matrix in Dakar region from 1995 to 2006 (ha) (6); (8); (1); (200): Land-use classes

Land-use Category		Construction Land (1)	Construction Land (2)	Construction Land (4)	Construction Land (200)	Total 2006	%
Cultivated Land	(6) (8) (9)	17.78 556.1 1141.9	4.9 735.1 363.5	0 3 0	0 43.5 5.9	**2872**	28.72
Forested Land	(7) (10) (16)	0 446.5 0	0 11.9 0	0 0 0	0 82.97 0	**541.37**	5.41
Unused Land	(11) (12) (73) (14) (100)	0 0 11.9 0 356.6	0 0 0 0 0	0 0 0 0 185.7	0 0 0 0 32.6	**586.7**	5.87
Water Body	(3) (5)	0 24.7	0 0.99	0 0	0 0.99	**26.7**	0.27
Total of conversion into land-use classes		2555.5	1116.4	188.7	166	**4026.8**	

Results on land use distribution from 1966 to 2006 evidence real expansion involving from 2,809ha to 12,925ha in the unsewered Thiaroye suburb area. The greatest increase occurred between 1995 and 2006. Statistical analysis shows land use changed significantly in Dakar over 11-years periods. Main land use change in the study area concern modification within land use category or conversion (Table 1) from land use category into an other category.

Rows show the area of cultivated land use change into construction land; of Forested land-use change into Construction land; of Unused land use change into Construction land and of Water body into Construction land. Columns show the area of different land-use classes within the construction Land category over the 11-years periods.

Main changes with time concerning groundwater quality deterioration were derived mainly from nitrate and to lesser extend sulphate and chloride. Lower nitrate concentrations (5-32mg/l) were observed in productions wells (F_{17}, F_{18}, F_{21}, F_{22}, and F19) during period prior to 1988 (Fig.9). Unsewered urban areas rapidly increase since 1988; it corresponds to high levels of nitrate (11-297mg/l) above the drinking–water standard. More recently (1995-2008) nitrate levels reach 500mg/l in the populated suburb area (Fig.10). The adjusted sanitation system map (2000) confirms the lack of the system on the densely suburb zone (Fig.11) where septic tanks leakage is the main source of pollution.

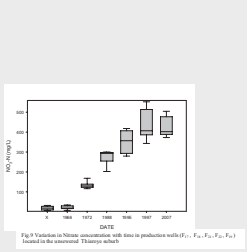


Fig.9 Variation in Nitrate concentration with time in production wells (F_{17}, F_{18}, F_{21}, F_{22}, F_{19}) located in the unsewered Thiaroye suburb

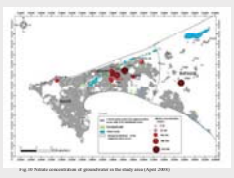


Fig.10 Nitrate concentration of groundwater on the study zone (April 2008)

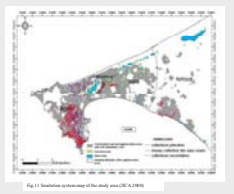
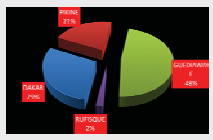


Fig.11 Sanitation system map of the study area (BCEOM)



Agglomerated area with population density. Dakar is the more densely populated region, with 4,387 inhabitants / km² over the mean


Improper septic tanks seeping from the bottom to groundwater


Domestic waste

Industrial waste

Example of uncontrolled waste deposits in "Mbeubeus" in the centre of Dakar

Conclusion

Approach developed and the resulting maps are useful for development of regional groundwater protection plans, policy analysis tools and pollution source control. The effective awareness of the local population and stakeholders can permit to implement strategies to ensure properly conceived tool for managing this valuable resource in urban environment.