Archives of Current Research International
6(2): 1-12, 2016; Article no.ACRI.30214
ISSN: 2454-7077

SCIENCEDOMAIN *international*
www.sciencedomain.org

Impacts of Rainfall Variability and Urban Sprawl on the Environment and the Population Well-being at Ouakam Commune, Dakar, Senegal

Mamadou Lamine Ndiaye[1*], El Hadji Amath Diodio Ndiaye[1], Vieux Boukhaly Traore[2], Amadou Tahirou Diaw[1] and Aboubacker Chedikh Beye[2,3]

[1]Training and Research Laboratory in Geoinformation, Cheikh Anta Diop University, Dakar, Senegal.
[2]Laboratory of Hydraulics and Fluid Mechanics, Cheikh Anta Diop University, Dakar, Senegal.
[3]Physics of Solid and Sciences of Materials, Laboratory, Cheikh Anta Diop University, Dakar, Senegal.

Authors' contributions

This work was carried out in collaboration between all authors. Authors MLN, VBT and EHADN designed the study, wrote the protocol and first draft of the manuscript, performed the calculation, the cartography and analysed the results. Authors ATD and ACB read and approved the final manuscript.

Article Information

DOI: 10.9734/ACRI/2016/30214
Editor(s):
(1) Sivakumar Manickam, Department of Chemical and Environmental Engineering, The University of Nottingham Malaysia Campus, Malaysia.
Reviewers:
(1) Joel Loitu Meliyo, Selian Agricultural Research Institute, Tanzania.
(2) Zoungrana Benewinde Jean-Bosco, University of Wurzburg, Germany.
Complete Peer review History: http://www.sciencedomain.org/review-history/16956

Original Research Article

Received 25th October 2016
Accepted 14th November 2016
Published 18th November 2016

ABSTRACT

In many Southern African countries, climate change observed these last years, had serious consequences on the environment and the well-being of urban populations. This study aims to analyze the consequences due to rainfall variability and urban dynamics in the Commune of Ouakam. Analysis of rainfall variability based on the calculation of the reduced centered variable allowing identifying surplus and deficit years. Urban dynamics analysis based on land use maps obtained through visual interpretation and post-classification approach to identify the types of change. A field survey was conducted among households and health facilities to gather further information on the issue relating to parasitic and respiratory diseases caused by the floods and the dynamics of land use. The results show a return of rainfall during the past two decades causing flooding in places. The dynamics of land use is manifested by a conversion of crops areas into

**Corresponding author: Email: mlndiaye02@gmail.com;*

habitation areas. This led to the development of irregular habitat from 2% in 1942 to 20% in 2014, public health problems with the proliferation of parasitic and endemic diseases and floods with their multiple damage in terms socioeconomic. This study is for local authorities, an important tool in understanding of the major difficulties the Ouakam commune faces Therefore, solutions can and must be considered immediately.

Keywords: Rainfall variability; land use changes; irregular settlements; public health; flooding; Ouakam.

1. INTRODUCTION

Urbanization appears to be among the evolutions of the last century, one of the most prominent features of the planet Earth [1-3]. It is highly manifest in the development countries [4-7]. In Senegal, rapid urbanization is one of the main features of the urban centers, especially Dakar, one of the great metropolises of West Africa [8-10]. Dakar is witnessing a spiral growth of population and settlements over time while a limited effort is made to better manage urban areas particularly in the outskirts [11-12]. The rapid population growth is mainly due to the massive exodus of rural populations because of the drought of 1970-1990. Covering an area of 550km² (i.e. 0.3% of national territory), Dakar's population had more than tripled since the 1970s. From 959 558 inhabitants in 1976 the population of Dakar increased to 3137196 people in 2013, representing a growth rate of about 6% per annum [13-14]. The development of cities is at the expense of natural space, generally considered of agricultural space [1-15]. The urbanization of Dakar has led the conquest of the old components of traditional agrarian villages [16]. The Municipality of Ouakam is one of those old agricultural lands that have undergone strong urbanization. Indeed, the East Village was home to many fields such as home field (*Tol-Keur)* and distant fields (*Lakkas*). In this commune, topographical, pedological and climatic conditions favor the development of these types of activities particularly in depressions. By cons west of the village more rugged erosion zone is marked by a concentrated runoff with many ravines in what is here called "Niayou Ouakam" hence a constraint to agricultural development in the area [17-18] A great part of Ouakam through aerial photos from 1942 1966 and 1978 remains in the grip of an herbaceous vegetation. However these areas (vegetation zones and cultures) have experienced significant changes in particular from the 1990s. The changes are manifested by a regressive vegetation dynamics and cropping areas, this into housing areas and therefore, the reduction in the tax base of the Ouakam. The strong lust of Ouakam as the urban centre, is attributed to its geographical location whereby it's adjoined directly to the Atlantic Ocean and its elevation of 50 m above sea level [19-20]. To the airport of Dakar (3 km) and the city of Dakar which is an administrative, and commercial capital. The attraction of Ouakam is essentially due to significant land reserves and the practice of land speculation [21]. The land use of the Ouakam commune is the result of anarchic urbanization which does not meet urban standards. It results in a development of spontaneous settlements often housed in areas of depressions and where sanitation is difficult. The expansion observed in Ouakam commune, is made haphazardly and consequently causing social inequalities, spatial disparities in access to basic social services (health, education, drinking water, sanitation, and housing). The health problems are becoming more recurrent in this area particularly with the increase parasitic diseases. In the last decade, the commune of Ouakam has often been confronted by flooding causing important socioeconomic damage. The present study aims to assess the consequences of rainfall variability and urban dynamics in the commune of Ouakam. It is through this study, o establish the relationship between rainfall, land use patterns, and recent difficulties arising from a lack of habitat planning. These results implement a tool of knowledge and action for better governance of local communities.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The Commune of Ouakam is located at the western of Dakar, between the longitude 17° 30' 0" and 17° 28' 20" West and latitude 14° 42' 30" and 14° 44' 10" North (Fig. 1). It covers an area of 4.5 km² and its population is estimated to 58 418 in 2015 [14]. In Ouakam, there are three forms of habitats: traditional, informal and planned settlements. It is situated on an average altitude of 50 m. Ouakam is characterized by a coastal type of microclimate due to its advanced position in the Atlantic [10]. This is strongly influenced by maritime trade winds and the monsoon which respectively set from November to June and from July to October in directions N-NW and S-SE. It is characterized by two seasons, a rainy season from June to October and a dry season from November to May. The average annual rainfall is estimated at 400mm [22-23]. The minimum temperatures range (12℃ to 20℃), maximum temperatures range from (28℃ to 36℃). The average temperature is between (20℃ and 28℃). The population of the Municipality of Ouakam is now estimated at about 58418 inhabitants [14] against 28193 people in 1988 and 7262 inhabitants in 1972 [24].

2.2 Data Collection

In this study, we have used remote sensing data consisting of aerial photographs of the years (1942, 1966, 1978 and 1997) and satellite images of the years (2002, 2009 and 2014).The choice of these dates is justified by their availability and high resolution. We have also used rainfall data at Dakar raingauge over the period from 1960 to 2013. These are provided by the ANACIM (National Agency of Civil Aviation and Meteorology) which is a national organization specializing in the collection of climate data. A field survey is organized from households and health facilities in the commune of Ouakam. The goal is to collect information on the factors of land use change, habitat type, health problems and the impact of floods. For this, the questionnaires have administered to households and an interview guide to health facilities. These informations helped us to understand the contours and problems related to rainfall variability and land use changes. ArcGIS and GPS tools are used for the analysis of remote sensing data.

2.3 Data Analysis

2.3.1 Rainfall analysis

To analyze the rainfall variability of the commune of Ouakam, we have calculated the reduced centered variable. It given by equation (1) [25].

$$I_i = \left(\frac{Xi - \overline{X}}{\sigma}\right) \quad (1)$$

Ii = reduced centered variable;
Xi = rainfall of the year i (mm);
X = average of annual rainfall;
σ = standard deviation of rainfall over the study period.

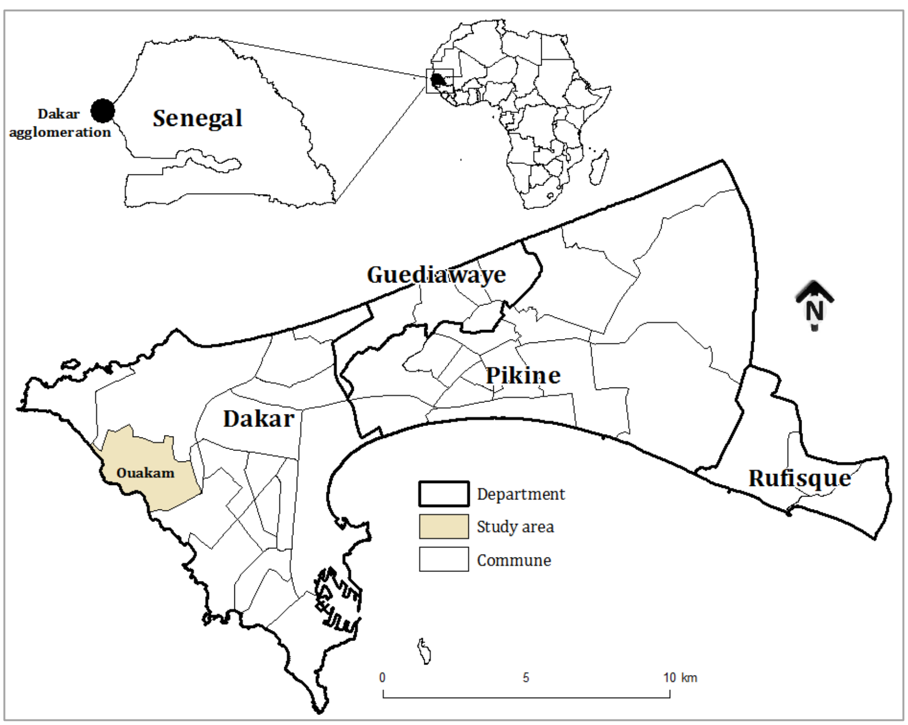

Fig. 1. Study area

This index allows observing the interannual variability and the periods of deficits and surplus rainfall [26]. A normal period is a period during which, the annual rainfall is sensibly equal to the average annual rainfall, i.e., the index value is equal to zero [27]. Period is wet, when the annual rainfall is higher than the average of annual rainfall, i.e., the index value is positive; period is dry when annual rainfall is less than average of annual rainfall, , i.e., the index value is negative.

2.3.2 Land use changes mapping

The classification concern the aerial photos and satellite images of various resolutions. They are first georeferenced using the method "image to image" to have the same resolutions, i.e. 5m.They also were projected to the Universal Transverse Mercator (UTM) projection WGS84 Zone 28 north. This step is necessary for studies of land use change. Then, we have proceeded with identification of land use classes. The identification involved discrimination and the delineation of units to be mapped. The factoring used for classification of objects included units shapes, textures tone. The visual interpretation method is used for image classification in ArcGIS software. For validation, we used the same number of ground truth points, i.e. 25 for each class. At the end of this operation, 30 land use classes are identified. They are grouped into 7 classes to facilitate the analysis of their dynamics, estimated through the formula (1) [17].

$$r = \left(\frac{tn - t0}{t0}\right) x\, 100 \qquad (2)$$

r = growth rate of land use unit between two time intervals
tn = area of land use unit in the year of arrival
t0 = area of land use unit to the starting year

3. RESULTS AND DISCUSSION

3.1 Rainfall Variability

The standardized rainfall index was analyzed by decadal over the period 1960-2012 for highlighting the trends with deficit or surplus. Fig. 2 shows variations obtained from the calculation of the centered reduced variable. Indeed, the succession of years highlights the extreme irregularity of the annual total; a flagrant irregularity in wet years (0 to 3) than for deficit years (0 to 2). This representation highlights the irregular character of the period 1960 to 2012 the Dakar region that is punctuated by two or three decadal series in successive dry trend.

Surplus and deficit trends are marked by a transition in 1968 (year with deficit -159.9 mm). According to some specialists, this date corresponds with the start of the drought in the Sahel [28]. By comparing the average of the series approximately 419 mm with the decadal averages it appears that the decades 1960-1969 and 2000-2014 are surplus with 584 mm and 485 mm respectively; while those against 1970-19801981-1990 and 1991-2000 are deficit in that order with 316.27 mm 385.7 mm and 324.08 mm (Fig. 3). The last decade (2000-2012) seems to indicate a trend of return of rainfall with a reduction in the strong field deficits. The

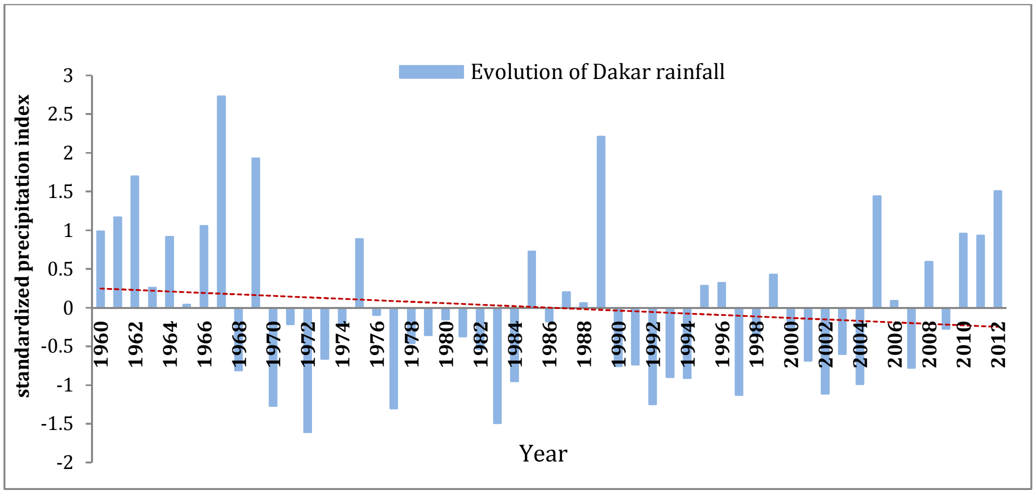

Fig. 2. Evolution of the standardized rainfall index

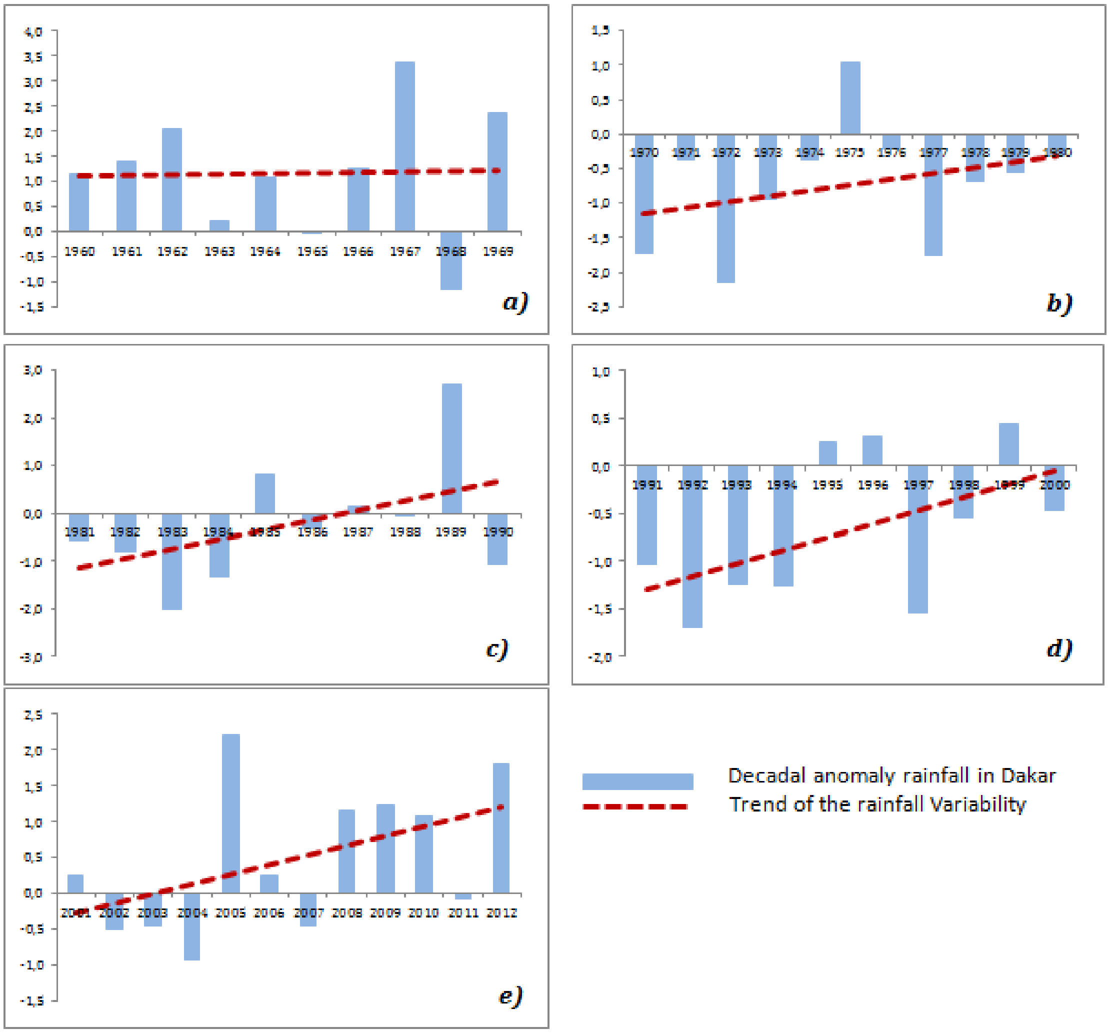

Fig. 3. Trends and decadal anomalies of reduced centered annual rainfall of Dakar region between periods: a) 1960-1969; b) 1970-1980; c) 1981-1990 d) 1991-2000; e) 2001-2012

consequences of rainfall fluctuation among other things are land use changes with the development of irregular habitat, flooding and public health problems.

Table 1. Accuracy assessment of images classification

Date of image	Overall accuracy (%)	Kappa
1942	85.92	0.83
1966	87.33	0.85
1978	87.02	0.85
2003	90.11	0.88
2009	91.30	0.89
2014	94.90	0.92

3.2 Land Use Changes

The classification results are evaluated using a confusion matrix. The overall accuracy of the images classification is between 85.92% and 94.90% and Kappa index, between 0.83 and 0.92 (Table 1). Overall, the accuracy of classification is considered good. Errors of omission and commission remain relatively low on all dates. Thus, the commune of Ouakam has experienced significant momentum between 1942 and 2014 regarding classes of housing and infrastructure, vegetation, crop areas, bare soil, road and beach. Table 2 and Fig. 4 present a better idea of rapid urban growth. With the transition matrices shown in Tables 3 to 7 the most significant changes are recorded between 1978 and 2003 and recently between 2009-2014. Between 1942 and 2014, the most important changes, concern the conversion of the crops areas and vegetation into built. It should be noted that the Commune of Ouakam has reached a very worrying level of artificialisation. Nowadays, the built occupies more than 61% of the area of Ouakam commune and more than 95% of habitable areas. This artificialisation was made fast and anarchistic manners like the development of irregular habitat with all the consequences that it can generate on the health and wellbeing of the populations of Ouakam.

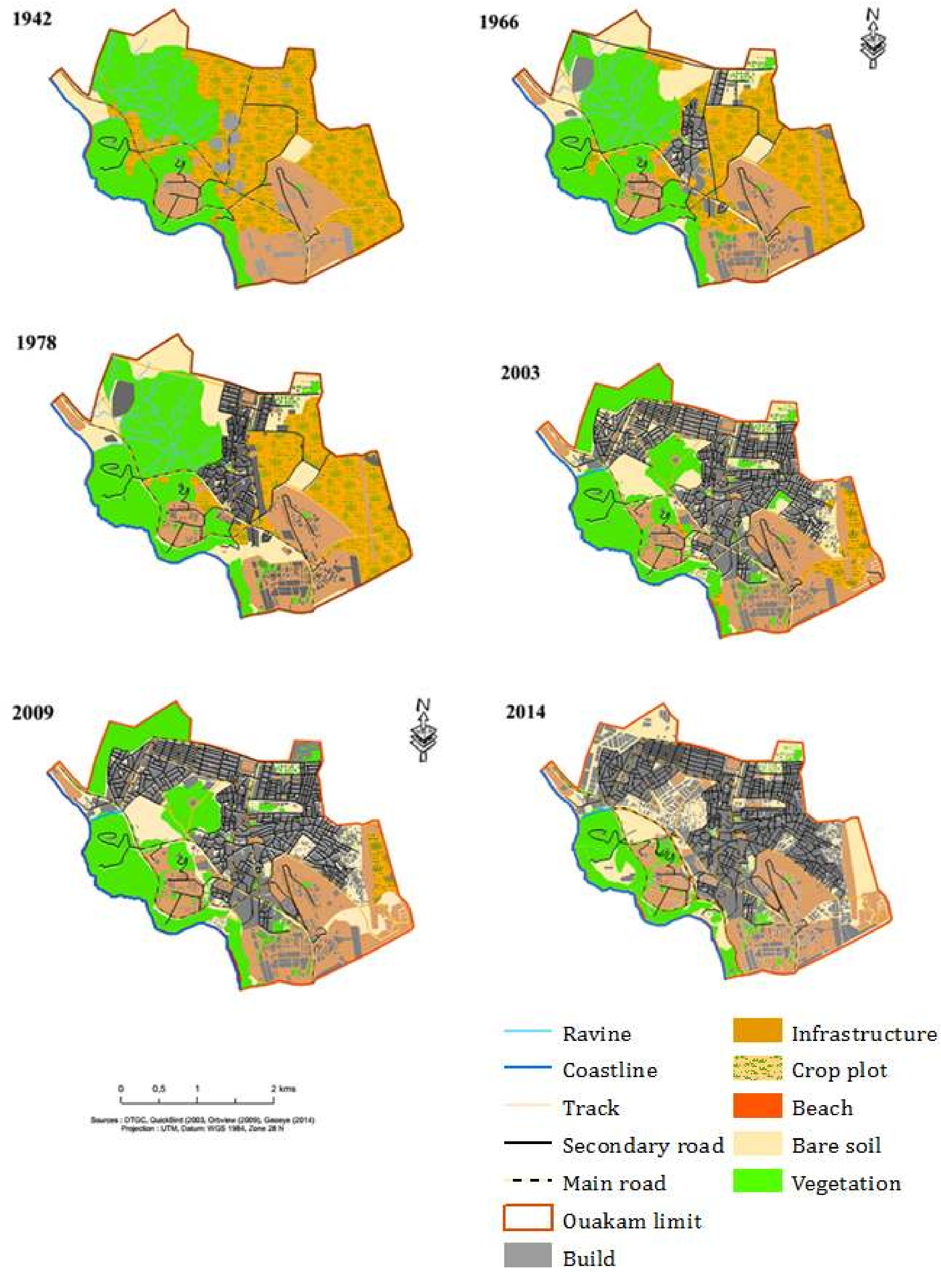

Fig. 4. Types of land use changes in the commune of Ouakam between 1942 and 2014

Table 2. Proportion of the state of land use between 1942 and 2014

Land use	Area (ha)						Area (%)					
	1942	1966	1978	2003	2009	2014	1942	1966	1978	2003	2009	2014
Build	27.15	66.39	89.56	190.19	215.86	269.99	4.15	10.15	13.67	29.03	32.95	41.12
Infrastructure	103.49	104.44	105.25	125.04	129.02	128.94	15.81	15.96	16.06	19.09	19.69	19.64
Crop plot	272.73	179.58	140.71	32,59	12.95	0	41.66	27.44	21.47	4.97	1.98	0
Beach	7.77	7.56	7.72	7,30	7.30	7,82	1.19	1.15	1.18	1.11	1.11	1.19
Road	10.80	15.19	18.66	40,79	41.46	43.43	1.65	2.32	2.85	6.23	6.33	6.61
Bare soil	42.20	89.62	99.31	110.47	96.81	131.74	6.45	13.70	15.15	16.86	14.78	20.06
Vegetation	190.44	191.63	194.17	148.76	151.75	74.74	29.09	29.28	29.63	22.71	23.16	11.38
Total	654.59	654.41	655.38	655.14	655.15	656.67	100	100	100	100	100	100

Table 3. Change matrix of land use between 1942 and 1966

1942-1966	Build	Infrastructure	Crop plot	Beach	Road	Bare soil	Vegetation
Build	25.34	8.29	24.83	0	0	0.34	7.70
Infrastructure	0.18	91.85	8.38	0	0	3.94	3.33
Crop plot	0	0	179.09	0	0	0	0.36
Beach	0	0	0	7.47	0	0	0
Road	0.90	0	3.99	0	10.17	10.17	0
Bare soil	0.45	0	39.98	0	0	37.73	11.21
Vegetation	0.15	0	17.30	0	0	0	171.13

Table 4. Change matrix of land use between 1966 and 1978

1966-1978	Build	Infrastructure	Crop plot	Beach	Road	Bare soil	Vegetation
Build	65.65	1.21	15.42	0	0.09	6.30	1.13
Infrastructure	0.70	102.39	0.02	0	0	1.64	0.40
Crop plot	0	0	140.70	0	0	0	0
Beach	0	0	0	7.14	0	0	0
Road	0	0	1.54	0	15.02	0	0.13
Bare soil	0	0	5.89	0	0	81.78	3.02
Vegetation	0	0	5.89	0.41	0	0	187.85

Table 5. Change matrix of land use between 1978 and 2003

1978-2003	Build	Infrastructure	Crop plot	Beach	Road	Bare soil	Vegetation
Build	86.67	2.29	53.88	0	0	23.07	27.96
Infrastructure	1.21	101.38	16.06	0	0	1.01	5.20
Crop plot	0	0	30.88	0	0	0	1.68
Beach	0	0	0	7.44	0	0	0
Road	0	0.58	8.56	0	20.23	4.04	8.25
Bare soil	0	0	27.48	0	0	40.14	38.67
Vegetation	0	0	4.25	0	0	31.27	112.95

Table 6. Change matrix of land use between 2003 and 2009

2003-2009	Build	Infrastructure	Crop plot	Beach	Road	Bare soil	Vegetation
Build	190.25	0.77	0.42	7.30	0	24.05	1.79
Infrastructure	0	124.27	3.41	0	0	0.08	0.05
Crop plot	0	0	12.95	0	0	0	0
Beach	0	0	0	7.30	0	0	0
Road	0	0	0	0	40.65	0.89	0
Bare soil	0	0	14.25	0	0	80.23	2.24
Vegetation	0	0	1.56	0	0	5.34	144.72

Table 7. Change matrix of land use between 2009 and 2014

2009-2014	Build	Infrastructure	Crop plot	Beach	Road	Bare soil	Vegetation
Build	204.43	7.16	0	0	0	35.23	30.31
Infrastructure	3.54	118.64	0.51	0	0	4.73	1.52
Crop plot	0	0	0	0	0	0	0
Beach	0	0	0	5.81	0	0.16	0.28
Road	0	0.37	0	0	40.50	2.14	0.93
Bare soil	0	0	12.44	0	0	65.57	45.94
Vegetation	0	0	0	1.09	0	0.59	72.78

3.3 Impacts of These Dynamics

3.3.1 Development of irregular settlement

In Ouakam, there are three habitat types: traditional, spontaneous and planned. So, traditional habitats occupying about 6.94% of the Commune against 13.24% and 26.21% for the spontaneous habitat and planned house respectively (Fig. 5). Most of land for these habitats comes from the conversion of crop lands. The development of irregular habitat in the commune of Ouakam is related to several factors such as poverty, dearness of social housing and the lack of viable space.

3.3.2 Public health problems

Occupation of fragile areas by irregular habitats promotes the spread of diseases including parasitic and respiratory. Therefore, our focus was to study the most frequent diseases in the municipality. The diseases analysis was based on medical record data mining from Medical Center of Garrison and the sinth health center. The identified diseases are presented on Table 8.

The main diseases encountered in the two health centres of Ouakam municipal were classified to be parasitic and respiratory.

3.3.2.1 Parasitic diseases

Malaria was prevalent in the municipality with 30.9% occurrences. Indeed, 84.1% of respondents in household surveys considered it the most prevalent disease in their household. Malaria morbidity was 42% during the rainy season, with a peak in September (21.6%). The

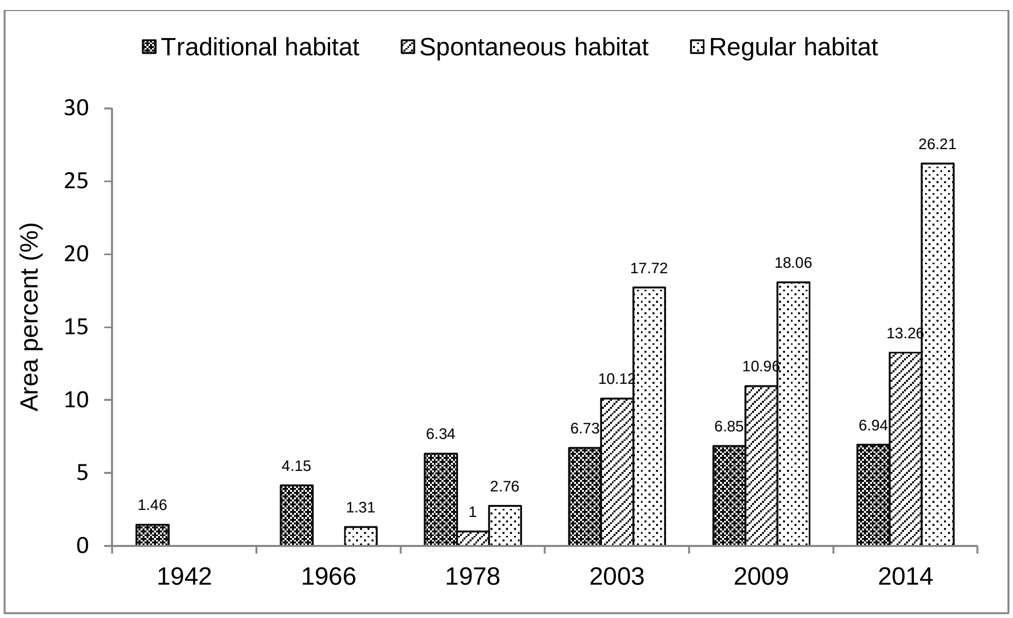

Fig. 5. Evolution of the habitat type in the commune of Ouakam

Table 8. Causes and consequences of disease morbidity from Ouakam health centers

Diseases	Causes	Consequences	Morbidity %
Frequency of parasitic diseases			
Malaria	Stagnation of sewage	Proliferation of mosquitoes	30.9
	Ponding water, dense vegetation cover	Infection zonal	
	Non-use of mosquito nets	Persistent disease	
Diarrheal diseases	Dirty and wastewater	High risk of disease	17.8
	Food unprotected		
Dermatose	Unsanitary conditions, Allergies	Skin damage risk	13.0
Frequency of respiratory diseases			
Bronchitis	Polluted soil and air	Eminence respiratory infections	13,5
Influenza			21,6
Tuberculosis	Contamination by T-bacteria	Chronic disability diseases to vulnerable populations	3,2

disease was favored by general poor sanitary conditions. Overall, sanitation often performed under poor conditions, also remains a factor in spreading of diarrheal and skin diseases. Diarrheal account for 17.8% of the main diseases of the municipality; of which approximately 47.2% of cases occur in the rainy season. Dermatosis affects 13.0% of the municipal population, mainly children affected in a proportion of 55.7%. Here it is largely related to hygiene and sanitation problems.

3.3.2.2 Respiratory diseases

The recorded respiratory diseases are influenza (flu), bronchitis and tuberculosis. They are contagious most frequently transmitted by air or contact via objects like saliva and running nostrils of sick persons. The Municipality of Ouakam is not immune to the risk of contamination due to overcrowding in concessions and high population densities that may cause the spread of disease. Indeed after malaria influenza is in a proportion of 21.6% the second source of disease in the municipality. Flu epidemics are often recorded in the year. Bronchitis accounts for 13.5% of the major diseases. In Ouakam, TB patients are treated at Ouakam Health Center. In 2012, 103 cases were registered against 84 cases in 2011 and 72 cases in 2010; i.e. an increasing of 30.1% between 2010 and 2012.

3.3.3 Flooding and its impacts

The phenomenon of flooding during rainfall is the accumulation of the waters due to topographic, soil-morphology, hydrogeological, and anthropogenic factors [29]. Indeed, the risk of flooding is intrinsically linked although some areas have more risky than others [30]. In the Commune of Ouakam the altitudes varies between 0 and 105 m signifying diverse terrain. The anarchic occupation of areas unsuitable for habitation, increase the risk of flooding. Neighborhoods such as Touba Ouakam and Cité Avion are the most concerned [31]. Field surveys have shown that floods are not new facts because of their location in depressions areas. In addition to the topographic character, heavy rainfall recorded in a short space of time also explains the frequent flooding in these neighborhoods (Touba and Ouakam Cité Avion). For example, 72 mm of rainfall recorded in Dakar August 14, 2012 in less than 24 hours, have shown the vulnerability to flooding of these areas which concentrate 35.9% of the total population of Ouakam commune [32]. Also, the vulnerability of these neighborhoods is related to the lack of a sewerage network, high population density, proximity of the web and the impermeable nature of the soil consisting essentially of clay [33]. Other vulnerabilities factors are discussed by the populations during field surveys, mainly related to the work of filling (Fig. 6). The surveys also showed that 2012 is recognized as the most flooded year in the Commune. Approximately 46% of households are affected by the floods, including 76% in districts of Touba Ouakam and Cite Avion. Significant damage was noted after the floods.

Fig. 6. Filling work of the road no. 241

The impact of seasonal floods have been direct the damage as illustrated by the plates below. The plates show that:

- ✓ There have been flooding and damage of some houses (indoors or outdoors), socio-economic infrastructure including the Quakam health center airport runway 01-19 and silting up of roads (Fig. 7);
- ✓ Overflow from septic tanks;

The flooding consequences at Quakam municipal have been:

- ✓ Destruction of real property material goods and money loss ;
- ✓ Abandoned homes (2.72 percent of surveyed households had to leave their homes temporarily and have been relocated to toddlers square by the Town Hall, or met by goodwill or neighbors);
- ✓ Increasing rate of prevalence of malaria and diarrheal diseases,
- ✓ Loosing livestock and poultry by drowning.

No large-scale interventions were considered to reduce the suffering of flooding disaster to Ouakam. However, temporary solutions have been adopted by individuals or collectively by the population, the authorities or associations, to limit the damage caused by the floods.

Fig. 7. Houses flooded to the plane (1) city, Touba Ouakam (2) and in the traditional neighborhood Bulgakov (3)

4. CONCLUSION

On the whole, the communes of Dakar region face significant difficulties related to climate variability and rapid and unplanned urbanization. The commune of Ouakam is no exception to this reality. In this study, we seek to analyze the consequences of rainfall variability and land use changes on the well-being of Ouakam populations. So, we have directed this study towards the exploitation of the data of remote sensing, rainfall and those related to field surveys. The results showed that these consequences are the development of irregular habitat, public health problems and recurrent flooding. These difficulties are related to the conversion of crops areas and natural spaces into habitation areas. In fact, the drought of 1970-1990 has facilitated the arrival of many migrants in the commune de Ouakam, which the most are middle income. The latter were installed on old agricultural spaces (wet spaces). This has increased the irregular forms of occupation in Ouakam. The irregular occupation represents about 20% of the area of Ouakam commune, i.e. 32% of the habitable areas. The traditional and spontaneous habitat, are the two forms of irregular occupation met in Ouakam, essentially erected in areas unfit for habitation. This form of irregular occupation and rainfall variability, have important implications for the well-being of populations. We also notes the development of parasitic diseases (malaria, diarrhea and dermatitis) and respiratory (bronchitis, influenza and tuberculosis). Vulnerability to flooding is greater in irregular settlements. For example, about 46% of households flooded in 2012, 76% are located in irregular neighborhoods particularly in Touba Ouakam and Cité Avion. Until then, no action was taken against these forms of illegal occupation. However, these problems already present, constitute essential challenges. Indeed, the good local governance requires the availability of information and its access. Given the many problems to consider, the most local authorities deem insufficient budget allocated to them. Therefore, it would be necessary for them to seek to optimize the municipal taxes levied. GIS tools provide for this purpose a great asset to their level in the optimal management of municipal revenues.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Beaujeu GJ. Urban Geography, Armand Colin, Paris. 1980;360.
2. Beaujeu GJ. urban geography Accurate, Armand Colin, Paris; 1995.
3. Gerin-Gratalou AM. Geography, Nathan, Paris. 2006;159.
4. Locoh Th. The role of families in the reception of migrants to African cities. In urban integration of migrants in Africa. CRDI-ORSTOM-URD. 1989;21-34.
5. Diop A. Dynamics of land use Niayes the Dakar region from 1954 to 2003: A case study of Great Niaye of Pikine and Yeumbeul, Master's Thesis, ISE. 2006;83.
6. Mainet G, Mainet-Valleix H. African cities: growth and regional diversity, Africa, Plural Continent. Ed. F. Bart. Cork SEDES / CNED. 2004;177-197.
7. FNUAP. State of world population: Unleashing the potential of urban growth. New York: Digital Services; 2007.
8. Seck A. Dakar West African metropolis. Institut Fondamental d'Afrique Noire, Dakar. 1970;516.
9. Mbow LS. Dakar: Urban growth and mobility, State Doctoral dissertation. University of Paris X Nanterre. 1992;2:709.
10. Dubresson A, Mbow LS. Dakar and the peninsula of Cape Verde. Atlas du Sénégal. Les Atlas de l'Afrique. Editions Jeune Afrique. 2000;48-51.
11. Mbow C, Diop A, Diaw AT, Niang CI. Urban sprawl development and flooding at Yeumbeul Suburb (Dakar, Senegal). African Journal of Environmental Science and Technology. 2008;4:75-88.
12. CSE. Land use dynamic in the Dakar region. Evolution of urban and peri-urban agricultural areas. 2004;31.
13. ANSD. General census of population and housing, Agriculture and Livestock (RGPHAE) 2013, Rapport Provisoire. 2014;36.
14. ANSD. Monographic study on real housing services in Dakar (EMSILD), Direction des Statistiques Economiques et de la Comptabilité Nationale. 2013;95.
15. Courade G, Bruneau R. Développement rural et processus d'urbanisation dans le tiers-monde. Cah. O.R.S.T.O.M., Sér. Sci. Hum. 1983;XIX(1):59-92.

16. Niasse B. The village in the city: Spatial dynamics and social changes in Ouakam, Master Thesis, UCAD. 2002;178.
17. Ndiaye ML. Dynamics of land use in the Dakar region from 1954 to 2009: A case study in Ouakam. Master's thesis in Geography, Cheikh Anta Diop University. 2012;133.
18. Ndiaye ML, Ndiaye EAD. Land use/land cover change detection for using multisource and multidate remote sensing data in the Dakar region from 1942 at to 2014: A case study in Ouakam. Study Report, Mohaamed 5 University / CRASTE_LF. 2015;57.
19. ANSD. Regional economic and social situation 2013. Research report. 2015;129. Available:http://www.ansd.sn/ressources/ses/SES-Dakar-2013.pdf
20. PDSD. Environmental action plan (P.ACT.E) 2013 - 2017 Research report. 2013;28. Available:http://www.villededakar.org/sites/default/files/DPDD-Ville-Dakar-PACTE-2013-2017-VF3.pdf
21. ACS. Urban development strategy of the great Dakar (2025), Cities Alliance, UN-HABITAT, Senegal. 2010;74.
22. Diop C, Sagna P. Vulnérabilité climatique des quartiers de Dakar au Sénégal: Exemple de Nord-Foire-Azur et de Hann-Maristes, Acts of the Colloquium "Renforcer la résilience au changement climatique des villes: du diagnostic spatialisé aux mesures d'adaptation" (2R2CV) 07 et 08 juillet 2011. Université Paul Verlaine -Metz, France. 2011;12.
23. Ndiaye ML, Traoré VB, Touré MA, Malomar G, Diaw AT, Beye AC. Contribution of remote sensing to the study of spatiotemporal evolution of rainfall in Senegal: Exploitation of TRMM 3B43 low spatial resolution. Journal of Multidisciplinary Engineering Science Studies. 2016;2(7):748-752.
24. DPS. General Census of population. Villages directory the Dakar region. 1988;14.
25. Jones PD, Hulme M. Calculating regional climatic time series for temperature and precipitation: Methods and illustrations. International Journal of Climatology. 1996; 16:361-377.
26. Goula BTA, Savané I, Konan B, Fadika V, Gnamien KB. Impact of climate variability on water resources and basins N'zo N'zi in Ivory Coast (tropical Africa). Vertigo. 2006; 7(1):1-12.
27. Saley MB, Tanoh R, Kouame KF, Oga MS, Kouadio SH, Djagoua EV, Oulare S, T. M. Youan Affian K. Jourda JP, Savannah I, Biemi J. Spatio-temporal rainfall variability and its impact on groundwater resources: The case of Abidjan district (southern Ivory Coast). 2009;18.
28. Sagna P. Dynamics of the tropical atmosphere, tropical climatology courses. License Geography (UV 308). 2009;58.
29. Antoine P. Urbanization in Africa and its prospects. 1997;92.
30. Wallez L. Floods in African western cities: Diagnosis and elements of building adaptive capacities in the large Cotonou, Master of Environment, University of Sherbrooke Master in Engineering and Environmental Management and Sustainable Development, University of technology of Troyes. 2010;90.
31. Mane AE. Spatial growth Ouakam: Causes and consequences of Geography Master's thesis, Cheikh Anta Diop University. 2000; 69.
32. IAGU. Floods in the suburbs of Dakar: Towards an adaptation by the improvements of buildings, infrastructure and local governance to reduce vulnerability of the assets of households and communities; 2014.
33. UNEP. Building urban resilience: Assessing Urban and Peri-urban agriculture in Dakar, Senegal. United Nations Environment Programme. 2014; 59.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/16956