Adequate urban soil occupation planning to face food crisis in the Sahel

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Abstract
Sahel countries are facing at present a threefold crisis, in particular a food crisis with a very weak economy. Non-occupied land areas should be considered as important resources that could be a solution to the problem. Throughout the world, productive land areas have been threatened by urbanization, which has progressively lost potential agricultural land. Sahel's coastal countries are facing this phenomenon with the pressure of increasing population migrations caused mainly by economic issues and climate change impacts. This paper is a case study of two coastal cities from Senegal (Dakar and Saint Louis). It aims to emphasize how well oriented soil occupation should be considered as a solution for enabling populations to overcome the changing climate and economic difficulties, while building a city. Location and evolution of cities are represented using Geographical Information System tools. With appropriate soil quality classification, questionnaires dealing with productivity of ongoing socioeconomic activities provided a convincing argument to support a pedoeconomic approach that concludes on how soil occupation planning could enable people to face efficiently the effects of the food crisis in the Sahel.

Key Words
Food crisis, Sahel, changing climate's effects, soil occupation, pedoeconomic approach, Geographical Information System.

Introduction

Located south of the Sahara desert, the Sahel is a wide semi-arid zone that has suffered tremendous crises that affect Sahelan wellbeing. Food security is an endemic crisis that goes along with periodic drought and flood. The ongoing discussion on global climate change emphasizes the implications of environmental policies and soil occupation, in the Sahel. The Sahel region is part of the world where all economic indicators, rank the countries belonging to this geographic area, as under the minimum human needs to survive (IDH, UNDP 1990/2009). The persistent food crisis that has been revealed to international audiences with the early 1970's drought became a key point of global political and economical cooperation within the region and of increasing interest for researchers. Climate change defined as "long term alteration of global weather patterns, especially increases in temperature and storm activities, regarded as potential greenhouse effects" or "statistical distribution of weather over period of time that range from decades to millions of years" did not cover Sahel rainfall variations from year to year (Ex Saint Louis registered 171 mm in 1986, 340 in 1987, 164mm in 1997, 446 mm on 2000 and 130 mm on 2004). However changing climate is increasingly taken into account by research done on crisis source analyses and their effects in the region. Economic and environmental policies are starting now to be built from results of this research in order to face a decreasing economy and environmental disaster. Floods covering some Sahel countries, from 2005 to 2009 and affecting cities, brought multidisciplinary studies on city building in the region. Urbanization is a global issue. The UN states that more than three quarter of earth's population will live in cities by 2015. Sustainability will depend on how cities are built and how to provide food to the growing population. Soil occupation, particularly when other resources are not available, is one of the solutions to the problem and must integrate ongoing global and local changes. Coastal cities, through their attraction constitute a special case study. The purpose of this paper is to propose a new approach of building cities in a way to overcome the changing climate's effects and economic difficulties. It is based on change observed in Dakar and Saint Louis cities starting in the early 1970's before drought periods and the recent 2000's with recurrent floods. The main objective is to demonstrate how pedoeconomic analyses could positively address climatic and economic problem in Sahelan coastal cities.

Materials

Aerial photos covering the territory taken in 1970 and 1990 at a scale of 1/50 000, have been interpreted for soil mapping and estimation of soil occupation. For soil mapping purpose, scenes of Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper Plus (ETM+) geometrically corrected at 30 by 30 m resolution have been interpreted for detection of change in soil cover. Geographical Information System

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(GIS) tools are used for gathering spatial information from different sources. Soils were described using a regional soil map 1/50 000 and geological map 1/200 000. Soil characteristics were defined using representative profiles. For present soil cover and occupation, Google Earth professional images of the located areas were extracted and read. Rainfall data were extracted from FAO-clim and an increasing number of implemented stations during the last four decades. Gaps in food security as estimated by CILSS, have been extracted from countries annual reports. Decades time series data of agricultural production from city areas were collected from the ground. ENVI software has been used for imageries treatment and ARC GIS for soil types and occupation mapping units.

Methods

Systematic radiometric and geometric correction using standardized methods have been used to connect images and to precisely locate growing cities. All images were corrected for sensor differences and normalized for differences by recalculating pixels into at satellite reflectance (Markham Beker 1986). Regarding interpretation of changes of fast growing cities areas and population, results on NDVI of the Sahel (Jönsson an Eklundh 2004) and precisely of Senegal (Bai and Dent 2007) have been used. Visual colored composed imageries analyses have been done to delimitate built areas. The calculation of NDVI for several periods allowed establishing the vegetation cover progress. Physical characterization of city changes comes from terrain verification by observation and questionnaires. Geographic Information System (GIS) technologies were used with geo-statistic methods and demographic enquiries result analyses to identify the size of cities. With GIS, the work progesses through four steps: i) Scanning to obtain raster data; ii) geo-referencing to adapt map coordinate universal Transverse Mercator (UTM) World Geodesic System 84 datum (WGS); iii) digitalizing raster for vector data; iv) interpreting to identify main soil occupations.

Results

Site location and soils

The specific geographic locations of the areas are shown on Figures 1 and 2 which contain soils types. Comparing soil quality in the global Sahel area and the Senegalese territory in particular, one can notice a relative natural richness due to relatively rich parent materials being volcanic rocks for Dakar city and alluvial silt and clay for Saint Louis. Good amounts of 2/1 clay occur.

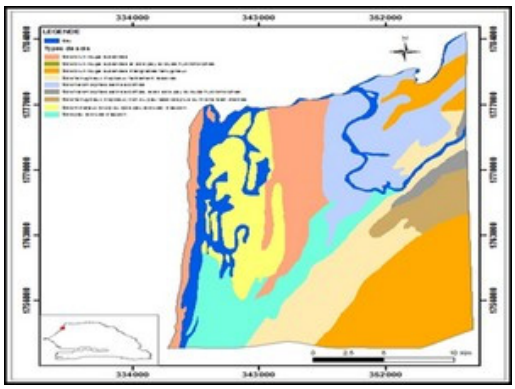

Figure 1. Saint-Louis soil map.

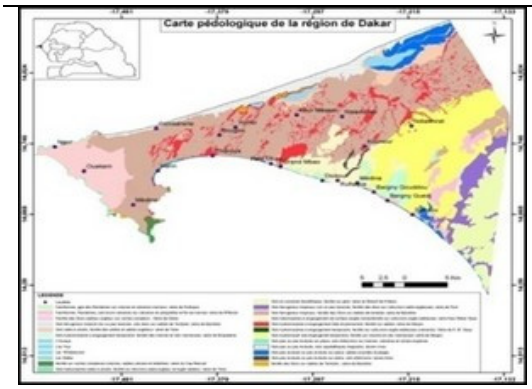

Figure 2. Dakar city soil map.

City building and population distribution

West African countries urbanization, from 1950 to 2020 are hereby described, including the Senegalese ones. In 2000 West African countries had about 1000 cities compared to less than 125, in 1950. Such progression rhythm will bring the number of agglomerations to more than 1430 by 2020. Unbalance between the first agglomeration that generally correspond to capital cities, and other cities, was growing from 1950 to year 2000 (Figures 3 and 4). Unbalance between secondary cities and capitals that characterize present dynamic processes of urbanization will not be in favor of sustainable development; as resources are not equitably distributed across the country. City growing processes induce competition between land functions, as land is needed for buildings, vegetation cover, recreation, water bodies and agricultural production. This competition will reduce cities food self sufficiency. Cities land should preserve best agricultural land. For the studied cases, the urbanization has progressed without taking into account value of natural resource in particular soils and water. Thus, good agricultural land is the first occupied by buildings, while water and food to feed growing populations are brought from more and more longer distances. The particular pedoclimatic zone called Niayes that is represented by a medium large band of land along the northern

Atlantic coast from Dakar to Saint Louis, which represents less than 4% of cultivated land is providing more than 40% of nationwide production.

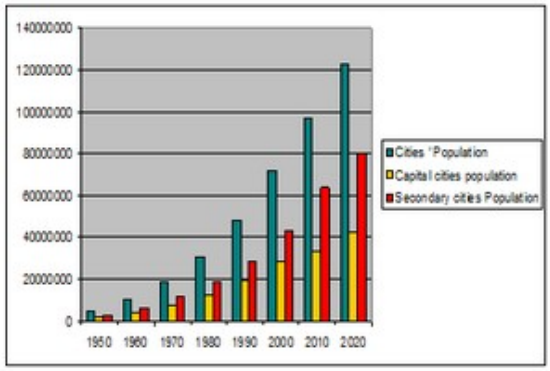

Figure 3. west African statistical population distribution

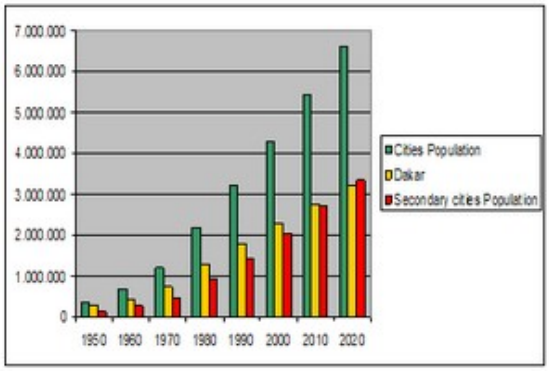

Figure 4. Senegal statistical population distribution.

Changes and Soil occupation

Global climate changes appear mostly through rainfall variation rather than warming temperature or sea level increase. This variation was noticed in the early 1970's drought, years before the worldwide concern on climate changes and is nowadays seen through recurrent floods starting in year 2000, and extending to all western Sahel in year 2009. A diachronic study of Dakar soil occupation, through imageries and photos interpretations and field survey based on knowledge of the site, lets one distinguish five major modes of soil occupation of the peninsula with increasing artificial or built areas (grey part) against reduction of agricultural zone, natural vegetation, water bodies and naked land (Fall *et al.* 2009). Dakar city is the most fascinating examples in the Sahel region, but the phenomenon is widespread all along the coastal region of the Sahel.

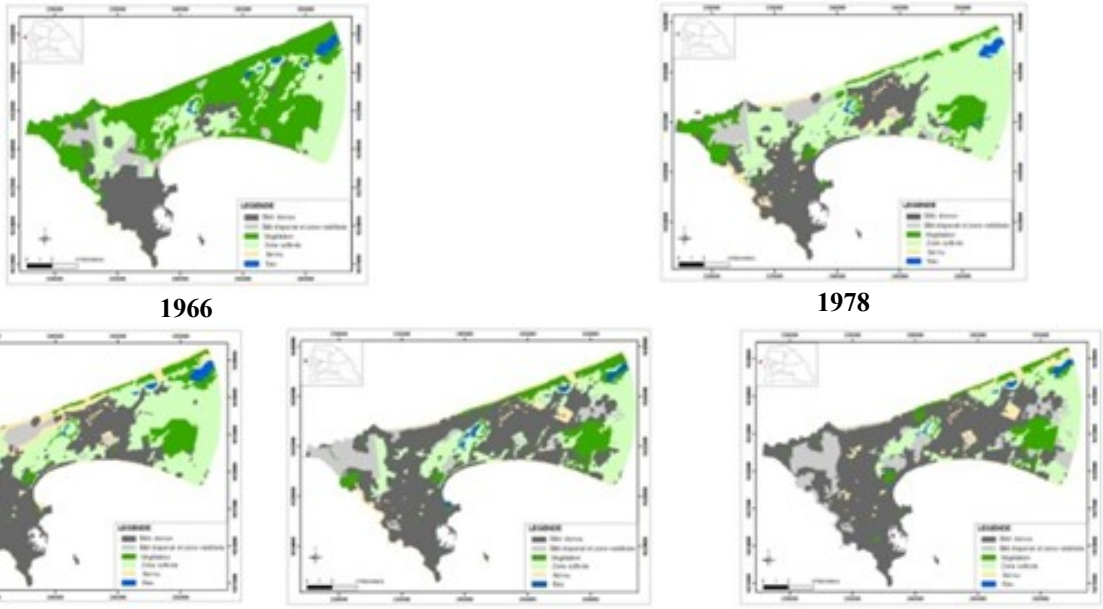

Figure 5. Dakar city diachronic dynamic after Fall and al (2009).

Flooding and food production

Human development needs to explore all land services while building a city. With return to the present rainfall pattern progressively since 2000, all expertise has been concerned by the phenomenon. In particular soils scientist have proposed a new vision on building cities through better consideration of soil quality in relation to land functions and occupation (Fall 2007). For this paper, Dakar and Saint Louis city lands classification have been extracted from a nationwide global soil suitability evaluation (Fall 2009). Based on this soil quality distribution, land building should be directed to land non suitable for agriculture, while suitable lands is dedicated to food production. This does not mean that Dakar and Saint Louis should be rebuilt but taking flooding issue as an opportunity; some part of cities could be reallocated to other occupations.

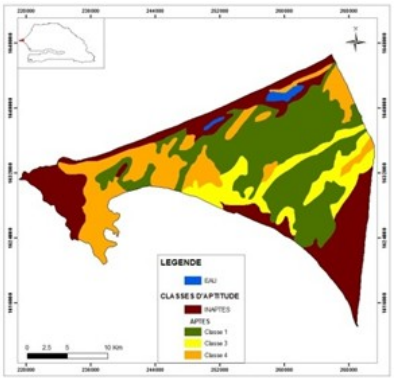

Figure 6. Dakar soil class aptitude (after Fall 2009).

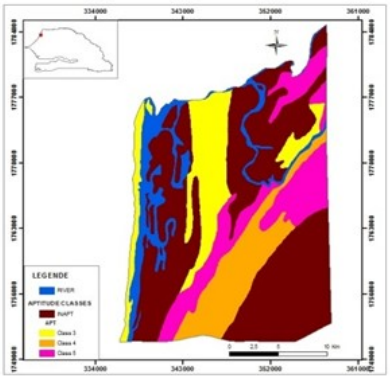

Figure 7. Saint Louis soil class aptitude (after Fall 2009).

Conclusion

All citizens are required to contribute urban plan extension and management in order to guaranty consideration of all sources and effects of global changing. This study open new field of research for city building in the Sahel such as: methods of land evaluation and classification, modeling land spatial occupation evolution, integrating densification of data collection such as meteorological stations, flood occurrence and its effects on agricultural production.

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