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Assessment of environmental impact of population pressure and land use activities

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Abstract
Degradation of the environment, water and forests in the Republic of Guinea has become a real obstacle to sustainable development of the country. As an excellence area for mining extraction, Siguiri prefecture has experienced rapid population growth in recent years, accompanied by an unprecedented boom in mining activities. Thus, this study was carried out to evaluate the impacts of these phenomena on the environment in the urban municipality (Siguiri-centre) and in the two mining cities (Kitinian and Siguirini) of Siguiri prefecture. To achieve this goal, remote sensing techniques were used, Landsat 5 Satellites for 2009 and Landsat 8 for 2019 provided three categories of land cover, namely: land use, vegetation cover and water bodies. In addition, a written and face-to-face interview was also conducted to identify sources of environmental degradation and destruction. The results of the analyses indicated that land use has increased significantly in all the study areas, respectively 31%, 21%, and 24% for Siguiri-centre, Kintinian, and Siguirini, while the vegetation cover and water bodies have significantly reduced. On the other hand, the results of the interviews with the local authorities indicated that the rampant urbanization, the increasing mining exploitation and the agricultural activities are the main factors of deterioration of the environmental conditions in Siguiri prefecture. The results of this study will enable decision-makers and researchers to identify areas of investigation in order to contribute to the protection and conservation of the environment in the study areas.

Keywords: environmental impact, population pressure, land cover analysis, remote sensing, interview

1. Introduction

Land use is the human use of land for economic, residential, conservation, recreational and government purposes; the concept of land use is strictly related to the development of the human community [1]. However, rapid urbanisation over the past two decades in developing countries has had a detrimental effect on land use and land cover practices. Several studies have been conducted to address this issue, for examples [2, 3, 4]. Rapid development observed in developing countries is without significant environmental burden as it involves specially land transformation, forest destruction, and high consummation trends [5]. Many studies indicate that the urbanization process has a profound impact on small and medium-sized cities in many developing countries, social progress has significantly boosted land use / land cover change and has produced a series of negative impacts on environment [6, 7].

The environmental situation of Guinea is characterized by the continuous degradation of its natural resources (deforestation, erosion and soil degradation, pollution and nuisances, drying up and silting up of rivers, loss of biodiversity, uncontrolled urbanization, mining, etc...) favoured and accelerated by the virtual absence of control mechanisms and a very strong impoverishment of the population in recent years. Unfortunately, the country has only weak capacity to deal with it [8]. However, one of the most fundamental elements of water and land resource planning and management is the assessment of these resources, which takes into account the identification of resources and the assessment of their capacity, their reliability and quality, involving measurements and data collection [9]. Therefore, analysing land-use/land cover changes provides a better understanding of the extent and location of land-use changes and their effects [10].

Land cover refers to a body of water, cultivated land, built up area, vegetation, fallow land, ice cover, rock / soil, artificial cover and many more observed on the land [11, 12, 13]. Although land cover changes can be monitored by traditional methods such surveys, satellite remote sensing provides more information on the geographical distribution of land use/land cover changes, as well as the advantage of cost and time savings. It is important to note that remotely sensed imagery provides an effective means of obtaining information on temporal trends and spatial distribution of urban areas needed for understanding, modeling and projecting land cover changes [14]. Remote sensing is an attractive source of thematic maps, such as those illustrating land cover, as it provides a cartographic representation of the Earth's surface that is spatially continuous and highly coherent, as well as available at various spatial and temporal scales [15]. Thematic mapping from remote sensing data is usually based on image classification, this can be done by visual or computer-assisted analysis. Therefore, mapping is essential for land use / land cover analysis, which impacts several environmental processes, integrities and properties. Local and global monitoring of land use is possible through remote sensing technology in the form of spatial, spectral and temporal resolution.

This study is motivated by the fact that planning and management of water and land resources requires an assessment of these resources, which takes into consideration the identification of resources and the assessment of their capacity and reliability, thus implying measures and data collection. Siguiri-centre, Kintinian, Siguirini are respectively the urban municipality and the two

mining cities of Siguiri prefecture were this study has been conducted.

2. Materials and Methods

Study areas

The Prefecture of Siguiri is located 798 km from Conakry, the capital of Guinea. 133 km from Kankan, the capital of the administrative region, and 212 km from Bamako (Mali). It includes the urban municipality of Siguiri and 12 rural municipalities and 129 districts (Figure 1). It is limited to the north and east by the Republic of Mali, to the west by the prefectures of Dinguiraye and Kouroussa and to the south by the prefecture of Kankan and Mandiana. Siguiri prefecture has a population of 695,449 people [16]. Siguiri-Centre, Kintinia and Siguirini were the subject of this study due to the fact that the first one is the urban municipality of Siguiri prefecture and the other two are rural municipalities where industrial mining is immense through two large mining companies, namely the Anglogold Ashanti Company of Guinea (SAG) in Kintinia and the Mining Company of Dinguiraye (SMD) in Siguirini, which, by their expansion, are real transformers of the natural environment in the Prefecture of Siguiri.

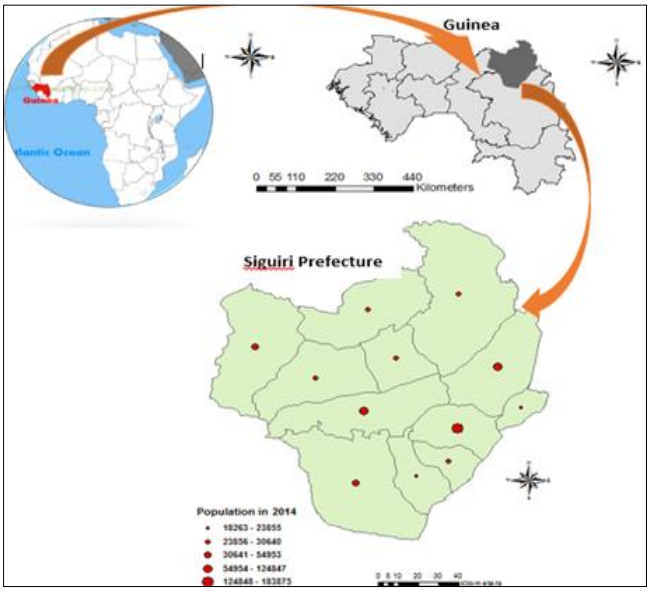

Fig 1: Geographic location of the study area in Siguiri Prefecture, Guinea

Siguiri-Centre is a city in northeastern Guinea on the Niger River, it is a sub-prefecture and capital of the Prefecture of Siguiri in the Kankan region (Figure 1). Its population was estimated at 183,875 in 2014 [16], it is the urban municipality of Siguiri prefecture. Kintinian, established as a rural municipality in 1992, is attached to Siguiri prefecture, located in the extreme north-east of the Republic of Guinea, about 850 km from the capital Conakry (Figure 1). The municipality encourages inhabitants to participate in all forms of activities related to the development of the village's lands as part of individual or community achievements on family or collective lands, including the filling of old gold mining wells, development of agriculture using organic manure and harnessed culture, community reforestation. Siguirini is a city and rural municipality of Siguiri Prefecture. In 2014, the population of Siguirini was 54,953 people**.** The community achievements of the Mining Company of Dinguiraye (SMD), subsidiary of Nordgold multiply in the localities which shelter the mine. From education to drinking water supply and sanitation, everything is taken into account. Actions that help maintain good neighbourly relations with the local community.

Table 1: Classification scheme of land cover with a description

Classes	Description
Land use	Areas totally or partially transformed by human activities such as built-up areas (habitats), mining and agricultural areas, etc.
Vegetation	Lands in a more or less natural state covered by savannah and shrubs
Waters	Areas of landmass that are constantly covered with water

Data source and analysis

In this study, satellite data for the years 2009 (Landsat 5) and 2019 (Landsat 8) were obtained from the United States Geological Survey (USGS) archives (http://earthexplorer.usgs.gov/) and used to generate land cover maps (Figure 2). Due to the lack of field observations at the time of imaging, actual ground data was collected by visual interpretation of the high-resolution images available in Google Earth (http://earth.google.com). This method has been used in other studies, for example [17].

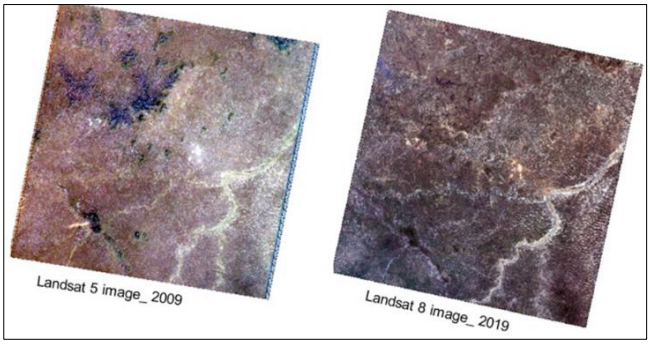

Fig 2: Satellite images of the study areas

Pre-processed images were analysed using unsupervised classification of ISODATA algorithm (Itterative Self-Organizing Data Analysis) to improve image quality and readability of features using spatial analysis of ENVI. The overall accuracy of the three-class classification averaged 87% for the two years. The analysis of the image is obtained by calculating the changes indicated in percentage and differentiated by colour in Figure 3. Initially, five classes of land cover were identified. However, based on field observation from high resolution images in Google Earth and the previous land cover map and local knowledge about the study areas, these five classes were grouped into three categories of interest, namely land use, vegetation, and water (Table 1). All analyses and mapping were done using ENVI and ArcGIS software.

Interview with local authorities

In this study, a written and face-to-face interview was conducted at the Prefectural Office of Environment, Water and Forests of Siguiri. The representative of the section of the environment and that of the section of water and forests were the targeted informants during this interview. The main objective of the interview was to identify the main sources of destruction and degradation of the environment, water and forests in Siguiri prefecture and to understand the difficulties and future actions of the local authorities in dealing with these problems. The results of this interview are summarized in the next sessions.

3. Results and Discussion

Land cover changes

The analysis of the ten-year land cover change of three municipalities of Siguiri prefecture was carried out using remote sensing techniques and geographical information systems (GIS). The results indicated that land cover in these areas has changed significantly over the last decade. Fig. 3 shows that Siguiri-Centre in 2009, although land use was already evolving (Figure 3.a), but in 2019, the vegetation of this city has significantly reduced ceding way to urban growth and expansion of the city (Figure 3.d).

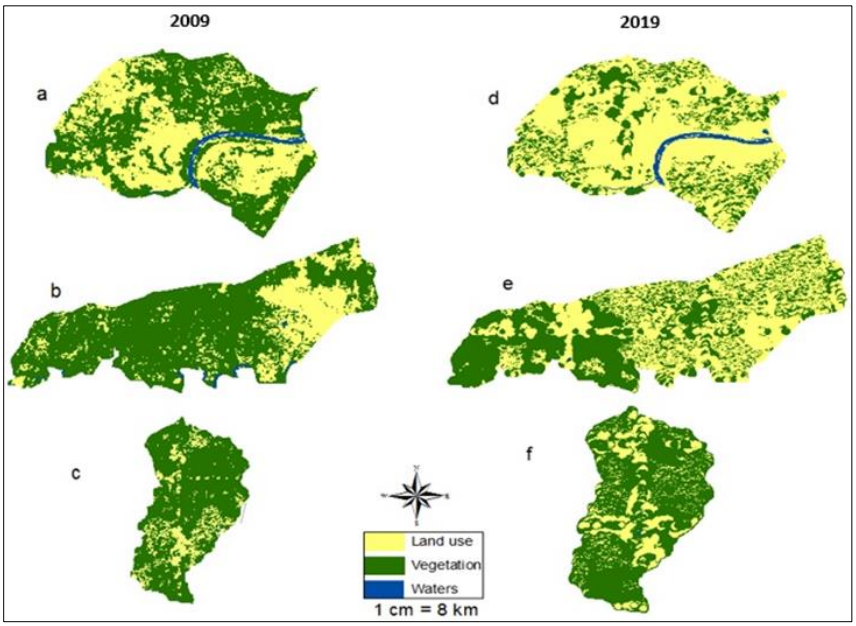

Fig 3: Land cover maps of the municipalities of Siguiri-Centre (a,d); Kintinia (b,e); and Siguirini (c,f) in 2009 and 2019

However, in kintinian, the main drivers of land cover change are largely attributable to mining activities. In addition, Siguirini in 2009 was almost completely covered with vegetation (Figure 3.c) which, in 2019, left an important space for the exploitation activities to lands, mainly the mining activities (Figure 3. f). Table 2 shows that the results are relatively different from one municipality to another and conform to the changes observed on the maps in Figure 3 concerning the three types of land cover identified in this study. The results clearly show that in 2019, the impacts of human activities on the environment have increased considerably for all three municipalities compared to 2009. And this increase for Siguiri-centre is more significant, mainly because of the pattern of urban growth in this city being the capital of Siguiri prefecture. This result supports many conclusions highlighting the environmental impacts of urban growth and human activities in developing countries, some examples are given in [18, 19, 20].

Table 2: Estimates of the areas occupied by each land cover in 2009 and 2019 in km

Landuse type	Period	Kintinian	Siguiri-Centre	Siguirini
Land use	2009	897042.6	740076.3	656804.7
	2019	1108508.4	895973.4	1293297.3
Vegetation	2009	27694058.4	1207548	28243071
	2019	3394632.6	250865.1	3686031
Waters	2009	19268.1	250211.7	940.5
	2019	2007	242685.9	741.6

The evolution of anthropogenic actions on the lands through the constructions, and other land use activities (mines, agricultures and breeding) undoubtedly generates the disappearance and the reduction of the vegetative cover of inland areas. However, in Siguiri prefecture in general, mining activities, particularly the uncontrolled exploitation of small itinerant miners, are among the real factors of the destruction of green spaces (vegetation) and land deterioration. A comparison of the types of land cover between 2009 and 2019 for the three municipalities was done to visually compare them in graphical form (Figure 4). The result clearly shows that in 2019, anthropogenic land uses for various activities increased significantly compared to 2009 in the three

study areas (Figure 5). As a result, the vegetation cover has decreased considerably, however, the areas covered by water decreased more or less between 2009 and 2019 in all the three municipalities (Table 2) in way that during this period, for Kintinian in 2009, 19 268.1 km were covered by water and in 2019, were reduced by 2007 km (Table 2). Thus, for Siguiri-Centre, Figure 5 shows that there is a larger gap between the area occupied by water and other areas (land use and vegetation) in 2019 compared to 2009.

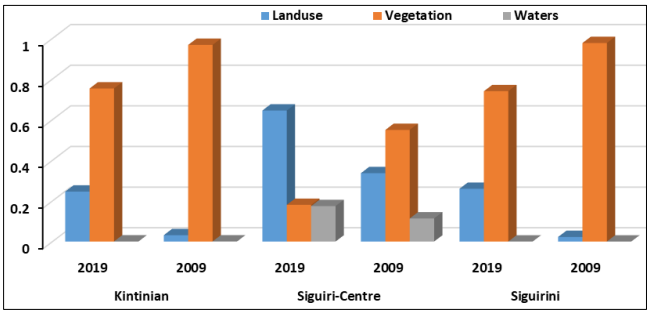

Fig 4: Comparison of land cover types in 2009 and 2019

Although the area occupied by water decreased more in 2019 compared to 2009 for the municipality of Kintinian (Table 2), Figure 5 shows that the water surface in 2019 is slightly important compared to the surface of the land use and vegetation. The reduction in the area occupied by water between 2009 and 2019 in Siguirini is not as important as in Kintinian, and their proportion relative to other areas is slightly significant (Figure 5). However, land use activities not only result in the loss of water bodies, as noted in this study, but seriously affect water quality, particularly in areas where water management policies are not sufficiently implemented. The impact of these activities can lead to real environmental problems for water bodies and adjacent areas by changing the hydrological characteristics of these areas, which in the long term may lead to deterioration [21].

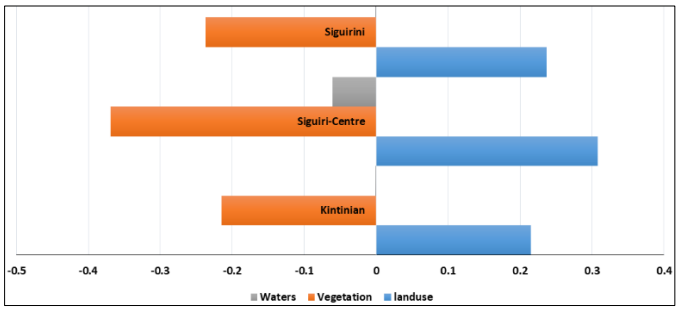

Fig 5: Differences in land cover changes in 2009 and 2019

Impact of land use activities on the environment, water and forests

In order to identify the main sources of destruction and degradation of the environment, water and forests in Siguiri prefecture and the difficulties encountered by local authorities in dealing with environmental problems, a written and face-to-face interview was conducted at the Prefectural Office of Environment, Waters and Forests of Siguiri. The results of this interview indicated that the causes of environmental and land degradation in the Prefecture of Siguiri are numerous and include the following: Urbanization and demographic pressure, mining activities (artisanal and industrial), dredging (gold mining in rivers with archaic machines) and the destruction of water source heads, excessive cutting of trees, bushfires and illegal hunting, inappropriate agriculture and livestock activities, brick kilns and silting of rivers by anthropogenic actions, and anarchic occupations of the riparian zones. Based on this result, the environmental, water and forest degradation factors in Siguiri prefecture can be summarized as follow:

Urbanization and demographic pressure

The population estimates of three municipalities in 1996 and 2014 are presented in Figure 6 [16]**.** The result indicates that in the last two decades, the population has increased by 98,575 for Kintinian, 129, 204 for Siguiri-center and 31,203 for Siguirini. The urban growth in Siguiri prefecture is one of the most dynamic in Guinea, and this rampant urbanization, accompanied by a sharp acceleration of the expansion of the prefecture, is undoubtedly one of the fundamental factors of the degradation of the natural environment of waters and lands. Urbanization increases the impervious surface, generates pollution and transforms the configuration, composition and context of the vegetation cover and therefore has direct or indirect impacts on aquatic systems [22].

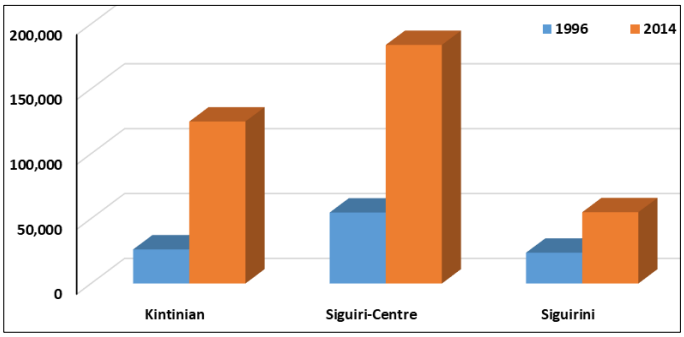

Fig 6: The population estimates of the three municipalities in 1996 and 2014

Today, in Siguiri prefecture, particularly in the urban municipality of Siguiri, population growth has subjected nature to unprecedented pressures. Numerous other studies in this regard have demonstrated the link between urban sprawl and population pressure with environmental degradation, mainly land and water resources [23, 24, 25, 26].

Artisanal, semi-industrial and industrial mining

Gold mining activities in Siguiri prefecture account for more than 85% of the causes of environmental degradation. In general, the prefecture of Siguiri is today seriously affected by the consequences of gold mining activities at several scales. Although these activities in Siguiri benefit a large number of the population, they can nevertheless pollute the air, soil and water environments as well as landscapes through dust generation, leachate production and as a consequence of an absence of vegetation cover, drying up of rivers, and depletion of agricultural land (Figure 5). Other adverse effects of mining on environment include loss of biodiversity, erosion, contamination of surface water and groundwater [27, 28]. In addition, due to the loss of vegetation to mining activities (Table 2), temperatures in

the prefecture are regularly very high, and streams are drying up causing citizens in some remote areas to travel long distance to get water to drink.

Agriculture and livestock

Although agriculture and livestock farming are declining in favor of mining activities in many rural areas of Siguiri prefecture, they still remain an important activity and are carried out by a large number of village communities. However, slash-and-burn agriculture, which is the main type of agriculture utilised in Guinea, and particularly in Siguiri prefecture, is an agrarian system in which the fields are cleared by fire, which allows a transfer of fertility, are then cultivated for a short time period before being left fallow, most often forested, with a long revolution [29].This type of agriculture has adverse effects whose consequences have repercussions both on the agro-ecosystem and on the health of the local population. These impacts include: loss of vegetation cover, soil erosion, loss of soil fertility, sedimentation of rivers, etc. In addition, traditional livestock farming used in rural areas of Siguiri is also an important factor in environmental degradation. Thus, a new Food and Agriculture Organization (FAO) report indicates that livestock is one of the main causes of the most pressing environmental problems, namely global warming, land degradation, air and water pollution, and the loss of biodiversity [30]. The traditional extensive breeding practiced in Guinea is a large anthropogenic user of land. As such, many studies have examined the effects of agricultural land-use activities on the environment, mainly in developing countries where the control mechanism is often lacking or insufficient [1].

Challenges and perspectives to mitigate environmental threats

In general, environmental degradation is occurring at a disturbing rate in Siguiri prefecture, unfortunately, the country has only weak capacity to deal with it [8]. During the interview, local authorities reported numerous deficiencies in the protection and conservation of the environment, namely: Insufficiency of conservation officers on the fields and the lack of professionalism of certain environmental protection and conservation officers, lack of logistics, training and travel means, and unawareness of the people about the environment.

However, in recent years, the Guinean Government, through its Ministry of the Environment, Water and Forests, has developed a strategic framework for the management and development of the environment and the natural resources which contain it have been defined and more or less implemented through documents such as [8]:

National water resources management policy and strategy

The diagnosis that led to the development of this policy revealed that the main problems related to the management and development of water resources are as follows: insufficient knowledge in all of their resources components (atmospheric water, continental and marine surface water, phreatic and deep groundwater); insufficiency and in some places, lack of hydro-ecological monitoring systems for national and shared river basins; silting up of portions of rivers and certain lakes and ponds; localized pollution phenomena due to industrial, agricultural and / or artisanal activities; insufficient capacity of the services and bodies in charge of the management of water resources in particular and the environment in general, particularly at the decentralized territorial level.

Environmental objectives of land management

The main objectives of land management are: to increase agri-silvo-pastoral production and productivity; contribute to soil restoration and carbon sequestration; control the pollution of surface and groundwater; reduce the proliferation of invasive plants such as Melilotus sp. in Maritime Guinea or Chromolaena odorata in Forest Guinea. In addition, in the interview conducted during this study, local authorities highlighted the following measures to mitigate environmental problems in the Prefecture of Siguiri: Compensate and restore all degraded sites of the prefecture in accordance with the national policy of environmental protection in the Republic of Guinea; contribute to the fight against global warming in accordance with agreements ratified by Guinea, fighting against bad practices of use of our natural resources (including water and forests); ongoing awareness of bushfires, excessive logging, river degradation, hunting and illegal capture of wildlife; the village communities participate in the sustainable and concerted management of the environment. This is an approach of the prefectural authorities to fight against the excessive utilisation of woods in artisanal gold mining, that of chemical substances and mechanized gold panning in the waters of the Tinkisso River. In addition, the Guinean Government has adopted a code on the protection and enhancement of the environment, a National Environmental Action Plan (NEAP), Sectorial policies, Strategies and action plans, as well as several other laws and regulations to promote the rational exploitation of natural resources and the protection of the environment in the perspective of sustainable development of the country [8].

4. Conclusion

A study including both a spatial analysis of the environment as well as an interview of the local authority was carried out. Remote sensing techniques were used to analyse land cover in 2009 and 2019 in order to assess changes in land use activities, vegetation cover and inland waters. The results of this study showed that Siguiri prefecture suffers a severe degradation of its natural environment. This phenomenon is attributable to three main factors identified during the interview with local authority, namely: rapid urbanization, increasing mining, and agricultural activities. However, other elements are also notable, such as poverty and the illiteracy of the populations, and the corruption of some responsible leaders. Decision makers must play their part by fully implementing the strategies developed to reduce the degradation of the Guinean environment, ensure the sound management of natural resources, protect and conserve water and forests, and reduce poverty in the Republic of Guinea. These strategies include the environmental protection and enhancement code, the national environmental action plan (NEAP), the agricultural development policy letter (ADPL), the national strategy and the biodiversity action plan, the mangrove master plan, the poverty reduction strategy, and the national water resources management policy and strategy.

5. Acknowledgment
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