A GIS technology and method to assess environmental problems from land use/cover changes: Conakry, Coyah and Dubreka region case study

L. Sylla a,*, D. Xiong a, H.Y. Zhang b, S.T. Bangoura c

a College of Environmental Science and Engineering, Dalian Maritime University, 116026 Dalian, China
b College of Urban and Environmental Sciences, Northeast Normal University, 130024 Changchun, China
c School of Environmental Studies, China University of Geosciences, 430074 Wuhan, China

Received 2 August 2011; revised 14 December 2011; accepted 19 December 2011
Available online 6 May 2012

KEYWORDS
Land use/cover;
Overlay method;
Geographic information system (GIS);
Topographic map

Abstract This study is the result of investigating the land use/cover surrounding Conakry city and its two neighboring cities from the past to the present periods which are herein after referred to as this “region” and the impact of numerous changes during that time. These changes have become a major concern for the Guinean government and scientific community. Using map interpretation with integration of remote sensing, GIS technology and a GIS method we investigated the land use/cover and a population dynamism model with the aims of promoting a sustainable recovery and future judicious utilization. We found out that these three cities are on the verge of being unified, as a result of the expansion of urban residential areas and the changing economic realities causing significant influences on this land use/cover change. The pattern of land cover 59 years ago presented a landscape relatively pristine, while that in the present period presents a landscape that is markedly in a degrading decline. During the past 59 years, land use/cover has been influenced by key factors that revolve around socio-economic development, climatic patterns, topography manipulation, and policy implementation influences. The level of degradation of the land use/cover has increased and will oblige the political, scientific and local communities to take note of the environmental changes and set up urgent, rigorous and coherent policies for the rational development and
1. Introduction

It sometimes seems inevitable that human and natural factors can cause landscape changes. However, knowledge of land use and land cover can be important in national plans if used to reverse deteriorating environmental quality trend, loss of wetlands, wildlife habitat and ecological pollution (Anderson et al., 1976). There is an increasing need for standardized land use and land cover information especially in critical areas of environmental concern like urban extension and forest clearing in the developing countries as they endeavor to catch up with the current development of economic globalization. Land use/cover changes were studied in Conakry, the capital city of the Republic of Guinea in West Africa, and its two surrounding prefectures of Coyah and Dubreka to determine the extent of these changes and the contributing factors to an observed rate of impoverishment of the ecosystems so as to find a sustainable solution. Previous studies have shown that land information about the existing land use/cover patterns and the changes they bring after a period of time are integral requirements for proper land use/cover.

This region was formerly a tropical forest with thick mangroves but compared with the rest of Guinean territory, the land use/cover of this region has changed considerably in recent years with a considerable diminution of vegetation due to local agricultural practices such as the cutting down of trees to make charcoal, the use of forest grounds as pastures by livestock owners during the dry season and a general deforestation. Problems of land ownership, enlargement of urban centers to accommodate more residents and bush fires are also common factors in this region. In addition, there is no doubt that these activities have had negative influences on both the climate and the regulation of the rivers and wetlands. Construction of new housing is also a key problem which might cause a rapid degradation of the area if rational management and proper, informed planning is not initiated. It is concern that has prompted this paper to consider solutions to solve this study region land use/cover change situation, with the aim of slowing down the degradation of this area land use/cover, while supporting its preservation and its rational management. The choice of this topic will allow justifying this ambition, of contributing to the knowledge of the zone which, is currently known to have undergone a considerable change in its land use/cover in spite of some efforts been made to improve the situation. This paper proposes certain solutions to the difficulties of that the region’s land use/cover. This can be a useful reference for the world in general and Guinea in particular with the aim of finding a solution to continuous degradation of our environment. The paper will be a database for the future generation. In addition, the GIS data used in the study will be important reference information. Indeed, the conservation of land use/cover, its rational management and control present many advantages. However, now days in many countries, such as the region under study, this conservation and management are confronted with serious problems. Hence, many researchers have taken an interest in this field. The objective of this study is to evaluate the land use/cover changes in this area, and then propose some solutions. Furthermore, show the worsening level of the degradation of this land use/cover that can allow the political and administrative authorities to set up a political body, rigorous and coherent for the rational exploitation and management of the land use/cover resources of this region and its local development. This body can also help to understand the land use/cover change process in tropical regions.

Remote sensing (RS) and geographic information system (GIS) have previously been used as tools for advanced ecosystem management in collecting remotely sensed data that can facilitate synoptic analyses of land use/cover patterns, and changes and projecting it to global scales over time (Wilkie and Finn, 1996). Studies of present land distribution to residents, recreation, agriculture, industry and other human activities in Conakry, Coyah and Dubreka can give information about their dynamism which is useful to policy planners and can indicate key areas for effective future regional sustainable development.

2. Study area

The study area consists of Conakry, Coyah and Dubreka in the maritime region of Guinea (Fig. 1). This study area covers a surface area of 8150 km² (or 3147 mi²) (Conde and Sow, 1998). It is bordered in the north by the prefectures of Boffa and Fria, in the north-east by prefecture of Télémé, in the east by the region of Kindia, in the south by prefecture of Forecariah and in the west by the Atlantic Ocean. Its population is estimated to be more than 1.3 million (Conde and Sow, 1998). The Correra River is the boundary to the north and that of the Maneah in Coyah to the south, (Riviere, 1966). Coyah and Dubreka are two satellite cities of Conakry, which is located at 93°2′ latitude north and 13°44′ longitude west.

This region of study is situated in part of Guinea named littoral Guinean. Its climate is the sub-tropical maritime type, hot and humid influenced by seasonal monsoons. Rain is abundant; it averages 4300 mm at Conakry and 5000 mm at Coyah and Dubreka. The average temperature in this region is 25 °C.

Vegetation consists of mangrove in the marshy zone, forests of palm trees, coconuts, gasoline forests, some grassland, small islands of primary forest formation, forest gallery along the river, mango trees and plantations in some places.

Relief of the region is characterized by estuaries and the littoral plains dominated by the cliffs and the Kakoulima Mountain Ranges reaching a height of 1007 m located 60 km northeast of Conakry. In this region, soil types include saline, hydromorphic temporary hydromorphy and ferrous. The hydrography of region is well served with water, with many rivers with their sources from the mountains of Fouta Djallon to the Atlantic Ocean. There is also the Konkoure River in the prefecture of Dubreka which sustains a hydroelectric dam at
Garafiri in Kindia, and the Soumba River. The Sarinka River is situated in the prefecture of Coyah.

Conakry is the most densely populated city in Guinea where the majority of industrial activities are concentrated. The region is mostly populated by the Soussou ethnic group.

3. Methods and materials

Evaluation of the land use/cover change caused by human–environment interaction process by using a GIS method.

Changes in land use/cover were examined through a combination of:

1. Land use/cover methods
   - Land use/cover classification (water, wetland, forest, grassland, agriculture and housing);
   - Population increase or decrease model;
   - Overlay method.

2. Data source and processing: (data for information)
   - Digitizing and interpreting two maps of two different periods:
     - Topographic map (past) – scale: 1/200,000.
     - ETM+ image (present) – resolution: 30 × 30.

In this research, we used a range of tools and software (Erdas 8.5 and ArcGIS 9.0). These processes have simplified the collection of data.

In this study, the classification of land use/cover between the past and present periods was divided into the following: water, wetland, forest, grassland, agriculture and residential. According to the population statistics obtained, a curve, a diagram and a formula for each of the three cities have been used to determine the population evolution (increase or decrease). For this task, Office Excel has been used. In this study, a GIS method called Overlay has been chosen, because it enables a clear comparison of land cover/land use between the past and present periods. This method enabled the comparison of results obtained in the past period map with that of present ETM+.

The principal objective was to have those parts which have changed on each of the two features. This overlay also enabled the obtaining of the table of statistics showing changes for each land use/cover element, as well as finding those elements which increased and those which decreased. Ultimately, it helped to understand the environmental situation in this region, the state of fauna, population and land use/cover in general.

During the 59-year period, the total area of land use/cover has changed. Thus, to understand these changes, those large fields which were previously occupied by forest and wetland have now been replaced by agriculture. In equal measure, that space once occupied by forest and wetlands has decreased in the entirety of the area, just as the domain of agriculture and grassland has increased. In coastal regions having many permanent and irregular rivers, the water previously occupied more space, but it has now decreased. It is important to note that the indigenous villages observed in the region have moved to

Figure 1 Study area map.
suburban areas, which have increasingly occupied more space. To understand and evaluate these various changes of area, see the Table 1 of surface statistics and figures for land use/cover between past and present periods (Figs. 2 and 3). Figure 2 and 3 shows the pattern of land use/cover in past period map, and pattern of land use/cover in present period map respectively.

4. Results

The land use/cover of this region has been subjected to severe changes that have been caused by human as well as natural factors. Table 1 shows the surface area of change between the various types of land use/cover in the comparison between past and present periods; this is after digitizing a topographic map and ETM+ image and using GIS method (Overlay). Water decreased in relation to other elements of land use/cover. Wetland (marsh): 46 km²; forest: 3 km²; agricultural fields: 12 km²; grassland: 0.17 km²; urban center: 3 km² and suburban: 2 km². The place of wetland occupied by other land use/cover elements is as follows: water: 104 km²; forest: 43 km²; agricultural fields: 117 km²; grassland: 1 km²; urban center: 2 km² and suburban: 28 km². The area formerly occupied chiefly by forests reduced an important part of its surface to other elements of land use/cover, as follows: water: 86 km²; wetland: 95 km²; agricultural fields: 617 km²; grassland: 70 km²; urban center: 136 km² and suburban: 119 km². Agriculture, decreased in surface area in relation to other elements of land use/cover as follows: water: 8 km²; wetland: 29 km²; forest: 2 km²; agricultural fields: 7 km²; grassland: 0.17 km² and urban center: 12 km². The area change of grassland to other land use/cover elements is as follows: water: 0.09 km²; wetland: 0.28 km²; forest: 3 km²; agricultural fields: 7 km²; urban center: 0.17 km² and suburban: 7 km². The urban area that decreased to other land use/cover elements was: water: 5 km²; wetland: 1 km²; forest: 4 km²; agricultural fields: 0.58 km² and suburban: 0.31 km².

<table>
<thead>
<tr>
<th>Past</th>
<th>Water</th>
<th>Wetland (Marsh)</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Grassland</th>
<th>Urban center</th>
<th>Suburban</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>–</td>
<td>46</td>
<td>3</td>
<td>12</td>
<td>0.17</td>
<td>3</td>
<td>2</td>
<td>66.17</td>
</tr>
<tr>
<td>Wetland (Marsh)</td>
<td>104</td>
<td>–</td>
<td>43</td>
<td>117</td>
<td>1</td>
<td>2</td>
<td>28</td>
<td>295</td>
</tr>
<tr>
<td>Forest</td>
<td>86</td>
<td>95</td>
<td>–</td>
<td>617</td>
<td>70</td>
<td>136</td>
<td>119</td>
<td>1123</td>
</tr>
<tr>
<td>Agriculture</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>0.58</td>
<td>–</td>
<td>0.17</td>
<td>7</td>
<td>17.54</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.09</td>
<td>0.28</td>
<td>3</td>
<td>7</td>
<td>–</td>
<td>–</td>
<td>0.31</td>
<td>10.89</td>
</tr>
<tr>
<td>Urban center</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>0.58</td>
<td>–</td>
<td>0.17</td>
<td>7</td>
<td>17.54</td>
</tr>
<tr>
<td>Total</td>
<td>203.09</td>
<td>144.28</td>
<td>82</td>
<td>753.58</td>
<td>72.17</td>
<td>153.17</td>
<td>163.31</td>
<td>1571.6</td>
</tr>
</tbody>
</table>

Figure 2 Pattern of land use/cover in past period map.
The rate of land use/cover severe regression in this region affects more the forest cover with: 1123 km$^2$–82 km$^2$; secondly wetland area with: 295 km$^2$–144.28 km$^2$, respectively during past and present periods. Nowadays this situation requires fast reflexion and intervention, because the forest for example plays a considerable role in the regulation of the climate, the protection of the rivers and easing the pollution, especially with the fact that this region concentrates almost the major part of the economic activities of Guinea particularly the industry which has is a negative consequence of pollution. Some elements have either changed or completely disappeared in the region. The indigenous villages observed in the region have clearly ceded their place to suburban areas which have occupied more space with: 163.31 km$^2$ presently, at the same time the urban centers have increased from 10.89 km$^2$ to 153.17 km$^2$.

This land use/cover change thus contains several realities or factors for this area. Thus the current state of this land use/cover is a fast and efficient intervention up to now and in future years?

5. Discussion on land use/cover changes driving forces

5.1. Climate

This region is situated within Maritime Guinea, between the 7th and 13th parallels of north latitude and lies entirely within the tropical zone. Climate is subtropical maritime type, hot and humid sub Guinean climate. Its proximity brings it under the strong influence of the sea and its disposition is almost parallel to the western edge of Fouta Djallon.

5.2. Population growth

The population of this region is in a period of strong growth resulting from the attractiveness of the capital city of Conakry and its proximity to the prefectures of Coyah and Dubreka, in which there is high concentration of principal economical activities of Guinea, as well as having both a high birth rate and migration. A visible consequence of rural migration to this region, as well as in the developing region is the emergence of the spontaneous habitats called shantytowns.

5.3. Land tenure

Due to the large increase in population, agricultural, forest and pasture places have been transformed into private habitats; because each inhabitant has the ambition to have his own residence.

5.4. Housing evolution

Housing was one of the most serious issues in this region. Different cities were not able to accommodate new inhabitants

Figure 3  Pattern of land use/cover in present period map.
and were obliged to expand; resulting in suburbs which have had a tendency to take on a greater and greater importance in the life of the urban unit. These suburbs developed independently along different major axes of communication. However, because of their location, the suburbs had an almost rural aspect, with the practice of agriculture, breeding livestock and other rural activities.

5.5. Income

The population use rzophora wood for cooking and wood is cut in the mangrove to make way for salt mining especially in Coyah. Carbonization has spread especially in Coyah and Dubreka and brick ovens are being constructed and operated to serve urban needs. These practices continue at the cost of the destruction of the forest, also causing changes in the climate.

5.6. The people’s diet

A vast majority of people in the region have a similar diet. Rice with fish or meat and red oil is the basic food. Oranges, man-goes and bananas, according to seasons, constitute an important supplement. This brings about an excessive exploitation of a certain agricultural sector, as well as marine and forest resources.

5.7. Agriculture

Agriculture is one of the principal economic activities in this region. The agricultural system which has been in use is an intensive type, involving inappropriate practices such as farming near river banks; leaving land fallow and not improving soil; polluting soil and water by uncontrolled usage of chemical products in agriculture; land reclamation; deforestation and using fires to clear agricultural fields.

5.8. Livestock raising

Small ruminants are bred in this region. For certain families, livestock constitute an important source of revenue. There is also poultry breeding. Nomadic pastoralism is practised especially by pastoralists who come during the dry season from other areas to the agricultural plains in search of new grazing land. This activity is as extensive as agriculture, and it causes significant damage to some land use/cover elements.

5.9. Industrialization

The activities of industries have had important influences on vegetation cover, soil and fauna. They have brought about landscape modification, seriously polluting the atmosphere, water, and soil and also strongly affecting natural resources which are being exploited.

5.10. Fishing

Fishing is an activity that has been practised in this region, particularly at Boulbinet in Conakry, since the time of the first inhabitants of the region. This is a complex activity tied to the exploitation of varying environments and using different techniques. The progressive revival of the fishing industry has required fishing harbors to be created at: Teminetaye, Dixinn and Bonfi, and the construction of cold storage plants and the purchasing of working materials, such as fishing nets and accessories. However, fishing as it is currently practiced is not subjected to rigorous monitoring. This has resulted in the exploitation of the fishery resources as well as a degradation of the marine biodiversity.

5.11. Transport

The transport system in this region was very rundown at the beginning of the 1980s. Currently, transport infrastructure has been immeasurably improved with the Sectorial Project of Transport (PST) for the construction of the roads and rural tracks, modernization of the port of Conakry, the program of renovation and modernization of Conakry airport, the creation of a mixed company for the management and exploitation of the Conakry airport and the renovation of the 36 km urban service railway from Conakry port to Coyah. However, improvements in the means of communication have continued to produce undesirable effects on the state of the soil and land cover in general.

5.12. Artisans

This activity contributed to change in land use/cover in the sense that this group of professionals used as raw materials, the resources of the forest and soil.

5.13. Belief

Today, certain sectors of the population in this region still continue protecting forests, referring to them sacred forests. Here are found both huge trees and sources of water. These places constitute for them a place for adoration and prayers; whereas this practice in other forests has been abandoned by the younger generation, bringing destruction or transformation in its wake. The Sacred Forest of Ratoma in Conakry is one such example.

5.14. Custom

Custom is explained by the fact that resources such as soil, water, animals and vegetation were managed and regulated in a collective way, according to customs, with a traditional authority responsible for the distribution of the fields, delimitation of reserved zones, protection of certain species of plants, regulation of transhumance and the use of fires to clear the agricultural fields. But the decline in the use of these customary rules in past 60 years has contributed to the degradation of the land use/cover elements.

5.15. Institutional factors

All the institutional structures to manage the environment and the natural resources are present in this region; but poor planning and follow-up capacity in the rational use of the natural resources, insufficiency of materials and means for the imple-
mentation of these programs do not allow for adequate protec-
tion and management of land use/cover.

Thus, according to different statistics, the land use/cover
pattern shows that it is the forests that have undergone the
greatest change, with 1123 km²; then followed by wetlands
(marsh), with 295 km². However, these two elements of land
use/cover have ceded land surface for agriculture of about
617 km² and 117 km², respectively, see Table 1. Also,
119 km² of forests have changed to suburban and 136 km²
have changed to urban center, while 104 km² of wetland sur-
faces have changed to water. Table 1 shows that the agricul-
tural areas of 753.58 km² of surface were occupied in this
land use/cover change between past and present periods. Also,
there has been a remarkable increase in conversion of the for-
est land cover by 82 km². (Fig. 4) above and Table 1 below. In
summary, land cover reduced by:

31.9% (change in area under cover divided by total area of
the region studied), as more land has gone to other various
land uses. Forest, grassland, wetland and water cover were re-
duced by 5.21%, 4.59%, 9.18% and 12.92%, respectively.

According to (Okude and Ademiluyi, 2006), the changing
pattern of land cover may be explained by a number of factors,
which include urbanization, industrialization, economic, hous-
ing development, increasing value of real properties, increasing
interest in real properties investment as a result of the uncer-
tainties associated with stocks and saving in the country,
devaluation of the Nigerian currency and inconsistencies in
economic and fiscal policies afflicting other forms of invest-
ment (Brand, 2001). In several regions of Madagascar, the an-
nual rate of deforestation is estimated at 0.5% for the area of
subsistence based on the system agriculture with the use of the
fire and 2.0% for those accessible by good roads; thus the im-
 pact of the road infrastructure.

In the case of Conakry, Coyah and Dubreka regions, the
land use/cover pattern change can be explained by a whole
variety of factors which come down to the following: natural
and causal (human factors) which includes the whole of the
meteorological phenomena (climate, rainfall, temperature
and humidity), population growth, land tenure ambition for
each inhabitants in the region, income of population, feeding
of the population, the region’s extensive agriculture and breed-

---

**Figure 4** (a–f). Maps of land use/cover types change between “past and present periods”. (a) Represents water change to others land use/
cover types. (b) Represents wetland change to others land use/cover types. (c) Represents forest change to others land use/cover types. (d)
Represents agriculture change to others land use/cover types. (e) Represents grassland change to others land use/cover types. (f)
Represents urban center change to others land use/cover types.
The effects combined of the whole of these factors have led to the current state of degradation and change of this land use/cover. However an important question is: can one extrapolate the result of this research on the whole of Maritime Guinea which has almost the same realities as this area?

6. Conclusion and recommendations

The results of this research show a degraded and disturbed land use/cover pattern in this region of study, with the change or disappearance of certain land cover elements. This has resulted from the combination of both natural events and the actions of the inhabitants, who are in continuous interaction with the environment. The outcome of this interaction has seen social, economical and environmentally negative consequences. The driving forces of future land use will bring demographic changes, economic growth and technological development (Alcamo and Busch, 2005).

This research shows that land use/cover pattern of this region of Conakry, Coyah and Dubreka, will likely worsen. The research further shows that land cover has greatly reduced by 31.9% as more land has gone to various land use. Forest, grassland, wetland and water cover reduced by 5.21%, 4.59%, 9.18% and 12.92%, respectively. It is hoped that these findings will encourage the political and administrative authorities to establish an urgent, rigorous and coherent policy for the rational exploitation and management of this regions environmental resources. In particular the rate of severe forest change in this region requires a fast response and intervention, since the forests play a considerable role in the regulation of the climate, the protection of the rivers and lessening of pollution.

The inhabitants are both the actors and spectators of these environmental problems; it thus needs the population of this area to assume responsibilities in guiding and controlling its development to safeguard the environment. In the final analysis, this research shows that detection and evaluation of the causes and consequences of land use/cover change may lead to a possible proposal for a solution, one based on the geographic information system (GIS). Still, the question is, does the geographic information system (GIS) have the capability to evaluate the current urban and pollution increase of this region?

However an important question remains, can someone extrapolate the result of this research to the whole of Maritime Guinea, which has almost the same realities as this region? Hopefully, first of all, this research will serve as a reference for future research, and secondly, it will provide a tool for understanding the dangers which confront this type of environment in general.

Acknowledgments

We thank the Guinean, and Chinese authorities, as well as the Embassy of Guinea in China for their assistance to bring this research project to fruition.

References

Brand, J., 2001. The impact of the infrastructure on the deforestation in Madagascar. FOFIFA.