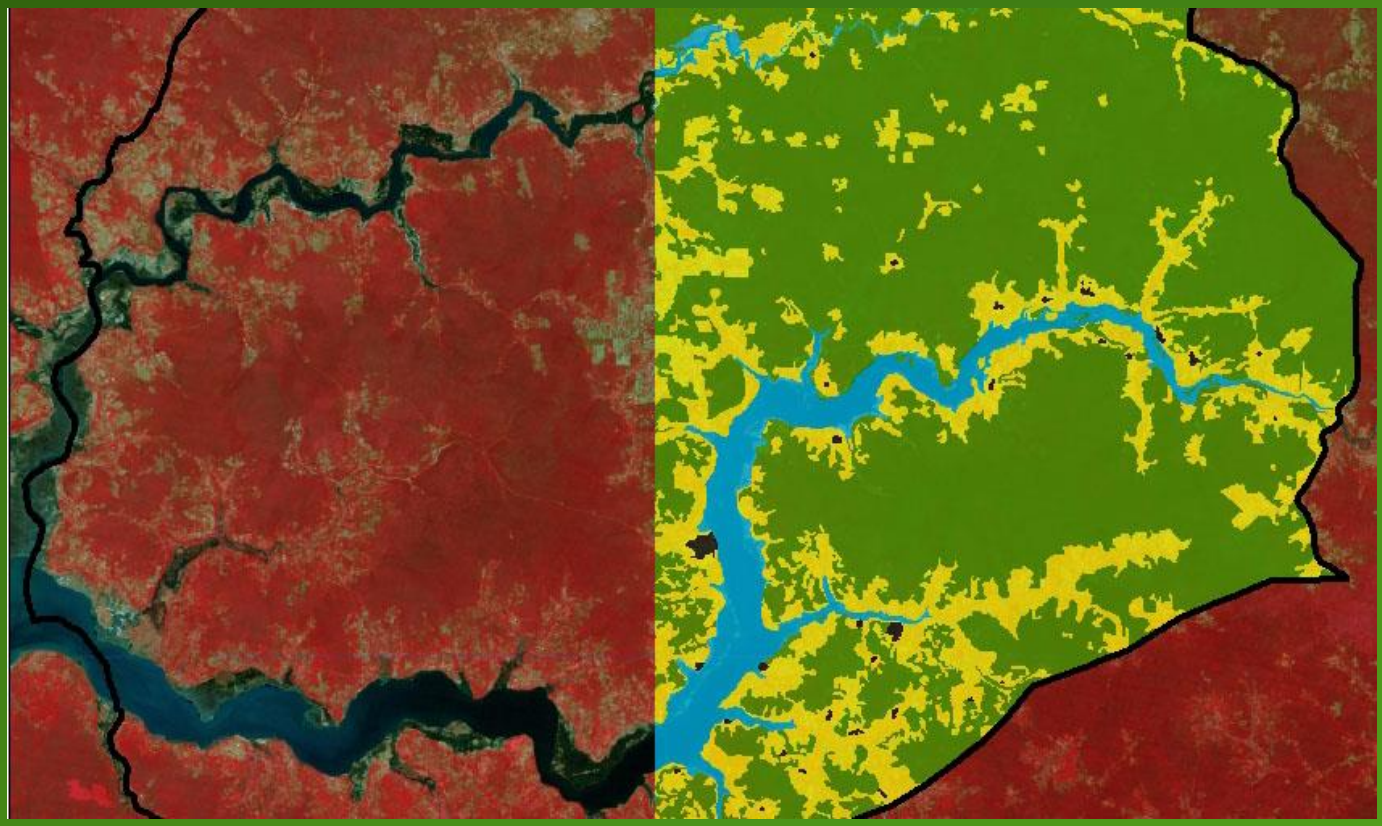
Programme d'Appui
au Programme National d'Investissement
de l'Agriculture du Sénégal

# DYNAMICS OF LAND COVER/LAND USE IN THE SEDHIOU REGION

## Dynamiques de l'Occupation/Utilisation des sols dans la Région de Sédhiou



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This study has been realised within the framework of the “Programme d’Appui au Programme National d’Investissement de l'Agriculture du Sénégal” (PAPSEN) by a team composed of researchers of the National Research Council (CNR) of Italy and the Senegalese Institute of Agricultural Research (ISRA):

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Consiglio Nazionale delle Ricerche

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# Acronyms

| | |
|---|---|
| **CSE** | Centre de Suivi Ecologique |
| **FAO** | Food and Agriculture Organization |
| **GLCN** | Global Land Cover Network |
| **HA** | Humid and natural areas |
| **IHC** | Irrigated herbaceous crops |
| **LADA** | Land Degradation Assessment in Drylands |
| **LC** | Land Cover |
| **LCCS** | Land Cover Classification System |
| **LU** | Land Use |
| **NV** | Natural vegetation |
| **PAPSEN** | Support Programme to the National Programme of Investments in Agriculture of Senegal |
| **RGPH** | Recensement Général de la Population et de l’Habitat |
| **RHC** | Rainfed herbaceous crops |
| **TP** | Tree plantations and orchards |
| **U** | Urban areas and rural settlements |
| **W** | Water |

# 1. Introduction

The Middle Casamance is experiencing during last '30 years slights changes in its productive structure, but important environmental changes due to the interaction of anthropogenic and physical factors. Population growth, internal displacement due to the Casamance conflict and migration from other Senegalese regions, have strong impacts on the ecosystems and the land use of the territory. In Senegal, the Casamance eco-region is the most humid and rich in terms of freshwater and forest resources, Nevertheless, climate change and variability are modifying the landscape and exacerbating natural resources degradation processes induced by anthropogenic causes.

The present study is a contribution to the better comprehension of Middle Casamance's rural production and to the identification of potential bottlenecks and limiting factors to agricultural development in Sédhiou Region. The study consists of an analysis of land cover/land use changes occurred in the last two decades (1990-2010) and aims to identify dynamics and limiting factors to agricultural development in Sédhiou Region. Indeed, territorial dynamics of land cover and land use can provide keys for interpreting dynamics of the different production systems.

Land cover/land use changes can be driven by anthropogenic and natural processes such as:

- climate-related change (long- and short term)
- cutting and clearing of forests (deforestation)
- grazing activities (intensification of rangelands)
- agricultural expansion (farming activities)
- fuel wood consumption
- wild fires
- urban expansions (urbanization)
- natural regeneration

The changes in landscape that are detectable through Land cover change analysis depend on the remote sensed images used for interpreting the Land Cover and on the used satellite time series. A general overview at regional scale (Sédhiou Region covers about 7,500 $km^2$) of main changes can be based on medium resolution satellite images, such as Landsat products. The FAO Global Land Cover Network (GLCN) programme produced for Senegal Land Cover maps that refers to 1990 and 2005. The land cover classifications system (LCCS) used by GLCN to realize these maps provides information of land cover and land use, mainly for agricultural classes. Such information can be used as indicator for changes in the productive structure.

# 2. Methodological approach

## 2.1 Land cover / land use

Land cover (LC) analysis was performed using Senegal LC classification made by GLCN Office at Centre de Suivi Ecologique (CSE) in Dakar (Senegal). The land cover legend of Senegal was set up using the FAO LCCS methodology. LCCS is a comprehensive, standardized a priori LC classification system. The LC analysis based on Landsat images photo interpretation, supported by high-resolution aerial images and field-surveys. The classification was accomplished using 30 m spatial resolution LANDSAT ETM images (bands 432) acquired in November 2005. These images, recorded in the dry season following the rainy one, are considered the most suitable as they facilitate the identification of the different classes, especially as regards natural vegetation. The classification was carried out at a scale of 1:100,000 and 70 classes, among unique and mixed, were identified for the Sédhiou Region giving a total of 1178 polygons. Unique classes were used only for areas that have a coverage considered uniform over their entire surface; on the opposite mixed classes are used for those surfaces that have two types of land cover classes that cannot be individually defined and identified due to different reasons (very small size, limits not well understood); therefore they are represented within a single polygon as mixed classes.

According to the purposes of the project, i.e. identifying the agricultural (rainfed, irrigated and perennial crops) and natural vegetation LC variation dynamics that occurred in the last twenty years in Sédhiou Region, the classes found in the study area have been reclassified in 7 new classes (Table 1). Using the same methodology implemented by LCCS methodology to perform statistical calculations of mixed classes, a percentage coverage of 60% was empirically assigned to predominant class and a percentage coverage of 40% to the other.

An accuracy assessment of Senegal LC classification was then performed using Google Earth images acquired in 2005 or in the closest available year. This assessment was carried out for the 4 classes of interest (rainfed herbaceous crops, irrigated herbaceous crops, tree plantations and natural vegetation) of PAP-SEN Project; the classification accuracy of 100 points randomly selected for each class was evaluated. It is important to point out that this accuracy assessment has provided only a qualitative evaluation because it didn't quantify how much each class has been overestimated or underestimated in terms of surfaces. This latter kind of assessment was empirically performed where possible. Please refer to the following paragraphs for accuracy assessment results of each class.

*Tab. 1 – Reclassification classes for the purposes of PAPSEN Project, original 2005 Senegal LCCS classes found in Sédhiou Region, percentage coverage assigned to each new class for statistical purposes (bold= unique classes; italic =mixed classes).*

| RECLASSIFICATION | LLCS CLASS DESCRIPTION | % CLASS 1 | % CLASS 2 |
|---|---|---|---|
| **RIVERS AND LAKES (W)** | **River** | 100 | 0 |
| | **Lake** | 100 | 0 |
| **HUMID AND NATURAL AREAS (HA)** | **Tidal Area** | 100 | 0 |
| | **Bare Soil temporarily flooded** | 100 | 0 |
| | **Bare Soil OR Sparse Shrubs and Herbaceous vegetation in temporarily flooded area** | 100 | 0 |
| | **Bare Soil OR Sparse Shrubs and Herbaceous vegetation in temporarily flooded area – Brackish water** | 100 | 0 |
| | **Closed to Open Herbaceous vegetation permanently flooded with brackish water** | 60 | 40 |
| | *Bare Soil temporarily flooded / Closed Herbaceous vegetation permanently flooded* | 60 | 40 |
| | *Closed to Open Shrubs temporarily flooded / Small Rice crops* | 60 | 40 |
| | *Closed Herbaceous vegetation permanently flooded / River* | 60 | 40 |
| | *Closed to Open Herbaceous vegetation temporarily flooded / Small Rice crops* | 60 | 40 |
| **URBAN AREAS AND RURAL SETTLEMENTS (U)** | **Urban Area** | 100 | 0 |
| | **Rural Settlements** | 100 | 0 |
| **TREE PLANTATIONS (TP)** | **Large to Medium Tree Plantation** | 100 | 0 |
| | **Large to Medium Tree crops** | 100 | 0 |
| | **Small Tree crops** | 100 | 0 |
| | *Large to Medium Tree crops / Small Rainfed Herbaceous crops with a layer of Sparse Trees* | 60 | 40 |
| | *Small Tree crops / Closed Gallery Forest* | 60 | 40 |
| | *Small Tree crops / Small Rainfed Herbaceous crops with a layer of Sparse Trees* | 60 | 40 |
| **RAINFED HERBACEOUS CROPS (RHC)** | **Large to Medium Rainfed Herbaceous crops** | 100 | 0 |
| | **Large to Medium Rainfed Herbaceous crops with a layer of Sparse Trees** | 100 | 0 |
| | **Small Rainfed Herbaceous crops** | 100 | 0 |
| | **Small Rainfed Herbaceous crops with a layer of Sparse Trees** | 100 | 0 |
| | *Small Rainfed Herbaceous crops with a layer of Sparse Trees / Small Tree crops* | 60 | 40 |
| | *Small Rainfed Herbaceous crops with a layer of Sparse Trees / Open Trees* | 60 | 40 |
| | *Small Rainfed Herbaceous crops with a layer of Sparse Trees / Very Open Shrubs with emergent Trees* | 60 | 40 |
| | *Small Rainfed Herbaceous crops with a layer of Sparse Trees / Very Open Trees* | 60 | 40 |
| | *Small Rainfed Herbaceous crops with a layer of Sparse Trees / Rural Settlements* | 60 | 40 |
| **IRRIGATED HERBACEOUS CROPS (IHC)** | **Large to Medium Irrigated Herbaceous crops** | 100 | 0 |
| | **Small Irrigated Herbaceous crops** | 100 | 0 |
| | **Large to Medium Rice crops** | 100 | 0 |
| | **Small Rice crops** | 100 | 0 |
| | *Small Rice crops / Small Rainfed Herbaceous crops with a layer of Sparse Trees* | 60 | 40 |
| | *Small Rice crops / Closed Gallery Forest* | 60 | 40 |
| | *Small Rice crops / Very Open Trees* | 60 | 40 |
| | *Small Rice crops / Closed to Open Shrubs temporarily flooded* | 60 | 40 |
| | *Small Rice crops / Closed to Open Herbaceous vegetation temporarily flooded* | 60 | 40 |
| | *Small Rice crops / Bare Soil temporarily flooded* | 60 | 40 |
| | | | |

| RECLASSIFICATION | AFRICOVER DESCRIPTION | % CLASS 1 | % CLASS 2 |
|---|---|---|---|
| NATURAL VEGETATION (NV) | **Closed Trees** | 100 | 0 |
| | **Closed Gallery Forest** | 100 | 0 |
| | **Open Trees** | 100 | 0 |
| | **Open Gallery Forest** | 100 | 0 |
| | **Open Shrubs** | 100 | 0 |
| | **Open Shrubs with emergent Trees** | 100 | 0 |
| | **Very Open Shrubs** | 100 | 0 |
| | **Very Open Shrubs with emergent Trees** | 100 | 0 |
| | **Very Open Trees** | 100 | 0 |
| | **Closed to Open Herbaceous vegetation with Sparse Trees and Shrubs** | 100 | 0 |
| | **Closed to Open Herbaceous vegetation** | 100 | 0 |
| | **Closed Herbaceous vegetation permanently flooded** | 100 | 0 |
| | **Closed to Open Herbaceous vegetation temporarily flooded** | 100 | 0 |
| | *Closed Trees / Open Shrubs with emergent Trees* | 60 | 40 |
| | *Closed Gallery Forest / Small Tree crops* | 60 | 40 |
| | *Open Trees / Small Tree crops* | 60 | 40 |
| | *Open Trees / Small Tree crops* | 60 | 40 |
| | *Open Trees / Small Rainfed Herbaceous crops with a layer of Sparse Trees* | 60 | 40 |
| | *Open Trees / Small Rainfed Herbaceous crops – Isolated* | 60 | 40 |
| | *Open Trees / Very Open Shrubs with emergent Trees* | 60 | 40 |
| | *Open Gallery Forest / Small Rainfed Herbaceous crops with a layer of Sparse Trees– Isolated* | 60 | 40 |
| | *Open Shrubs with emergent Trees / Large to Medium Rainfed Herbaceous crops with a layer of Sparse Trees* | 60 | 40 |
| | *Open Shrubs with emergent Trees /Small Rainfed Herbaceous crops – Isolated* | 60 | 40 |
| | *Very Open Shrubs with emergent Trees / Small Tree crops* | 60 | 40 |
| | *Very Open Shrubs with emergent Trees / Small Rainfed Herbaceous crops with a layer of Sparse Trees* | 60 | 40 |
| | *Very Open Shrubs with emergent Trees / Small Rainfed Herbaceous crops with a layer of Sparse Trees– Isolated* | 60 | 40 |
| | *Very Open Shrubs with emergent Trees / Small Rainfed Herbaceous crops – Isolated* | 60 | 40 |
| | *Very Open Trees / Large to Medium Tree crops* | 60 | 40 |
| | *Very Open Trees / Small Rainfed Herbaceous crops with a layer of Sparse Trees* | 60 | 40 |
| | *Very Open Trees /Small Rainfed Herbaceous crops with a layer of Sparse Trees– Isolated* | 60 | 40 |
| | *Very Open Trees / Open Shrubs with emergent Trees* | 60 | 40 |
| | *Closed to Open Herbaceous vegetation with Sparse Trees and Shrubs / Bare Soil temporarily flooded* | 60 | 40 |

## 2.2 1990-2005 land cover change detection

An analysis of LC changes in Sedhiou Region during 1990-2005 period was performed by IBIMET comparing 30 meters resolution LANDSAT TM images acquired in 1990 and 2005. The resulting LC change map has been classified according to the 7 classes of interest (river and lake; humid and natural areas; urban areas and rural settlements; tree plantations; rainfed herbaceous crops; irrigated herbaceous crops; natural vegetation) as described in the previous paragraph.

## 2.3 Land cover and population dynamics comparative analysis

The comparative analysis of land cover and population dynamics was based on the comparison of LC evolution during 1990-2005 period and population change dynamics during 1988-2008 period; the goal was to understand the relationship between natural and anthropogenic dynamics occurred in Sédhiou Region and more in deep to identify LC change drivers that may be related to demographic trends. Considering the structural and socio-economic characteristics of the study area, LC evolution analysis was focused on changes related to "rainfed agricultural crops" class; in fact this class is the one that most emphasizes human pressure on environmental resources of Sédhiou Region. In this analysis population data were aggregated to Communauté rurale (rural municipality) level. Furthermore, population data related to two periods have been used:

- 1988 population census data (RGP 1988); these data were originally provided in disaggregated form for each village, but were then aggregated according to the actual Communauté rurale boundaries;
- 2002 population census data projected to 2008 (projection of RGPH 2002 data provided by ISRA); these data were originally aggregated according to the actual Communauté rurale and Commune Urbaine (urban municipalities; there are 8 in Sédhiou Region: Bounkiling, Madina Wandifa, Goudomp, Samine Tanaff, Diattacounda, Sédhiou, Diannah Malary, Martsassoum) boundaries. In this analysis, Commune Urbaine population data were added to those of the Communauté rurale that surround the Commune urbaine area.

Population dynamics analysis was performed at Communauté rurale level. A deeper analysis related to Communes Urbaines or individual main urban centers was not possible. As a consequence it is not possible to highlight here in a proven way population movement dynamics from rural areas to urban centers or different growth rates for Communautés rurales and Communes Urbaines during the period 1988-2008.

In order to facilitate the comprehension of population dynamics, in the final comparative analysis the population growth rates of the Communautés rurales were normalized to the regional growth rate.

## 2.4 2013 field campaign

During 2013 summer, a field campaign in Sédhiou Region was performed by researchers of IBIMET Institute (Fig. 1); one of the objectives was to better understand the trends detected in the present study, to verify if they are still performing and if new others are emerging. The field campaign was organized into two steps: first, semi-structured interviews have been carried out with key informants nearby regional and departmental line services, such as Agriculture, Water and Forest (Eaux et Forêts), ARD (Regional Development Agency), etc.; thus, field visits have been organized in the areas where specific trends were observed from Land cover change analysis. As already mentioned, field visits aimed to a qualitative verification of the observed dynamics but they were not structured for a verification of the 2005 LCCS classification considering that there is a time gap of 8 years.

Field visits could not be done in Goudomp Department for accessibility and security reasons.

Many observations collected in the field campaign have been included in the discussion of observed trends and help to understand the main drivers of observed dynamics. They also allowed to suggest recommendations for further research deepening.

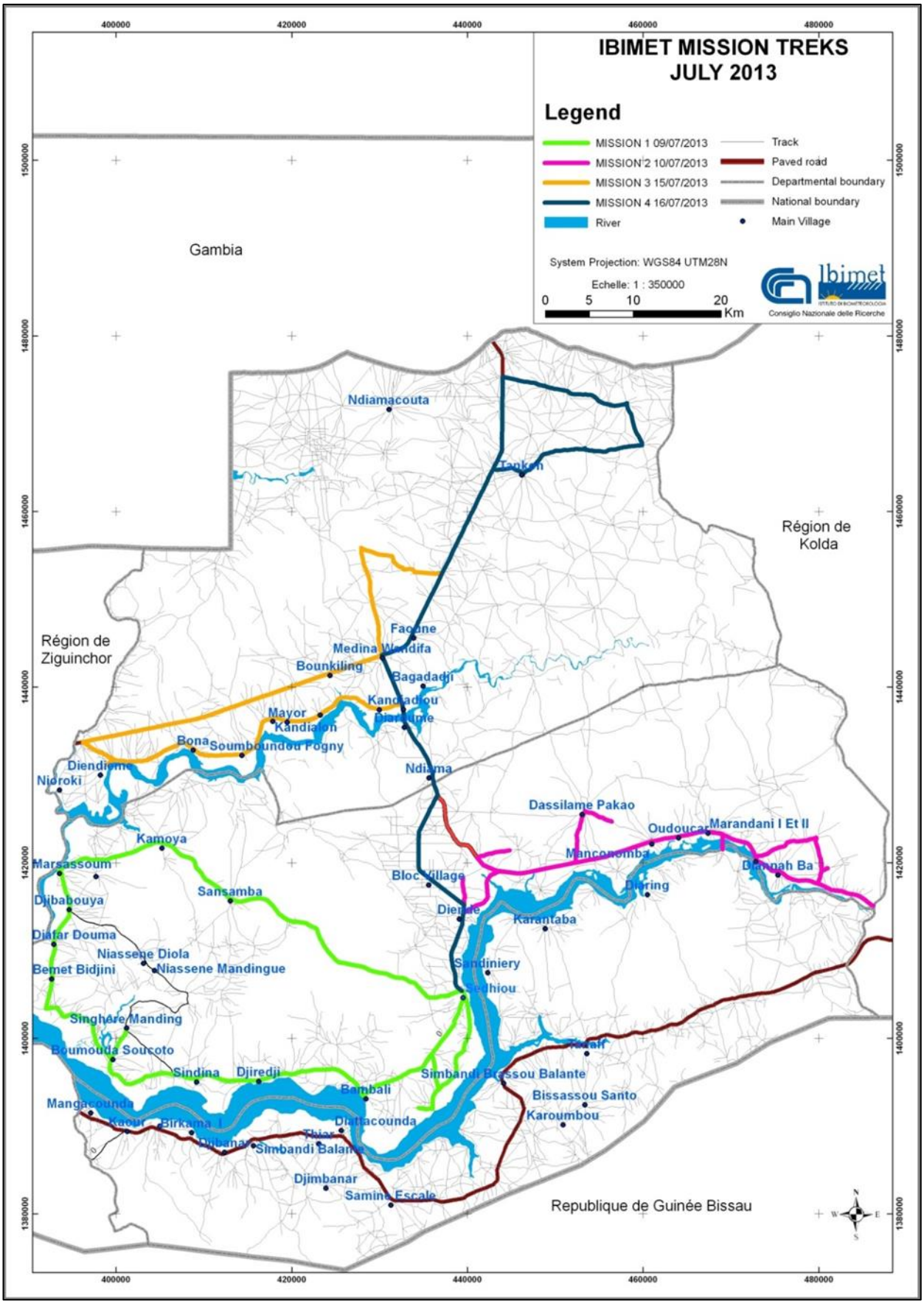


*Fig. 1 – IBIMET mission treks carried out during July 2013 field campaign.*

# 3. Sédhiou Region

The Sédhiou Region covers an area of 7,340 km$^2$. It is composed (Fig. 2) of three administrative departments (Bounkiling, 2,889 km$^2$; Sédhiou, 2,725 km$^2$; Goudomp, 1,725 km$^2$), which are subdivided into 32 rural communities (Communautés rurales) and 8 hurban municipalities (Communes urbaines). The population of the region was estimated in 2008 at 406,786 inhabitants with an average density of 55 in/km$^2$. The region lacks of morphological reliefs, it is crossed by Casamance River and its right affluent Soungrougrou; in correspondence with the smaller tributaries, small valleys were formed by erosion and are traditionally sown to rice. The climate is characterized by the african monsoon during more than 8 months per year with an average annual rainfall > 800 mm. The region is reach in forest resources and includes 12 forest reserves (forêts classes) with a total surface of 84,500 ha.

Rainfed agriculture is done by farmers on highlands and main crops are finger millet, sorghum, maize and rice. Lowlands are cultivated mainly with rice. Tree fruits plantations are also diffused, mainly mangos and cashew.

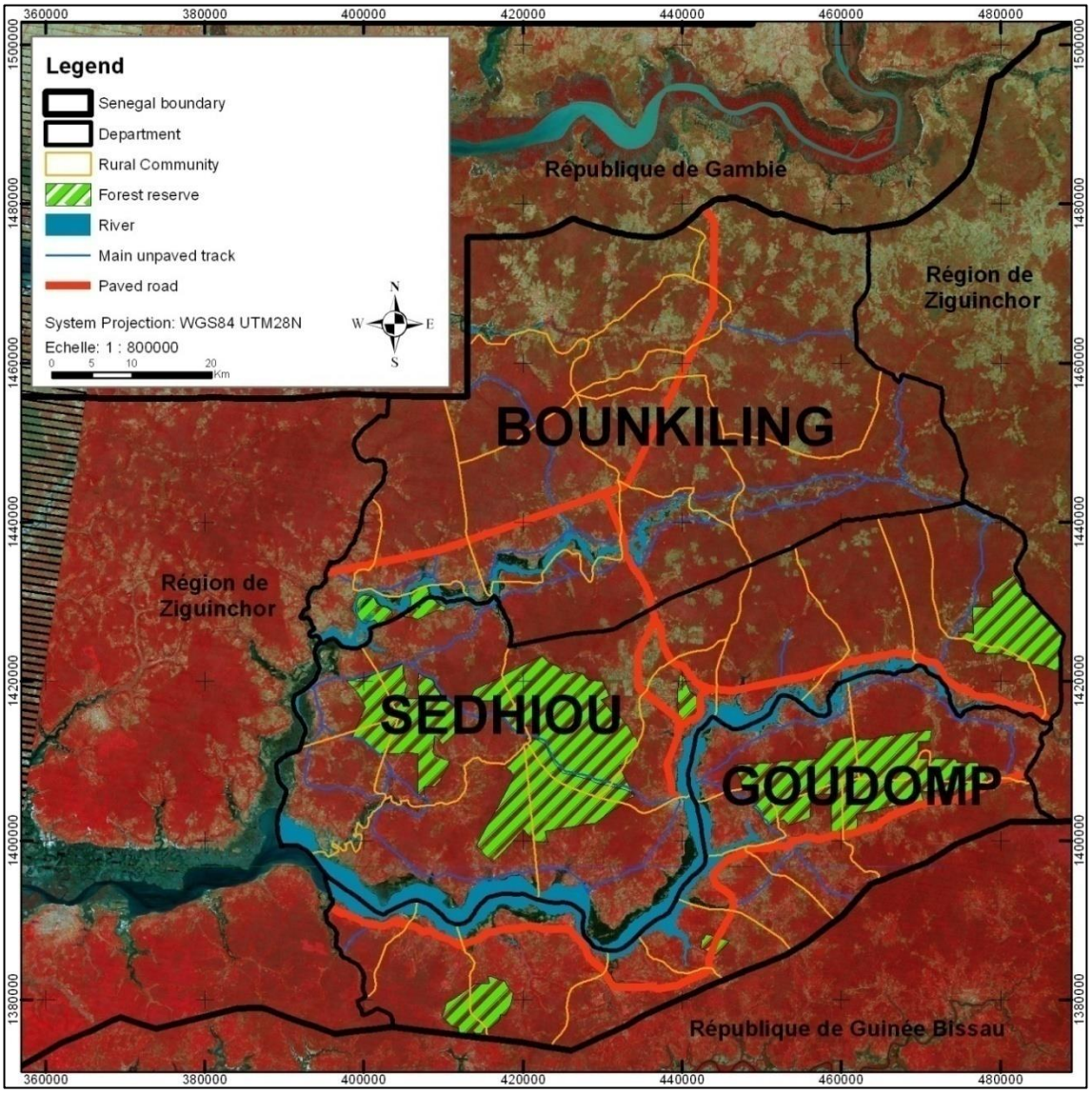


*Fig. 2 – Administrative boundaries of Sédhiou Region, main road network, rivers and Forêts Classées (forest reserves). Background: False color Landsat Image (Red=Vegetation).*

Region's road network is composed by:

- Paved National Road N4 (Trans Gambia Highway) which crosses Sédhiou Region in the north;
- Paved National Road N6 Ziguinchor-Kolda; it is characterized by poor conditions and crosses Sédhiou Region in the South (left bank of Casamance river);
- Paved Provincial roads RN21, RN22 and RN23 that connect Sédhiou to N4 and to Kolda ;
- An extensive network of rural tracks often not accessible during rainy season.

# 4. 2005 Sédhiou Region land cover

Figure 3 shows 2005 LC map according to the reclassified LCCS legend. Most of the territory is covered by various forms of natural vegetation ranging from dense forest to open arboreal formations, or shrubby and grassy savannas. Agricultural areas occupied about a quarter of the total surface with a strong predominance of the rainfed herbaceous crops.

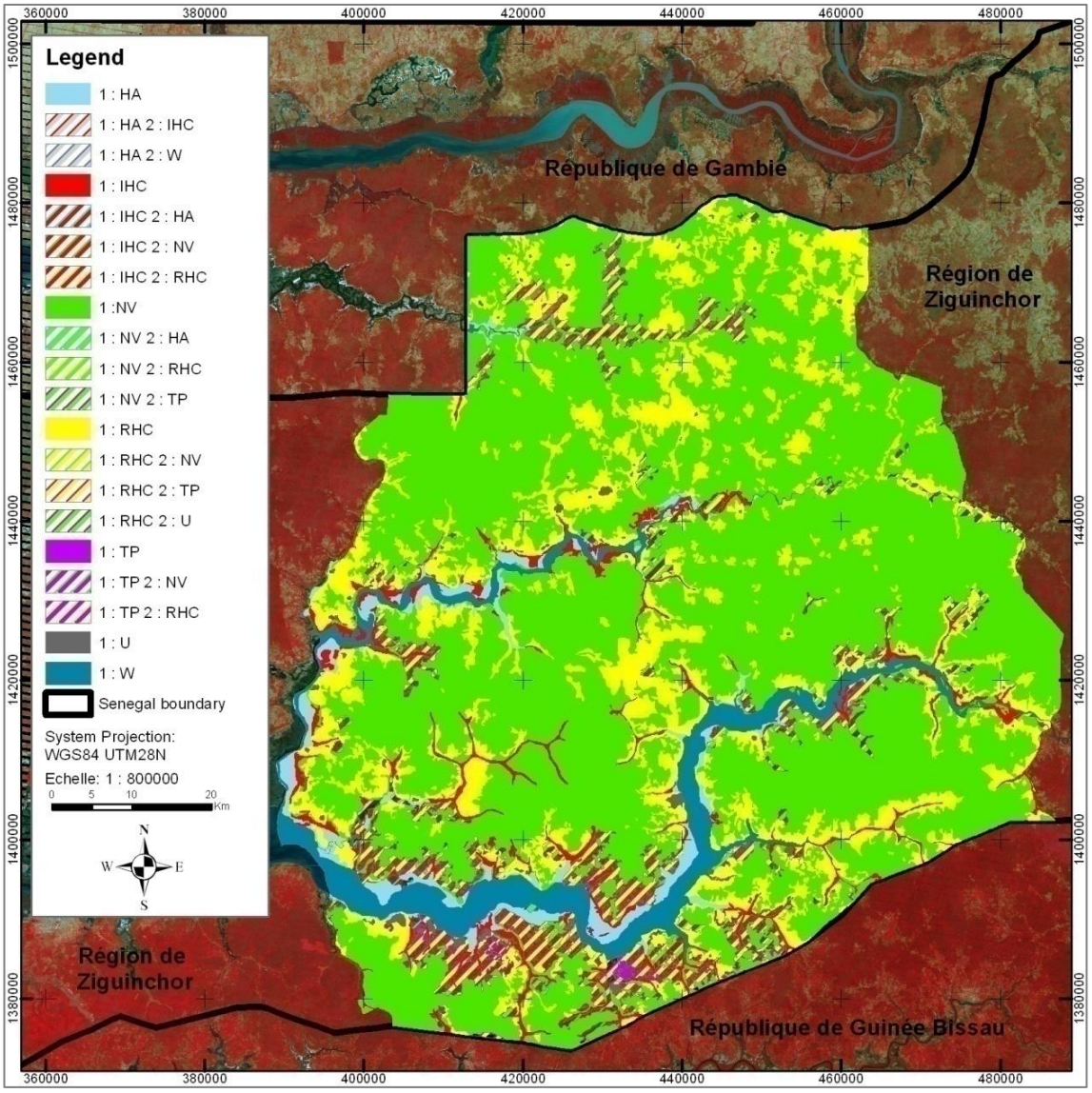


*Fig. 3 – 2005 Land cover map for Sédhiou Region according to 7 classes reclassification (1=first class; 2=second class; HA= humid and natural areas; IHC= irrigated herbaceous crops; NV= natural vegetation; RHC= rainfed herbaceous crops; TP= tree plantations; U= urban; W= water.*

According to the new classification, surfaces and their coverage percentage related to total Sédhiou Region area are reported for each new class in Table 2.

*Tab. 2 – Classes, areas (Km$^2$) and coverage percentages in Sédhiou Region and its Departments in 2005.*

| CLASS | BOUNKILING DEPARTMENT | | GOUDOMP DEPARTMENT | | SÉDHIOU DEPARTMENT | | SÉDHIOU REGION | |
|---|---|---|---|---|---|---|---|---|
| | AREA | % | AREA | % | AREA | % | AREA | % |
| HUMID NATURAL AREAS (HA) | 44 | 1.5 | 40 | 2.3 | 108 | 4 | 192 | 3 |
| IRRIGATED HERBACEOUS CROPS (IHC) | 50 | 1.7 | 80 | 4.6 | 95 | 3.5 | 224 | 3 |
| NATURAL VEGETATION (NV) | 2011 | 69.6 | 973 | 56.4 | 1731 | 63.5 | 4716 | 64 |
| RAINFED HERBACEOUS CROPS (RHC) | 707 | 24.5 | 461 | 26.7 | 578 | 21.2 | 1747 | 24 |
| TREE PLANTATION AND ORCHARDS (TP) | 0 | 0 | 21 | 1.2 | 1 | 0 | 22 | 0 |
| URBAN AREAS AND RURAL SETTLEMENTS (U) | 0 | 0.4 | 1 | 0.9 | 0 | 0.4 | 38 | 1 |
| RIVERS (W) | 66 | 2.3 | 135 | 7.8 | 200 | 7.3 | 401 | 5 |

## 4.1 Natural vegetation (NV)

"Natural vegetation" (NV) class covers about two-thirds of the surface of Sédhiou Region. The Department with the highest NV percentages (Fig. 4) is Bounkiling (69.61%), followed by Sédhiou (63.54%) and Goudomp (56.40%). NV percentages show greater variability at Communauté rurale level with some Communautés almost completely covered by natural vegetation (Diambati, Kanta Peulh Kandion Mangana) and others with a natural vegetation coverage lower than 50%. The Communautés with the highest NV percentages are located in the eastern part of the region.

Accuracy assessment gave a value of 93/100 for this class; this high result is related to the widespread presence of NV over the entire region. The visual assessment performed on Google Earth has thus demonstrated a high reliability of data related to this class; some inaccuracies in the delineation of boundaries between NV and RHC class were noticed and appeared to be related to the original mapping scale (1:100,000) and to a difficult identification of areas that are no longer cultivated and that therefore are returning to natural vegetation.

The region has several forest reserves (Fig. 4), 8 "*forets classes*" and 2 "*roneraies*", covering a total area of approximately 805 km$^2$ spread over 16 Communautés rurales inside Sédhiou and Goudomp Departments.

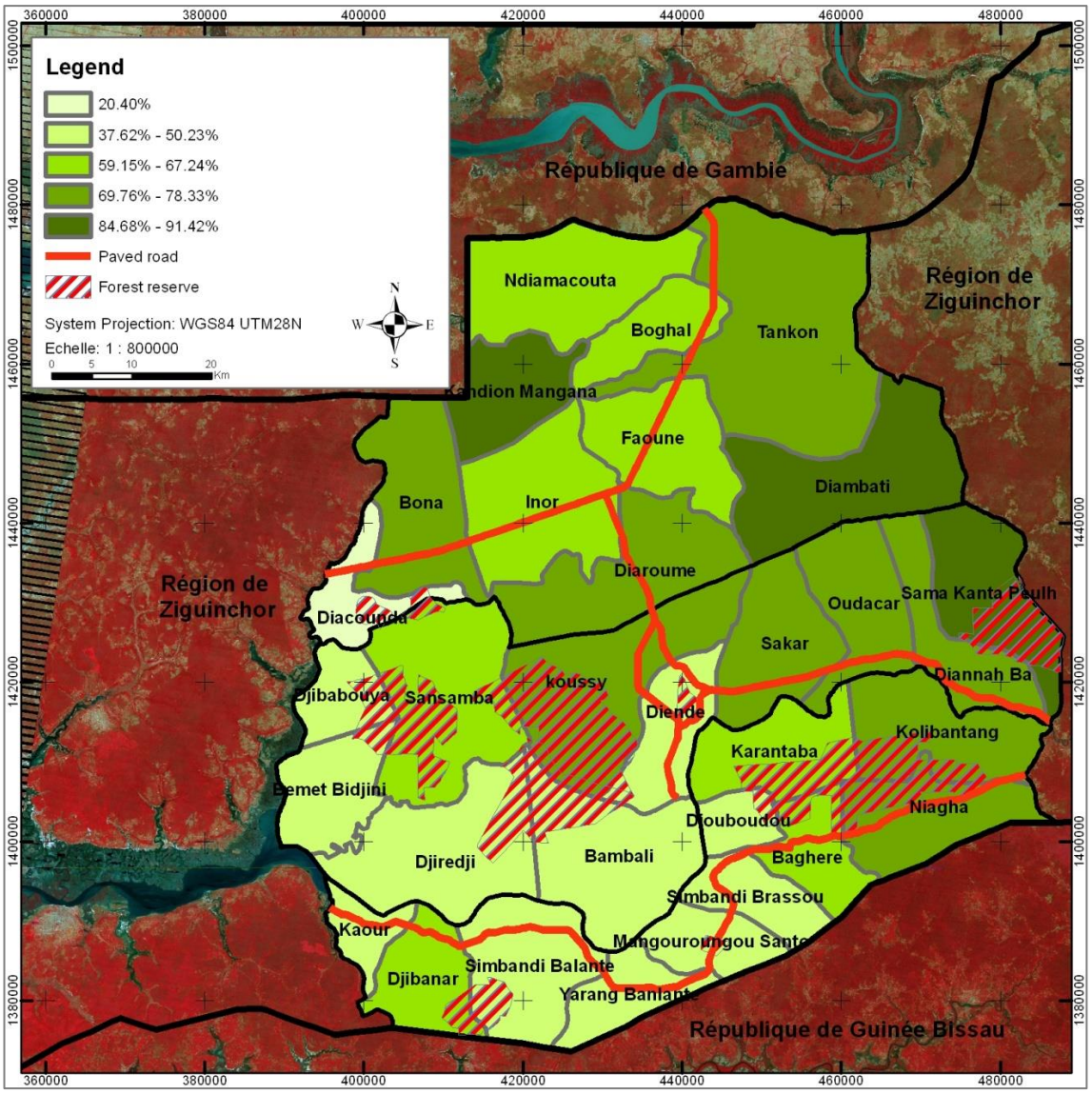


*Fig. 4 – "Natural vegetation" (NV) class coverage percentages for each Communauté rurale of Sédhiou Region in 2005. Background: False color Landsat Image (Red=Vegetation).*

## 4.2 - Rainfed herbaceous crops (RHC)

"Rainfed herbaceous crops" (RHC) class covered in 2005 approximately 1.746 km$^2$, corresponding to 23.80% of Sédhiou Region. It must be highlighted that this class includes not only those areas that were really sown and cultivated in 2005, but also those surfaces identified by photo interpretation as areas generally used for rainfed agricultural purposes (with the exception of perennial crops listed as "Tree plantations"). Therefore this class collected also those surfaces which in 2005 were fallow ("*jachère*") or recently abandoned and that were not correctly identified by photo interpretation. This aspect explains why in this study RHC area is much higher than the total regional agricultural area (approximately 1000 km$^2$) reported by agricultural statistics of "Agence Nationale de la Statistique et de la Démographie" that is referred only to surfaces effectively sown. Most of this class area consists of crops with field size smaller than 2 hectares and with a layer of natural trees having a cover ranging from 1% to 15%. Only the Plaine de

Sefa area (around 60 km$^2$), located in the central part of Sédhiou Department (Diende and Koussy Communautés rurales), consists of crops with field size bigger than 2 hectares. RHC departmental coverage percentages are more or less uniform ranging from 21.2 to 26.7% (Table 2). Variability is greater at Communauté rurale level (Fig. 5); those located in the south (Simbandi Balante, Yarang Banlante, Mangouroungou Holy Simbandi Brassou, Dioboudou, Baghere) and in the north-east (Ndiamacouta, Boghal, Tankon, Faoune) are characterized by the highest percentages (30-40%). On the other hand, Communautés rurales located in the eastearn area of Sédhiou Department, together with Kandion Mangana, showed the lowest RHC pcentages with values ranging from 7 to 15%.

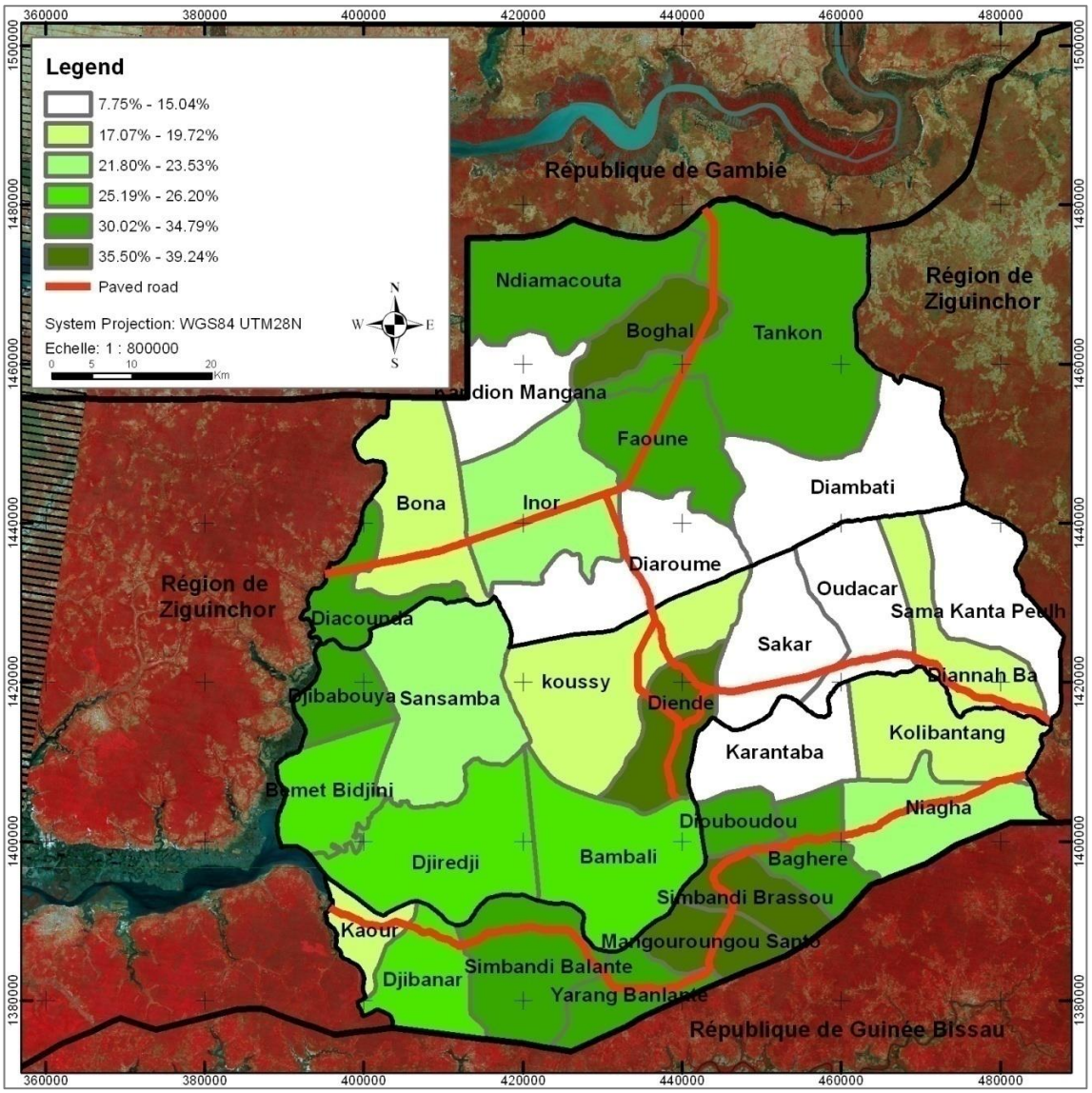


*Fig. 5 – "Rainfed herbaceous crops" (RHC) class coverage percentages for each Communauté rurale of Sédhiou Region in 2005. Background: False color Landsat Image (Red=Vegetation).*

Accuracy assessment (Fig. 6) gave a value of 58/100 for this class. The factors that seem to affect this low value might be various:

- the mapping scale (1:100,000); when control points are located on edges of RHC polygons, that are in most cases small and jagged, validation performed on Google Earth high resolution images indicated that their delineation is often not precise.
- the LANDSAT image resolution (30 m) that in some cases did not allow a clear distinction of the transition from RHC to NV;

- the presence, inside RHC areas, of rural settlements that were not outlined;
- RHC surfaces are in some cases not correctly delineated and include abandoned areas; this aspect was clearly shown by Google Earth high-resolution images.

Despite Google Earth accuracy assessment results, it is not possible to assess whether the RHC class is overestimated or underestimated.


*Fig. 6 – Example of accuracy assessment for "rainfed herbaceous crops" (RHC) class performed on Google Earth (2005 image). Control point (green icon) is located inside an actually not cultivated area; the polygon effectively covers an agricultural area.*

## 4.3 - Irrigated herbaceous crops (IHC)

IHC includes all classes that according to LCCS classification correspond to irrigated herbaceous crops (covering an area of approximately 225 km$^2$). Nevertheless, it is almost entirely composed of lowland rainfed rice crops with field size smaller than 2 hectares. Such cultivations (222 km$^2$) are usually conducted in lowlands areas ("bas-fond") that are located or inside valleys or on the banks of Casamance and Soungrougrou rivers. Only around 2 km$^2$ of IHC class consist of effectively irrigated rice crops with field size bigger than 2 hectares, while 2 km$^2$ are occupied by other kinds of irrigated crops. Accuracy assessment performed on Google Earth (Fig. 7) indicated a low level of precision (31/100) for this class. The reason seems to be related to the small size of rice fields and therefore to their difficult identification. IHC area appears clearly overestimated because in most


*Fig. 7 – Example of accuracy assessment for "irrigated herbaceous crops" (IHC) class (red boundaries polygon) performed on Google Earth (2005 image). Control point (green icon) is located inside an area covered by natural vegetation; rice crops can be recognized in the central area.*

cases it includes not only rice crops but also the natural vegetation within the valleys.

IHC departmental coverage percentages (Tab. 2) ranged between 1.7% (Bounkiling) and 4.6% (Goudomp). Irrigated cultivations were found mainly in the Communautés rurales (Fig. 8) located close to Casamance and Soungrougrou rivers; their coverage percentage, that appears overestimated, didn't exceed 10%.

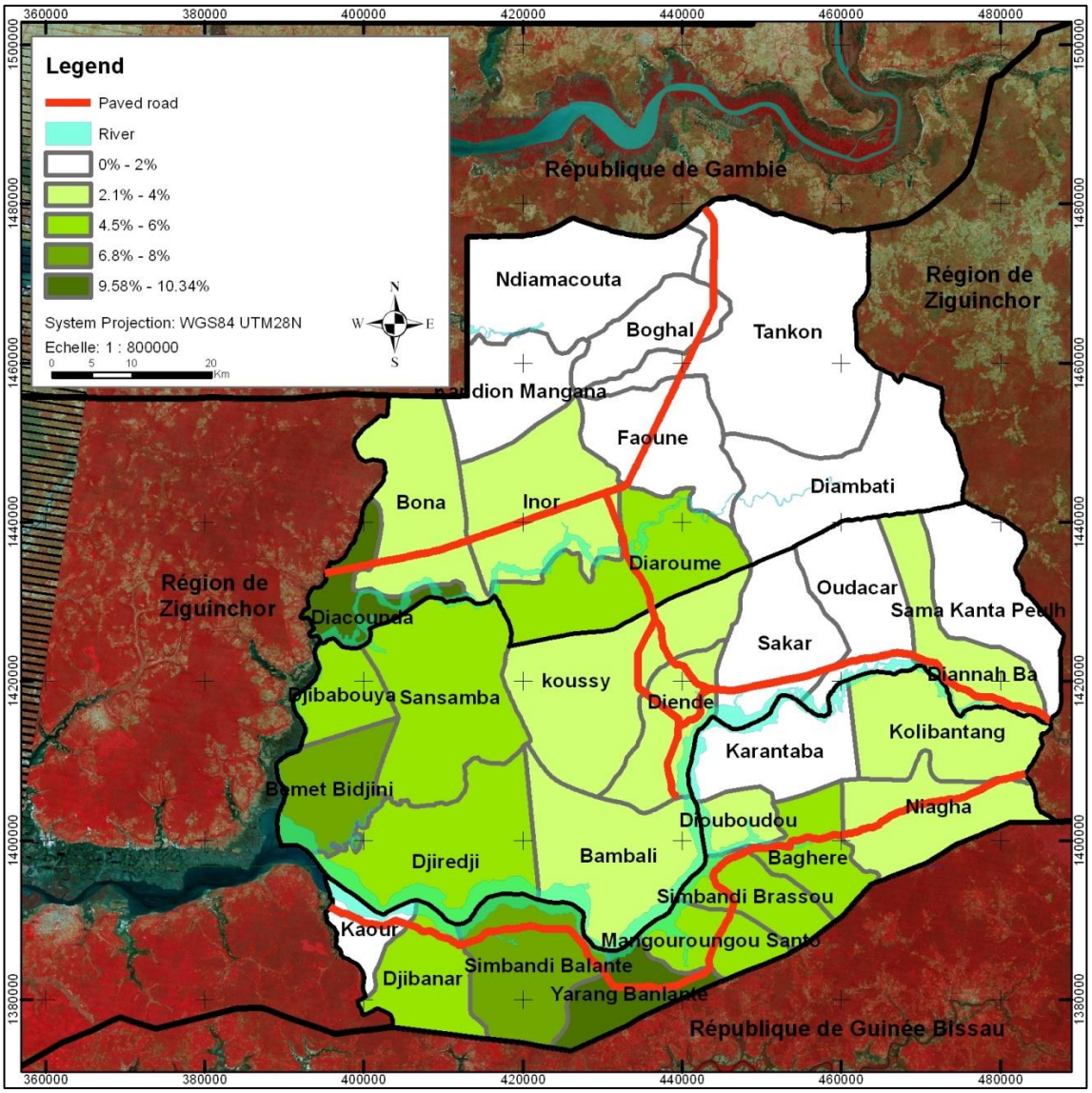


*Fig. 8 – "Irrigated herbaceous crops" (RHC)class coverage percentages for each Communauté rurale of Sédhiou Region in 2005. Background: False color Landsat Image (Red=Vegetation).*

## 4.4 - Tree plantations and orchards (TP)

This class includes areas covered by tree plantations and orchards, in most cases with size greater than 2 hectares. This class covers 21.90 km$^2$ corresponding to 0.3% of the entire area. It has been found almost exclusively in south-western area of Sédhiou Region (Fig. 9): in Goudomp Department and more specifically in Kaour, Djibanar, Simbandi Balante, Bambali, Mangouroungou Santo and Yarang Banlante Communautés rurales; it is almost absent in Communautés rurales located in the other two departments except for Diannah Ba and Diacounda. In these Communautés rurales the coverage percentage never exceeds 3.5%.

Accuracy assessment has given for this class a value of 97/100; however, it appears clearly underestimated. This is mainly related to the fact that reflectance of orchards is almost identical to that of natural arboreal vegetation and consequently its identification is difficult.

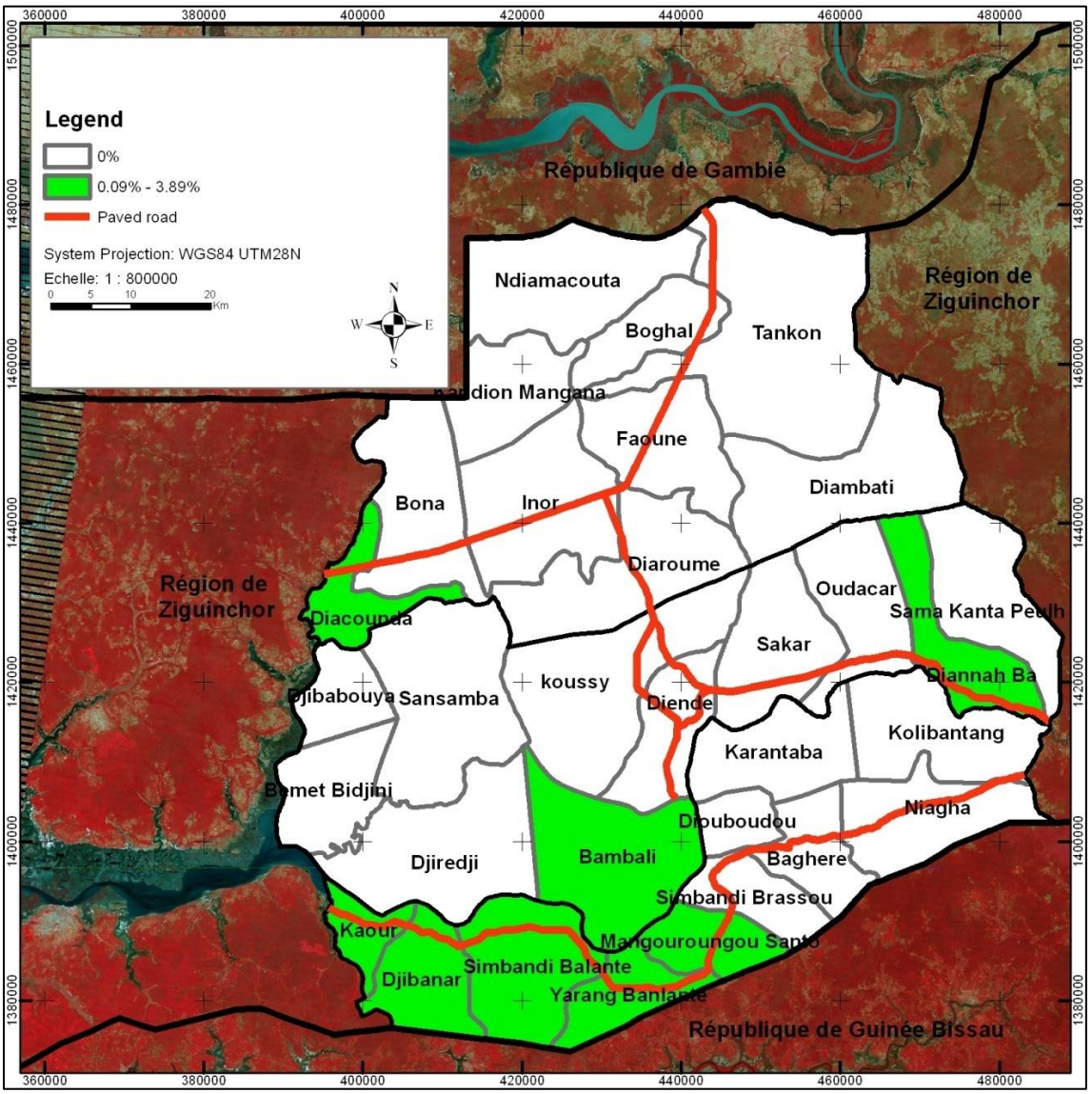


*Fig. 9 – "Tree plantations and orchards" (TP) class coverage percentages for each Communauté rurale of Sédhiou Region in 2005. Background: False color Landsat Image (Red=Vegetation).*

## 4.5 - Urban areas and rural settlements (U)

This class includes both urban areas and rural settlements. It covers a very low percentage of Sédhiou Region, around 0.5%. Accuracy assessment indicated that this class is underestimated due to the fact that several rural settlements have not been identified and often included in RHC class.

## 4.6 – Rivers (R)

This class includes areas covered by rivers, mainly Casamance e Soungrougrou, with a coverage percentage of around 5.5% on the whole Sédhiou area.

## 4.7 - Humid and natural areas (HA)

This class includes natural areas temporally or permanently flooded; it covers around 2.6% of Sédhiou Region.

# 5. Land cover changes during 1990-2005 period

LC changes during 1990-2005 period are given in Table 3 for the whole Region and its Departments. Surfaces interested by LC changes cover 614 km$^2$ corresponding to 8.3% of total Sédhiou area. The highest LC changes were recorded in Bounkiling (11.7%) Department, followed by Goudomp (7.5%) and Sédhiou (5.4%). At Communauté rurale level (Fig. 10), the highest changes occurred in those Communautés located in the northeast (Faounè and Tankon) and southwest (Kaour and Djibanar) with percentages higher than 20%; on the contrary changes were lower than 5% for 12 Communautés, located mainly in the southeast.

*Tab. 3 – LC change areas (km$^2$) and percentages for Sédhiou Region and its Departments (period 1990-2005).*

| CLASS | BOUNKILING DEPARTMENT | | GOUDOMP DEPARTMENT | | SÉDHIOU DEPARTMENT | | SÉDHIOU REGION | |
|---|---|---|---|---|---|---|---|---|
| | AREA | % | AREA | % | | AREA | % | AREA |
| HUMID NATURAL AREAS (HA) | 0.31 | 0.70 | 0 | 0 | 0 | 0 | 0.31 | 0.16 |
| IRRIGATED HERBACEOUS CROPS (IHC) | 0.95 | 1.94 | 0 | 0 | 0.29 | 0.30 | 1.23 | 0.55 |
| NATURAL VEGETATION (NV) | -183.16 | -8.35 | 63.54 | 6.98 | 3.99 | 0.23 | -115.64 | -2.45 |
| RAINFED HERBACEOUS CROPS (RHC) | 181.73 | 34.58 | -65.77 | -12.48 | -5.87 | -1.01 | 110.09 | 6.30 |
| TREE PLANTATION AND ORCHARDS (TP) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| URBAN AREAS AND RURAL SETTLEMENTS (U) | 0.18 | 1.74 | 2.23 | 16.60 | 1.60 | 16.18 | 4.01 | 10.58 |
| RIVERS (W) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

LC changes affected mainly three classes: “rainfed herbaceous crops” (RHC), “natural vegetation” (NV), “urban areas and rural settlements” (U). There were not relevant variations for “natural humid areas” (HA) and “rivers” (R) classes. “Irrigated herbaceous crops” (IHC) area showed an increase of 1.2 km$^2$, corresponding to 0.5% of the whole region; however this LC change was not statistically significant considering, as previously mentioned, that this class is hardly recognizable by the use of LANDSAT images and was overestimated in 2005. Therefore it is not possible to properly evaluate the change dynamics regarding low-land (“*bas-fond*”) areas between 1990 and 2005 only by the use of LANDSAT images. Given that during the last 20 years several “*bas-fond*” areas were heavily deteriorated and they are no longer usable (salinization and acidification problems and/or lack of maintenance), statistical data presented here

for this class are not reliable nor particularly useful for a better understanding of the occurred trend. A specific study, based on high-resolution satellite images, should be performed to assess changes regarding those valleys used for small rice fields.

Changes were not recorded for “tree plantations and orchards” (TP) class; this is probably related to what explained earlier, i.e. such arboreal areas are characterized by a reflectance firm similar to that of natural vegetation present in the south of the region. Therefore this class not only has been underestimated in 2005, but also LC changes from this class to natural vegetation or viceversa were not identified.

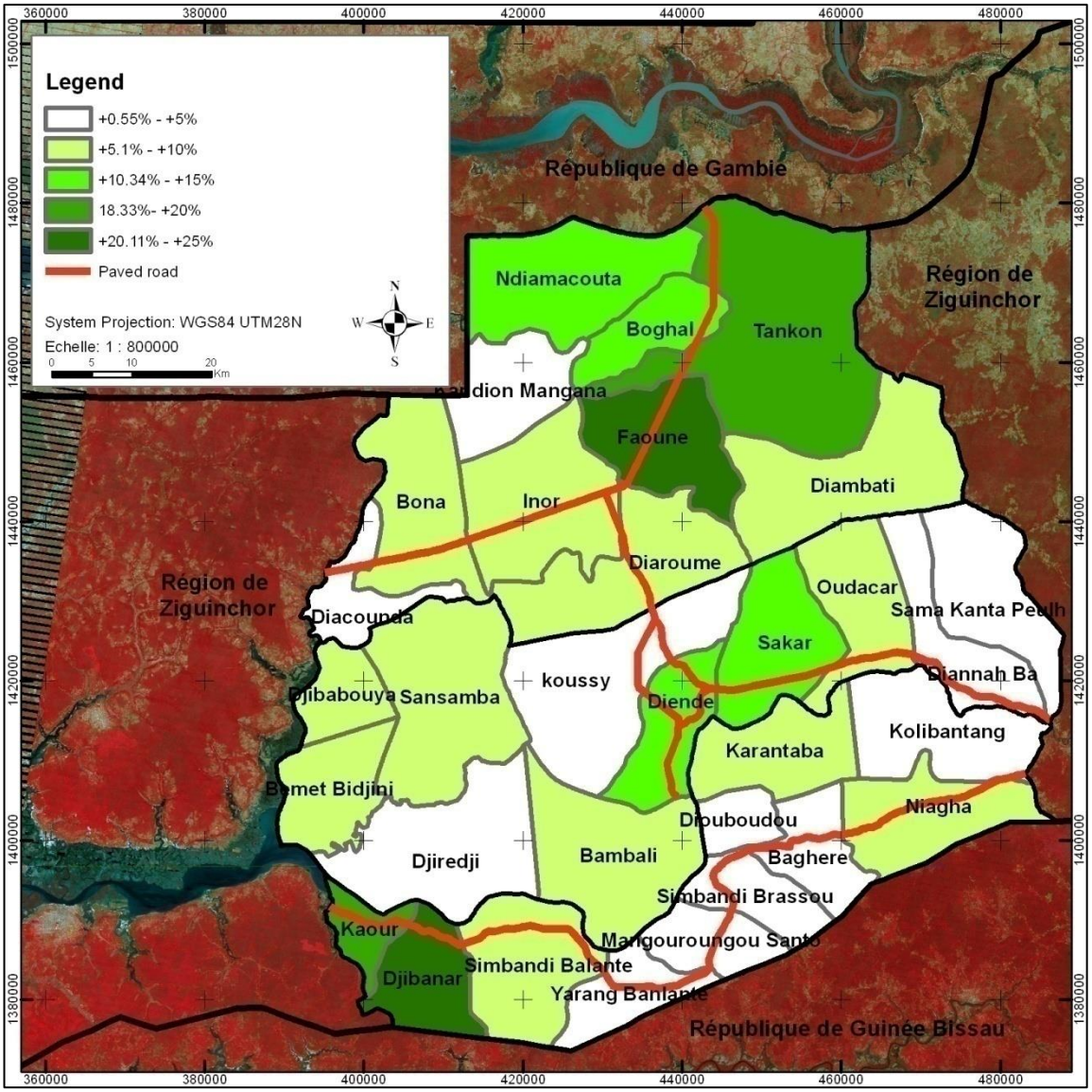


*Fig. 10.– LC change percentages for each Communauté rurale of Sédhiou Region (period 1990-2005). Background: False color Landsat Image (Red=Vegetation).*

An increase (+10.6%) was recorded for "urban areas and rural settlements" (U) class over the whole region; this result is consistent with the increase of population recorded in Sédhiou Region, but it has a low statistic value considering that such class is evidently underestimated both in 1990 and 2005.

A decrease (-116 km$^2$, corresponding to 2.5% of Sédhiou Region) was recorded for "natural vegetation" (NV) class; this represents a signal of the pressure that is occurring on the natural resources of the area. However different trends were recorded at departmental level (Table 3): a decrease in Bounkiling (-8.35%); almost no changes in Sédhiou (+0.23%) and an increase in Goudomp (+7%). The negative trend recorded for Bounkiling Department is the result of different tendencies at Communauté rurale level (Fig. 11): a considerable decrease for those located in the northeast (between +12 and +19% for Faounè, Tankon, Ndiamacouta and Boghal); moderate decreases (between -3.5 and -4.5%) for Diaroumè, Diambati and

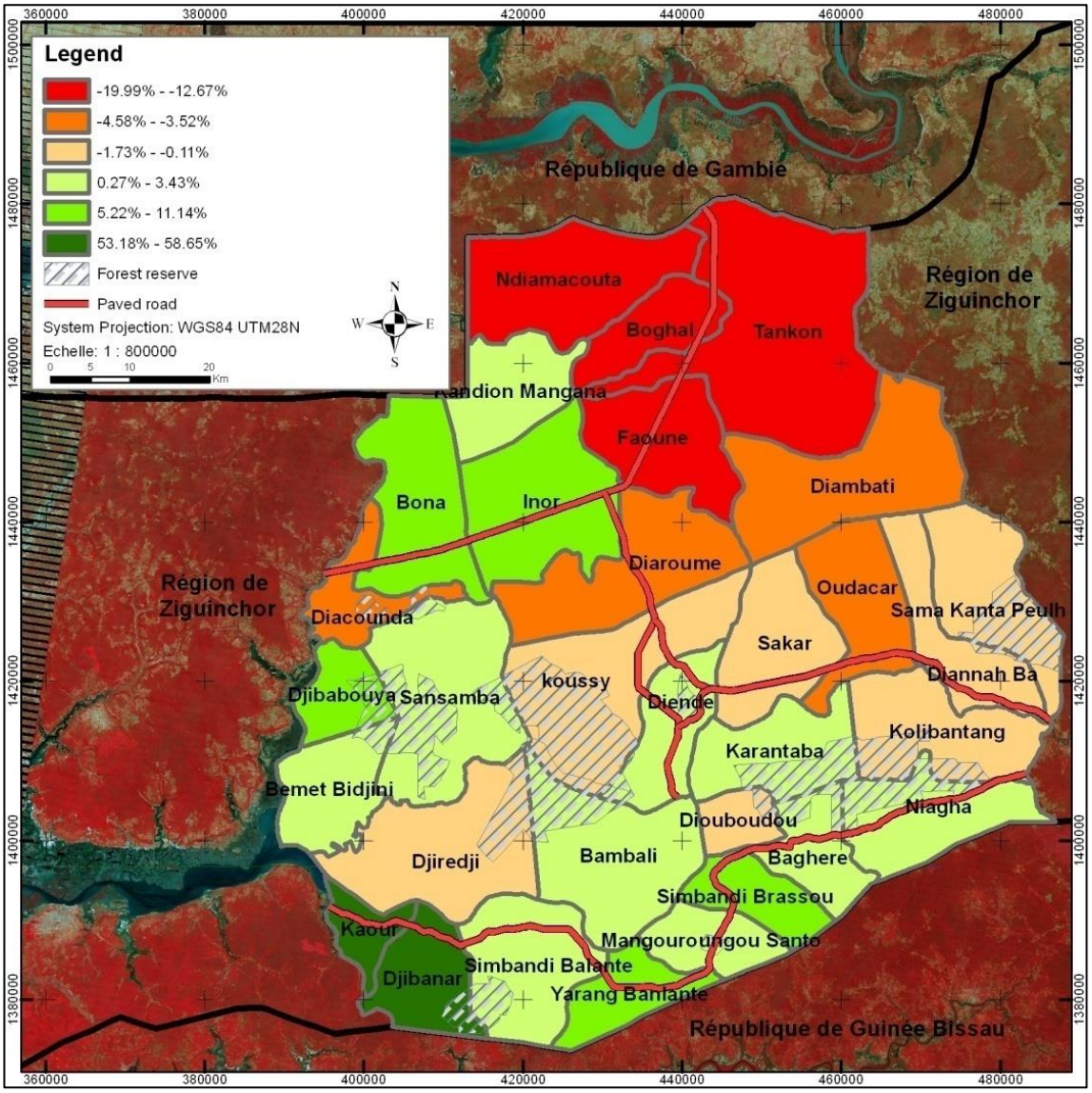


*Fig. 11 – "Natural vegetation" (NV) class changes (%) for each Communauté rurale of Sédhiou Region (period 1990-2005). Background: False color Landsat Image (Red=Vegetation).*

Kandion Mangana; increase for Kandion Mangana, Bona (+7%) and Inor (+11%). Different trends were found also for the Communautés rurales of Goudomp Department: moderate variations (between -1.7 and +5.9%) in most Communautés and a sharp increase of natural vegetation in Kaur and Djibanar, respectively with +53.2 and +58.7%.

On the whole, moderate small changes related to natural vegetation were recorded for those Communautés rurales that include *"forêts classées"* and *"roneraies"*. LC changes within forest reserves were very low, generally with an agricultural land decrease in favor of natural vegetation; the only marked exception was observed for Bafata *"forêt classée"* (Djibanar and Simbandi Balante Communautés rurales) with an increase of rainfed herbaceous crops (RHC). On the other hand, it has been noticed by supervisors of *Eaux et Forêts Service* that in some cases natural tree vegetation has been replaced with cashew cultivations, an aspect that was not highlighted by this analysis.

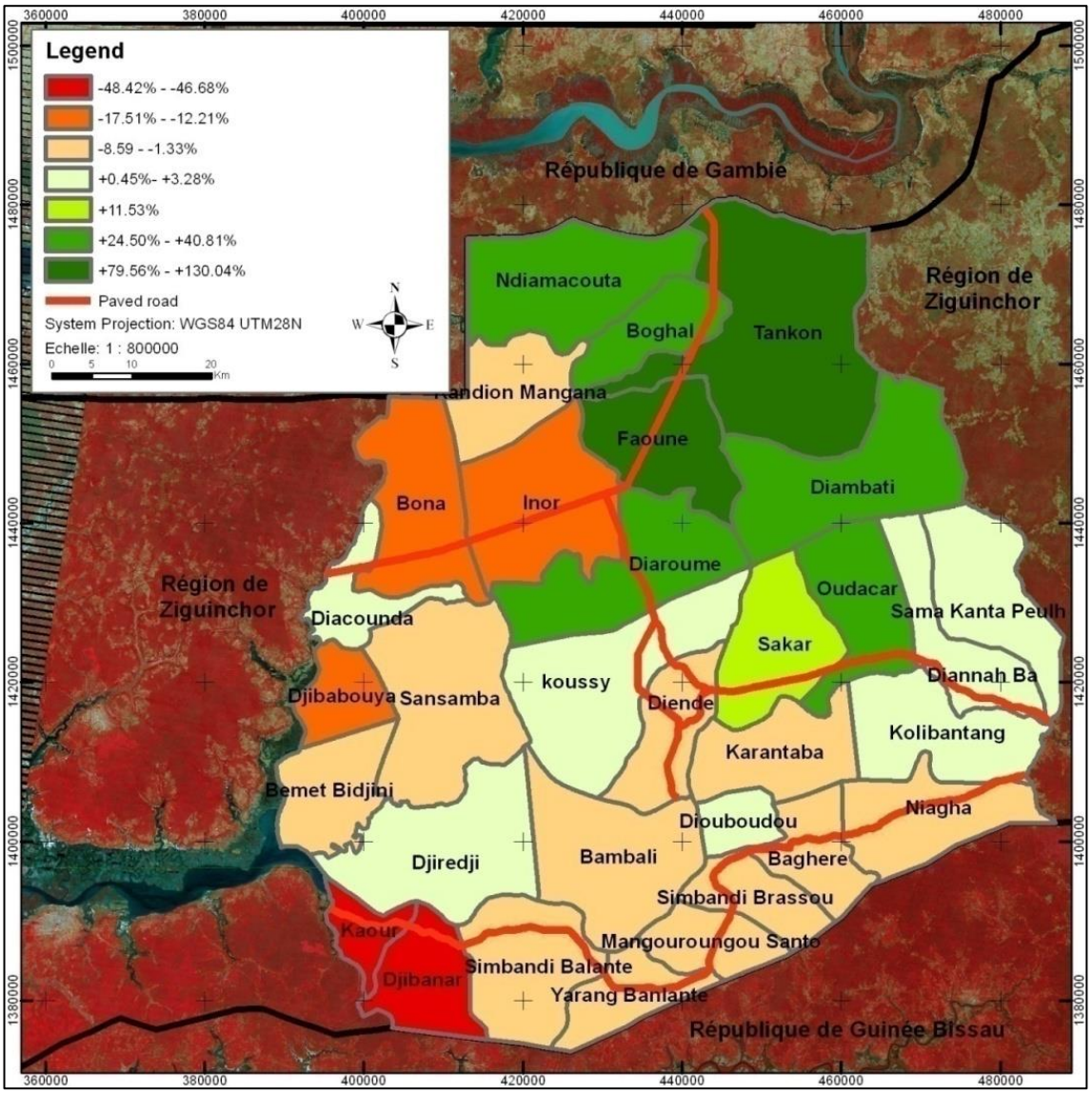


*Fig. 12 – "Rainfed herbaceous crops" (RHC) class changes (%) for each Communautés rurales of Sédhiou Region (period 1990-2005). Background: False color Landsat Image (Red=Vegetation).*

All these LC changes related to "natural vegetation" class are generally reverse to those recorded for "rainfed herbaceous crops" (RHC) class. RHC showed an increase in Bounkiling Department (+34%), a slight variation in Sédhiou (-1%), and a decrease of -12% in Goudomp. Regarding Bounkiling Department, a sharp RHC increase (Fig. 12) was found for Faoune (+80%) and Tankon (+130%) Communautés rurales; increases between 24 and 40% for Dairoume, Diambati, Boghal, Ndiamacouta; moderate variations for Kandion Mangana (-1.6%) and Diacounda (+2.4%), decreases for Bona (-16.5%) and Inor (-17.5%).

Moderate variations were recorded in Sédhiou Department for the majority of Communautés rurales, except increases for Oudacar (+11.5%) and Sakar (+33.5%) and a decrease (-12 %) for Djibabouya; moreover Plaine de Sefa area, characterized by crops with field sizes bigger than 2 hectares and located in Diende and Koussy Communautés, is practically unchanged. Lastly, moderate decreases were found in Goudomp Department for almost all Communautés rurales except Kaour and Djibanar (decrease of around -50%).On the whole, LC change dynamics in Sédhiou Region can be summarized as follows:

- Strong increase of rainfed herbaceous crops, resulting in a decrease of natural vegetation, in the north-east (Fig. 13). This trend is caused by immigration movements from the central areas of Senegal of Wolof people looking for new agricultural lands.

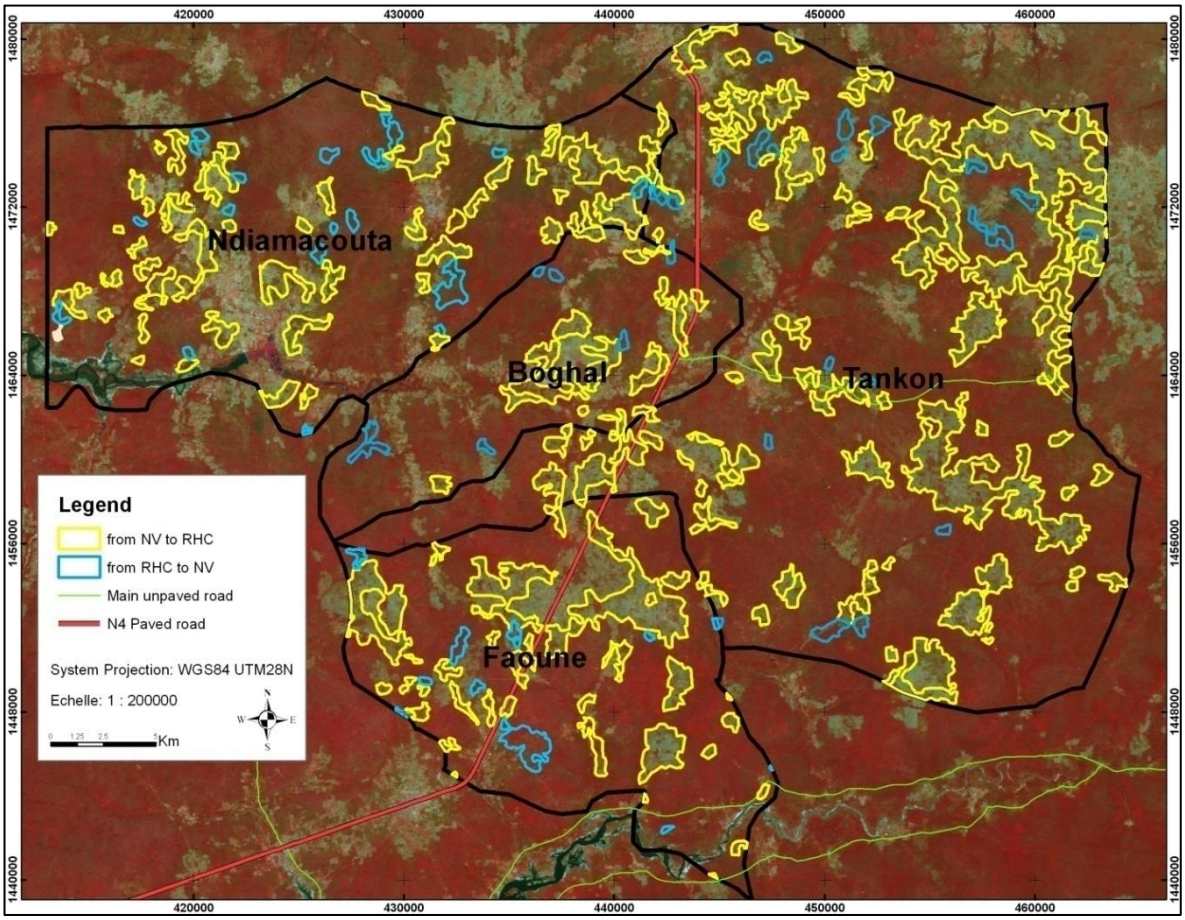


*Fig. 13 – Main LC changes (period 1990-2005) occurred in northeastern Communautés rurales (Tankon, Faoune, Boghal and Ndiamacouta). (NV= natural vegetation; RHC= rainfed herbaceous crops). 432 LANDSAT image acquired in November 2005. Background: False color Landsat Image (Red=Vegetation).*

- Reduction of rainfed herbaceous crops, with a resulting increase of natural vegetation, in the northwest (Bona and Inor Communautés rurales)(Fig. 14); this evolution is inverse to what occurred in the northeast and is probably linked to the fact that new Government Services (like Prefecture) were located in this area (Bounkiling Commune Urbaine) leading to urbanization processes. Therefore new job opportunities were created, also induced by N4 road paving, and a consequential abandonment of agricultural lands happened.

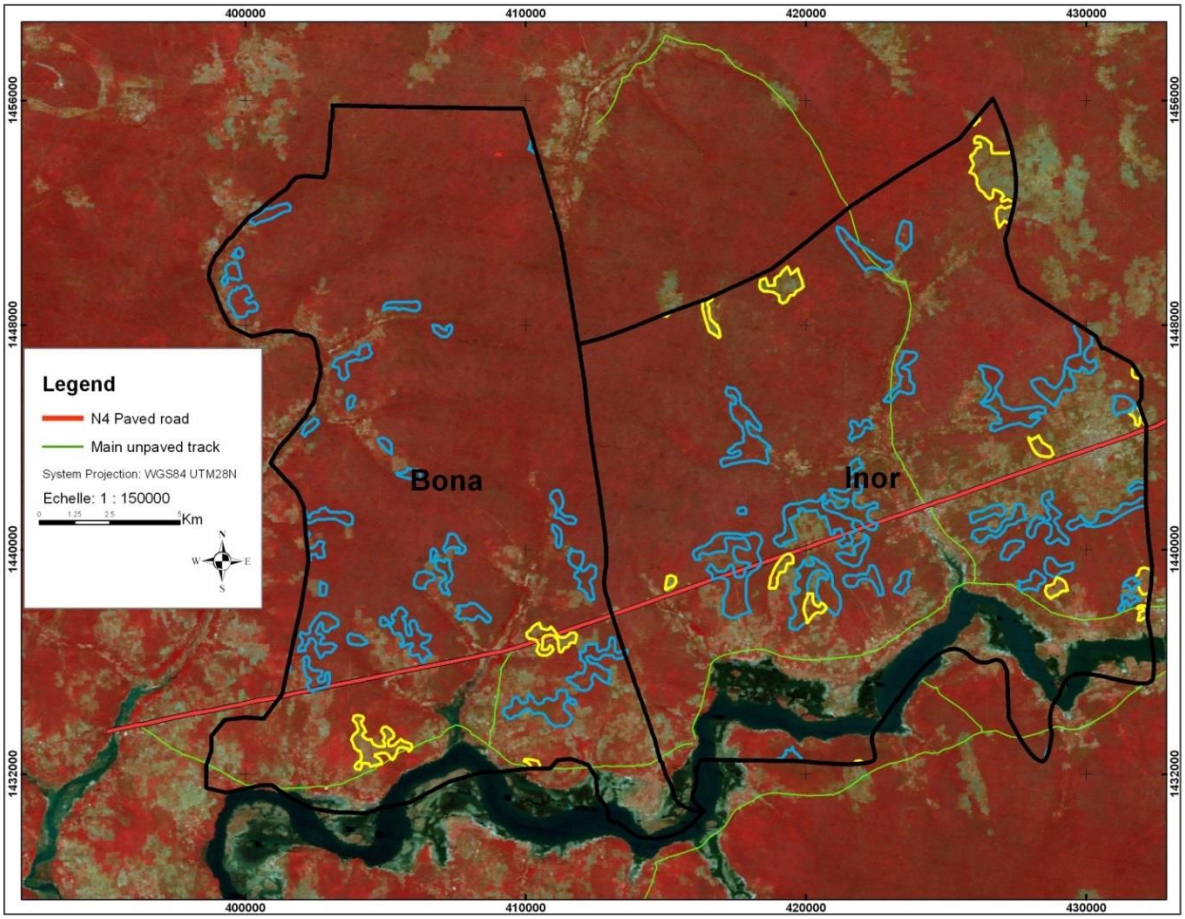


*Fig. 14 - Main LC changes (period 1990-2005) occurred in northwestern Communautés rurales (Inor and Bona). (NV= natural vegetation; RHC= rainfed herbaceous crops). 432 LANDSAT image acquired in november 2005. Background: False color Landsat Image (Red=Vegetation).*

- Significant reduction of rainfed herbaceous crops in the southwest (Kaour and Djibanar Communautés rurales) with return to natural vegetation (Fig. 15); this trend is linked to the fact that this area was previously the most accessible of the region through N6 paved route towards Ziguinchor. Later Goudomp Department became almost isolated due to the bad conditions of N6 route; this had serious repercussions especially in the western area that had the greatest amount of agricultural surfaces. Other factor that probably caused this evolution was the insecurity of the area caused by the Casamance Conflict, a low-level civil war that has been waged between the Government of Senegal and the Movement of Democratic Forces of Casamance. During the end of the 90' the conflict reached the highest intensities with thousands of deaths. Moreover after the conflict the presence of mines in the south near the boundaries with Guinea Bissau discouraged rural activities. This trend is consistent with the gradual loss of economic importance of Goudomp Department.

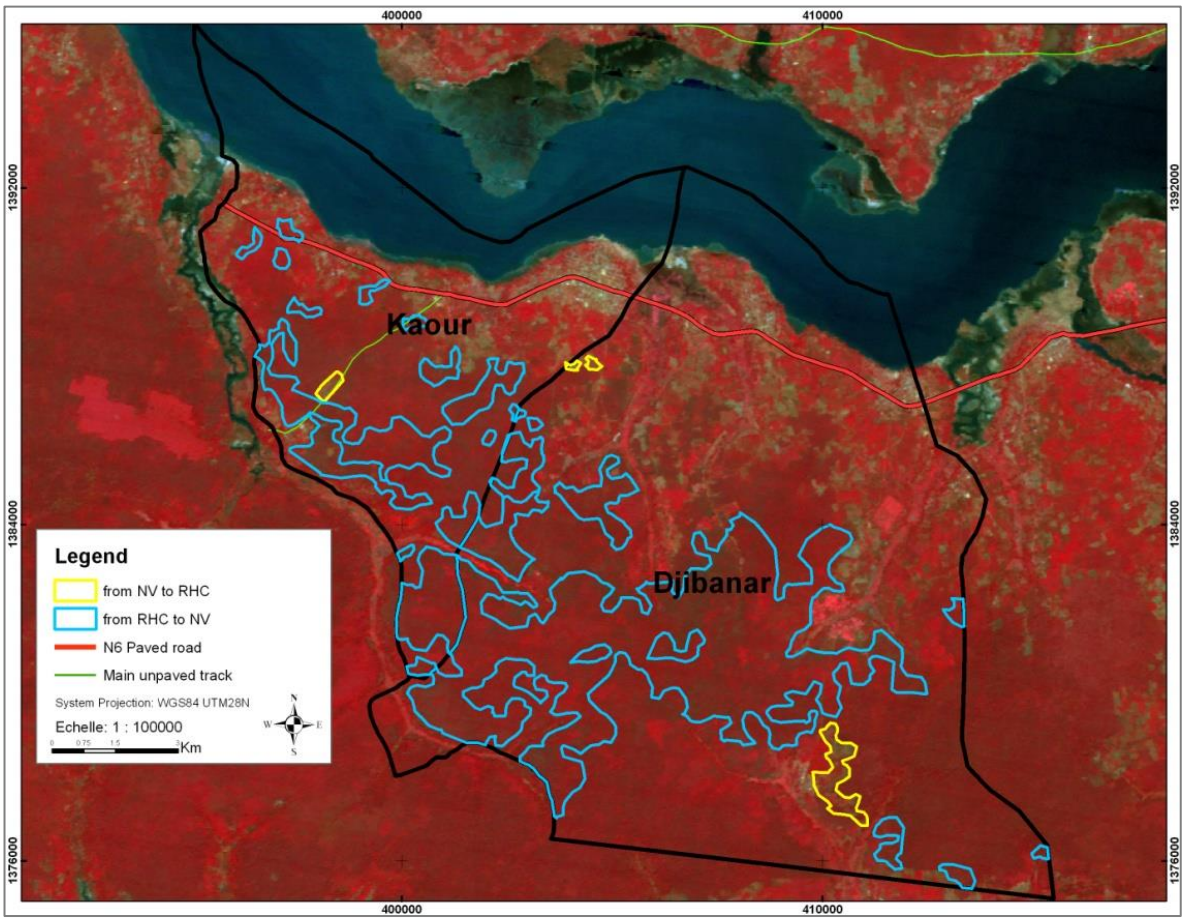


*Fig. 15 – Main LC changes (period 1990-2005) occurred in southwestern Communautés rurales (Kaour and Djibanar). (NV= natural vegetation; RHC= rainfed herbaceous crops). 432 LANDSAT image acquired in November 2005. Background: False color Landsat Image (Red=Vegetation).*

- Moderate changes in Sédhiou Department although it is less isolated compared to the past due to the construction of R22 and R23 paved roads that connect Sédhiou town to N4. Plaine de Sefa area, characterized by extensive cultivations, has remained almost unchanged. Eastern Communes, except Oudacar and Sakar, did not seem to take advantage, from a agricultural-productive point of view, of the construction of R21 paved road towards Kolda. Very few changes were recorded in the eastern and southeastern areas: here, a rural social structure still prevails in a territory with a high percentage of natural vegetation and few agriculture, mainly of subsistence.

# 6. Sédhiou Region population dynamics

Sédhiou Region population dynamics were analyzed using 1988 Census data and 2008 estimates based on 2002 Census data. 2008 population estimates were chosen because they were the most recent available data aggregated according to the actual Communautés rurales boundaries; therefore these were the only data able to highlight departmental and Communauté rurale dynamics.

Population of Sédhiou Region (Table 4) was in 1988 over 280,000 inhabitants with a density of 38.42 ab/km$^2$. This density was much higher than those of neighboring regions (Kolda and Velingara) that were characterized in 1988 by respectively 15.8 and 17.5 ab/km$^2$. The region was characterized by a large number of small villages (several hundreds), 2 villages with a population of between 5,000 and 10,000 inhabitants (Goudomp and Marsassoum) and only one town with a population of almost 13500 inhabitants (Sédhiou). Sédhiou and Goudomp Departments were more populated (just over 100,000 inhabitants) than Bounkiling (73000). Departmental population densities, ranged from 25 ab/km$^2$ (Bounkiling), to 39 ab/km$^2$ (Sédhiou) and to 59 ab/km$^2$ (Goudomp). The low population density found in the north depended presumably from its isolation and its traditional pastoral vocation; Sédhiou Department, even though the administrative regional center (Sédhiou town) was inside its boundaries, was poorly reachable; in fact R21, R22 and R23 roads were still not paved. Goudomp Department on the contrary had the best road network thanks to R6 paved road and represented the most important area both in terms of demography and economic and productive importance. Population densities per Communauté rurale (Fig.16) were higher in the southwest, while the whole eastern area, particularly the northeast, had low population densities.

*Tab. 4 – Population, densities and growth rates during 1988-2008 period in Sédhiou Region and its departments.*

| | POP. 1988 | ab/Km$^2$ 1988 | POP. 2008 | ab/Km$^2$ 2008 | GROWTH RATE 1988/2008 |
|---|---|---|---|---|---|
| DEP. BOUNKILING | 73004 | 25.27 | 105,065 | 36.36 | 1.84 |
| DEP. SÉDHIOU | 106,997 | 39.27 | 157,783 | 57.91 | 1.96 |
| DEP. GOUDOMP | 102,081 | 59.10 | 143,938 | 83.34 | 1.73 |
| REG. SÉDHIOU | 282,082 | 38.42 | 406,786 | 55.41 | 1.85 |

According to 2002 census data projected to 2008, regional population was in 2008 around 406,000 inhabitants with a density of 55.41 ab/km$^2$ and a growth rate of 1.83% during 1988-2008 period. This growth rate is however not uniform across the twenty years period: it is lower (1.34%) from 1988 to 2002, then increases to 2.84% during 2003-2008 period. The growth rate measured during the period 1988-2002 is also lower than that of neighboring Regions Kolda and Velingara (respectively 3.1% and 3.2%). In 2008 urban population percentage reached 18.43% (63330 inhabitants). Departmental growth rate ranged from 1.73% (Goudomp) to 1.96% (Sédhiou). This trend is consistent with the loss of productive and economic importance of Goudomp Department for the reasons mentioned above. On the other hand, the higher growth rate recorded for Sédhiou and Bounkiling appears to be linked to their improved accessibility achieved by the creation of paved roads. Regarding Communauté rurale population densities (Fig. 19), the highest values were found in the southwest and, except for Diannah Ba, in those Communautés rurales that contain a Commune Urbaine (i.e. a main locality). The northeastern and eastern areas are generally still characterized by lower population densities.

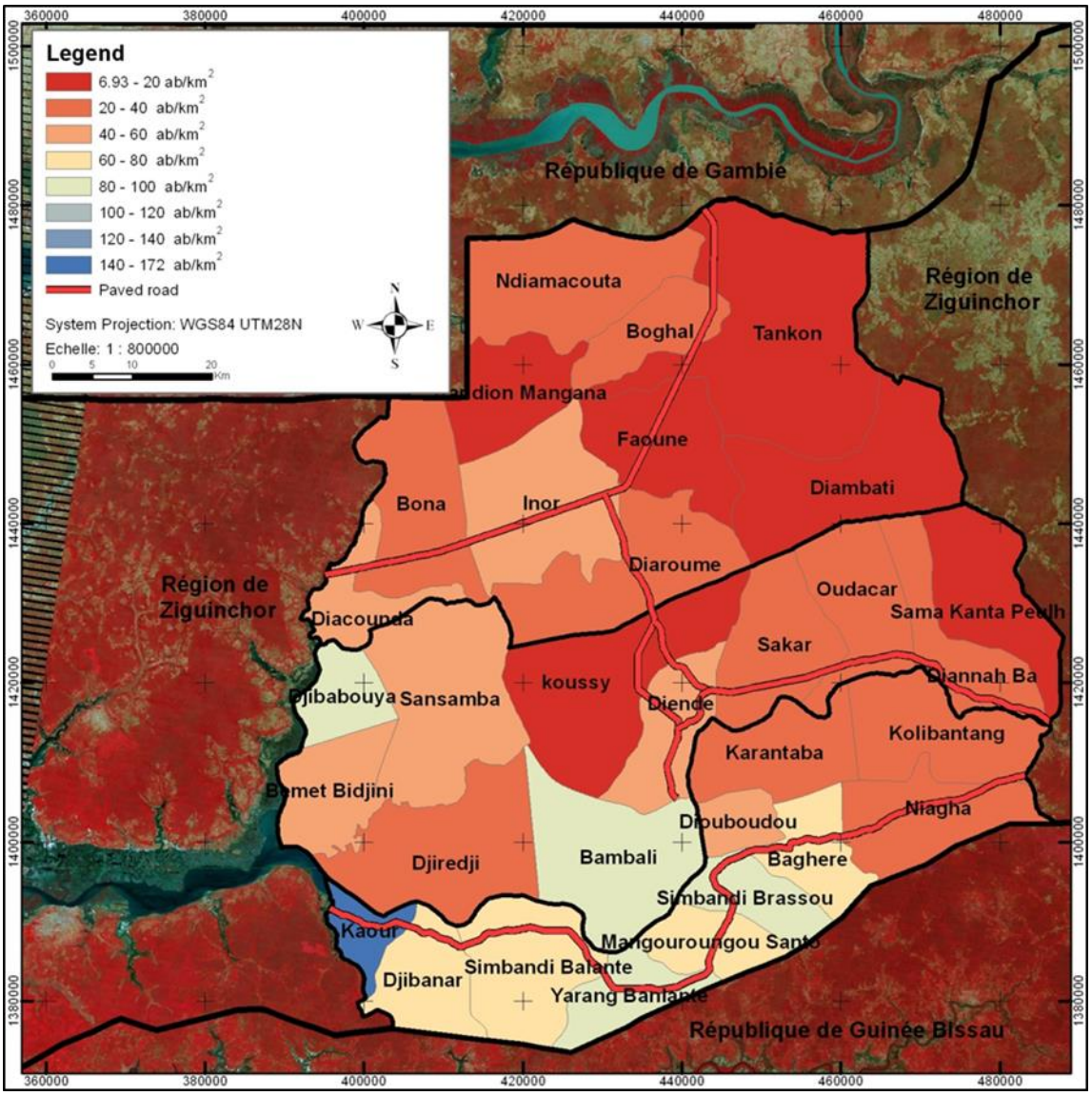


*Fig. 16– 1988 Population densities (ab/Km2) per Communauté rurale of Sédhiou Region. Background: False color Landsat Image (Red=Vegetation).*

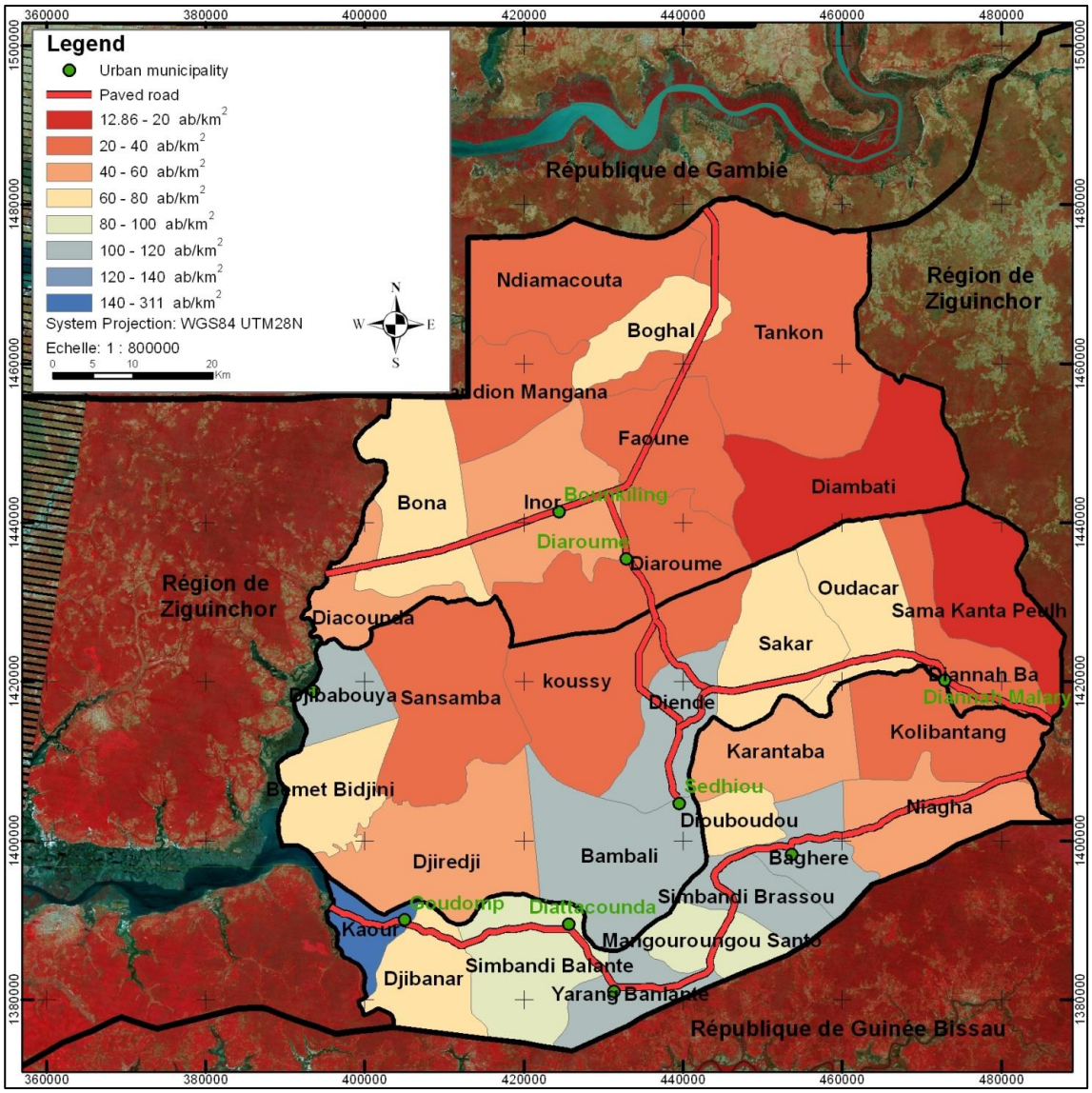


*Fig. 17– 2008 Population densities (ab/Km$^2$) per Communauté rurale of Sédhiou Region. Background: False color Landsat Image (Red=Vegetation*

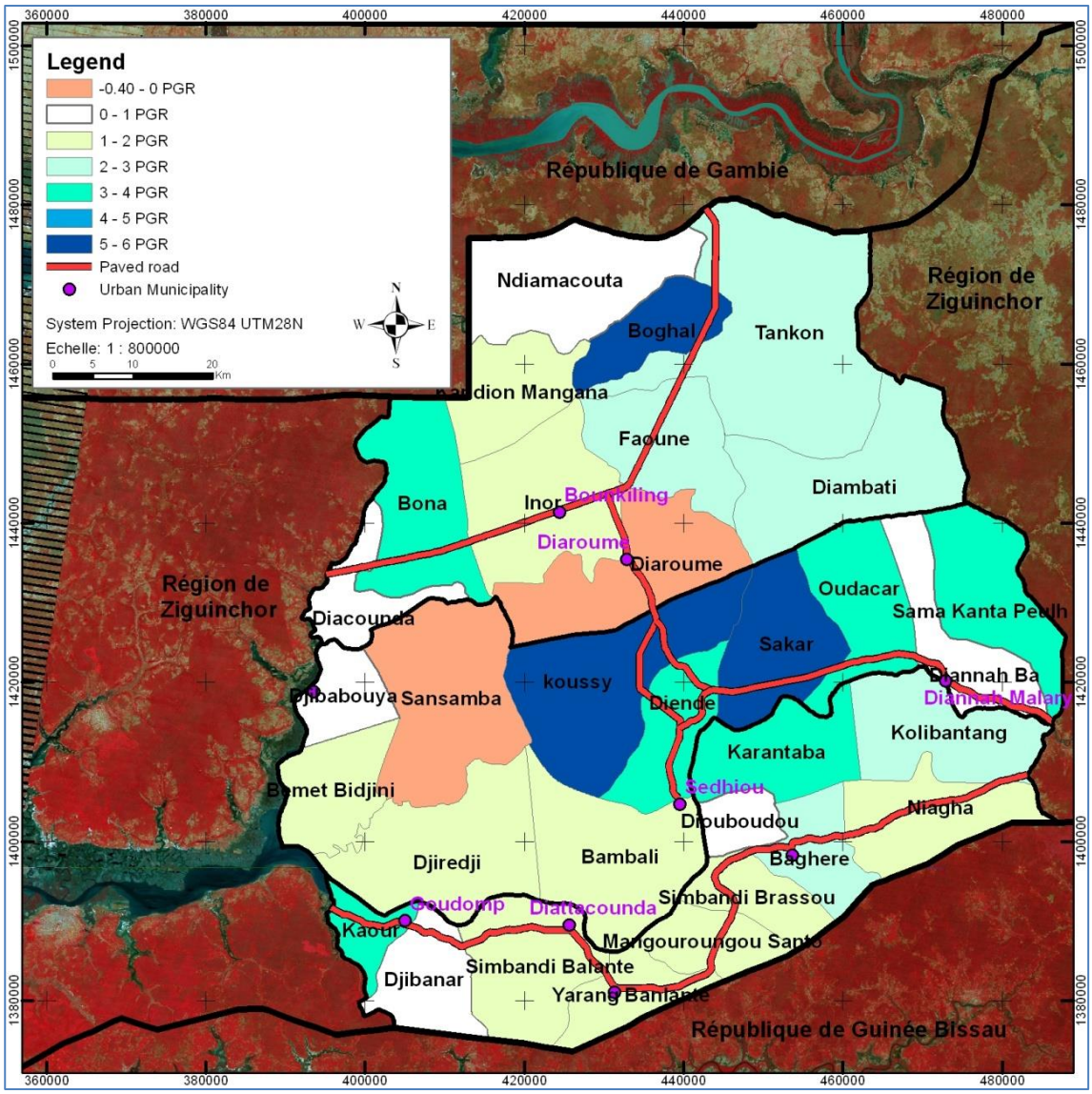


*Fig. 18 Communauté rurale population grow rates (PGRc) during 1988-2008 period. Background: False color Landsat Image (Red=Vegetation).*

# 7. Conclusions

The present study has identified some dynamics that characterize Sédhiou Region and others related to specific Communautés rurales. Sédhiou Region did not show homogeneous trends throughout the whole area, but rather conflicting dynamics and five different areas were identified (Fig. 19):

**Northeast (Bounkling Department)**: area traditionally sparsely inhabited and poorly devoted to agriculture that actually is increasing its population and where agriculture shows the highest growth in terms of surfaces. The main dynamic is a sharp increase of rainfed agricultural land to detriment of natural vegetation (resulting in an exploitation of forestry natural resources) and a significant increase of population (except Ndiamacouta). As mentioned above, this trend probably depends on its improved accessibility, on its position nearby Gambia to which it is connected by N4 paved road, on immigration movements from the central areas of Senegal of people looking for new agricultural lands, on the creation of specific production markets (Faoune is actually an important area for the production of charcoal). Regarding Ndiamacouta, this Communauté rurale lives a strong increase of agricultural lands in the east, but in the west near the boundary with Gambia there are security problems that pushed resident people to move away.

**Northwest (Bounkling Department)**: area traditionally characterized by a low population density. A decrease of rainfed agricultural land with return to natural vegetation was recorded. As explained above, this is probably linked to the fact that the creation of new Government Services generated new job opportunities that lead to a consequential abandonment of agricultural lands. Moreover the paving itself of R4 offered new trade opportunities to resident people. The administrative and economical importance reached by Bona Communauté rurale is probably the explanation also to the fact that the increase of population in the Communautés rurales of this area was generally lower (except Bona) compared to that of the whole region.

**West (Department of Sédhiou):** decrease of rainfed agricultural land in Djibabouya, Bemet Bidjini and Sansamba Communautés rurales; there is also a low population growth rate for Djibabouya and Bemet Bidjini, and even a decrease of total population for Sansamba that is caused by the creation of the Yassine "*forêt classée*". This trend is probably related to the poor state of local road network that is composed only of unpaved tracks and departmental roads.

**Center (Department of Sédhiou)**: area characterized by a fast population growth rate (Koussy, Diende, Sakar and Oudacar Communautés rurales) and very modest changes regarding rainfed agricultural surfaces. Two exception were identified: Diaroumè had a low population growth rate and the reason is related to the fact that there are not important villages in this Communauté rurale and therefore people moved, according to actual urbanization processes, from their little villages to more important localities located in other nearby Communautés; Oudacar lived a strong increase of agriculture and this is probably linked, as for the northeast area, to recent immigration movements from the central areas of Senegal of people looking for new agricultural lands. On the whole, the trend of this area is probably due to the good level of accessibility reached by the recent paving of R21, R22 and R23 roads and due to the fact that the important agricultural Plaine de Sefa area (the only area in Sédhiou Region with agricultural fields greater than 2 ha) is almost unchanged during the last two decades.

**East (Department of Sédhiou)**: this area shows moderate changes regarding both population and agricultural surfaces; it remains one of the most rural areas of the region. From the present analysis, it seems that the construction of the R21 paved road, which touches marginally Diannah Bah and Sama Kanta Peulh Communautés rurales, did not have an impact on the area, at least

referring to the period of the analysis. Nevertheless, recent immigration flows from northern regions, show that in this area the trend could be similar in the future years to that of eastern Bounkiling.

**South (Department of Goudomp)**: this area shows a strong decrease of agricultural land surfaces, especially for Kaour and Djibanar Communautés rurales. The population growth rates are above the regional average only for Kaour and Baghere Communautés rurales; these latters include respectively Goudomp and Tanaff urban localities and presumably centralize both urbanization processes and migratory movements from Guinea Bissau and from more insecure areas that have lost their productive relevance.

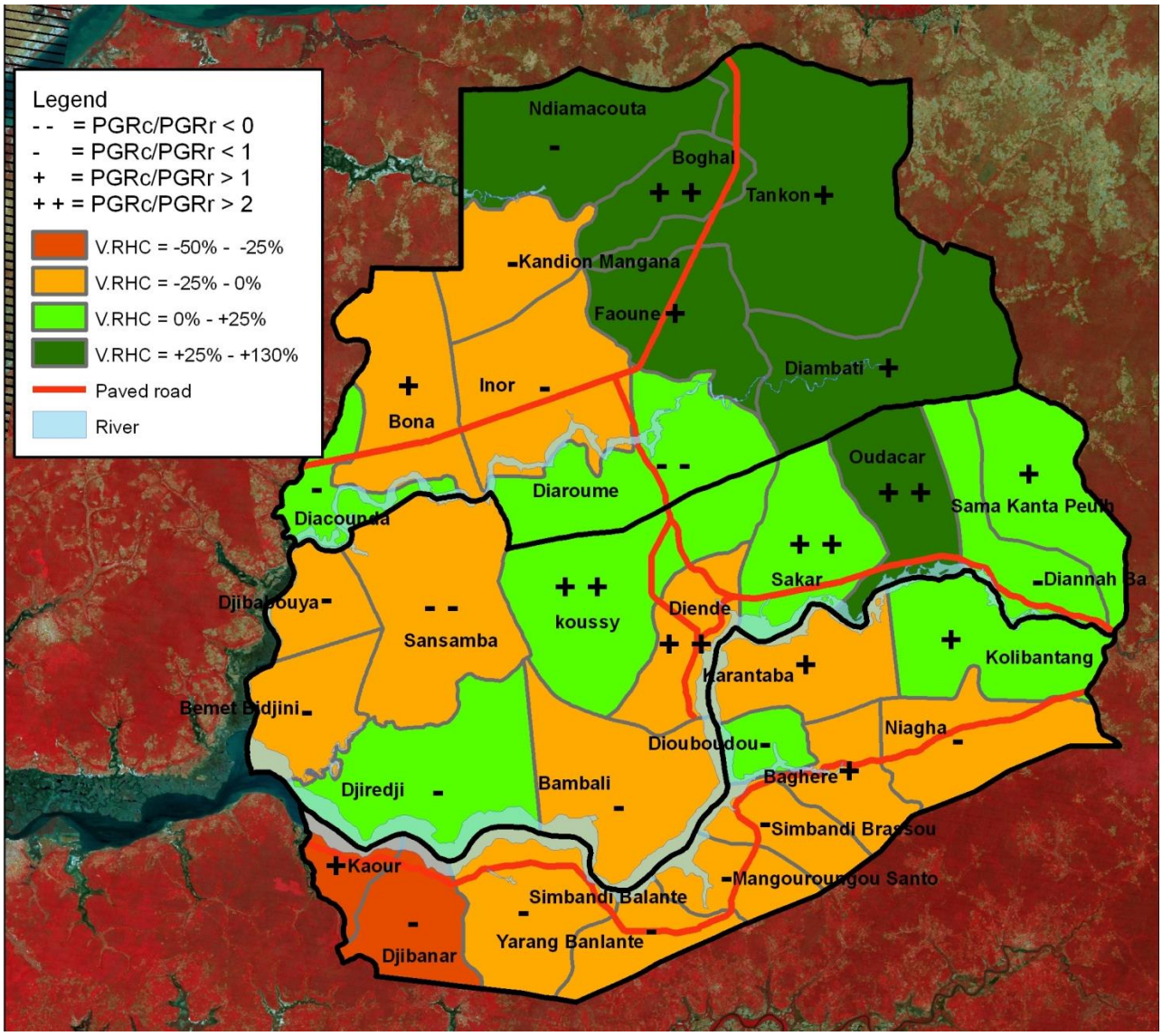


*Fig. 19 Comparison between "rainfed herbaceous crops" class percentage changes (V.RHC) and Communauté rurale growth rates normalized to Sédhiou Region growth rate (PGRc/PGRr). Background: False color Landsat Image (Red=Vegetation).*

# 8. Comments and recommendations

The present study was done on the basis of the available information and data. The analysis has shown some limitations, regarding both land cover and population data. A finer analysis is needed to better understand the evolution of certain land cover classes, in particular: i)“ irrigated agricultural areas” (IHC), ii)” tree plantations and orchards”(TP), iii) impacts of population fluxes interesting the northern part of the region.

**Irrigated herbaceous crops (IHC)**: Field visits and interviews hold in Sédhiou indicated that Land Use changes are strongly affecting the rizicultural system, i.e. rainfed rice areas are increasing in the highlands while a reduction of rice fields in lowland (“*bas-fond*”) areas is evident. Indeed, many lowland areas, even equipped with anti-salt dams, appeared abandoned or under-exploited. The decline of lowland rice cultivation and the consequent land use change, bringing often to an accelerated degradation of valleys, is due to a complex mix of physical, economic and social drivers. Nevertheless, analyzing and monitoring the extent of this phenomenon appears as a critical issue in order to understand regional production systems dynamics and potentials. Landsat images did not allow a precise identification of cultivated valley areas due to the small size of rice plots. Thus, a specific study based on high-resolution satellite images should be performed in order to assess land use changes regarding the valleys used to produce lowland rice.

**Tree Plantations and orchards (TP)**: Field visits and interviews hold in Sédhiou indicated that a key aspect in recent Land Use changes is a diffuse implantation of new cashew cultivations. It has been observed specially in Sédhiou Department, but also, though to a lesser extent, in the Bounkiling one. According to supervisors of Eaux et Forêts Service cashew cultivations are also threatening Sédhiou forest reserves and are replacing the natural vegetation that occupied agricultural lands in Goudomp Department. The analysis for this land cover class did not allow to appreciate any change, mainly due to the almost identical spectral firm of tree plantations and surrounding forest. A specific analysis based on high-resolution satellite images could allow to overtake these limitations mainly related to the low spatial and spectral resolution of Landsat images.

**Land Cover and Population dynamics:** The analysis shows clear trends of Land Cover changes and population dynamics in the northern part of the region. In this area, the population pressure, increased by recent fluxes of migration from the north of Senegal, on the agro-ecosystem of Tankon, Boghal, Ndiamacouta, Faoune and Diambati Communautés rurales appeared stronger and stronger. On one side the increasing loss of natural vegetation due to human pressure seemed evident, on the other a quite total lack of infrastructures for the new colonies was recorded. Regarding population dynamics analysis, better results could be achieved when the 2012 Census data of single localities will be available from the Agence Nationale de la Statistique et de la Démographie. Then the analysis could also be extended to 2012 by interpreting 2012 Landsat images. This would provide an updated picture of the regional actual situation showing if emerged dynamics on the 1990-2005 period are still continuing or not, or whether new ones are arising. Certain areas may currently live both social and environmental changes that this analysis, related to 1990-2005 period, could not identify.

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