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Remote sensing mapping of the rice fields and vegetal cover in the sub-watershed of Ebinkine (Lower Casamance, Senegal)

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Abstract

Rice lowland Lower Casamance is facing a double bind , climate and soil salinization , noticeable in rice areas sub-basin of Ebinkine which covers an area of 2,429.7 ha. This led to the implementation of anti-salt dams and micro-dams in the valleys. The aim of this work is to study the dynamics of paddy fields and vegetation cover in this sub- Watershed from processing and analysis of satellite images. The methodology used is mainly based on a supervised classification of Landsat TM satellite images of 1984, 1992 and Landsat ETM + 2000 and 2010 associated with fieldwork. The analysis of the dynamics of land use show that rice fields occupying 615.0 hectares in 1984; 581.1 hectares in 1992; 402.2 hectares in 2000 and 415.8 hectares in 2010. The sharp decline of rice cropping is caused by a rainfall defect, as well as mismanagement of the water after the establishment of micro-dams in the sub watershed in 1996. These have led to a flood of 123.6 hectares of rice paddies in the upstream areas of the watershed. Meanwhile, an increase in shrub-trees-savannah between 2000 and 2010, it is the result of natural regeneration promoted by the expansion of plantations of *Anacardium occidentale*. However, recent illegal timber exploitation has increased between 2000 and 2010 in the area.

Keywords: Lower Casamance, micro-dams, satellite images, cartography, supervised classification, Land cover

1. Introduction

Lower Casamance, southern Senegal located in the region of Ziguinchor, covers an area of 7,339 km2 (Figure 1). In terms of climate, it belongs to coastal South Sudanese domain (Sagna, 2005), which in this position makes it one of the wettest areas of Senegal. It is traversed by many rivers and valleys during (the Casamance River and its tributaries) with a concentration of surface and subsurface runoff and promoting cultivation of these depressions. Lower Casamance is subject to salinization exacerbated by climate variability, since 1968 marked by a significant decline in rainfall and a change of water regime and reduced flows of the Casamance River and its tributaries (Sane, 2005). Some of the valleys are also marked in their operation by a deep invasion of the sea inland because of the low slopes (less than 1%). Agricultural activities, the main sources of income and food for the population are affected. Therefore, controlling perceived as a strategy to secure rice production water, resulting in the development of small hydro-agricultural works of traditional design. The purpose of these hydraulic micro-structures is profitable some of those affected by salinization and rainfall deficit to intensify rice production valleys. These various questions, salinization lowlands and valleys, evolution of rice and production of anti-salt Lower Casamance micro-dams, raised in the 1960s the interest of many researchers including Diédhiou, 2004; Montoroi, 1996; Brunet, 1994; Boivin and Brunet, 1990; Berton, 1988; Aubrun, 1987; Barry, 1987; Marius, 1987; Marzouk, 1981; Beye, 1975, 1981;. Moreover, the construction of modern anti-salt micro-dams is known only been here the last two decades. The proliferation of these types of structures accentuates the change in land use, been little work in the area. This theme has become essential in most cartographic inventory and monitoring of environmental phenomena (Ouattara and *al*., 2006). And this is because the planning and monitoring of rice spaces are a constant concern of those involved in the management of water resources, we undertook this study of the sub-watershed of Ebinkine, characterized by a predominance of rice (over 80%). The main activity is influenced by climatic factors that induce significant changes. Remote sensing is an appropriate tool to understand the spatio-temporal changes of land use (Lambin, 1988). With their wide spatial coverage, high repeatability and low cost, Landsat images are preferred data to identify differences zone status by observing at different dates (Inglada, 2001). The use of satellite data for mapping land cover change is now widespread (Chavez and Mackinnon, 1994), especially as the maximum time interval of thirty years for Landsat images. The main factors limiting the sensing changes are differences in weather conditions, acquisition geometry and ground conditions (Muchoney and Haack, 1994, Song et al, 2001). In addition, the strong dependence of the spectral characteristics is one of the main reasons for the lack of reliability of the classified map (Manandhar, 2009). To overcome this constraint own remote sensing, we relied on field data to improve the classification accuracy and reliability of land obtained from Landsat data from 1984, 1992, 2000 and 2010 cards.

1.1 ***Presentation of the study area***

The study area covers the sub watershed of Ebinkine (Figure 1), located between 12 ° 55'et 12 ° 59 'north latitude and between 16 ° 25'30" and 16 ° 30'30" of west longitude, in the rural community of Djinaky, Bignona. This sub-basin is traversed by numerous valleys. It is the watershed backwater Baïla a slope of 0.0125%. It spreads over 70 km from NE to SW and 35 km from NW to SE, with low elevations (0 to 37 meters). Impoundment was in 1996 with the aim to promote the intensification of rice by desalination of rice paddies.

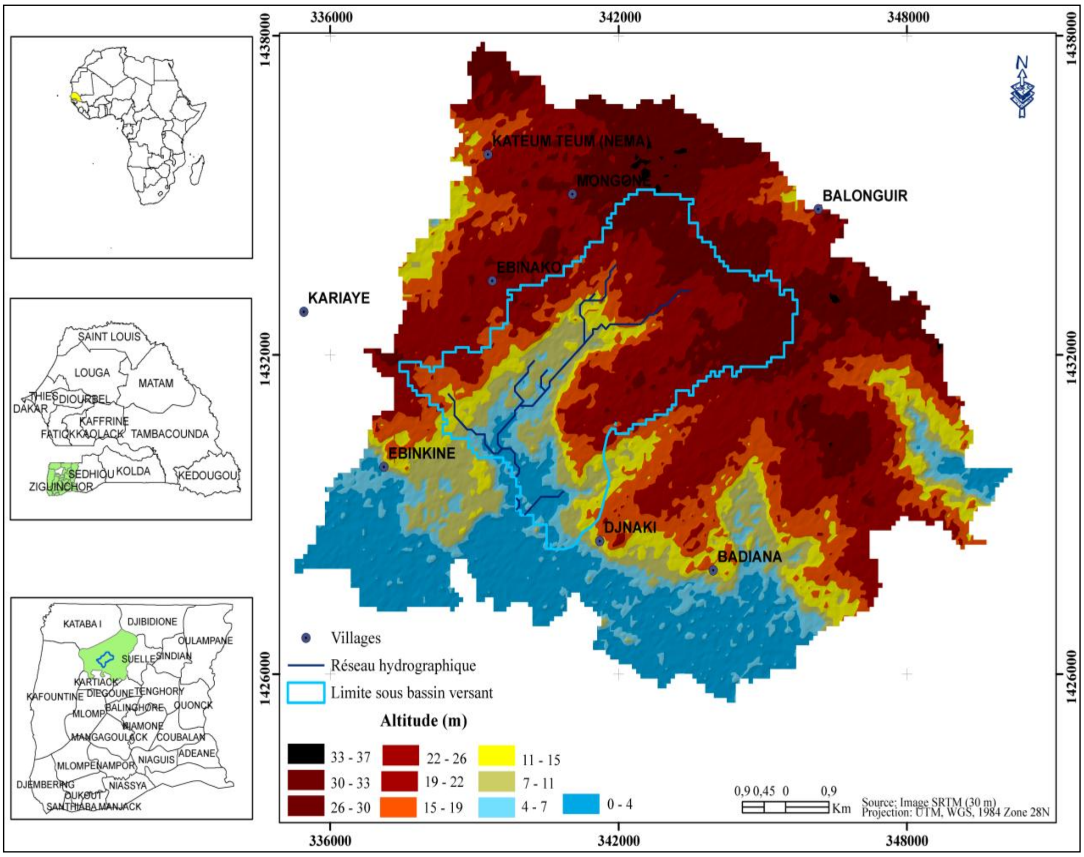

Figure1: Location of Ebinkine sub-watershed

2. *Material and Method*

2.1. *Climate Data*

The data used here are climatic, satellite and ground control. The analysis of climate data from 1960 to 2010 covers the area of Diouloulou situated 20 km from the sub-basin and with the only weather station close to our study area. Figure 2 shows two distinct periods in the evolution of annual rainfall, 1960-1970 and 1971-2010; 1970 can be considered breaking year. Indeed, it is from this date that starts declining rainfall amounts precipitated in the sub watershed Ebinkine.

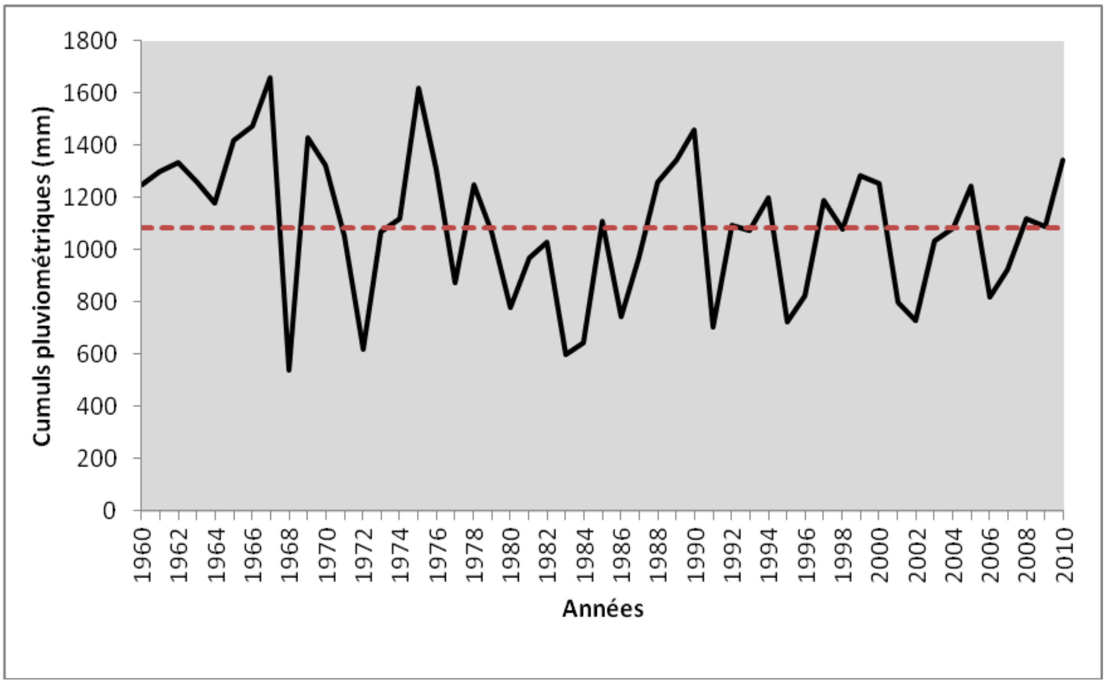

Figure 2: Annual rainfall of Diouloulou station between 1960 and 2010

This change in two periods, one period excess and deficit is much more visible on the graph centered differences reduced (Figure 3). The period 1960 -1970 is in excess when compared to the average of 1960-2010 (1084.5 mm) with only one year of deficit in 1968 (538.8 mm). The 1971-2010 phase of deficit continues today even though there falls a few excess pockets. Examination of the distribution of rainfall in the catchment in the basin Ebinkine therefore shows a great annual variability of distribution, with a general downward trend.

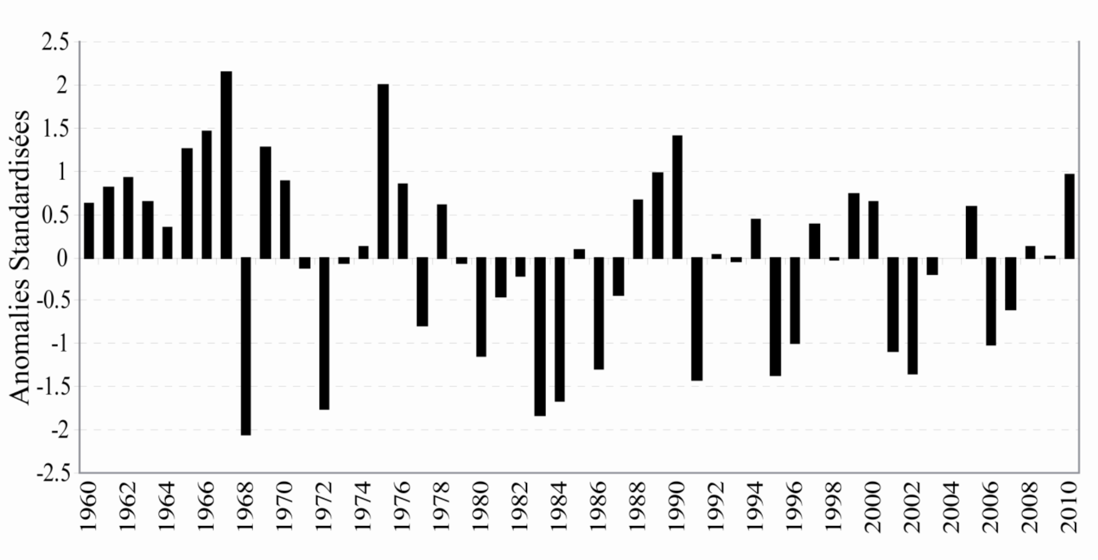

Figure 3: Standardized anomalies of annual rainfall of Diouloulou between station 1960 – 2010

2.2. ***Measuring the salinity of rice land***

To assess the impact of micro-dam on the salinity of rice land, a composite soil sampling was conducted randomly upstream of the anti-salt micro-dam. Samples are collected at the top 25 cm of soil. The determination of the salinity was carried out at the Laboratory of Analytical Methods to the Research Institute for Development (IRD) in Dakar.

2.3. ***Satellite data used***

Mapping the land was based on Landsat TM (Thematic Mapper) of 18 November 1984 of 16 November 1992 and Landsat ETM + (Enhanced Thematic Mapper) from 06 November 2000 and 28 December 2010 (Table 1). The year 1984 was characterized by a drought while 2010 was marked by a slight increase in rainfall. The images were selected period end of the rainy season to minimize exaggerations canopy related to herbaceous; the date of mid-November and December after being (Mbow, 2003) a period characterized by a ground cover related to the density of woody vegetation. In addition, the advantage of the dry season is to have a low cloud cover. Images used are from the database of United State Geological Survey (USGS). Field observations on the types of vegetation and cultivation areas were made in November 2010. Auxiliary data (GPS surveys, topographic map at 1/50000 interviews with rice) were obtained from fieldwork conducted between November and June 2010. Selection of training areas, is in the company of local farmers takes account of homogeneous entities, the land and vegetation cover. Surveys GPS points were used as benchmarks. Using multidates image required atmospheric correction, calibration strips have been used for this purpose. Image processing, including their calibration, carrying colorful compositions and supervised classification is based on the performance of the ENVI software while developing land use maps and changes has been made possible by GIS tools ArcGIS.

Table 1: Satellite data used

Data	Date of acquisition	Spectral Range (µm)	Nominal spectral location	Resolution
ETM^+	06/11/2000	1. [0.45-0.51]	Blue	30 x 30
	28/12/2010	2. [0.52-0.60]	Green	30 x 30
		3. [0.63-0.69]	Red	30 x 30
		4. [0.75-0.90]	Near-IR	30 x 30
		5. [1.55-1.75]	Mid-IR	30 x 30
		6. [10.40-12.50]	Thermal-IR	60 x 60
		7. [2.09-2.35]	Mid-IR	30 x 30
		8. [0.52-0.90]	Panchromatic	15 x 15
TM	18/11/1984	1. [0.45-0.52]	Blue	30 x 30
	16/11/1992	2. [0.52-0.60]	Green	30 x 30
		3. [0.63-0.69]	Red	30 x 30
		4. [0.76-0.90]	Near-IR	30 x 30
		5. [1.55-1.75]	Mid-IR	30 x 30
		6. [10.40-12.50]	Thermal-IR	120 x 120
		7. [2.08-2.35]	Mid-IR	30 x 30

2.4. ***Image processing***

The use of multitemporal image required an atmospheric correction as advocated (Lamachère and Puech, 1996), Richter (1997). The images were georeferenced and calibration bands was performed. To avoid mismatches due to the difference of Landsat and optimize the overlay images for diachronic analysis, data from 1984, 1992 and 2000 were rigged compared to the 2010 image corrected from GPS surveys. To detect changes occurred, we performed unsupervised classification in this trouble to facilitate the choice of the different classes. For further work, we perform a pseudo-supervised classification (Fotsing, 1998). This model of classification is to perform successive partitions on a set of pixels and to isolate As the pixels considered correctly classified. The choice of this method is due to the strong heterogeneity of the elements of the land in the sub-watershed and the likelihood of confusion of some components, namely the paddy not flooded and flooded paddy fields on the one hand the tanne rice and dewatered other parts. Hierarchical clustering begins by determining the number of classes and the selection of training plots to achieve a cartographic synthesis through successive selection of top-ranked elements. The choice of the number of classes is based on the mapping information collected images with field data collected between November and June 2010. Deductions classes are also faced with external data that provides information on the nature of the occupation soil. To estimate the overall performance of the classification, 800 control points are collected in the field. This collection is performed prior to image processing at a rate of 20 to 50 points per class at the highest end of typology implementation for image processing. Points are defined by a random sample drawn from a regular grid of points spaced 2 km covering the entire image and supplemented by stratified sampling for classes underestimated when sampling random (Girard & Girard, 1999). The geographical coordinates of each point used to locate the field with a margin of error of between 3 and 5m with a GPS map Garmin 62st.

2.5. ***Cartographic analysis***

The results of the supervised classification by maximum likelihood were exported in vector format in the ArcGIS software for the completion of the mapping process. Nine classes of land represented by the habitation, saline waterway, dense dry forest, palm grove, the paddy not flooded, flooded paddy, shrub-trees-savannah, the tanne and muddy wetland have been identified, with statistics on the area (Table 2). Crossing cards helped highlight the changes of land use in the catchment Ebinkine between 1984-1992, 1992-2000 and 2000-2010 with conversions and modifications noted during these periods.

3. **Results**

The classification results were used to assess the dynamics of land use. To test reliability, we conducted a confusion matrix for each image used, with overall accuracies of 89-94% and kappa values of 0.92; 0.89 and 0.87, respectively for 1984, 1992,2000 and 2010. (Table 2). Overall, the confusion matrices of the four processed images show a good separation of the shrub-trees-savannah (good ranking more than 91% of pixels) and paddy not flooded (over 86% of pixels) relative to the other classes. Errors of omission and commission remain relatively low for the first two classes, in the order of 1.65% and 2.99% in 1984 and 1992 and 4.08% and 6.85% in 2000 and . 2010 However, there are proportions of misclassified pixels, relatively high for the frame, set to 41.6% in 1984; 45.2% in 1992; 41.5% in 2000 and 39.6% in 2010 as well as errors of commission and omission highest that can be explained by reflectance values of neighboring habitation from those tanne and paddy not flooded.

The classification made it possible to generate statistical results on areas of different land use classes (Table 3).

Table 2**:** Accuracy Assessment of images classification

Date of image	**Overall accuracy (%)**	**Kappa**
18 /11/ 1984	93.90	0,92
16 /11/ 1992	91.33	0,89
06/ 11/ 2000	89.38	0,87
28 /12/ 2010	89.70	0,87

Table 3 : Evolution units of land sub-watershed of Ebinkine

Type of land cover	Areas							
	1984 hectares	%	1992 hectares	%	2000 hectares	%	2010 hectares	%
Habitation	42,4	1,8	50,1	2,0	53,2	2,2	98,2	4,0
Saline waterway	6,2	0,3	7,4	0,3	21,6	0,9	27,3	1,1
Dense dry forest	753,9	31,0	681,0	28,0	820,9	33,8	575,2	23,7
Palm grove	16,9	0,7	17,0	0,7	17,9	0,7	19,5	0,8
Paddy not flooded	615,0	25,3	581,1	24,0	402,2	16,7	415,8	17,1
Flooded paddy	0,0	0,0	0,0	0,0	123,6	5,1	50,5	2,1
Shrub-trees-savanah	880,1	36,2	952,3	39,2	849,4	34,9	1132,6	46,6
Tanne	49,9	2,0	60,6	2,5	30,0	1,2	56,1	2,3
Muddy wetland	65,3	2,7	80,2	3,3	110,9	4,5	54,5	2,3
total	**2429,7**	**100**	**2429,7**	**100**	**2429,7**	**100**	**2429,7**	**100**

3.1. ***State land use for 1984-2010***

Mapping land cover in 1984 showed a significant vegetation, mainly consisting of the dense dry forest, shrub-trees-savannah and palm grove, on an area of 1651 hectares, or 67.9% of the total under watershed. The shrub-trees-savannah with 880.1 hectares is the largest plant formation, followed by dense dry forest with 753.9 hectares. The exposed rice occupy the central part of the valley with 614.9 hectares or 25.3% of the area of the sub-basin (Figure 4 A).

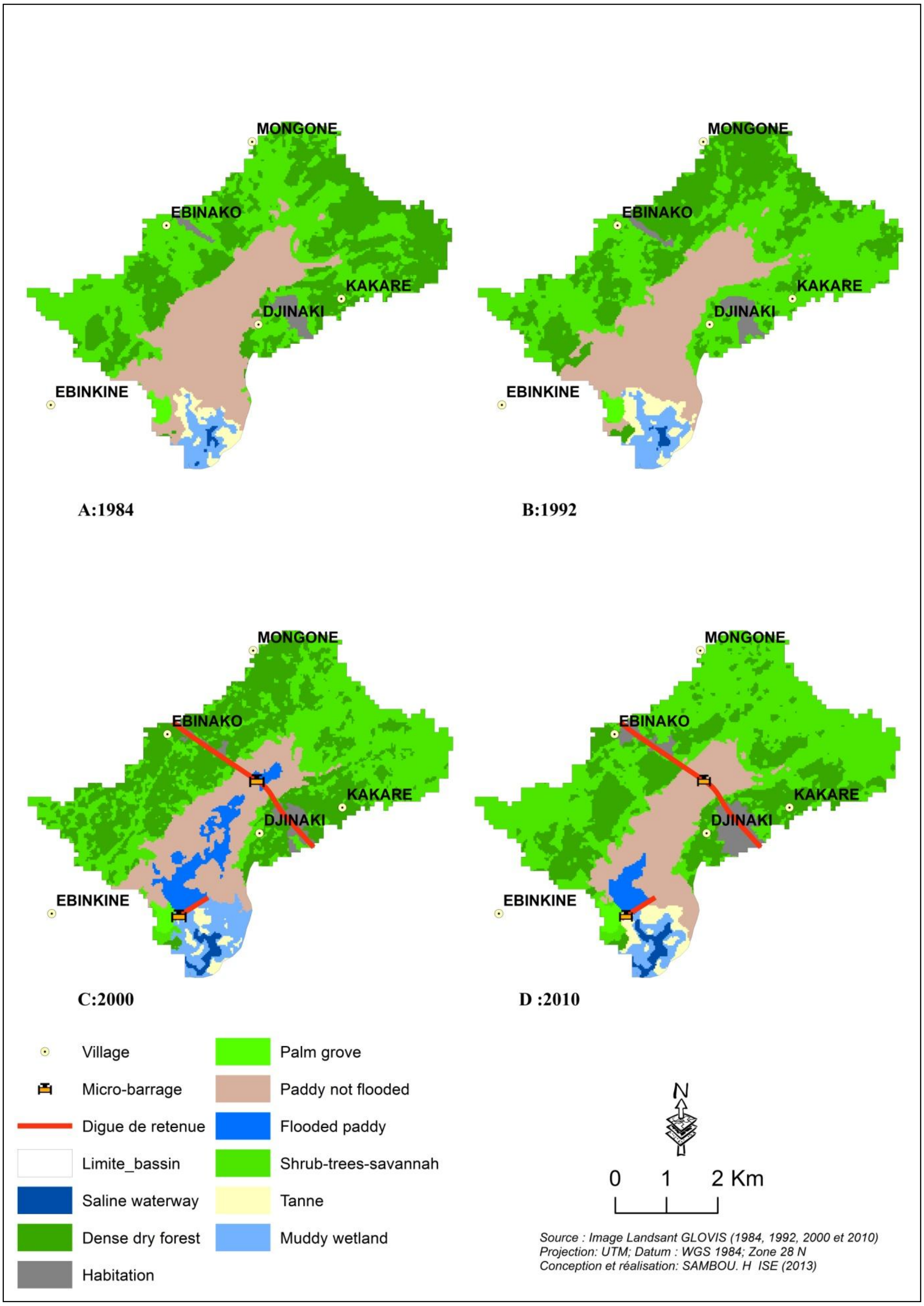

Figure 4: Land use in the sub-watershed of Ebinkine in 1984 (A) 1992 (B) 2000 (C) 2010 (D)

During 1992, the shrub-trees-savannah has increased by 72.17 hectares or 8.2% from the year 1984 It is the type of dominant land use in 1992 with 952.3 hectares. The area of dense dry forest of about 681 hectares, was down 72, 9 hectares (9.7%) in 1992 compared to 1984, the exposed rice in 1992 also experienced a decline of 5.5 % (Figure. 4 B). Between 1992 and 2000, the area of dry forest has increased, reaching 820.8 hectares or 33.8% of the sub basin. Note the appearance of flooded paddy downstream unwatered paddy not flooded an area of123.62 hectares (Figure. 4 C). Unwatered paddy not flooded fields decrease at a rapid rate (decreased 16.55% contribution of this class between 1992 and 2000, the same trend is observed for the shrub-trees-savannah which fell 10, 8% from 1992 to 2000. In 2010, vegetation cover, mostly consisting of dense dry forest (575.2 acres), the park (19.5 hectares) and shrub-trees-savannah (1132.5 hectares), has increased in size and is 71.1% of the sub watershed mapped (Figure. 4 D). Dense dry forest has been a sizeable reduction from 820.8 hectares in 2000 to 575.2 hectares in 2010, a decrease of approximately 10.1%. These results show a spatial-temporal fluctuation of vegetation (Figure 5).

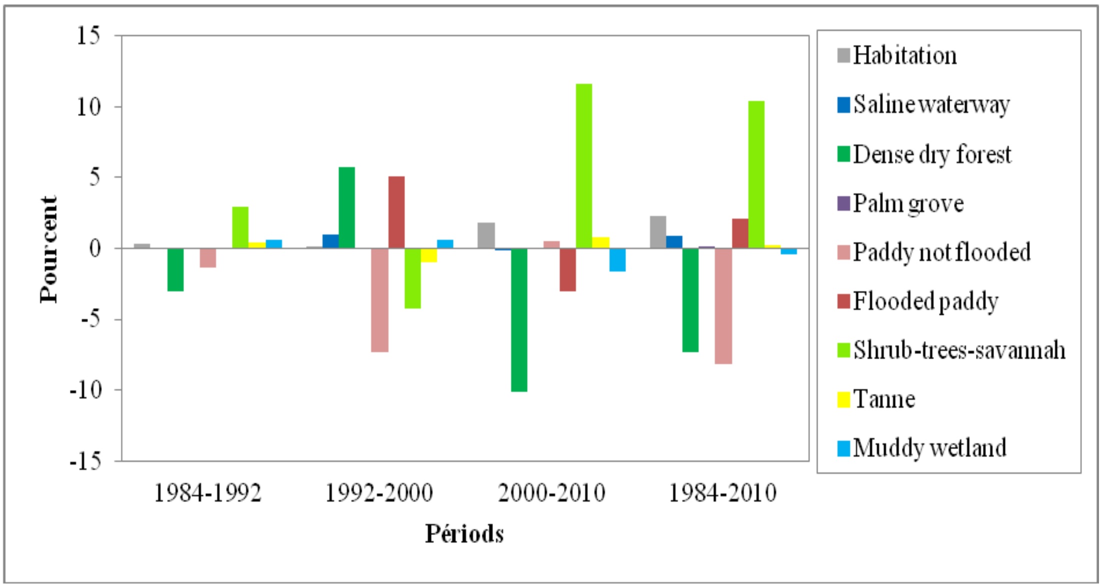

Figure5: Evolution of land use in the sub-watershed of Ebinkine

The area of flooded paddy has shrunk by 3% from 123.6 hectares in 2000 to 50.50 hectares in 2010. Consecutively, the exposed rice increased 0.5% from 402.24 hectares in 2000 to 415.8 hectares in 2010. With an area of 53.2 hectares and 98.2 hectares in 2000 in 2010, the frame has increased dramatically. Despite the presence of water in sufficient quantity and in a sustainable way upstream of the non-salt micro-dam and reduced salinity (Figure 6) micro-dam, the valley more or less homogeneous with a grass cover provided (coverage about 90%) is under-exploited.

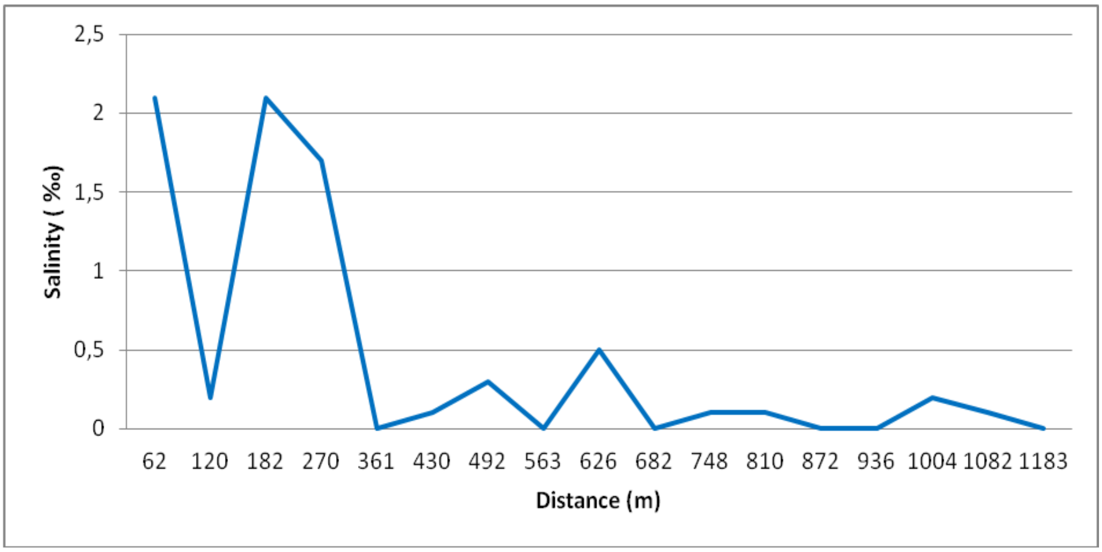

Figure 6: Evolution of salinity upstream of the micro-dam

3.2. ***Analysis of spatio-temporal changes of land***

Cards change of land made by crossing two situations (1984-1992, 1992-2000 and 2010) indicate cases of stability and especially conversion. Examination of Figure 7A shows that 44.8% of the shrub-trees-savannah in 1992 was made in 1984 by the dense dry forest. Similarly in 1984, 13.6% of the rice area dewatered were converted into different types of occupation of the soil, including 7.2% in shrub-trees-savannah. And if the exposed rice fell in some places during this time interval, they experienced an increase in others, thus gaining an area of 41.6 hectares, or 4.7% of the shrub-trees-savannah. However, it should be noted that for all the changes, the types of land use remained stable between 1984 and 1992 were predominant compared with those having undergone a conversion. Map changes from 1992 to 2000 (Figure 7 B) allows us to observe significant conversions. The transfer matrix of the land was used to quantify the different changes. The most remarkable fact is the regression of dewatered rice where 33.8% of the area have been converted into other types of land with in detail, 8.1% in shrub-trees-savannah and 19.0% in flooded rice fields. The conversion of rice dewatered in shrub-trees-savannah can be explained by regeneration of plant species such as *Anthostema senegalensis*, *Daniellia oliveri* ... in the abandoned rice fields. Meanwhile, 66.2% of dewatered rice remained stable between these two dates. The area of dense dry forest has increased in 2000. This increase is explained by the transformation of other types of land, mainly the conversion of 40.8% of the shrub-trees-savannah in dense dry forest. This conversion is also noted in other thematic classes. This is the case of mudflats which 44.7% of the area in 2000 came from the salt flats. The major changes observed between 2000-2010 are made of conversions. The principal is noted in dense dry forest class that sees 54% of its area transformed shrub-trees-savannah and 4.3% in habitation, 41.2% of the area of dry rainforest remaining unchanged. Similarly, some units of the sub-watershed also showed a conversion of their area including shrub-trees-savannah which 25.8% is converted into dense dry forest and flooded rice with 61% converted rice dewatered in 2010 (Figure 7 C). Other conversions are also noted in the sub-basin units. This is the shrub-trees-savannah converted to 25.8% dry dense forest and 61% of flooded paddy fields become dewatered in 2010.

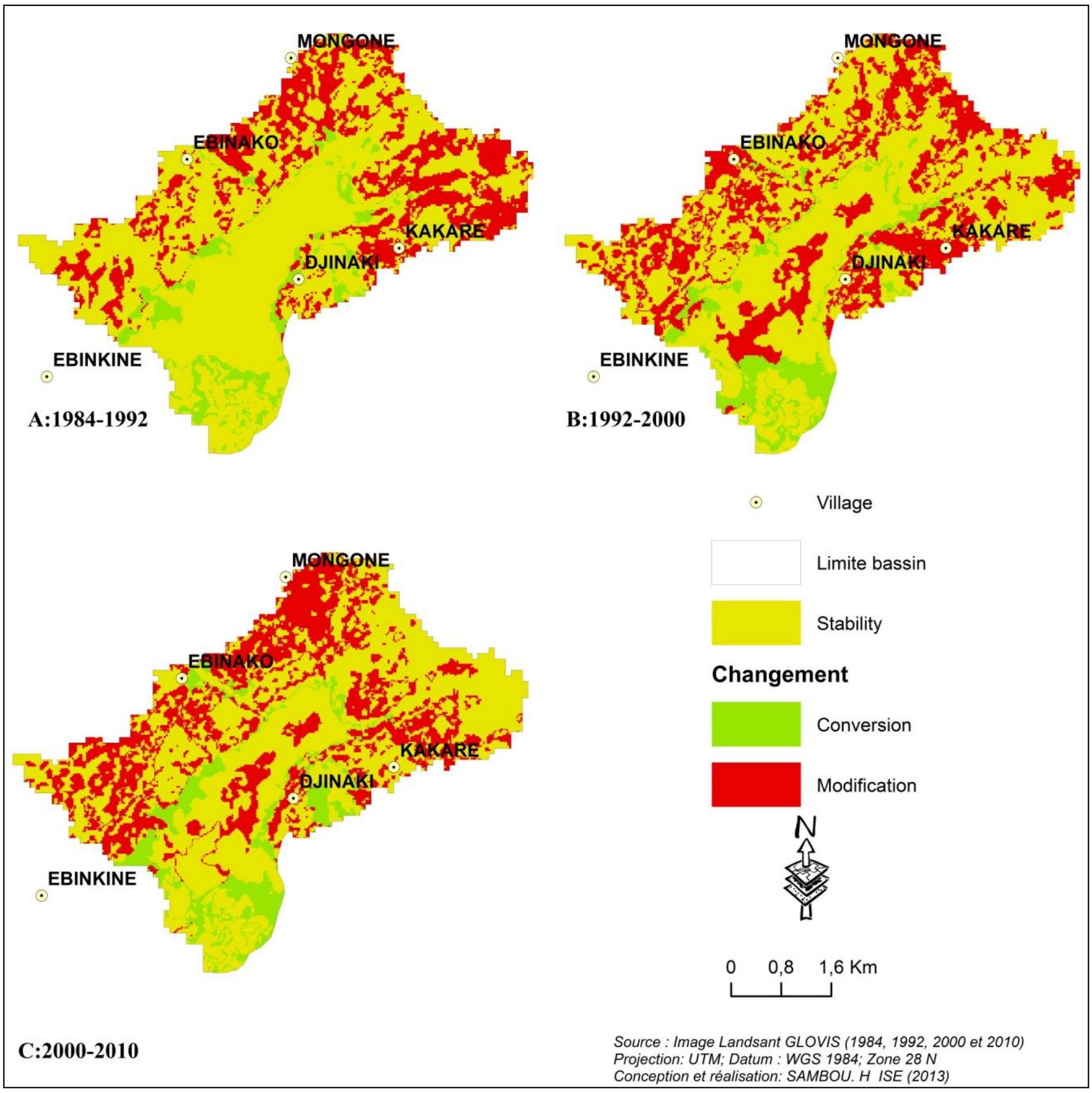

Figure7: Map of changes in land use between 1984 to 1992 (A) 1992-2000 (B) 2000-2010 (C) in the sub-watershed of Ebinkine

4. **Discussion**

Resolution Landsat (30m) could also influence the accuracy of the classification of small areas (Bamba, 2010). Some classes do not pose a problem of interpretation **(**Saline waterway, tanne**).** Others, however, are marked by some uncertainty. Example, earthen houses with straw roofs are not easily identifiable as straw absorb light. In any case, the park around homes is an indicator of human presence but a problem for their delineation. Similarly, the rice acreage dewatered represent the areas under cultivation, with some exceptions as some flooded compartments are subjected to wet rice cultivation. The class of shrub savannah trees may interfere with the class of dense dry forest in a few cases: it is still generally well differentiated. However, shrub-trees-savannah is slightly overestimated between 2000 and 2010 and is locally influenced by mango orchards (*Mangifera indica*) and cashew (*Anacardium occidentale*), booming especially in the northern part of the sub-watershed. Figure 8 is an illustrative example of the expansion and operations made on the cashew apples in the area of sub-watershed.

Figure 8: Operating almond plantation in *Anacardium occidentale*, April 2010 [Sambou, 2013]

Despite these reservations, the results however, cannot be challenged fundamentally: the rice growing areas indeed experiencing a sharp decline (from 1.3 to 8%). This disturbing case is comparable to observations recently implemented epigraphs in other watersheds in the Lower Casamance (Sambou, 2014). For cons, the shrub-trees-savannah increased slightly (from 3 to 10.4%). In addition, however, the upstream portion of works is often poorly equipped and suddenly the rice paddies are subjected to prolonged flooding (Figure 9).


Figure 9: Profile view of the micro-dam Ebinkine November 2012 [Sambou, 2010]

5. Conclusion

The study of land carried out by remote sensing using Landsat images, revealed significant changes' to the land in the watershed under Ebinkine. Analyses show that the impact of climate change is effective and results in a decline in rice area. The impact of the construction of micro-dams in these dynamic globally is not clearly visible, both because of their achievement, their management. The analyzes also indicate that water retention is usually permanent despite mismanagement and evaporation. This is against the fundamental assigned to this type of work (rice intensification and reduced salinity) objectives and shows their importance in terms of control of water resources.

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