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Research Article

Spatio-temporal Evolution of Land User and Changes in Dense Dry Forests in the Municipality of Santhiaba Manjaque in Lower Casamance (Southern Senegal)

Hyacinthe Sambou[1, *], Fode Amata Drame[1], Seyni Sane[2]

[1]Institute of Environmental Sciences, Cheikh Anta DIOP University, Dakar, Senegal
[2]Higher Institute of Professional Education (ISEP), Bignona, Senegal

Abstract

In Senegal, forest ecosystems have faced increasing pressure in recent decades. These pressures, both natural and anthropogenic, lead to observable changes in the forest landscape. Lower Casamance, the only site that hosts the country's last remaining relics of dry dense forests, is not spared. The nature and the intensity of these changes affecting the dry dense forests remain poorly understood. The purpose of this study is to assess the dynamics of the dry dense forests in the township of Santhiaba Manjaque and to explain their causes. A diachronic analysis of Landsat satellite data was carried out and the supervised classification approach using the maximum likelihood method was chosen to discriminate classes and produce land cover maps for 1988, 2006, and 2024. Transition matrices were used to highlight the changes undergone by the different land cover units. The results showed a significant trend marked by an increase in the surface areas of dry dense forests and woody savannah, with 855.27 and 575.37 hectares respectively between 1988 and 2024. Conversely, a sharp decrease was observed in shrub savanna, with a loss of 771.47 hectares. Furthermore, the creation of change maps revealed that from 1988 to 2024, 628.54 ha of woody savannah and 452.16 ha of shrub savannah were converted into dry dense forests. The ongoing spatial transformations in the township of Santhiaba Manjaque include modifications recorded within the different vegetation formations and conversions between the classes of natural vegetation formations and the other land cover units. This study helped to shed light on the ongoing spatial transformation processes in the landscape of the township of Santhiaba Manjaque and to determine indicators that can serve as a basis for the management and conservation of forest resources in Senegal.

Keywords

Dry Dense Forests, Spatio-temporal Evolution, Land Use, Santhiaba Manjaque, Lower Casamance

1. Introduction

Forest ecosystems perform many socio-economic and environmental functions that are of great importance to local communities and beyond. Without them, the impacts of climate change on the environment and humans would be more devastating. In Senegal, forest ecosystems offer enormous potential for wood and non-wood forest products [1]. In Lower

*Corresponding author: Hyacinthe.sambou@ucad.edu.sn (Hyacinthe Sambou)

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Casamance, in addition to their economic role, forest ecosystems play a major cultural role. They are home to sacred sites where communities perform rituals and preserve their cultural identity. It is in these places that important decisions affecting the lives of communities are made.

However, in recent years, deforestation has become a pressing issue worldwide, particularly in developing countries [2]. According to the [3], global forests covered an estimated 3,869 million hectares in 2000, 94 million hectares less than ten years earlier. According to the same source, Africa stood out with the highest continental deforestation rate, estimated at 0.78%. Western Sudano-Sahelian Africa (Mauritania, Senegal, Guinea-Bissau, Mali, Burkina Faso, Niger, and Chad), despite its limited forest resources, performed slightly better than the continent as a whole, with an annual decline of 0.72% (FAO, 2001). In most of the countries concerned, anthropogenic actions are the most significant factors [4-7]. In Senegal in particular, forest area is being lost at a significant rate [8]. Uncontrolled logging and land clearing for agricultural purposes are the two main direct causes of deforestation [9]. Other anthropogenic factors are responsible for the decline of forest ecosystems. Bushfires are considered to be the main anthropogenic agents responsible for the formation of savannas at the expense of the Sudanese forest [10-13], and the relatively slow rate of forest expansion in Senegal [14].

Governments and NGO partners are making considerable efforts to reduce the environmental impact of deforestation through reforestation and reforestation programs, but the problem of degradation remains. However, it must be noted that objective information on the evolution of forest resources is very rare in West Africa [15] and elsewhere in the world [16]. We believe it is essential to have access to reliable, up-to-date information on the state of forest resources in terms of surface area and conservation strategy. Today, Lower Casamance is the only place in Senegal where remnants of dense dry forests can be found. In Senegal, the vast majority of studies focus on vegetation cover dynamics and have been conducted across large geographical areas. Few studies focus specifically on areas that are home to the only remaining relics of dense dry forests [17]. These studies therefore do not provide accurate information on the state of forest ecosystems. The aim of this study is to assess the spatial dynamics of dense dry forests based on a diachronic analysis of the landscape between 1988 and 2025.

2. Materials and Methods

2.1. Description of the Study Area

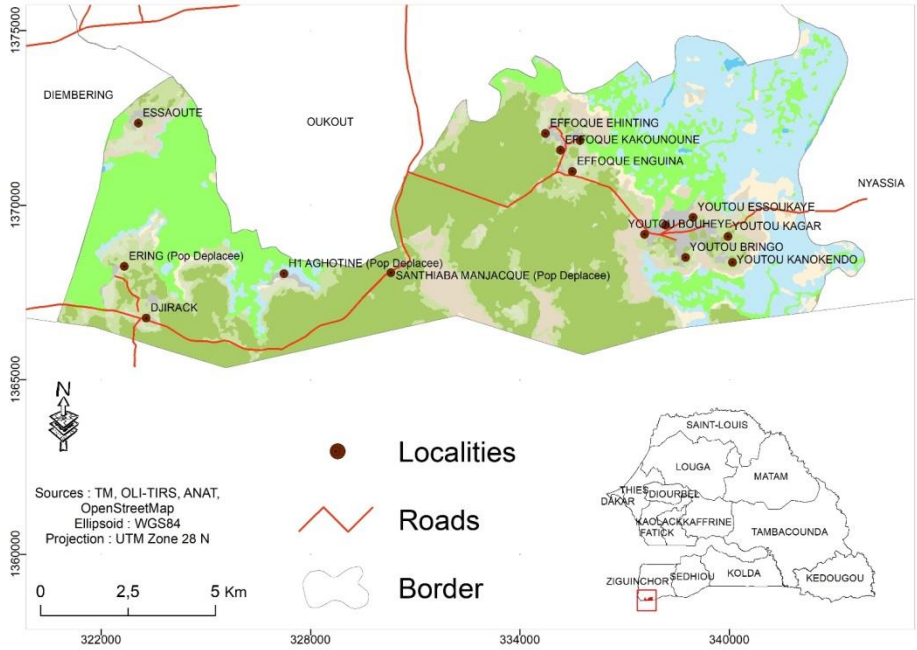

Figure 1. *Location map.*

The municipality of Santhiaba Manjaque is located in the district of Cabrousse, department of Oussouye, region of Ziguinchor (Lower Casamance). It is bordered to the north by the municipality of Oukout, to the south by the Republic of

Guinea-Bissau, to the east by the municipality of Nyassia, and to the west by that of Diembéring (Figure 1). Covering an area of 127.5 km², the municipality of Samthiaba Manjaque is located between 12°21'30“ and 12°26'30” north latitude and 16°26'30“ and 16°36'30” west longitude and comprises 15 villages.

From a climatic point of view, the municipality of Santhiaba Manjaque is part of the coastal Sudanese climate zone [18]. It is one of the rainiest municipalities in the Ziguinchor region, with 1,200 to 2,000 mm of rainfall according to [19] and two alternating seasons: a dry season from November to May and a rainy season from June to October. However, climate variability sometimes makes this situation unpredictable. Temperatures range from 27 ℃ to 30 ℃, with lows during cooler periods between 15 ℃ and 18 ℃. The terrain of the municipality is relatively flat, characterized by a slight elevation difference of no more than 10 m. It consists of plains and plateaus [20]. These plateaus are dotted with valleys and lowlands that provide an advantage for agricultural activities. Two types of soil dominate in the municipality: hydromorphic soils suitable for rice cultivation [21] and halomorphic soils favored by the advance of the salt tongue. The municipality of Santhiaba Manjaque is one of the most forested municipalities in the department of the Ziguinchor region. It is home to the Basse Casamance National Park, the only park in Senegal consisting mainly of dry dense forest vegetation. However, there is also some sparse forest to the east and west of the municipality, but it is small in size. Due to the density of the hydrographic network, there are also mangroves.

2.2. Satellite Data Acquisition

This study required the use of three Landsat satellite images (Table 1). The study was conducted over three periods: 1988, the year that marked the end of the severe drought of the 1970s; 2006, which marked the gradual return of rainfall to normal levels; and 2024, which represents the current situation at the study site. It is also the year in which the field missions were carried out. Landsat images were chosen for this study because they offer medium spatial and temporal resolution data that is freely available [22, 23]. The images used in this study were all taken during the dry season because cloud cover and cloudiness are relatively low during this period. Furthermore, using images from the same season in a study of changes helps to reduce seasonal effects [24].

Table 1. *Characteristics of Landsat images used.*

Year	Sensor	Acquisition date	Resolution
1988	Landsat TM	10/03/1888	30 m
2006	Landsat ETM+	17/02/2006	30 m
2024	Landsat OLI	26/02/2024	30 m

2.2.1. Preprocessing of Landsat Images

The Landsat images used were all georeferenced in the Universal Transverse Mercator (UTM) projection system, zone 28 N, based on the WGS 84 (World Geodetic System) reference ellipsoid. Subsequently, a geometric correction was applied to the 1988 and 2006 images by referring to the most recent image from 2024, based on the geographic coordinates of 60 invariant and well-distributed ground control points at each of the study sites [25]. The root mean square error (RMSE) was less than the pixel value. Preprocessing operations were performed using ENVI 5.6 software. False-color composites were then created using the infrared, near-infrared, and red spectral bands in the red, green, and blue channels. The radiometric values of these extreme reflectance areas are used to perform a linear stretch of the different spectral bands [26].

2.2.2. Image Processing

To better discriminate vegetation, a false color composite was obtained by combining the red, near-infrared, and infrared bands, the latter two being known as the most suitable for vegetation discrimination [27]. This color composition was followed by supervised classification on all selected images, leading to visual interpretation and identification of training areas. This supervised classification, based on the maximum likelihood algorithm, was applied [6]. For each pixel, it provides a confidence index linked to this choice, in addition to the class to which it is assigned [28]. ENVI 5.6 software was used for preprocessing Landsat images and classifying land cover, and ArcGIS 10.8 software was used for map layout.

2.2.3. Post Classification

The purpose of this section is to refine the results obtained from image processing. As some land cover classes do not appear correctly or are confused with other units, visual digitization on screen was used to supplement the automatic classification in order to highlight units that were not properly identified by the previous classification and to highlight the different land cover classes [29]. The nomenclature of the different land cover classes was based on the work of [30, 31].

2.3. Field Truth Mission

This is a very important step that allows the information contained on the map to be accurately confirmed. Image 2024 was used as a reference to validate the classification of land cover classes in the 1988 image. On these images, a maximum number of training areas were sampled in different land cover classes. This improves the overall accuracy of the classification of reference images [32]. For security reasons limiting movement in the area, the field verification mission only covered the most accessible points, which had been previously identified. These points were verified in the field using a GPS receiver and confirmed on maps.

2.4. Data Analysis

Changes in land cover were determined using a transition matrix from 1988 to 2024 in the form of a condensed square matrix describing changes in units during the period under consideration [33].

2.5. Transition Matrix

Transition matrices are produced to describe changes in land use over a given period [34]. They have therefore made it possible to highlight the different forms of conversion or modification that the various land cover units underwent between 1988 and 2024. The number X of rows in the matrix indicates the number of land cover classes at time t0, the number Y of columns in the matrix is the number of land cover classes converted or modified at time t1, and the diagonal contains the areas of vegetation formations that remained unchanged. The transformations are therefore carried out from rows to columns. The areas of these different land cover classes were calculated by cross-referencing land cover maps between different dates using the Intersect function in the Arctoolbox toolbox in ArcGIS 10.8 software. The rate of change (Tc) in land cover between two dates was calculated for each land cover class based on the formula developed by [35].

$$TC = \frac{A2-A1}{A1} * 100$$

A1 and A2 are the initial and final areas of the land cover class, respectively. Positive values of Tc indicate increases in the land cover class, while negative values indicate losses of vegetation in that class.

3. Results

3.1. Dynamics of Different Land Use Units in the Study Area Between 1988 and 2024

Figures 2 and 3 show maps and statistics for the different land use units in the municipality of Santhiaba Manjaque in 1988, 2006, and 2024. A total of nine (09) land use units were mapped in the municipality. These include dry dense forests, dwellings, woody savannah, shrub savannah, agricultural areas, tan, mangroves, waterways, and mudflats.

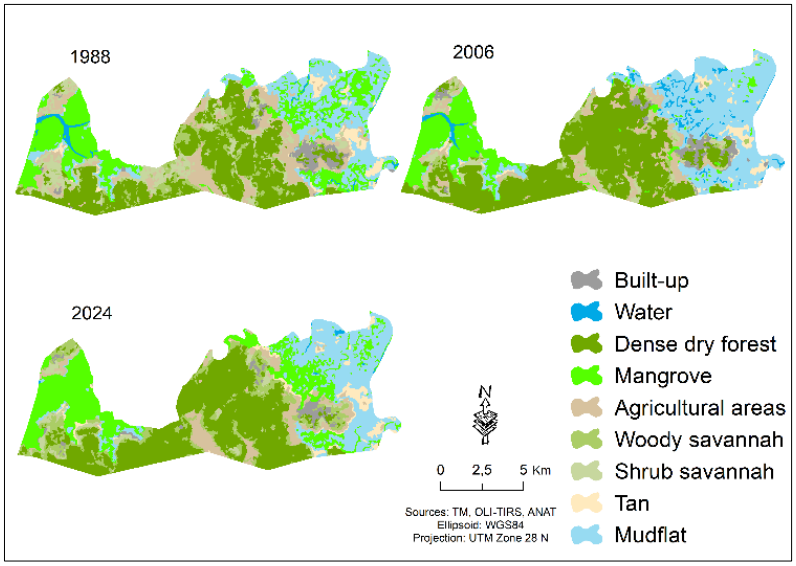

Figure 2. *Land use maps for the years.*

Analysis of the maps shows that between 1988 and 2024, the areas covered by different types of vegetation in the municipality underwent significant spatial changes (Figure 2). In 1988, dry forests covered 3,526.23 ha and were the dominant land use in the municipality. Woody savannah covered 716.47 ha and shrub savannah covered 1,236.40 ha. As for mangroves, they covered 2,538.25 ha of the landscape and were the second largest land use category. Agricultural species covered 1,582.96 ha of the municipal landscape and mudflats covered 2,269.45 ha. In 1988, there were very few watercourses and buildings in the municipality, covering 160.58 ha and 360.37 ha respectively. Finally, tan covered 400.24 ha of the landscape.

In 2006, the area covered by dense dry forests increased, now covering 4,838.58 ha of the landscape, an increase of 1,312.35 ha. Shrub savannah and woody savannah occupied 600.53 ha and 390.22 ha respectively at that date. These two vegetation types declined in area by 635.87 ha and 326.26 ha respectively. As for mangroves, they also experienced a decline in area, falling from 2,538.25 ha in 1988 to 1,584.44 ha in 2006, a decrease of 953.81 ha. Tan and agricultural areas also declined by 57.78 ha and 575.24 ha, respectively. Unlike

ponds, mudflats increased in size between 1988 and 2006. Their surface area increased from 2,269.45 ha in 1988 to 3,304.27 ha, representing an increase of 1,034.82 ha.

In 2024, the area covered by shrub savannah declined from 600.53 ha in 2006 to 464.93 ha in 2024 (Figure 3). At the same time, there has been an increase in the area of woody savannah. From 390.21 ha in 2006, their area increased to 1,291.84 ha in 2024, an increase of 901.63 ha. In contrast, there has been a decline in the area of dry dense forests in the municipality, from 4,838.58 ha in 2006 to 4,381.49 ha in 2024, corresponding to a decline of 457.09 ha. At that date, there was also a decline in mudflats and agricultural areas, from 3,304.27 ha in 2006 to 2,394.87 ha in 2024 for mudflats and from 1,007.73 ha to 874.50 ha for agricultural areas.

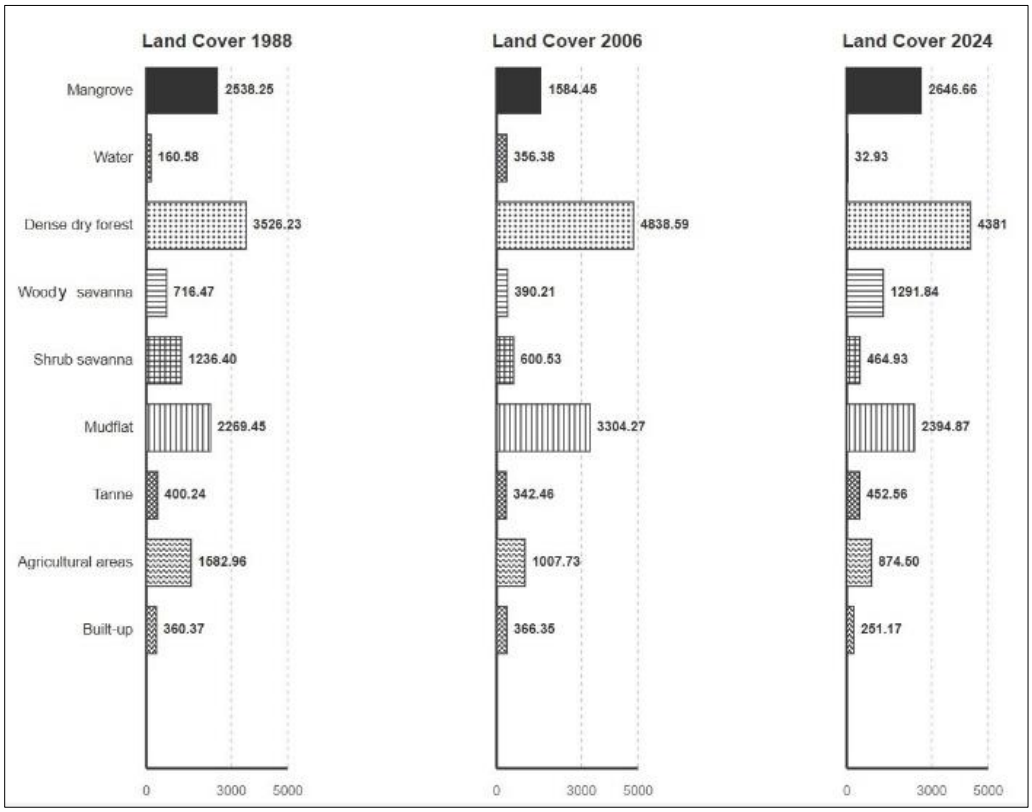

Figure 3. *Land use statistics for the municipality of Santhiaba Manjaque between 1988 and 2024.*

Between 1988 and 2024, the municipality was dominated by vegetation formations. Woody savannah, dry dense forests, and mangroves all increased in area. In contrast, shrub savannah declined between 1988 and 2024. However, there has been an increase in the area covered by tan and mudflats. At the same time, the area of agricultural land has decreased significantly between 1988 and 2024.

3.2. Land User Changes from 1988 to 2024

The changes that have occurred in the different types of land use are illustrated by the transition matrices (Tables 2, 3 and 4).

Between 1988 and 2006, the land use types with positive rates of change in the municipality were dense dry forests, watercourses, dwellings, and mudflats, with rates of 37.22%, 121.93%, 1.66%, and 45.6%, respectively (Table 2). Apart from these land cover types, the others recorded negative rates of change, the most significant of which were observed in shrub savannah (-51.43%) and woody savannah (-45.54%). Mangroves and agricultural areas recorded change rates of -37.58% and 36.34%. Shrub savannas underwent the most significant changes between 1988 and 2006, with 602.57 ha converted to dense dry forests and 189.43 ha to woody savannah. At the same time, 639.59 ha of woody savannah are also being converted into dry dense forests. In parallel, there has been a significant conversion of agricultural land into shrub savannah, covering 323.53 ha. In contrast, 132.82 ha of shrub savannahs were converted into agricultural land. In summary, between 1988 and 2006, shrub savannahs recorded the greatest change in area. Dense dry forests gained the most, with an increase of 1,571.98 ha between 1988 and 2006.

Table 2. Transition matrix for land use types between 1988 and 2006 (ha).

Class 1988 / Class 2006	B	W	DDF	Ma	AA	WS	SS	Tan	Mu	Total 2006 (t2)	Gain	Tot2-Tot1	TC (%)
B	160.44		19.77	4.86	113.98	1.18	52.44	9.45	4.23	366.35	205.91	5.98	1.66
W	0.09	102.87		163.22	0.36		0.9	0.27	88.67	356.38	253.51	195.8	121.93
DDF	113.13	0.07	3266.6	9.8	200.52	639.59	602.57	0.27	6.03	4838.58	1571.98	1312.35	37.22
Ma	10.98	38.08	11.83	1371.6	41.76	6.66	15.84	1.98	85.72	1584.45	212.85	-953.8	-37.58
AA	15.82	0.54	145.32	9.73	639.57	26.55	132.82	15.12	22.27	1007.74	368.17	-575.22	-36.34
WS	13.55		48.42	3.58	85.16	37.3	189.43	10.53	2.25	390.22	352.92	-326.25	-45.54
SS	16.59		32.49	4.55	323.53	4.83	196.49	3.33	18.72	600.53	404.04	-635.87	-51.43
Tan	4.58			2.16	43.6		1.8	232.33	57.99	342.46	110.13	-57.78	-14.44
Mu	25.19	19.02	1.8	968.75	134.49	0.36	44.11	126.96	1983.58	3304.26	1320.68	1034.79	45.6
Total 1988 t1	360.37	160.58	3526.23	2538.25	1582.96	716.47	1236.4	400.24	2269.47	12790.97			
Lost	199.93	57.71	259.63	1166.65	943.4	679.17	1039.91	167.91	285.88	4800.19			

Between 2006 and 2024, most of the vegetation cover was converted to woody savannah. 661.39 ha of dense dry forests and 220 ha of shrub savannah were converted to woody savannah. The most significant conversions were observed in mudflats, with 925.55 hectares converted to mangroves and 135.43 hectares of agricultural land converted to shrub savannah. In contrast, 162.34 ha of shrub savannahs are converted into agricultural land. At the same time, 153.74 ha of mudflats are converted into tan between 2006 and 2024. The most significant change between 2006 and 2024 is the gain of 1,164.55 ha of mangrove forest. Very few mangroves have been converted and modified into other types of land cover. They are the most stable types of land cover between 2006 and 2024. Three land use classes recorded positive coverage rates: mangroves with 67.04%, woody savannah with 231.06%, and tans with 32.15% (Table 3). However, water is the land use category that recorded the largest negative change, at -90.76%. Mudflats lost the largest area, at 1,160.84 ha.

Table 3. Transition matrix for land use types between 2006 and 2024 (ha).

Class 2006 / Class 2024	B	W	DDF	Ma	AA	WS	SS	T	Mu	Total 2024 (t2)	Gain	Tot2-Tot1	TC (%)
B	134.14	54.26	2.88		17.69	2.7	12.51	7.47	19.53	251.18	117.04	-115.17	-31.44
W		28.67	0.06			4.2				32.93	4.26	-323.45	-90.76
DDF	10.24	0.31	4021.27	7.38	186.16	131.53	24.15	0.27	0.18	4381.49	360.22	-457.1	-9.45
Ma	0.99	224.68	1.84	1482.11	7.74	0.01	3.29	0.45	925.55	2646.66	1164.55	1062.21	67.04
AA	109.08	32.96	38.28		456.32	9.92	162.34	12.02	53.57	874.49	418.17	-133.24	-13.22
WS	68.73		661.39		29.42	149.33	220	157.47	5.49	1291.83	1142.5	901.62	231.06

Class 2006 / Class 2024	B	W	DDF	Ma	AA	WS	SS	T	Mu	Total 2024 (t2)	Gain	Tot2-Tot1	TC (%)
SS	28.57		64.79	3.36	135.43	16.51	211.25	2.25	2.78	464.94	253.69	-135.59	-22.58
T	8.02	1.53		3.33	26.64	4.86	15.03	239.42	153.74	452.57	213.15	110.11	32.15
Mu	6.58	102.72	0.54	17.63	28.43	4.68	14.49	80.58	2139.23	2394.88	255.65	-909.39	-27.52
Total 2006t1	366.35	356.38	4838.59	1584.45	1007.73	390.21	600.53	342.46	3304.27	12790.97			
Lost	232.21	416.46	769.78	31.7	431.51	174.41	451.81	260.51	1160.84	3929.23			

Between 1988 and 2024, shrub savannah (1,109.53 ha), agricultural areas (899.88 ha), and mudflats (709.58 ha) were the land cover types that lost the most area. In contrast, dense dry forests gained the most area between 1988 and 2024, with 1,298.23 ha, followed by woody savannah with 1,214.88 ha (Table 4). At the same time, the most significant rate of change was observed in woody savannah, at 80.31%.

Table 4. *Transition matrix for land use types between 1988 and 2024 (ha).*

Class 1988 / Class 2024	B	W	DDF	Ma	AA	WS	SS	T	Mu	Total 2024 (t2)	Gain	Tot2-Tot1	TC (%)
B	138.93	23.13	4.95		26.55	2.61	42.57		12.43	251.17	112.24	-109.2	-30.3
W		8.76		10.04					14.13	32.93	24.17	-127.65	-79.49
DDF	31.89	0.29	3083.26	3.29	180.98	628.54	452.16	0.27	0.81	4381.49	1298.23	855.26	24.25
Ma	9.9	133.6	4.5	1895.96	37.1	1.08	15.73	13.14	535.65	2646.66	750.7	108.41	4.27
AA	26.55	0.18	27.33	18.2	683.08	3.12	70.61	26.86	18.57	874.5	191.42	-708.46	-44.76
WS	107.21	0.09	333.89	19.39	251.87	76.97	492.08	0.54	9.81	1291.85	1214.88	575.38	80.31
SS	24.64	0.09	51.79	3.17	231.33	4.14	126.87	6.48	16.42	464.93	338.06	-771.47	-62.4
T	5.98		1.89	13.19	105.99		16.65	207.1	101.76	452.56	245.46	52.32	13.07
Mu	15.27	17.57	0.45	570.06	66.06		19.73	145.85	1559.87	2394.86	834.99	125.39	5.53
Total 1988 (t1)	360.37	160.58	3526.23	2538.25	1582.96	716.47	1236.4	400.24	2269.47	12790.97			
Lost	221.44	174.95	424.8	637.34	899.88	639.49	1109.53	193.14	709.58	5010.15			

The change map for the municipality of Santhiaba Manjaque for the period 1988-2006 (Figure 4) reveals the various changes undergone by dense dry forests. Dense dry forests gained 639.59 ha at the expense of woody savannah and 602.57 ha at the expense of shrub savannah. However, between 2006 and 2024, dry dense forests lost 661.39 ha to woody savannas. Between 1988 and 2024, dense dry forests gained 1,298.23 ha, of which 628.54 ha was at the expense of woody savannah and 452.16 ha came from shrub savannah.

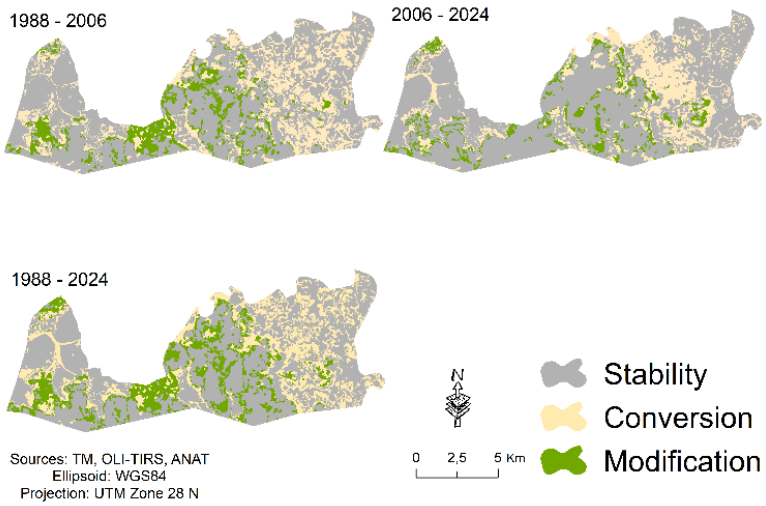

Figure 4. *Change maps in the municipality of Santhiaba Manjaque between 1988 and 2024.*

4. Discussion

The diachronic analysis of land use in Santhiaba Manjaque in 1988, 2006, and 2024 reveals spatial dynamics that are part of the environmental transformations observed in West Africa. These changes result from the interaction between climatic factors and anthropogenic pressures, as demonstrated by [36-38] in their respective studies in West and Central Africa, Benin, and Senegal.

The remarkable recovery of mangrove forests (+108.41 ha between 1988 and 2024) after a period of degradation is part of a trend of ecological resilience observed in other municipalities in Casamance. This increase in mangrove area could be explained by numerous reforestation campaigns initiated by local communities, sometimes supported by NGOs such as OCEUNIUM, which work to restore forest ecosystems, particularly mangroves. [38], in their study on Kaour, documented a 35.85% decline in vegetation cover between 1990 and 2006, followed by an 81.33% regeneration by 2024. This capacity for recovery suggests ecological resilience processes specific to Casamance ecosystems.

The decline in agricultural land (-44.76% over 36 years) can be explained by several converging factors. The effects of the Casamance conflict documented by Sène and Coly (2021) led to the flight of a large part of the population and the abandonment of many villages. This situation has had a major impact on traditional agricultural practices. Progressive salinization, evidenced by the expansion of salt marshes (+13.06%), amplifies this phenomenon of agricultural decline, as observed by [39] in the Senegal River Delta.

The significant transition from shrub savannas to woody savannah (+80.34%) reflects a process of positive ecological succession. This dynamic, also noted by [37] in the Lama territory in Benin and [40] in agroforestry parks in the Sudanian zone of Côte d'Ivoire, could be explained by a decrease in anthropogenic pressures such as intensive grazing and bush fires, favoring the natural regeneration of woody vegetation. However, the expansion of dense dry forest (+24.26% over 36 years); although positive, masks a phase of regression after 2006, suggesting renewed anthropogenic pressure.

Sène and [41] showed that 50.40% of households in Santhiaba Manjaque encounter difficulties in transporting sick people to health centers. This situation could partly explain the decline in building construction observed after 2006 (-31.44%). However, this surprising decline may also be the result of errors in the classification of satellite images. The commune's isolation, caused by its dense hydrographic network, limits access to basic services and hinders infrastructure development.

The sharp decline in water surface area (-90.76% between 2006 and 2024) is consistent with the regional climate trend highlighted by [36], whose statistical analyses reveal a rainfall deficit affecting all of West Africa since the late 1960s. This water instability directly affects mangrove ecosystems and agricultural activities, creating increased vulnerability to climate change. Santhiaba Manjaque presents a changing landscape marked by partial but fragile ecological regeneration, simultaneously facing worrying agricultural abandonment and accessibility issues. The relatively high stability rates (61.21% over 1988-2024) should not obscure the profound changes affecting certain vulnerable areas, particularly agricultural land and tanneries. Integrated management combining agricultural restoration, mangrove protection, and improved accessibility appears essential to ensure the sustainable development of this Casamance commune.

5. Conclusions

This study, which aims to assess the dynamics of dry dense

forests in the municipality of Santhiaba Manjaque and explain their causes, has revealed a spatio-temporal evolution of land cover and land use units. The results revealed an expansion of dry dense forests and woody savannah despite a slight decline observed between 1988 and 2006. At the same time, agricultural areas declined significantly during the same period. However, although this study shows an expansion of dry dense forests, it also highlights the gradual anthropization of the shrub savannah landscape, which is declining significantly. In fact, in this southern part of the country, vegetation protection is based on peasant and cultural initiatives structured around the sacred. This type of protection seems well suited to preserving forest ecosystems in the area. Furthermore, the security crisis in southern Senegal is causing populations to flee to neighboring Guinea. This displacement has had negative repercussions on agricultural activities, particularly rainfed rice cultivation, which is the main agricultural activity in the area.

To continue preserving dry dense forests and woody savannah, the government must strengthen farmers' initiatives through decrees recognizing this effective model for conserving and preserving woody forest resources. This study could also serve as a basis for local decision-makers to define priority areas for intervention in restoring degraded areas and managing forests.

Abbreviations

B	Built-up
W	Water
DDF	Dry Dense Forest
Ma	Mangrove
AA	Agricultural Areas
WS	Woody Savannah
SS	Shrub Savannah
T	Tan
MU	Mudflat

Author Contributions

Hyacinthe Sambou: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Fode Amata Drame: Formal Analysis, Methodology, Resources, Software, Validation, Visualization

Seyni Sane: Formal Analysis, Investigation, Methodology, Software, Visualization

Conflicts of Interest

The authors declare no conflicts of interest.

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