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Spatio-Temporal Dynamics of Land Cover and Ecosystem Degradation in Madarounfa and Gabi, Niger

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Abstract

Across the Sahel, the combination of rapid population growth, extensive agriculture, uncontrolled livestock grazing, and high demand for fuelwood has led to accelerated degradation of vegetative resources. This study assesses, through remote sensing (Landsat MSS and 7 imagery) and geographic information systems (GIS), the spatio-temporal dynamics of land cover in the communes of Madarounfa and Gabi (Niger) between 1987 and 2017. Five land cover classes were mapped: water bodies, gallery forests, savanna, steppe, and bare soil. Results reveal severe ecological degradation: savanna declined by 8,752 ha and gallery forest by 9,083 ha, while bare soil expanded dramatically from 47,583 ha to 59,069 ha (57% of the total area). The expansion of the steppe likely reflects the degradation of formerly wooded formations. These changes are attributed to intense anthropogenic pressures including deforestation, agricultural expansion, uncontrolled grazing, and high population density combined with climatic variability, characterised by 17 rainfall-deficient years over a 32-year period. Together, these drivers accelerate desertification, threaten biodiversity, and undermine critical ecosystem services. The study confirms the effectiveness of remote sensing for monitoring landscape change over time and underscores the urgent need to implement integrated strategies for sustainable land management, ecological restoration, and community-based awareness to reverse this critical environmental trend.

Keywords: Land Use; Remote Sensing; Degradation; Madarounfa; Gabi

1. Introduction

Forests and natural vegetation formations play a fundamental role in maintaining ecological balance and supporting ecosystem functions. They protect soils against erosion, regulate the water cycle, contribute to global carbon cycling, and promote the conservation of plant and animal biodiversity [4], [12]. In the Sahelian region, these formations, particularly savannas and gallery forests, are critical pillars of ecological resilience against desertification and the impacts of climate change [11]. They provide rural populations with essential goods such as fuelwood and non-timber forest products, as well as vital ecosystem services including pollination, microclimate regulation, and soil fertility maintenance [21], [33].

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However, these ecosystems face mounting pressures of both anthropogenic and climatic origin [33]. Across the Sahel, the combination of rapid population growth, extensive agriculture, uncontrolled livestock grazing, and high demand for fuelwood has led to accelerated degradation of vegetative resources [7], [1]. In Niger, recent studies indicate a significant decline in woody vegetation, with annual loss rates estimated between 0.5% and 1.2%, depending on the region [2], [14]. This trend is exacerbated by increasing climatic variability, characterised by increasingly erratic rainfall seasons and a rising frequency of droughts [24], [30]. Research conducted in Burkina Faso [20], Senegal [25], and Ethiopia [30] confirms this degradation dynamic, highlighting the widespread conversion of savannas and natural forests into bare soils or degraded agricultural lands. Land cover is the physical appearance of land, representing its ecological status. It is dynamically changed due to human interventions, natural disturbances and successions [30]. Land use/land cover (LULC) changes driven by urbanisation have profoundly influenced habitat quality, threatening ecosystem resilience and biodiversity [32]. Globally, the Global Land Degradation Outlook [34] estimates that one-third of terrestrial land is now degraded, affecting over one billion people. Rapid urbanisation and population growth are amplifying challenges such as urban flooding and the intensification of heat island effects, posing significant risks to cities worldwide [31]. In this context, remote sensing and geographic information systems (GIS) have become indispensable tools for spatio-temporal monitoring of land use and for informing ecological restoration policies [23].

In the communes of Madarounfa and Gabi (Maradi Region, Niger), where population density exceeds 116 inhabitants/km^2, pressure on natural resources is particularly acute. This study thus contributes to an urgent scientific effort to diagnose spatial and temporal landscape transformations, aiming to generate evidence-based data to support sustainable land management in Sahelian environments.

1.1. Geographical setting

The Department of Madarounfa occupies the southernmost part of the Maradi Region, located in south-central Niger. Covering an area of 3,500 km^2, it represents 9% of the region's total area, which has a population of 448,863 inhabitants [14]. This is a densely populated area, with a population density exceeding 116 inhabitants per km^2 [10], concentrated primarily along two valleys: the Goulbi Maradi and the Gabi valleys. Madarounfa lies between 13° and 15° north latitude and 6° and 8° east longitude. It is bordered to the north and west by the Department of Guidan Roumdji, to the east by the Department of Aguié, and to the south by the Federal Republic of Nigeria, with which it shares a border approximately 100 km long [14].

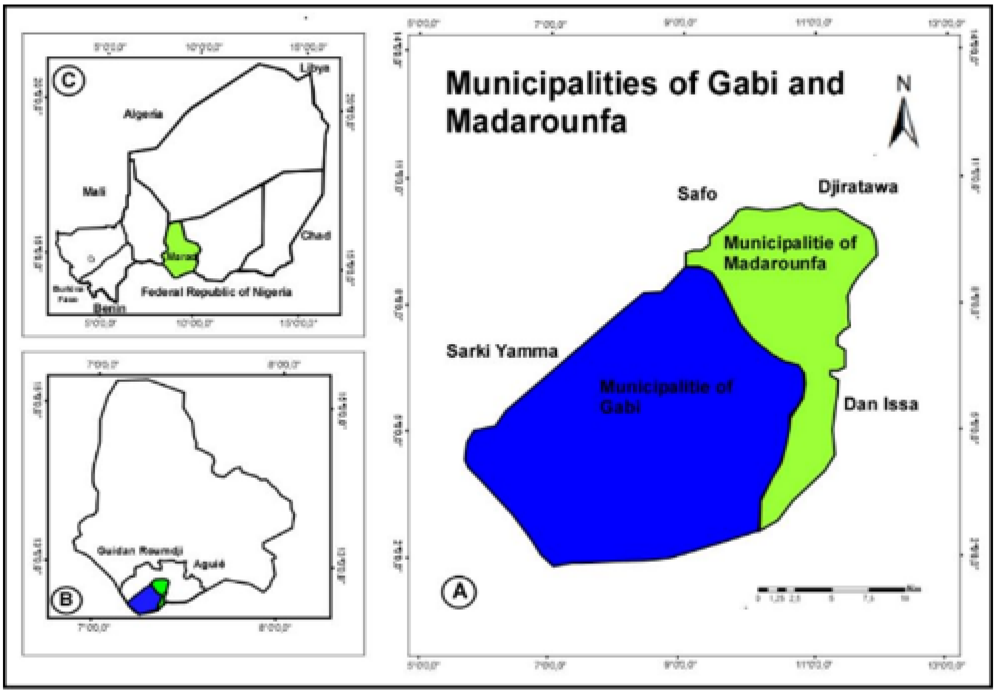

Figure 1 Geographical location of the communes of Madarounfa and Gabi.

The study area experiences a Sahelo-Sudanian climate, characterised by a long dry season (8–9 months) and a short rainy season (3–4 months) [13]. The mean annual rainfall recorded between 1984 and 2015 is 501.44 ± 67.18 mm. Mean maximum temperatures during the coolest and hottest months are approximately 14°C and 41°C, respectively.

The standard deviation indicates high interannual rainfall variability; indeed, 17 out of the 32 years analysed were rainfall-deficient, approximately one in every two years.

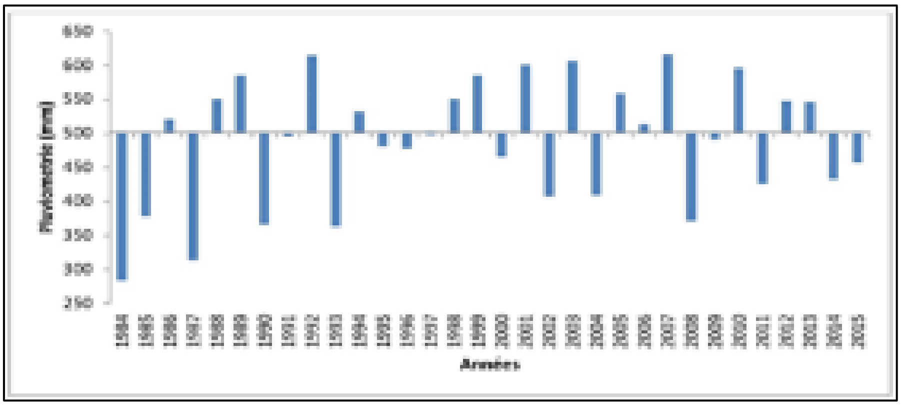

Figure 2 Interannual variability of rainfall in the study area from 1987 to 2015. (Meteorological Station at Maradi Airport)

2. Materials and methodological approach

2.1. Data Used

This table presents the primary geospatial datasets utilised in this study, along with their formats, spatial resolutions, sources, and specific objectives. Shapefiles at a scale of 1:200,000, provided by the CFDG-Niger, were used to precisely delineate the boundaries of the study area. Landsat 7 satellite imagery (GeoTIFF format, 30 m spatial resolution) and Landsat MSS imagery (GeoTIFF format, 69 m spatial resolution), downloaded via the USGS EarthExplorer platform (https://earthexplorer.usgs.gov), were employed for land cover mapping.

Table 1 Characteristics of satellite data

Shapefiles	Shape	1 :200,000	CFDG-Niger	Extraction of study area boundaries
Landsat 7	GeoTIFF	30×30 m	https://earthexplorer.usgs.gov	Land use/land cover mapping
Landsat MSS	GeoTIFF	69×69 m	https://earthexplorer.usgs.gov	Land use/land cover mapping

2.2. Methodology

A series of digital image processing operations was conducted to analyse the spatio-temporal dynamics of land use within the study area. Land cover map production began with the identification and acquisition of Landsat scenes corresponding to the Path/Row coordinates covering the communes of Madarounfa and Gabi. Images were downloaded via NASA's Earth Explorer platform (https://earthexplorer.usgs.gov_) for the years 1987 (Landsat MSS) and 2017 (Landsat 7), prioritising dry-season imagery (mid-September to December) with cloud cover ≤10% to ensure optimal interpretability [27]. Image preprocessing included radiometric correction and filtering using ENVI 5.3 software. Only spectral bands ranging from visible to near-infrared were retained (bands 1, 2, and 3 for MSS; bands 3, 4, and 5 for OLI/TIRS), as these wavelengths provide the most effective spectral discrimination for land cover classes and contain approximately 90% of the spectral information relevant to live vegetation [5], [9], [23]. Image mosaicking was then performed to ensure complete spatial coverage of both communes. False-colour composites were generated to enhance visual discrimination of pixels and facilitate identification of land cover units [15], [25].

Spectral signatures exhibiting uncertainty were geolocated and ground-truthed using GPS field surveys. Digital classification was based on the Yangambi vegetation typology [4] and an interpretative key incorporating site-specific criteria such as geomorphological units, soil texture, laterite crusts, sandstone outcrops, termite mounds, and traces of human activity (e.g., fire scars, grazing patterns), following the Niger NOS land cover nomenclature [18].

Due to the limitations of automated classification methods which are often prone to errors caused by high spectral reflectance variability across land cover types [23], [5] a visual on-screen classification approach was adopted. This method, analogous to supervised classification, involved the manual and exhaustive digitisation of spectrally homogeneous units directly on false-colour composite imagery. This technique significantly improved classification accuracy, particularly for challenging classes to distinguish in Sahelian environments, such as rain-fed agricultural fields.

3. Results and Discussion

Based on Landsat imagery acquired from two distinct time periods (1987 and 2017), a comparative analysis was conducted to assess changes in vegetation cover within the communes of Madarounfa and Gabi. Table 2 summarises the evolution in surface area for each land cover class between 1987 and 2017. Woody vegetation formations, specifically savanna and gallery forest, exhibited significant regression over this 30-year interval.

Table 2 Dynamics of land use units in Madarounfa and Gabi

Land use unit	Area (2017) (ha)	%	Area (1987) (ha)	%	Change (%)
Water bodies	1,145	2	290	1	+1
Gallery forest	5,209	4	14,292	11	-7
Savanna	10,347	10	19,099	24	-14
Steppe	27,352	27	21,859	49	+12
Bare soil	59,069	57	47,583	15	+42
Total	**103,123**	**100**	**103,123**	**100**	

Table 3 provides an assessment of the quality of the land cover maps generated for the years 1987 and 2017, using three validation metrics: the Kappa coefficient, automated overall accuracy, and field-based (ground-truthed) overall accuracy.

Table 3 Accuracy assessment of land use classification in Madarounfa and Gabi (1987 and 2017)

Indice de validation	1987	2017
Coefficient kappa	0,9	0,75
Précision Globale automatique en %	90	84
Précision Globale terrain en %	75	75

3.1. Land Use in 2017

Table 4 shows the various land cover areas across the two communes (Gabi and Madarounfa). Land cover units are divided into five classes (water bodies, gallery forests, savanna, steppe, and bare soil), with surface areas provided in both square meters and hectares. These data enabled us to calculate the extent of each land cover class in the communes of Madarounfa and Gabi for the year 2017.

Table 4 Land use surface areas in the two communes (Gabi and Madarounfa) in 2017

Land use unit	Color	Gabi (m^2)	Madaroufa (m^2)	Total area (m^2)	Numbers of samples per unit	Total area (m^2)	Area (ha)
Water bodies		10031	2696	12727	6	(11454300	1145,43
Gallery forest		45223	12653	57876	20	52088400	5208,84
Savanna		90755	24209	114964	18	103467600	10346,76
Steppe		219874	84040	303914	25	273522600	27352,26
Bare soil		455688	200638	656326	30	590693400	59069,34

Visual interpretation and supervised classification of the 2017 Landsat 7 image enabled the mapping of land cover in our study area (Figure 3). The identified land cover classes include: Water body, Gallery forest, Steppe, Bare soil, Woody savanna, and Degraded forest.

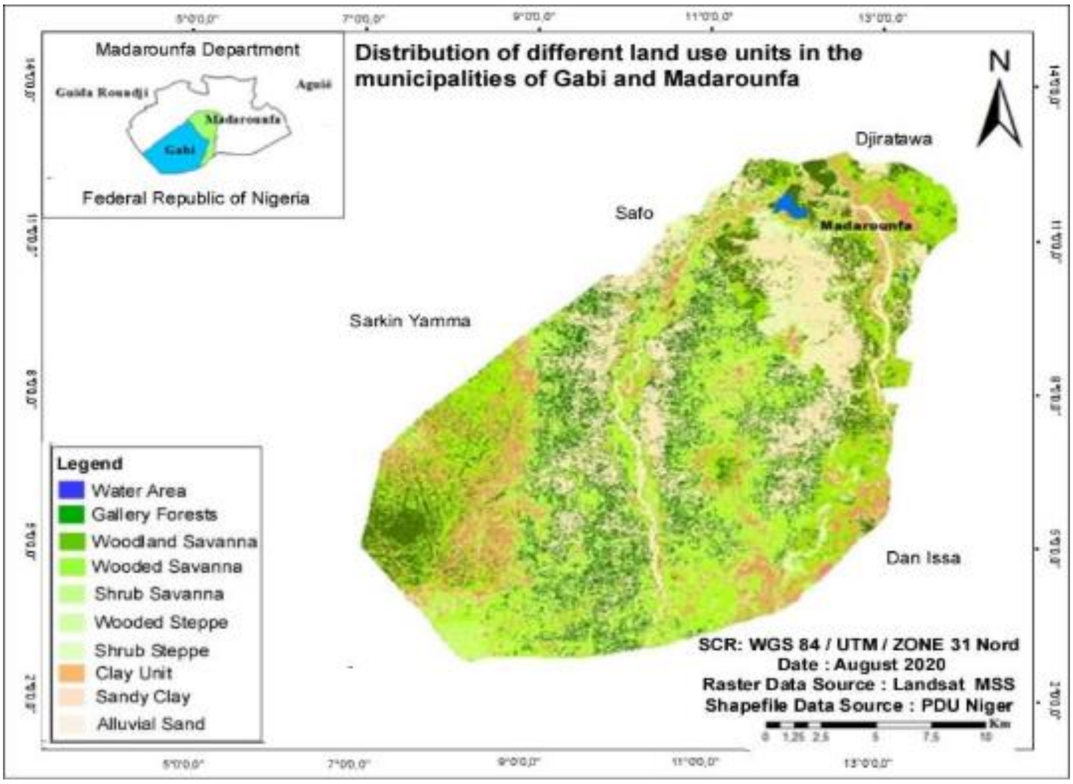

Figure 3 Land use classes in the communes of Madarounfa and Gabi in 2017.

Figure 3 illustrates the spatial distribution and proportional coverage of land cover classes across the communes of Madarounfa and Gabi in 2017. Mosaics of savanna and associated steppe cover a combined area of 105,731.5 ha, predominantly located in the southern and central parts of the communes. Gallery forests, covering 129,304.8 ha, are primarily concentrated in the northeastern sector.

3.2. Land Cover in 1987

Table 5 presents the land cover areas for the two communes (Gabi and Madarounfa) in 1987. Land cover units are classified into five categories: water bodies, gallery forests, savanna, steppe, and bare soil. Surface areas are provided in both square meters and hectares, enabling the calculation of the extent of each land cover class within Madarounfa and Gabi communes for the year 1987.

Table 5 Land use surface areas in the two communes (Gabi and Madarounfa) in 1987

Land use unit	Color	Gabi (m^2)	Madaroufa (m^2)	Total area (m^2)	Numbers of samples per unit	Total area (m^2)	Area (ha)
Water bodies		3	608	611	7	2908971	290,8971
Gallery forest		11	30008	30019	12	142920459	14292,0459
Savanna		42	40075	40117	15	190997037	19099,7037
Steppe		26144	19770	45914	18	218596554	21859,6554
Bare soil		66916	33028	99944	23	475833384	47583,3384

Visual interpretation and supervised classification of the 1987 Landsat MSS image enabled the mapping of land cover in our study area. The identified land cover classes include: Water body, Gallery forest, Steppe, Bare soil, Woody savanna, and Degraded forest.

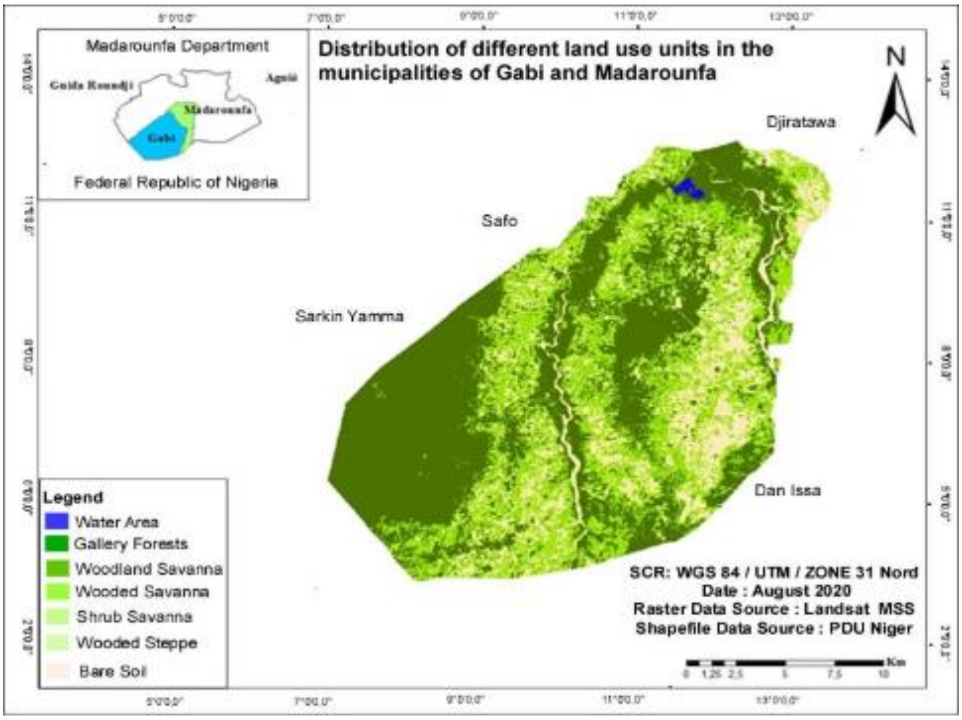

Figure 4 Land use classes in the communes of Madarounfa and Gabi in 1987.

Figure 4 presents the spatial distribution of land cover classes across the communes of Madarounfa and Gabi in 1987, each occupying distinct proportions of the total communal area. Mosaics of savanna and associated steppe, covering 40,959.36 ha, are predominantly located in the southern and central parts of the communes. Gallery forests, with an area of 14,292.05 ha, are primarily concentrated in the northeastern sector.

The results of this study on the communes of Madarounfa and Gabi reveal severe degradation of natural vegetation formations between 1987 and 2017, with a loss of 8,752 ha of savanna and 9,083 ha of gallery forest largely replaced by the expansion of bare soil, which now covers 57% of the total area. This trend aligns with broader patterns observed across Niger, where anthropogenic pressures, rapid population growth, and high demand for fuelwood are accelerating deforestation [2], [12], [1].

This trajectory reflects a regional phenomenon shared across West Africa. Similar dynamics have been documented in Burkina Faso [22], Benin [27], and Senegal [25], where mounting human pressures drive the large-scale conversion of natural ecosystems. At the continental scale, countries such as Ethiopia [30] and Nigeria face comparable levels of desertification. Globally, these findings resonate with the alarming trends highlighted in the Global Land Degradation Outlook [34], which estimates that one-third of the Earth's land surface is now degraded. Despite varying local contexts, the combined effects of resource overexploitation and climatic variability, here evidenced by 17 rainfall-deficient years out of 32 [13], are undermining ecosystem resilience. This underscores the urgent need for integrated strategies encompassing sustainable land management, ecological restoration, and continuous remote sensing-based monitoring to reverse degradation trends.

4. Conclusion

This study successfully characterised the dynamics of vegetation formations in the communes of Madarounfa and Gabi between 1987 and 2017, using remote sensing, field data, and geographic information systems (GIS). The methodological approach combined digital processing of Landsat imagery with ground-truth validation, enabling accurate discrimination of land cover classes. Mapping land cover changes over this 30-year period revealed significant landscape transformations. Notably, vegetation formations exhibited variable dynamics across thematic classes, reflecting the complex interplay of anthropogenic and climatic drivers.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] H. Abdourhamane, M. Boubé, M. Ali, S. Mahamane, and I. Abassa, "Characterization of the spatio-temporal dynamics of land use in the Dan Kada Dodo - Dan Gado classified forest complex (Maradi region, Niger)," 2012, 11 p.

[2] M. Ali, S. Mahamane, B. Yacoubou, I. Abassa, A. Ichaou, K. Saley, and A. Diouf, "Diachronic analysis of land use and vegetation characteristics in the commune of Gabi (Maradi region, Niger)," 2007, 9 p.

[3] M. Ali, S. Mahamane, M. B. Danjimo, K. Saley, B. Yacoubou, A. Diouf, B. Morou, I. M. Maarouhi, I. Soumana, and A. Tanimoune, "Plant Biodiversity in Niger: State of Current Knowledge," 2009, 13 p.

[4] A. Aubréville, "Yangambi Agreement on the Nomenclature of African Vegetation Types," Trop. Woods For., vol. 51, pp. 23–27, 1957.

[5] M. Bachir, "Dynamics of Ecosystem Services in the Oum Zessar Watershed (Southeastern Tunisia)," M.S. thesis, Nat. Inst. Agron., Tunisia, 2013, 102 p.

[6] N. Boulain, "Association between subterranean termites and grasses in a West African savanna: Spatial pattern analysis shows a significant role for Odontotermes n. pauperans," 2004, 99 p.

[7] H. Breman, J. J. Kessler, and D. Xu, The distribution and canopy cover of woody species. Int. Livestock Centre for Africa, 1995.

[8] Y. Enonzan, "Use of remote sensing and GIS in the sustainable management of protected areas: The case of the Dogo-Kétou classified forests in Benin," 2010, 82 p.

[9] B. Essifi, "Comparative study of erosion risks around water points in the Dahar and El Ouara rangelands in the Tataouine region: Application of remote sensing and GIS," M.S. thesis, Fac. Lett., Arts Humanit. Manouba / Inst. Arid Reg., Médenine, 2008, 122 p.

[10] M. Harouna, "The Management of Returnees from Libya in the Municipality of Tchintabaraden (Niger): The Challenges of Emergency and Sustainability," 2012, 20 p.

[11] Y. Hountondji, "Environmental Dynamics in the Sahelian and Sudanian Zones of West Africa: Analysis of Changes and Assessment of Vegetation Cover Degradation," Ph.D. dissertation, Univ. Lomé, 2008, 152 p.

[12] A. Ibro and G. Assoumane, "Land Use in Niger's Classified Forests and Analysis of Change Dynamics," Forest Resour. Assess. Programme, FAO, 2009, 25 p.

[13] A. Ichaou, "Characterization of Lowland and Sandy Plain Formations: A Prerequisite for a Better Understanding of Their Regeneration Dynamics," MHE/LCD, PAFN, Niamey, Niger, 2004, 91 p.

[14] Nat. Inst. Stat. (INS), "Presentation of the fourth results of the General Population and Housing Census (RGP-H) Niger," 2012, 15 p.

[15] K. D. Kpedenou, O. Drabo, A. P. Ouoba, C. E. D. Dapola, and T. K. T. Tanzidani, "Land Use Analysis to Monitor Landscape Changes in the Ouatchi Territory in Southeast Togo Between 1958 and 2015," CERLESHS Pap., vol. 31, no. 55, pp. 203–228, 2017.

[16] S. Mahamane, "Land Use and Plant Evolution in the Department of Maradi," 2001, 43 p.

[17] A. Mama, B. Sinsin, and J. T. C. Codjia, "Anthropization and Landscape Dynamics in the Sudanian Zone of Northern Benin," 2013, 11 p.

[18] Minist. Environ. Fight Desertif., "Nomenclature for the Construction of Land Use Databases (NOS) in Niger South of the 16th Parallel," 2001, 69 p.

[19] F. Olivier, "The Use of the Walloon Forest," 2005, 54 p.

[20] S. Paré, "Ecosystem-Based Forest Management in the Boreal Forest," 2008, 28 p.

[21] R. Habou, A. Diouf, B. A. Bationo, A. Mahamane, K. N. Segla, K. Adjonou, R. Radji, A. D. Kokutse, K. Kokou, and M. Saadou, "Demographic structure of natural populations and spatial distribution of Pterocarpus erinaceus Poir seedlings in the Tiogo forest in the Sudanian zone of Burkina Faso," 2015, 13 p.

[22] M. Larwanou, T. Adam, and A. Mahamane, "Effect of agro-ecological variables on the distribution of vegetation in the human-affected Dasga palm-tree forest in Niger," 2005, 17 p.

[23] T. M. Lillesand and R. W. Kiefer, Remote Sensing and Image Interpretation, 3rd ed. New York, NY, USA: John Wiley & Sons, 1994.

[24] B. Sambou, "Statistical model of daily rainfall in the Sahelian zone: Example of the upper basin of the Senegal River," 2004, 15 p.

[25] M. A. Sarr, "Mapping land use changes between 1990 and 2002 in northern Senegal (Ferlo) using Landsat images," Cybergeo: Eur. J. Geogr., no. 472, 2009. [Online]. Available: https://doi.org/10.4000/cybergeo.22706

[26] T. Vroh Bi, K. L. Kouadio, A. G. N'Guessan, and A. N'Zo, "Floristic and structural diversity at a voluntary nature reserve in Azaguié, southeastern Côte d'Ivoire," 2010, 11 p.

[27] J. Avakoudjo, A. Mama, V. Kindomihou, and B. Sinsin, "Land use dynamics in the W National Park and its periphery in northwestern Benin," 2014, 18 p.

[28] S. A. Toy, "Analysis of the impact of the spread of teak (Tectona grandis L.f.) on landscape structure in the Atlantique Department (Southern Benin)," Ph.D. dissertation, Univ. Abomey-Calavi, 2012, 190 p.

[29] G. Wispelaere, Vegetation mapping of the “W” Complex. Montpellier, France: CIRAD Éditions, 2002.

[30] S. S. Dhruw, N. G. Patil, N. Anurag, R. K. Naitam, N. Kumar, and A. Kumar, "Land use/land cover change detection using remote sensing and GIS approach in Sawangi watershed of Yavatmal district, Maharashtra, India," Int. J. Plant Soil Sci., vol. 35, no. 18, pp. 335–345, 2023. [Online]. Available: https://doi.org/10.9734/ijpss/2023/v35i181752

[31] B. V. Nabikandi, A. Hami, K. V. Kamran, and A. Russo, "Evaluating urban ecosystem services and resilience using remote sensing and InVEST model: A case study of flood risk control and urban cooling in Tabriz," Sustain. Cities Soc., p. 106654, 2025. [Online]. Available: https://doi.org/10.1016/j.scs.2025.106654

[32] B. Veisi Nabikandi, A. Rastkhadiv, B. Feizizadeh, S. Gharibi, and E. Gomes, "A scenario-based framework for evaluating the effectiveness of nature-based solutions in enhancing habitat quality," GeoJournal, vol. 90, no. 2, p. 55, 2025. [Online]. Available: https://doi.org/10.1007/s10708-025-10345-1

[33] F. Shoja, B. Veisi Nabikandi, and B. Feizizadeh, "Spatiotemporal analysis of urbanization-driven land use changes in Tehran Province using novel technologies," J. Geogr. Cartogr., vol. 8, no. 2, p. 11630, 2025. [Online]. Available: https://doi.org/10.3390/jgc80211630

[34] UNCCD, "Global Land Outlook. Summary for Decision Makers. Second Edition," United Nations Convention to Combat Desertification, Bonn, 2022. [Online]. Available: https://www.unccd.int/sites/default/files/2022-04/GLO2_SDM_low-res_0.pdf.