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Research Article

DIACHRONIC STUDY BY SPATIAL REMOTE SENSING OF CHANGES IN PLANT COVER IN MINING SITES IN THE POURA GOLD MINE

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Abstract

During the decade 2010-2020, Burkina Faso experienced a significant mining boom. However, this phenomenon, although presenting enormous opportunities, is also a source of pollution and considerable negative impacts on vegetation. This study, carried out on the site of a former mine in Burkina Faso (Poura and surrounding artisanal sites) aims to evaluate the changes made in the vegetation under the influence of industrial and artisanal mining during the three phases: before, during and after mine operation. Landsat images from 1981, 2001 and 2021 were used to classify vegetation along with statistics on land use. The transition matrix has been created. The land use map for these three periods as well as the change map were produced. The results in the mine area indicate a reduction of forest land in favor of other occupations. The areas of wooded savannahs decreased from 1,285 ha in 1981 to 6 ha in 2001 and gallery forests from 51 ha to 39 ha. However, over the same period we are witnessing an improvement in shrub and grass savannahs of 5% of its initial surface area. The same goes for rainfed crops and agroforestry which increased by 20%. The period from 2001 to 2021 is marked by the closure of industrial mining and an increase in artisanal mines. This change in exploitation mode is marked by an increase in gallery forests and tree savannahs from 39 ha to 77 ha and from 6 ha to 57 ha respectively to the detriment of shrub and grass savannahs which lost 42% of their surface area. As for crops and habitats, they increased by 75% and 4% respectively. The typology of changes in land use showed a degradation of the plant cover due to industrial and artisanal exploitation. The industrialization of mining has had a negative impact on wooded areas, namely gallery forest and tree savannah, while artisanal mining has had a negative impact on shrub and grass savannahs. These degradations, whether industrial or artisanal, have converted land occupation units into fields and habitats. The degradation of the ecosystems of this area results from an action combined with factors linked to mining and the growth of fields to respond to the increase in the population coming from elsewhere in search of the precious stone. This activity must be supervised through training and awareness raising so that it can benefit the population, without having a negative impact on the environment.

Keywords: Mining sites, Land degradation, land use types.

INTRODUCTION

The continued degradation of West African vegetation cover is partly due to population growth and climatic factors. To this end, Burkina Faso, a Sahelian country, is faced with serious problems of accelerated degradation of natural resources (Akiekou, 2009). This phenomenon is increasingly exacerbated in mining sites. In addition to meeting the need for land for the construction of infrastructure, these areas face the advance of the agricultural front and the anarchic exploitation of forest resources including wood energy to meet the strong demand of the population. moved to search for gold. Indeed, Burkina Faso has significant mining potential. Since the 2010-2020 decade, there has been an unprecedented increase in mining sites, particularly in the gold sector which has constituted one of the important pillars of the national economy since this period. Although mining offers multiple socio-economic benefits to the country, it must be recognized that it is most often accompanied by pollution, soil degradation, deforestation, loss of biodiversity, etc. The commune of Poura is a gold mining town par excellence. It is home to both industrial and artisanal mining operations and constitutes an economic boon for the populations, with poorly managed social and environmental consequences (Bohbot, 2017). The gold miners carry out unprecedented excessive cutting of wood to maintain their holes, for their spontaneous dwellings and their sheds. The use of cyanide, acid and zinc in the search for the yellow metal Non-compliance with environmental texts results in water pollution, soil degradation, deforestation and loss of biodiversity (SP/CNDD, 2016).

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ended up polluting the water table, and the cultivable soils were disturbed and became unsuitable for agricultural use. This land degradation combined with the harmful effects of climate change is one of the most serious contemporary environmental problems. To resolve the problems raised and reduce the harmful effects of climate change, several possible solutions are being considered in order to have quantified data to allow the authorities to make appropriate decisions. This is how remote sensing appears to be one of the possible solutions. Changes in land use are often known, but it is their magnitude that differs depending on the type of pressure and ecological and environmental conditions. To this end, remote sensing will be a powerful tool for studying the dynamics of degradation (SOULAMA *et al.,* 2014). The general objective is to reduce the harmful effects of climate change in mining sites through remote sensing. Specifically, this involves: (i) evaluating the variables that are the land occupation units in the Poura gold mine; (ii) produce land occupation statistics for the years 1981, 2001 and 2021; (iii) determine the changes in use of the periods covering 1981, 2001 and 2021. The hypothesis put forward claims that forest resources have degraded with mining in the commune of Poura during the last forty (40) years.

MATERIALS AND METHODS

Study environment

The study area is the rural commune of Poura, Balé province, in the southern part of central Burkina Faso (Figure 1). It extends over an area of 101.81 km² and is located between 2°42'30" and 2°49' west longitude and between 11°34'30" and 11°44'30" latitude north.

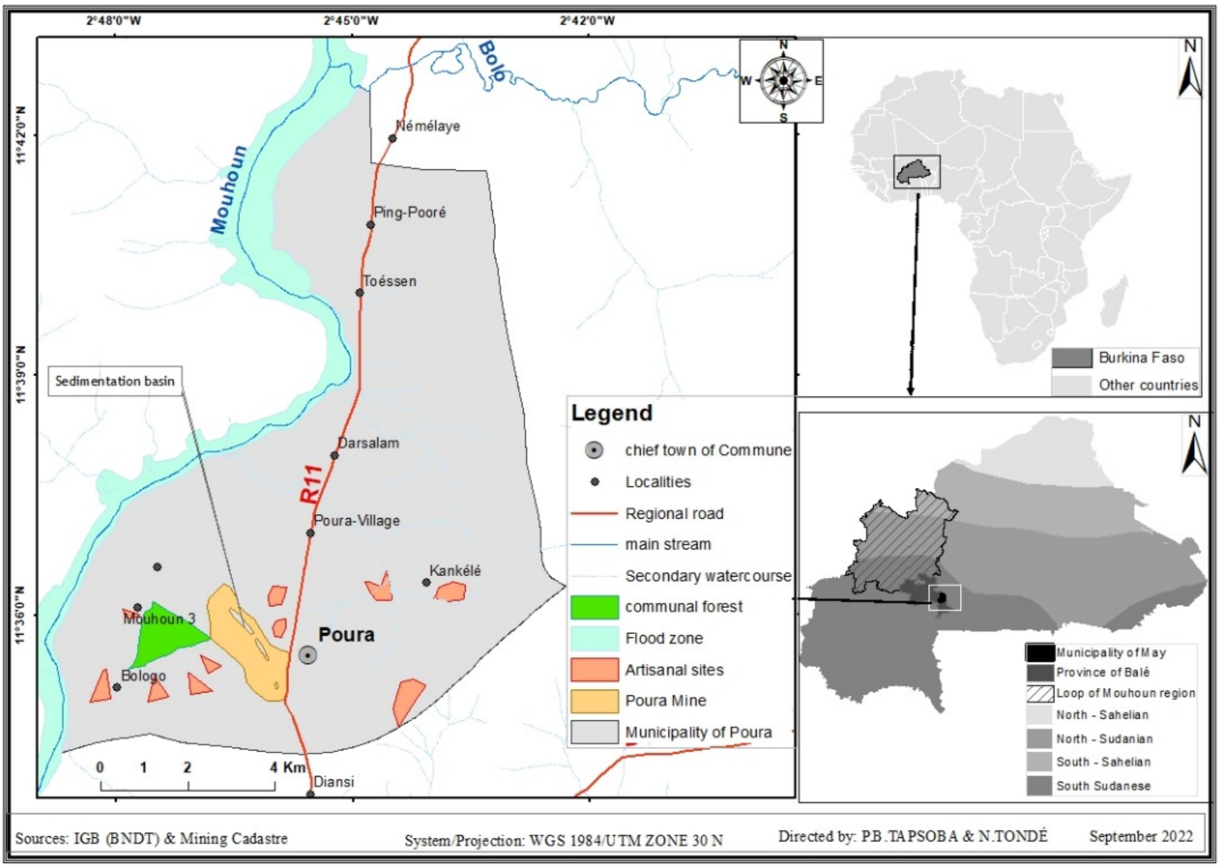


Figure 1. Location of the municipal forest, the industrial site and the artisanal sites in the commune of Poura

It is located in the South Sudanese phytogeographic zone and is part of the Sudano-Sahelian band with an annual rainfall varying between 811.3 ± 84.41 mm. The quantities of rainwater recorded during this period vary between 511.00 mm and 1022.2 mm. (PCD, 2020). Its climate is characterized by the alternation of a dry season, from October to April, and a rainy season which extends from May to September (Thiombiano and Kampmann 2010). The vegetation is predominated by shrubby and grassy savannahs in forest relicts to the South, West and East of the study area. The area is located in the watershed of the Mouhoun River, one of the main rivers of Burkina Faso. The commune of Poura is one of the first gold mining areas. It has an industrial gold mining site which remained without activity after its closure in August 1999 (ORCADE, 2006).

Study Material and Method

Delimitation of the study area: The study area covers a radius of 2 km around the industrial mine. In fact, this limit was made on the basis of documentary research, discussions with resource people and data from surveys carried out. These surveys have shown that the greatest pressure exerted on forest resources is around the 2 km radius from the old industrial mine. In addition, this radius takes into account not only artisanal exploitations but also the municipal forest of Poura which constitutes a reserve zone for the forest resources of the municipality.

Choice of period and acquisition of satellite data: The study covered the years 1981, 2001, and 2021, i.e. steps of 20 years. These steps allow us to observe changes in land use that took place before and after the operations of the Poura mine.

Landsat satellite images were used to monitor the spatiotemporal dynamics of land occupation over the reference years selected, which is the installation of the mine. This is scene 198-052 Landsat5 ETM 2001; nineteen eighty one ; and 196-052 Landsat8 OLI from 2001, 2021. These are archive images, with free access. They were uploaded to the website https://earthexplorer.usgs.gov. These images, which have a spatial resolution of 30 m x 30 m, do not offer good precision but they were retained because of their availability over the reference years of the study. The periods of the images used are between November and February of 1981, 2001, 2011. The choice of these periods is justified by the nature of the information sought, the link of which must be established with the evolution of the different types of forest formations. Two images taken in the dry season and in the wet season allowing better discrimination of fields with high chlorophyll activity from natural vegetation were used. In addition to satellite images, the National Topographic Data Base (BNDT) of Burkina Faso from 2012 produced by the Geographical Institute of Burkina (IGB) was used. The NTDB includes basic geographical information such as the road and hydrographic network as well as toponymy. It was used as a base map on which the land use databases of the study site were superimposed. Field data were also collected in addition to satellite images for the validation of the classifications made.

Satellite image processing: The semi-automatic satellite image processing method was used. The steps followed are: preprocessing, classification, field control and error correction, classification evaluation, editing of maps and land use statistics.

The different stages of satellite image processing are illustrated in Figure 1.

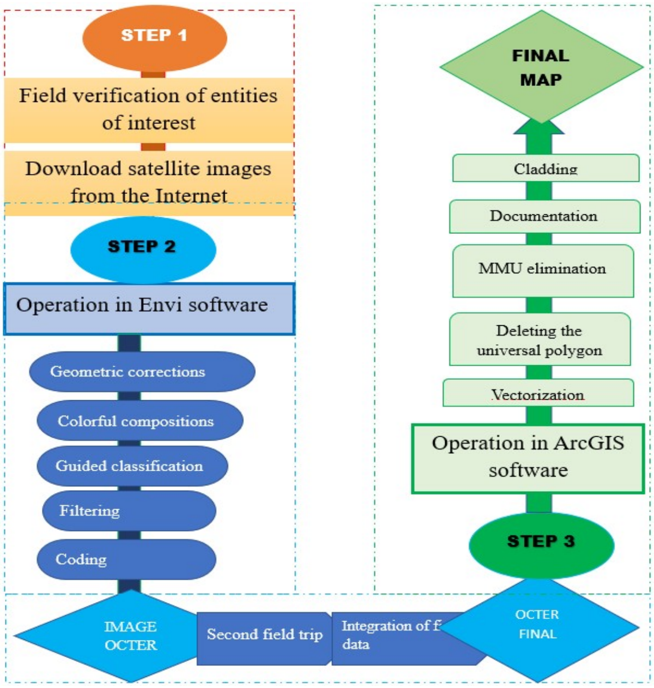


Figure 1. Steps in satellite image processing

Preprocessing of satellite images: The satellite images used had already undergone pre-processing which consisted of geometric corrections by the supplier before being put online on the download site. The preprocessing carried out as part of the study only concerned corrections linked to atmospheric and radiometric disturbances. The objective of preprocessing operations is to correct the geometric and radiometric deformations of platforms and specific sensors, in order to improve the readability of images by eliminating all atmospheric effects (Jofack-Sokeng, 2016). With a view to better discrimination of land occupation entities, colored compositions were produced for each of the images, according to the spectral bands deemed relevant (TABOPDA *et al.,* 2010; SOULAMA *et al.,* 2014). Thus, a near infrared/red/green colored composition (bands 5 / 4 / 3) was chosen for all the processed images because it better characterizes the plant cover.

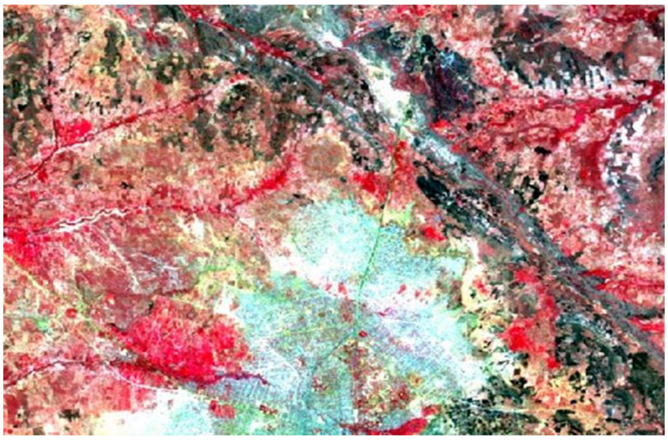


Figure 2. Colored composition of 2021 Lands at image of the study site

From the colored compositions, visual interpretations were made based on the BDOT 2012 nomenclature of Burkina Faso (MEDD, 2011b). Visual interpretation is an operation which consists of displaying the image on the screen and identifying objects, and judging their meaning and importance. The interpretation is based not only on the reflectance values of each pixel in the image. This also takes into account the spatial and spectral information of the images (shape, color, size, structure, texture, neighborhood, shadow), auxiliary information collected in the field and existing documentation on the theme and the environment. study. The interpretation made it possible to identify and separate the large land occupation units such as agroforestry territories, tree savannah, shrub and grass savannah. It should be noted that rainfed crops and agroforestry areas and bare soils have an almost similar spectral signature for which field monitoring made it possible to discriminate between them.

Supervised classification of satellite images: For this step, supervised classification was used. It is an image processing method which is based on a priori knowledge of the spatial components of the study area. It consisted of selecting a sample of pixels representative of the different land use units identified on the basis of their reflectance. The maximum likelihood algorithm of the Envi 5.3 image processing software was used to classify the multi-date satellite images. The classified images underwent a certain amount of post-classification processing in order to sharpen contiguous themes. These treatments also made it possible to eliminate isolated pixels before the vectorization of each image. After filtering, the results obtained were automatically digitized. This led to a conversion of the different classes from raster to vector (polygon) using Envi 5.3 software to obtain shapefiles. It is this type of file that was edited to generate maps and land use statistics for the study site using ArcGis software.

Field trip: The detection of different land occupation units based on satellite images alone remains difficult, which is why it is necessary to rely on data collected in the field (SARR, 2009 cited by LEROUX, 2012). The GPS receiver was used for recording the geographical coordinates of the objects and the field verification of the occupied units sought. The first field trip was carried out at the beginning of December 2021. It made it possible to observe the different land occupation units in the area and record their geographical coordinates with GPS. These collected geographic coordinates were used to identify the training sites for classification. We retained the following occupation units: Gallery forests, tree savannahs, shrub and grass savannahs, rainfed crops and agroforestry territories, habitats, bare soils and water surfaces. A validation output of the classification carried out was made in August 2021.

Evaluation of the classification accuracy of processed satellite images and validation of the results: As part of this study, the confusion matrix and the Kappa index were used. The confusion matrix evaluates the overall accuracy of the mapping and classification results for each of the given thematic units. This makes it possible to determine errors of commission (EC) and errors of omission (EO) in the classification process. As for the Kappa index (IK), it makes it possible to evaluate in the confusion matrix, the agreement between the results obtained (an established map) and the truth on the ground. It ranges from 0 to 1 and has 5 categories: very poor agreement from 0 to 0.20; weak agreement 0.21 to 0.40; moderate agreement 0.41 to 0.60; substantial agreement 0.61 to 0.80; almost perfect agreement of 0.81 to 1.

Edition of maps and statistical data generated: The editing of maps and land use data by reference year of the study was carried out using ArGis software. After the vectorization of the thematic layer, it followed the deletion of the universal polygon, the elimination of the smallest minimum cartography unit. (MMU) and unclassified features, the combination of adjacent polygons, the documentation and dressing (symbology) of maps and the production of statistics. Land cover types were classified into forest land and other land. Forest lands are defined according to the MEVCC (2020a) criterion. In the context of the study, forest lands include tree savannah, shrub savannah and grassy savannah. The other lands consist of rainfed crops and agroforestry areas, bare soil and habitats. Land cover statistics generated from ArcGis were exported to Excel for analysis purposes.

Identification and typology of areas of change: Image processing and vectorization are followed by spatial analysis using Envi 5.3 and ArcMap 10.5 software. Cross-referencing land use maps (1981, 2001 and 2021) made it possible to map the dynamics of land use units over 40 years. A transition matrix (Table 4) generated from spatial analyses, describes the changes in state of thematic classes during the period considered (SCHLAEPFER, 2002). Two transition matrices were thus constructed as part of the study. They respectively compare the supervised classifications of 1981 and 2001 and the supervised classifications of 2001 and 2021. The variations were calculated using the following formula: $V = \frac{S1-S0}{t1-t0}$ With V: variation; S1: area year 1; S0: area year 0; t1: year 1; t0: year 0

RESULTS

Verification of classifications and edition of land use maps

Seven land cover classes were finally mapped (figure). They are represented by gallery forests, tree savannahs, shrub and grass savannahs, rainfed crops and agroforestry areas, bare soils, habitats and water surfaces. The discrimination between the different thematic classes is statistically significant (TSAYEM 2000; TABOPDA *et al.,* 2006) with overall statistical precisions of 81.77%, 82.06% and 82.63% respectively for the years 1981, 2001 and 2021.

Image processing on ENVI and Arc Gis software allowed us to produce land use map 2 for 1981, 2001 and 2021.

State of land occupation in 1981, 2001 and 2021

Generally speaking, forest areas decreased between 1981, 2001 and 2021. The statistics below from image processing show the evolution of areas between the three dates. In 1981, forest lands occupied a good place. Shrub and grass savannahs occupy first place with 55%, tree savannahs in second place with 25% and 1% for gallery forests which occupy third place. In 2001, shrub and grass savannahs (60%), rainfed crops and agroforestry territories (35%) and habitats 3%. In 2021, rainfed crops and agroforestry areas occupy 75%, shrub and grass savannahs 18% and habitats 4%.

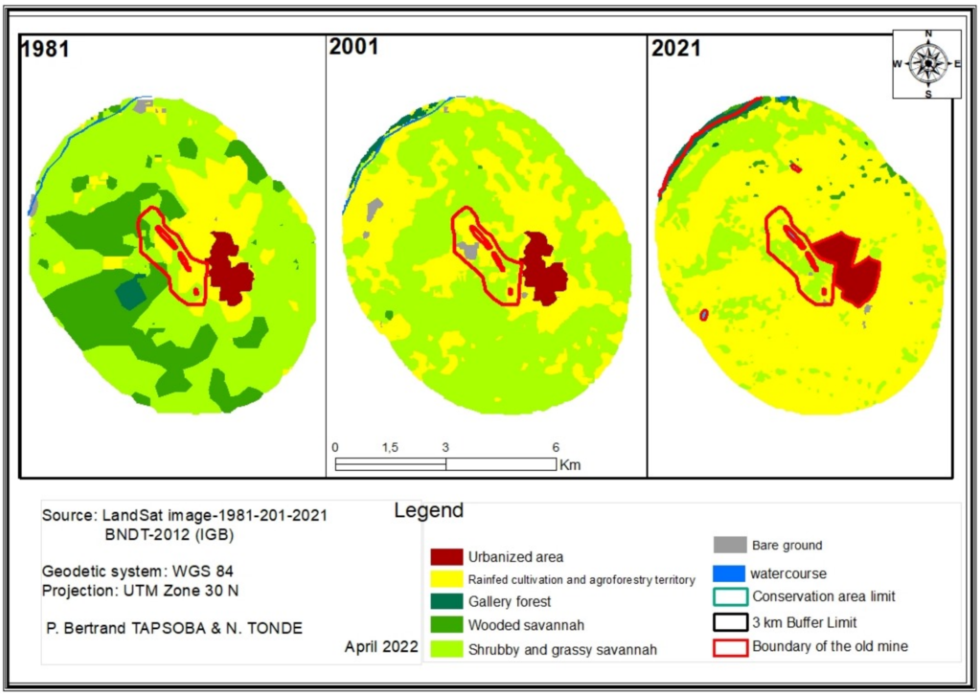


Figure. Land occupation of 2 km radius around the Poura mine in 1981, 2001 and 2021

Table 1. Proportions of different land uses and their gap from 1981-2021

Unité d'occupation	Area 1981		Area 2001		Area 2021		Variations		
	Hectares	%	Hectares	%	Hectares	%	2001-1981	2021-2001	2021-1981
Forest gallery	51	1%	39	1%	77	1%	-0,60	1,90	1,30
Tree savannah	1 285	25%	6	0%	57	1%	-63,95	2,55	-61,40
Shrub and grassy savannah	2 838	55%	3 080	60%	933	18%	12,10	-107,35	-95,25
Rainfed cultivation and agroforestry territory	760	15%	1 802	35%	3829	75%	52,10	101,35	153,45
Habitat	153	3%	153	3%	189	4%	0,00	1,80	1,80
Bare ground	23	0%	30	1%	9	0%	0,35	-1,05	-0,70
Body of water	24	0%	24	0%	40	1%	0,00	0,80	0,80
Total	5 134	100%	5 134	100%	5134	100%	0,00	0,00	0,00

Variations in land use

The analysis of transfers of occupation between 1981 and 2021 essentially shows two phenomena: the decrease in forest land and the increase in other land (crops, bare soil and habitats). A 20% reduction in forest land is noted. This phenomenon increased between 2001-2021 with a 40% increase in crops. From 1981 to 2021 there has been a loss of 61% of forest land. During the period 1981 and 2001, there was a decrease in forest land, notably gallery forests (-0.60 ha) and tree savannahs (-63.95 ha) on the one hand and an increase in shrub and grass savannahs (12 .10 ha) and rainfed crops and agroforestry territories (52.10 ha) and bare soils (0.35 ha) on the other hand (Figure 3).

Figure 3. Evolution of land occupation units in the study area between 1981 and 2001

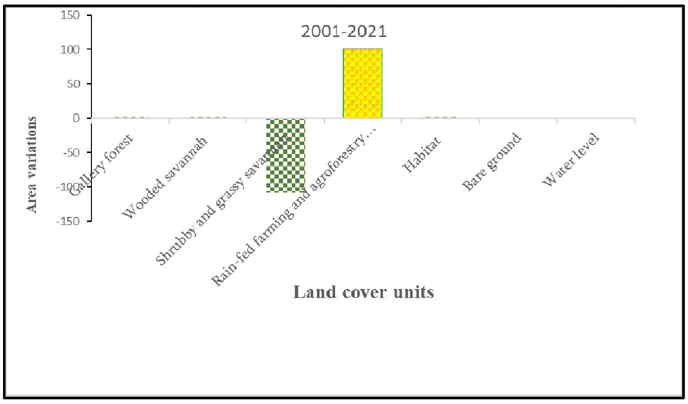


Figure 4. Evolution of land occupation units in the study area between 2001 and 2021

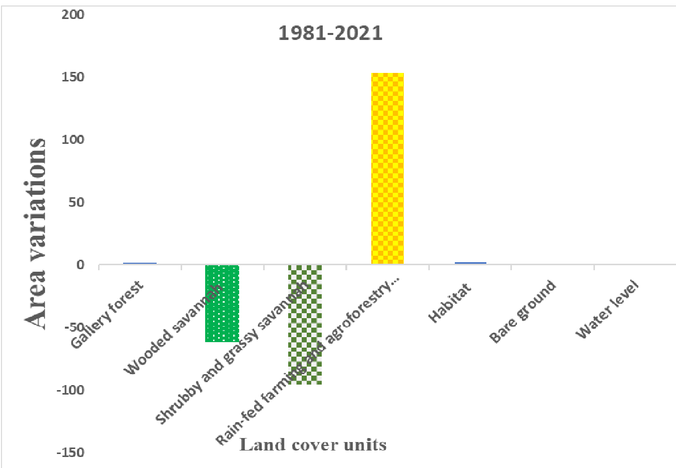


Figure 5. Evolution of land occupation units in the study area between 1981 and 2021

The period of 2001 and 2021 is marked by a recovery of forest lands, namely gallery forests (1.9 ha) wooded savannahs (2.55 ha) and an increase also in rainfed crops and agroforestry territories (101.35ha) and habitats (1.80 ha). In the same period we notice a fall in shrub and grass savannahs (-107.35 ha) and bare soils (-1.05 ha) (Figure 4). Throughout the period of the study (1981; 2021), there was an increase in other lands which include rainfed crops and agroforestry territories (153.45 ha), habitats 1.80ha and a decrease in savannah forest lands. trees (-61.40 ha), shrub and grass savannahs (-95.25 ha) (Figure 5).

Typology and spatial distribution of the changes that have occurred

This part allows us to understand the variations that occurred in the different land occupation units experienced by the area from 1981 to 2001 on the one hand and from 2001 to 2021 on the other hand. The typology of the changes that occurred (Table 2 and 3) shows that throughout the period studied, all the occupation units experienced variations in their surface area during the study period. Table 3 shows the diagonal areas that remained constant. Areas at the top of the diagonal had a loss and areas at the bottom of the diagonal had a gain.

The analysis of Table 2 of the change matrix shows that during the period from 1981 to 2001 the diagonal areas remained constant between this period. Thus, 59% of shrub and grass savannahs, 29% of rainfed crops, agroforestry areas as well as housing remained stable. All forest lands experienced a decline in their surface area ranging from 20.8 ha to 963.3 ha in 2001. Thus from 1981 to 2001, gallery forests and tree savannahs became either rainfed crops, agroforestry territories or, shrubby and grassy savannahs or bare soils. An area of 222.6 ha of shrub and grass savannah is occupied by fields and 1.4 ha have become bare soil and 20.4 ha are fields. The period from 2001 to 2021 (table 3) group, was marked by an increase in the surface area of fields in the zone to the disadvantage of gallery forests, tree savannahs, shrub and grass savannahs. From 1,801.69 ha in 2001, it increases to 3,866.31 ha in 2021, an increase of 40%. The areas of gallery forests were converted into tree savannah (0.35 ha), shrub and grass savannah (0.04 ha) and water surface (9.44 ha). Tree savannahs (34.04 ha) were transformed into rainfed cultivation and agroforestry territory (2,370.30 ha) into habitat 28.7 ha, water surface (8.26 ha) and bare soil (0.15 Ha). Shrub and grass savannahs (274.55 ha) have been converted into habitat (33.24 ha), bare soil (8.56 ha) and water surface (12.92 ha).

Edition of the land occupation unit variation map

Spatially, the variation in land occupation units from the period from 1981 to 2021 represented through map 4 shows stable land occupation units, losses, gains. Stable units concern units that did not vary between 1981 and 2021, losses concern forest units (gallery forest, tree savannah, shrub and grassy savannah) which are converted into other land (field, habitat, body of water, bare soil) and the gains are the transformations of other lands into forest lands. The variation map above shows that during the period covered by the study, 72.61% of the surface of the study area, formerly made up of forest formations, experienced a variation and was converted into other land occupation units. On the other hand, 4.18% of the area saw a resurgence of forest land, other land which was transformed into forest land. In contrast to this trend, 23.18% of the study area did not undergo any change.

Table 2. Land occupation matrix from 1981 to 2001

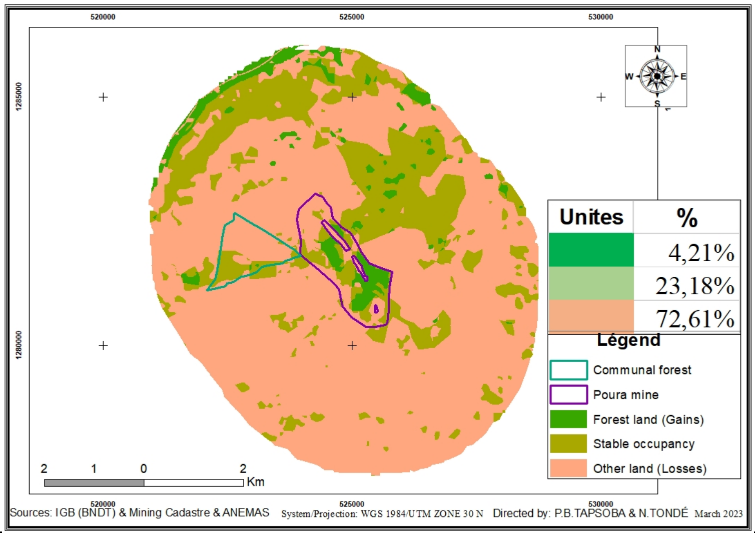
Land occupation unit in 1981	Unité d'occupation des terres en 2001								
	Forest gallery	Tree savannah	Shrub and grassy savannah	Rainfed cultivation and agroforestry	Habitat	Watercourse	Bare ground	Grand Total	%
Forest gallery			29,9	20,8				50,7	1%
Tree savannah	5,6	4,4	1 005,10	258			7,5	1 280,70	25%
Shrub and grassy savannah	22,6	0,6	1 801,30	963,3			27,4	2 815,10	55%
Rainfed cultivation and agroforestry territory	2,6	0,6	222,6	525,6			7,6	758,9	15%
Habitat					152,9			152,9	3%
Watercourse						24,1		24,1	0%
Bare ground			1,4	20,4		0,3	0,1	22,2	0%
Grand total	30,7	5,6	3 060,30	1 788,10	152,9	24,4	42,6	5 104,70	100%
%	1%	0%	60%	35%	3%	0%	1%	100%	

Source: Field data and image processing

Table 3. Land occupation matrix from 2001 to 2021

Land occupation unit in 1981	Unité d'occupation des terres en 2021								
	Forest gallery	Tree savannah	Shrub and grassy savannah	Rainfed cultivation and agroforestry territory	Habitat	Bare ground	Water surface	Grand Total	%
Forest gallery	29,29		17	7,71		0,08	12,96	67,05	1%
Tree savannah	0,35		34,04	18,41		0,06	1,18	54,04	1%
Shrub and grassy savannah	0,04	0,07	618,15	274,55	0,6	23,01	5,3	921,71	18%
Rainfed cultivation and agroforestry territory		1,18	2 370,30	1 446,30	24,76	19,46	4,31	3 866,31	75%
Habitat			28,7	33,24	127,03	0,03		189	4%
Watercourse			0,15	8,56	0,55			9,26	0%
Bare ground	9,44	4,3	8,26	12,92	-	-	0,28	35,2	1%
Grand Total	39,12	5,56	3 076,59	1 801,69	152,93	42,64	24,03	5 142,56	100%
%	1%	0%	60%	35%	3%	1%	0%	100%	

Source: Field data and image processing



Map 4. Changes in land use units between 1981 and 2021

DISCUSSION

The confusion matrices overall show that there are no huge confusion or omission errors between classes. Given the complexity of the Sahelian landscape, such a result can be explained by the quality of the images and the choice of training sites (GEYMEN and BAZ, 2008). Indeed, the images are chosen in such a way as to avoid confusion between crops and natural vegetation on the one hand and on the other hand between vegetation and bush fires which reflect in the near infrared and cause class confusion. (DIALLO *et al.,* 2011; MAMA *et al.,* 2013). The diachronic analysis of land use units shows an even more exacerbated tendency towards degradation in the shrub savannah which is gradually replaced by fields. Along watercourses, land degradation results in a dynamic of reduction in gallery forest vegetation and an increase in fields. PRIPODE (2006) underlines this same observation of anthropization of gallery forests in the eastern area of Burkina Faso. The same trends are noted in other West African countries, notably in Mali (DIALLO *et al.,* 2011), Ivory Coast (KOUASSI *et al.,* 2012) and Niger (MAMA *et al.,* 2013) where these authors showed that dense formations, particularly gallery forests and shrub savannahs, are the most affected by anthropogenic activities. The reduction of forest land in favor of crops and habitats results from the galloping demographics of urban and rural communities over the last 40 years (Diallo, 1993). In the case of Poura, this rhymes with the installation of one of the first industrial mines in Burkina Faso. Indeed, the installation of a mine, whether artisanal, semi-industrial or industrial, always leads to internal migration towards these areas. According to the General Population and Housing Census (RGPH, 2020), the population of the commune of Poura has experienced an increase of 68% over the last fourteen years with a population density which has increased from 118 to 198 inhabitants per km². The consequences of this phenomenon are the increase in demand for forest products and arable land. This continued demand and the cost of respecting environmental protection texts constitutes a constraint leading artisanal mining operators to work illegally. As SAWADOGO, 2021 points out in his study in South-West Burkina Faso.

The decrease in wooded savannahs and gallery forests (between 1981 and 2001) corresponds to the period of industrial mining in Poura. Not only was this mine open pit but also used large means for the extraction of gold. In addition, the operating permit is located in wooded areas along temporary watercourses. As for the decrease in shrub savannah and bare soils (2001 to 2021), it coincides with the period of the establishment of artisanal gold panning. It is practiced with rudimentary means (daba, pickaxe, etc.) and attacks non-forested areas. Indeed, artisanal gold panning, given its informal nature, poses several economic, social and environmental issues. It offers an income opportunity that does not require any particular skills to a young, poorly qualified population with no real prospects (SAWADOGO, 2021). However, this artisanal exploitation is not without consequences on environmental resources as well as on the population. Gold panning is the cause of numerous environmental degradations. The main problems observed are: deforestation and water and soil pollution (Bamba *et al.,* 2013). The transition matrix shows environmental degradation for the benefit of human activities. However, this degradation is not continuous and is marked by a degradation of wooded and shrub savannahs in favor of agricultural areas and gold panning. Although gold mining techniques are partly responsible for this state, their direct impact is local (SAVADOGO 2021). The increase in the population and its needs for wood energy (firewood, charcoal) and wood for the construction of homes, the manufacturing of sheds for spontaneous markets has stimulated wood cutting by local populations and an increase in agricultural areas. The cutting of wood by the local population is at the origin of the gradual disappearance of wooded and shrub savannahs in favor of fields (SAVADOGO 2021). These local practices contribute greatly to the degradation of plant cover. These results demonstrate that in addition to gold panning techniques, the economic activities developed by indigenous people to indirectly benefit from gold panning also contribute to environmental degradation. At the soil level, when they are not directly excavated for gold, they are polluted by the release of toxic substances such as mercury or cyanide. Indeed, a similar study in the commune of Kampti (SAVADOGO, 2021) revealed that the commune is experiencing degradation of plant cover due to gold panning. The same is true for groundwater located near mining sites and contaminated with heavy metals. The transition matrix also demonstrated the most visible impact which is the conversion of rainfed crops and agroforestry territories to bare soils. This illustrates the degradation of the soil due to the progression of gold panning activity to the detriment of agriculture. The change map shows a resurgence of forest areas in the operating permit of the former Poura mine. When the mine closed, the site benefited from special protection and gold miners were strictly prohibited. This protection accompanied by a favorable climate allowed the vegetation to rebuild over time. The results of the comparative study on burned plots, cut down, subjected to early fires and a protected plot in the Tiogo forest showed that the protected one has the best forest statistics (KOALA, 2016). The same study that the vegetation was repeated over the space of 20 years on a cut and protected plot. Environmental degradation is not only due to the techniques used in gold panning, but also to the practices of the local population to meet their wood needs and to take part in sharing the artisanal mining revenue. The degradation of vegetation units in the Sahelian zone is mainly due to poor agricultural practices and overgrazing. Populations are able to adapt to the new state of the environment through the development of soil agricultural exploitation techniques (KADÉBA, SOUNGALA et al 2019).

Conclusion

The desire to contribute to a better knowledge of the dynamics of forest resources led to a study of the spatio-temporal dynamics of vegetation to identify the overall trends in the evolution of mine resources and their causes. The processing of satellite images made it possible to know that the evolution of forest resources in the commune of Poura took place in two phases. The phase from 1981 to 2001 marked by the installation and operation of the Poura industrial mine which was characterized by a large loss of forested savannah land (-25%), a gain of 5% of shrub savannah and 20% of rainfed crops and agroforestry territory. The second phase, which runs from 2001 to 2021, saw a large reduction in the area of forest land. Indeed, this period will be characterized by a strong variation in shrub savannahs (-42%) and fields which have seen an increase in cultivable land (40%). The transition matrix showed the decline of forest formations to the detriment of other lands that are developing. Alongside the ways of using resources (agriculture and livestock) which do not comply with sustainability standards, mining is also a factor in disrupting the environment. Indeed, our results corroborate with the idea of the necessary evil of the mining sector which today constitutes one of the most degrading factors of the environment (SAWADOGO 2021). The extent of degradation and the allocation of land occupation units depends on the mode of exploitation (artisanal, industrial). It is quite true that in this study there remain insufficiencies in disentangling the cyclical effects of mining from the human impact, but these results make it possible to sound the alarm to the municipal authorities, ANEEMAS and DEMAS who work in environmental and economic regulation and to invite them to redouble their efforts. The development of concerted and inclusive management initiatives, with all stakeholders, could allow the gold mining sector to be profitable without degrading the environment.

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