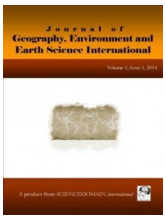

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Influence of Peripheral Socio-economic Interactions and Participatory Management on the Exploitation and Evolution of the Rusizi National Park (Burundi) from 1984 to 2015

Elysée Ntiranyibagira[1,2*], Bienvenu Sambou[1], Hyacinthe Sambou[1,2], Vieux Boukhaly Traore[2,3], Mamadou Lamine Ndiaye[2], Abou Thiam[1] and Fatimata Niang Diop[1]

[1]Institute of Environmental Sciences, Cheikh Anta Diop University, Dakar, Senegal.
[2]Geoinformation Laboratory, Cheikh Anta Diop University, Dakar, Senegal.
[3]Hydraulics Laboratory and Fluid Mechanics, Cheikh Anta Diop University, Dakar, Senegal.

Authors' contributions

This work was carried out in collaboration between all authors. Authors EN, BS and HS designed the study, wrote the protocol, managed the literature researches, collected the necessary data for this study, analyzed data, did the figures (maps), traced the graphs and wrote the first draft of the manuscript. Authors VBT and MLN completed the first draft of the manuscript. Authors AT and FND read, corrected and approved the final manuscript.

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ABSTRACT

The Rusizi national Park management is now disconnected from peripheral territorial dynamics. This study aims to analyze the evolution of the protected area considering both participatory management strategies and spatial socio-economic interactions. For this, an integrated methodology was used. This one combines the diachronic analysis of land cover from multi-temporal Landsat images (1984, 1990, 2000, 2011, 2015) using ENVI 4.5 and ArcGIS 10.1 softwares, field observations and measurements of anthropic threats on the natural resources using

**Corresponding author: E-mail: ebagira2010@yahoo.fr;*

GIS technologies and interviews and statistical analysis of the exploitation of the resources based on ANOVA and χ^2 tests using SPSS 16.0 software. The results show that the protected area has been considerably deteriorated. Its degradation is mainly due to massive and seasonal exploitation of vegetal resources that involves 84% of the supervised operators and 71% of illegal exploitation, generalized farming deforestation, bush fires and cattle grazing. Finally, we note a decline of vegetation cover of 29.9%, a decrease of water bodies of 31.24% and an extension of anthropized areas of 94.5% dominated by cultivated areas which are moving from the depths to the periphery and migrating from heights to the shallows. The increase in offenses results in a symbolic and low-paying participatory management and the presence of 35 villages which are depending on the park for more than 85% of their resources needs. The newest villages are strategically located within 3 km distance from the park where they are experiencing a very quick population growth and a lot of fraudulent markets for forest products. The operating revenues of the park are still too low to ensure self-financing, local development and control of threats. These results will help decision makers and park managers to define appropriated objectives, methods and tools for more efficient community-based management and sustainable use of natural resources.

Keywords: Rusizi national Park; peripheral interactions; Landsat image; land cover; participatory management; income from exploitation; degradation of resources.

1. INTRODUCTION

The integration between nature conservation and the local communities' development, which was initiated in the 1980s through integrated conservation and development projects [1] is lacking sufficient field effectiveness worldwide [2,3]. In Africa, protected areas are still facing significant exploitation pressures and accelerated degradation of their biodiversity, mainly due to rapid population growth, increasing urbanization and limited financial capacity of conservation agencies [6,5,1,4]. In Burundi, protected areas, which cover only 5.2% of the territory, are particularly threatened by agricultural reconversions [7] from poor and landless riparian populations who were violently expelled for many of them at the creation without prior compensation or relocation [8]. The riparian threats were exacerbated by the civil war between 1993 and 2005, which weakened the authority of the state and led to the widespread invasion of natural areas [9]. In order to reduce such pressures, the Rusizi national Park, which is the most threatened protected area by the conversion of land use [7] and which has the most unstable conservation status, initiated supervised exploitation of some resources in the late 1980s, in the framework of participatory management policies [10,11,12]. Despite this integrative approach and the co-management strategy established by the 2011 law, some partial studies showed that conflicts and riparian offenses have increased even if their true outlines were not analyzed [13,7,14]. These developments raise the question of the relevance and effectiveness of participatory management in the socio-economic and spatial context of the protected area. The study is analyzing the dynamics of the resource exploitation and the evolution of the Rusizi Park with reference to the management methods and socio-economic interactions that characterize protected areas and their peripheries [15,3,16,17]. Thanks to a transversal approach, it analyzes the way participatory management activities and peripheral interactions are influencing the real exploitation of the resources and the evolution of the protected area with regard to mechanisms and tools dedicated to the co-management of protected areas [18,19,20,7,21], territorial dynamics and the evolution of the riparian resources demand. The methodology used combines remote sensing techniques and field methods based on mapping, direct measurements and observations, interviews with key conservation actors and statistical analysis.

2. MATERIALS AND METHODS

The methodology is based on four integrated analysis including: (i) analysis of land cover dynamics from Landsat multi-date images from TM sensors for 1984, 1990 and 2011; ETM for 2000 and OLI-TIRS for 2015; (Ii) geo-spatial analysis of riparian interactions and threats using mapping techniques and the "Driving Forces, Pressure, State, Indicators, Responses" (DPSIR) model [22]; (Iii) the exploitation of resources analysis based on data from monthly management reports from 1987 to 2015; and (iv) the perception of the resources exploitation and evolution analysis through semi-structured interviews with stakeholders.

2.1 Study Area

The Rusizi Park is located 12 km from the city of Bujumbura, in its extension zone. It is bounded in the west by the Democratic Republic of Congo, in the north by Cibitoke Province, in the east by National Road 5 and in the south by Lake Tanganika. It has two guard areas, a connecting corridor and two buffer zones covering a total area of 10,673 ha as shown in Fig. 1. The plain of Imbo which encloses the park is the most arid natural region of Burundi. It is characterized by an annual rainfall of less than 900 mm, average monthly temperatures of 23 to 24.5ºC and an altitude varying between 775 m and 1000 m. The region has a great rainfall variability which is marked by longer dry seasons [23].

2.2 Image Processing and Analysis

The cutting, the colored composition and the classification of the images were carried out with the Envi 4.5 software. The classification of the images was supervised with use of the maximum likelihood algorithm [24,25]. The classifications of images have been field validated using a ground control points map for year 2015. For the previous years, the validation was operated using anterior studies results and semi-directive interviews with the former managers and the eldest rangers. After the homogenization of the images classifications with a 3 × 3 Kernel majority filter and their vectorization in Envi 4.5, the results were exported to ArcGIS 10.1 for land cover cartographic analysis. The crossing over of annual land cover maps enabled the generation of land cover change maps which are materialized by the transition matrices [26] whose analysis gives up the "zones of stability" and the "zones of change "which are either" modifications " or " conversions " [27,28].

2.3 Peripheral Dynamics, Interactions and Threats

The analysis of peripheral factors acting as guiding forces or impacting practices [29] was focused on: (i) the location of the park depending villages and markets ;(ii) the socio-economic characterization of the park depending villages; and (iii) the characterization of the dependence of the villages on the park. The location of the villages and markets was done

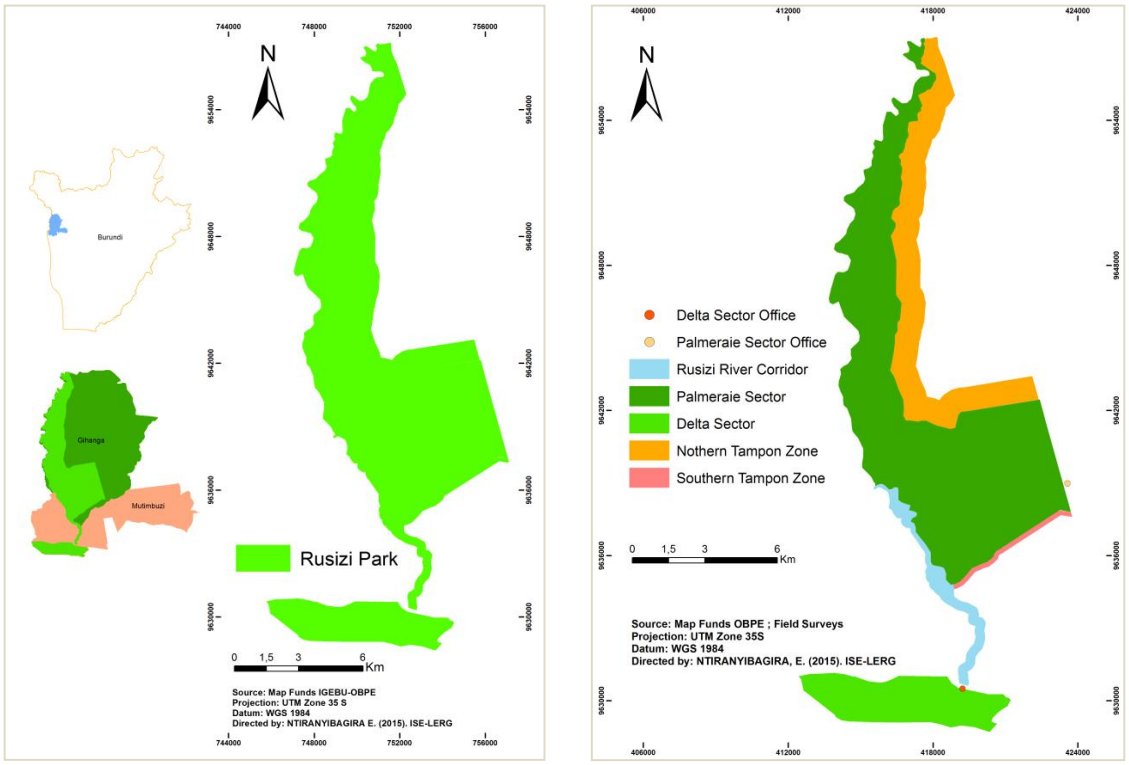


Fig. 1. The Rusizi national Park location and physical configuration

using GPS coordinates (Garmin 60) which were projected in the WGS 1984 UTM Zone 35S system for mapping with ArcGIS 10.1 software. The Socio-economic and park dependence characterization of the villages were carried out on the basis of technical reports, direct observations of traces and semi-directive interviews with stakeholders. The populations of the villages were determined by extrapolating census data from 1979, 1990 and 2008. The potential village threats were thus determined by "distance- access time", "resource dependence" and "demography" with reference to basic anthropogenic pressure indicators [30]; the "distance-access time" meaning both a distance to walk and a time for coming, working and going back home.

2.4 Ecotourism and Resources Controlled Exploitations

The analysis of responses (corrective actions) to threats to the park [29] was focused on: (i) the progress in participatory management [31,32,1]; (ii) the income-generating and self-sustaining capacity by ecotourism and resources exploitation [33,34,35,36]; and (iii) the use of operating revenues. The analysis of ecotourism focused on tourist attraction and financial parameters, such as entrance fees, registered money, collection rates and shortfalls. The analysis of resources supervised exploitation used the data from the management reports on revenue and operating taxes and the results of semi-structured interviews with specific operators on (1) the average daily production, (2) the duration of exploitation activities and (3) the unit selling price for the calculation of net monthly operating income. The results of the data pretreatments on ecotourism and resources exploitation were statistically analyzed using SPSS 16.0 software.

2.5 Perception of Exploitation Conditions and Resources Evolution

The analysis of the perception of the resources exploitation and evolution by specific operators was carried out by means of semi-structured interviews in focus groups. The synthetic assessment examined the following variables: (i) the taxation level, (ii) the production level, (iii) the availability of resources, (iv) the income level and (v) the fraud level. The quotation scale of the variables is: 1 (low), 2 (medium) and 3 (high).

2.6 Resources Fraudulent Exploitation

The analysis of the fraudulent exploitations covered the most damaging ten offenses which were defined by a multi-criteria method of prioritizing which gives the values and levels of impacts by rating and crossing criteria (Table 1). The criteria used are the frequency and

Table 1. Scoring criteria and rating scales for the classification of offenses

Criteria and scales of decreasing gravity	Frequency					Harmfulness					Vulnerability				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Highest number of annual cases (Class 1)															
Class 2															
Class 3															
Class 4															
Lowest number of annual cases (Class 5)															
Intense direct effects															
Moderate direct effects															
Intense indirect effects															
Moderate indirect effects															
Low direct and indirect effects															
Resources threatened with extinction															
Resources in decline															
Resources in balance															
Moderate increase in resources															
Strong growth in resources															
Impact value (IV)	$IV = f * n * v$ (1^3 à 5^3 ou 1 à 125)														
Level of Impact	IV (1-27) LI High					IV (30-64) Moderate					IV (75-125) Low				
Hierarchical order (HO)	Final classification of offenses by gravity														

harmfulness of the offenses and the vulnerability of the resources exploited. The methodology is an adaptation of the methods of rapid assessment and monitoring of protected areas developed by the World Wide Fund for Nature (WWF) and the World Bank based on the protected area assessment framework [37,38]. The results were statistically analyzed using SPSS 16.0 software.

3. RESULTS

3.1 Land Cover between 1984 and 2015

The classification of the images allow to identify different land cover classes including: i) *Hyphaene benguellensis* forest, ii) Dense forest relics, iii) Wooded savannah iv) Shrub savannah, v) Grassland savannah, vi) Aquatic vegetation, vii) water bodies, viii) Naked soils, ix) Cultivated areas, x) Built-up areas and xi) Burned areas (Fig. 2). It shows that we pass from ten classes in 1984, 1990 and 2000 to nine classes in 2011 and 2015. The vegetation cover of the park which represented 7739 ha in 1984 rose to 8312 ha in 1990; 3172 ha in 2000; 5832 ha in 2011 and 5425 ha in 2015, corresponding respectively to 72.49%; 77.87%; 29.71%; 54.63% and 50.83% of the extent of the park. In 1984 and 1990, it was the wooded savannah that constituted the dominant matrix of the landscape, with 43.78% and 45.23% of the area respectively; corresponding to 4,674 ha and 4,827 ha. In 2000, cultivated areas dominated the landscape, with 41.54% of the total area i.e. 4 441 ha. In 2011, the shrub savannah and cultivated areas co-dominated the landscape with 26.88% and 24.63% of the park area; i.e. 2,869 ha and 2,629 ha. In 2015, the landscape is co dominated by shrub savannah and cultivated areas occupying respectively 25.87% and 25.40%; i.e. 2,761 ha and 2,711 ha (Fig. 2).

3.2 Land Cover Changes between 1984 and 2015

The most remarkable changes in land cover between 1984 and 2015 are of two orders. On one hand, we note the disappearance of the wooded savannah and the dense forest relics respectively in 2000 and in 2011, as well as the decline of built areas, water bodies, bare soils, *Hyphaene benguellensis* forest and Grassland savannah which lost respectively 58% ,31% , 22% , 18% and 13% of their surfaces (Fig. 3). On the other hand, we observe an extension of burned areas and cultivated areas whose surfaces have increased by 6613% and 100%, raising from 24 ha to 1639 ha and from 1357 ha to 2711 ha (Fig. 3). Ultimately, vegetation cover and water bodies decreased of 29.9% and 31.2%; elapsing from 7 738 ha to 5 425 ha and from 378 ha to 260 ha respectively. In parallel, anthropized areas increased of 94.5% elapsing from 2,573 ha to 5,004 ha. The greatest deterioration of the park was recorded between 1990 and 2000, while the most positive developments were noted between 2000 and 2011 (Fig. 3).

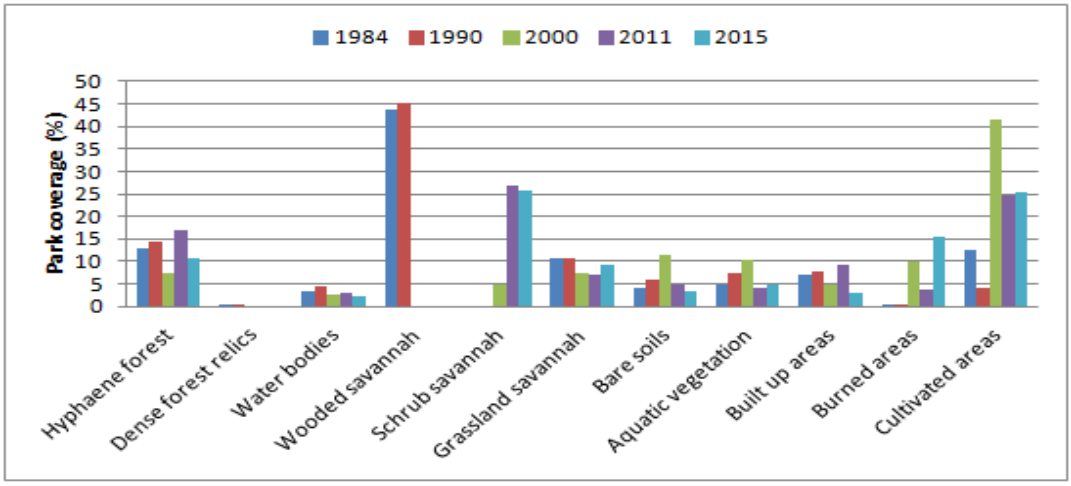


Fig. 2. Evolution of land cover classes between 1984 and 2015

The most notable surface transfers in land cover are the conversion of wooded savannah into cultivated areas (13.93%) and into burned areas (8.96%), the conversion of built areas into shrub savannah (3.27%), the conversion of cultivated areas into burned areas (2.77%) and shrub savannah (1.98%) and the conversion of grassland savannah into cultivated areas (1.81%) as reported in Table 2. The most stable land cover classes are *Hyphaene benguellensis* forest (7.29%), grassland savannah (5.88%) and cultivated areas (4.58%) which represent 76% of the overall stability of the park that covers only 23% of the protected area corresponding to an area of 2 500 ha (Table 2).

The cartographic analysis shows that the protected area has been quite fully occupied by crops at one time or another. The most important inside agricultural activities were recorded during years 2000, 2011 and 2015 (Fig. 4). Cultivated areas, which were located in the depths from 1984 to 1990, gradually moved to the periphery from 2000 onwards, concentrating in the median part of the protected area (Fig. 4) where they stabilized along the Rusizi, Mpanda and Kajeke rivers as well as around the Kimirabasore, Kameme and Mariba water bodies (Fig. 5).

The digital elevation models analysis shows that the cultivated areas are moving from high altitude towards rivers and water bodies below, from 820 m to 760 m, particularly during dry seasons and periods. In the lowest part of the park (780-760 m), the cultivated areas have increased from

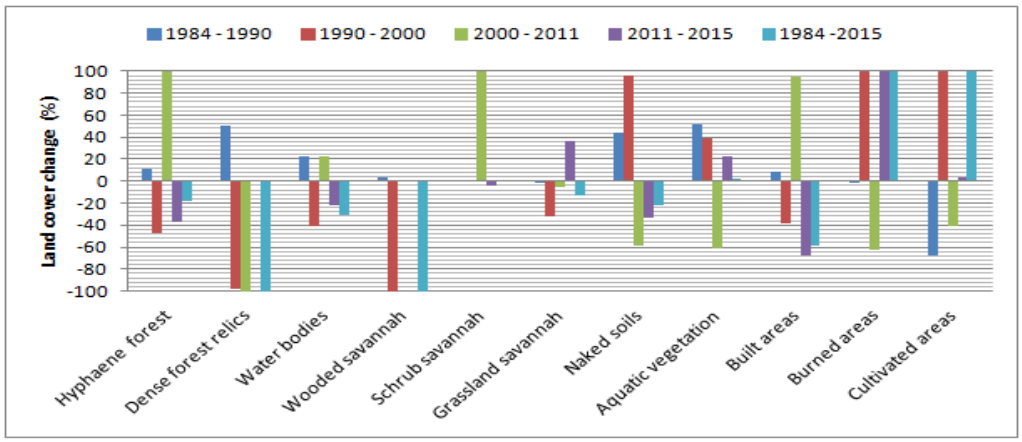


Fig. 3. Comparative spatial expansions of land cover classes between 1984 and 2015

Table 2. Land cover transition matrix between 1984 and 2015 (%)

		Year 2015										
	Classes	**A**	**B**	**C**	**D***	**E**	**F**	**G**	**H**	**I**	**J**	**Total**
Year 1984	A	1,51	0,63	0,22	0,02	0,24	0,00	0,31	0,53		0,06	3,52
	B	0,38	5,88	0,86	0,14	0,59	0,02	1,09	1,81		0,03	10,80
	C	0,03	0,80	7,29	0,66	1,57	-	0,91	1,64		0,01	12,91
	D	0,02	0,21	0,22	17,92	8,96	0,97	0,07	13,93		1,42	43,72
	E	0,00	0,05	0,00	0,03	0,02	-	0,01	0,11		-	0,22
	F	0,00	0,00	-	1,66	0,03	1,36	-	0,73		0,33	4,11
	G	0,31	0,53	0,77	0,15	0,66	0,01	2,01	0,35		0,02	4,81
	H	0,14	1,12	1,26	1,98	2,77	0,04	0,48	4,58		0,32	12,69
	I	0,01	0,09	0,00	-	0,01	-	0,02	0,02	**	-	0,15
	J	0,03	0,07	0,00	3,27	0,48	0,80	0,01	1,64		0,73	7,03
	Total	2,43	9,38	10,62	25,83	15,33	3,20	4,91	25,34		2,92	100

*A: Water bodies; B: Grassland savannah C: Hyphaene benguellensis forest; D: Wooded savannah; D *: Scrub savannah; E: Burned areas; F: Naked soils; G: Aquatic vegetation; H: Cultivated areas; I: Dense forest relics; J: Built up areas*

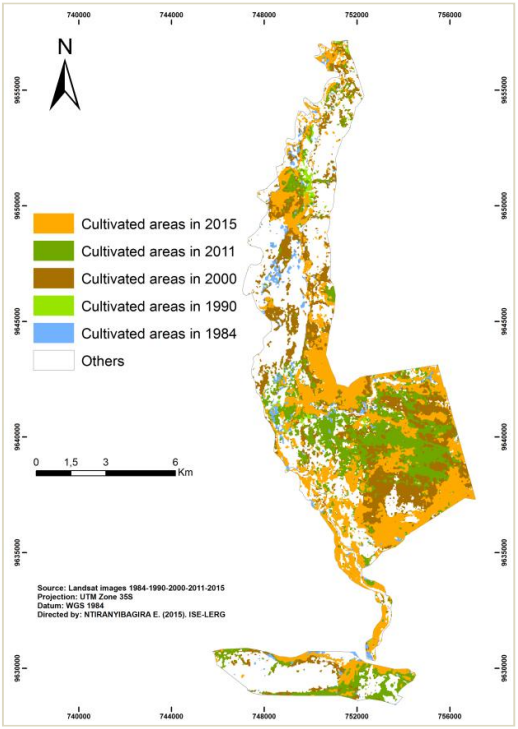


Fig. 4. Spatio-temporal dynamics of cultivated areas

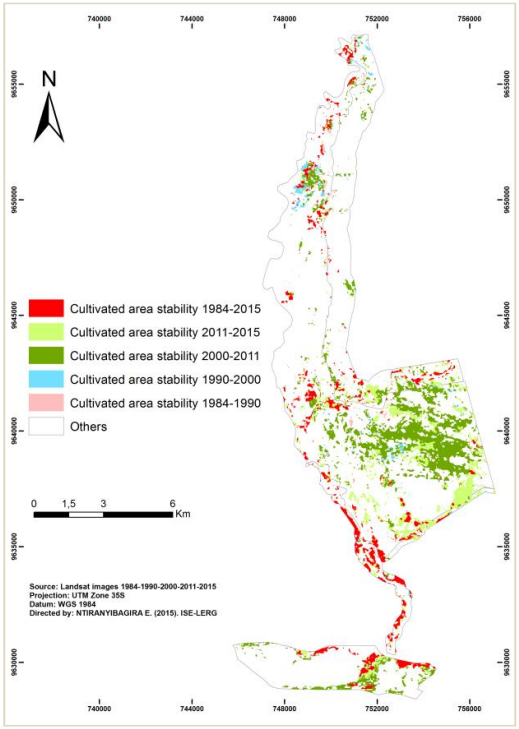


Fig. 5. Evolution of the cultivated areas' stability

94 ha in 1990 up to 441 ha in 2000, 565 ha in 2011 and 610 ha in 2015. The most important agricultural drainages have been realized between 1990 and 2000 and from 2000 to 2011 when they reached 251 ha and 143 ha, respectively. The cartographic analysis shows that the park has faced significant degradation between 1984 and 2015 (Fig. 6). By 2015, stable areas cover 23% of the park while the regression of vegetation, the progression of vegetation and non-vegetation conversions are representing 55%, 14% and 8% respectively (Fig. 7).

3.3 Peripheral Dynamics, Interactions and Threats

The park dependent villages are located in a radius of 15 km. They are characterized by a strong agropastoral activity which occupies 87.9% of them while only 12.1% are living from trade activities. The number of park dependent villages increased from 23 in 1990 to 35 in 2011. The majority of these villages (68.6%) are located at a maximum distance of 6 km which corresponds to a journey time of one hour's walk (Fig. 8). The park dependence of the villages is 100% for timber resources (wood, charcoal), 97% for livestock products (mineral salts, straw, pasture), 88% for agricultural resources (land, crops) and 83% for animal products (meat, fishes). All the park dependent villages own forest products markets. Many of them are fraudulent (69%) while others are agreed and known by the managers (31%) (Fig. 9).

The spatial distribution analysis of the park dependent villages created after 1980 shows that the new localities are mainly located between 0 and 3 km and between 5 and 10 km. They are strongly concentrated within less than 1 km far from the park (Fig. 10).

The increase in the number of riparian villages is accompanied by a decrease in their average distance to the park from 4.78 km in 1980 to 3.64 km in 2011 when the last village was created (Fig. 11). The number of the riparian villages obeys to a linear regression model whose equation is $y = 3.6x + 18.8$ ($R^2 = 0.85$) while their mean distance to the park follows a logarithmic regression model whose equation is $y = -7.704 \ln(x) + 46.876$ ($R^2 = 0.87$).

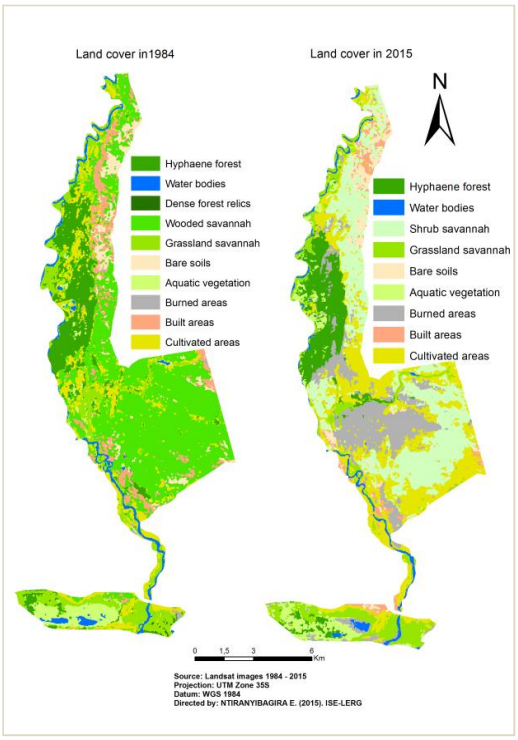


Fig. 6. Comparative land covers in 1984 and 2015

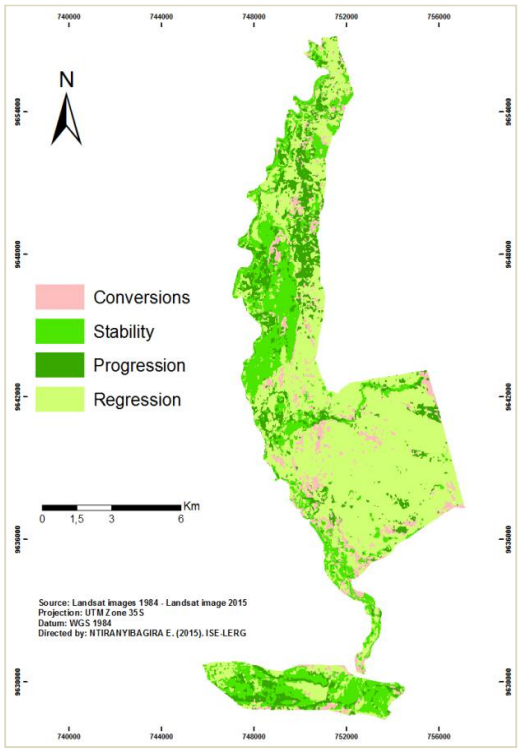


Fig. 7. Land cover changes between 1984 and 2015

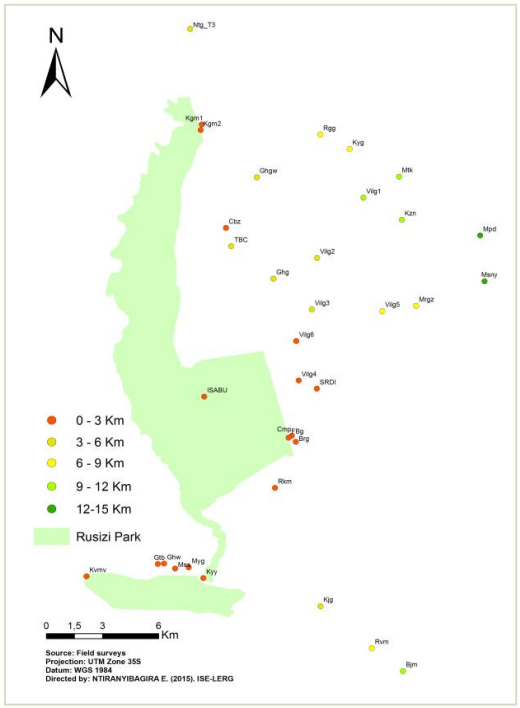


Fig. 8. Spatial distribution of riparian villages

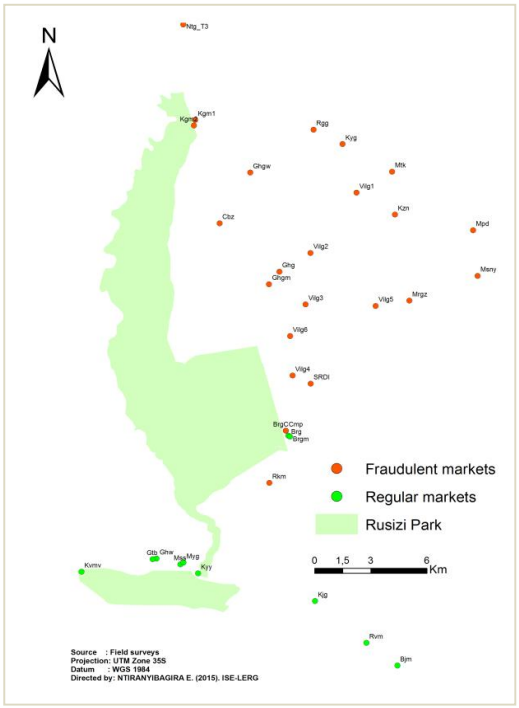


Fig. 9. Spatial distribution and status of the products' markets

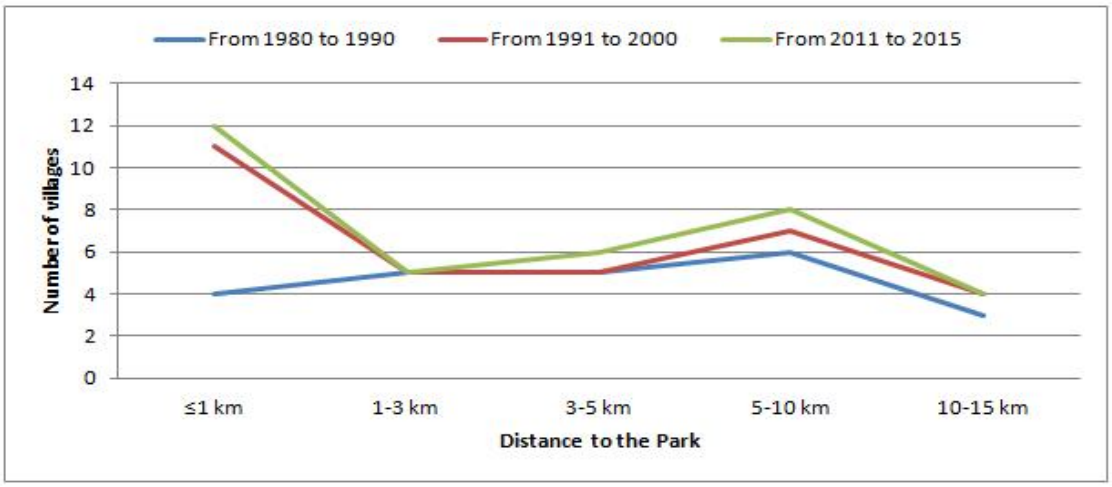


Fig. 10. Spatio-temporal evolution of the riparian villages

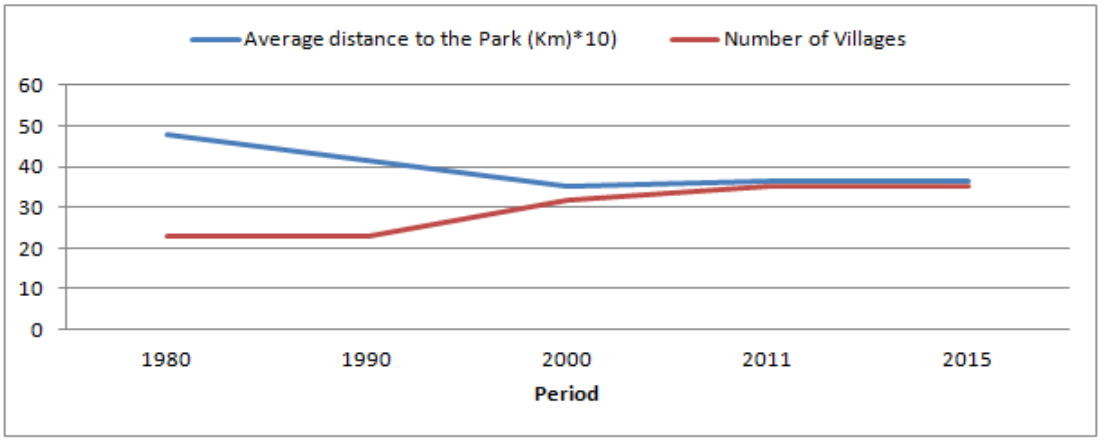


Fig. 11. Comparative evolution of the riparian villages' number and average distance

The spatial distribution analysis of park dependent populations shows that they are concentrated between 0 and 3 km, with a strong concentration within 1 km from the park. In terms of temporal evolution, we noted a considerable population increase between 1990 and 2000 followed by a population decline between 2000 and 2011, within 1 km distance from the park. However, a population decline was observed between 1990 and 2000 in the area located between 5 and 10 km. In general, an accelerated population growth was registered from 2000 between 1 and 10 km (Fig. 12).

3.4 Ecotourism and Touristic Incomes

The results of the analysis show that the tourist population follows a saw-tooth evolution. The largest numbers of tourists were registered before the civil war in 1993 and after the peace recovering in 2005. In terms of nationality and provenance, the ANOVA tests show that tourists are mostly foreigners (P-value = 0.000 <α = 0.05) and mostly residents (P-value = 0.000 <α = 0.05), with a respective average of 62% and 85%. Therefore, ecotourism is a local and seasonal activity which is dominated by resident expatriates. Annually, we have 1,683 tourists, US $ 3,231 touristic income, US $ 2.95 theoretical entrance fees, US $ 2.51 real paid fees, 40.6% recovery rate and US $ 1919 loss, average.

3.5 Resources Controlled Exploitations and Operating Revenues

The results show a shift from two types of resource exploitation in 1987 to five types since 1997. Free in the beginning, the resource

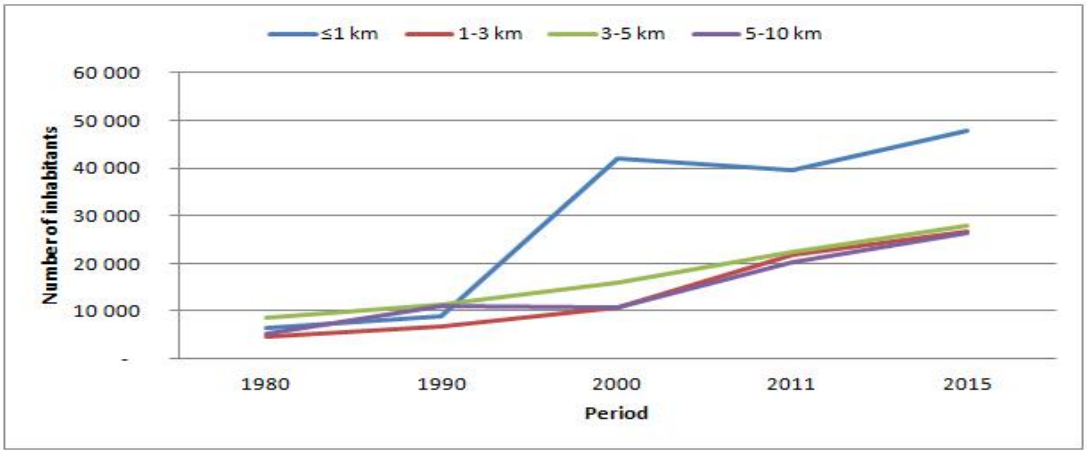


Fig. 12. Spatio-temporal evolution of the riparian populations

controlled exploitation continuously became a merchant activity through taxation and forest product marketing. The exploitation of resources is highly seasonal. It is more important in the dry season than in the rainy season. The activity is annually involving 61 operators and a ratio of 8 operators per 10 000 riparian population, average. Only 31.1% of the operators are market-based while 68.9% of them are self-consuming dead wood. The exploitation of vegetal resources occupies 84% of the operators of which 66% are collecting dead wood, 13% exploiting *Phragmites mauritianus* and 5% getting profit from *Hyphaene benguellensis*. Since the late 1990s, the average annual net monthly income of the operators has been declining leading to a decrease and a significant fluctuation of the operators number (Fig. 13), the enhancement of fraudulent exploitation through the development of fraudulent markets into the riparian villages (Figs. 8 and 9) and the overexploitation of natural resources which brought to a severe degradation of the park (Figs. 6 and 7). The monthly net income decreased from US $ 84.6 in 1987 to US $ 28.5 in 2015; the annual monthly average income being US $ 51.4 for a monthly operating fee of US $ 4.2 and a unit selling price of US $ 2.1 (Fig. 13). The exploitation of *Phragmites mauritianus* and mineral salts gives the highest monthly incomes which reach US $ 79 and US $ 74.7, while collecting dead wood for work is equivalent to US $ 1.3 per month. Conversely, the monthly park revenues increased from US $ 18.8 in 1988 to US $ 230.8 in 2015; the annual average revenue being US $ 159.9. Therefore, we note a growing income imbalance between the park and the operators which is mainly linked to the overtaxing of controlled exploitation which became too important since 2009 (Fig. 13).

When considering the whole annual average revenue of US $ 6,555 made of resource exploitation for US $ 1,919 (29%) and ecotourism for US $ 4,636 (71%), we can assume that the park is far from being self-financing because ecotourism report little when the essentials of resource revenues come from recurrent illegal activities. Indeed, resource exploitation revenues result from controlled exploitations with 39% and fraudulent activities up to 61%; i.e. 32% from penalties and seizures and 29% from clandestine slaughter of *Hippopotamus amphibius*. The ANOVA test (P-value = 0.000 <α = 0.05) of penalties and seizure revenues shows that there are significant differences between years. The highest revenues are related to the period between 2011 and 2015 which is subject to high taxes following the 2009 increases (Fig. 13)

3.6 Perception of Exploitation Conditions and Resources Evolution

The operators consider that the revenues are low. They are decreasing while competitive fraud is overall high (Fig.14). At the same time, they note that the most available resources with medium or high productivity (*Phragmites mauritianus*, *Hyphaene benguellensis*) are also affected by medium to high taxation and are subject to high competitive overexploitation (Fig. 14) which is leading to *Hyphaene benguellensis* forest and *Phragmites mauritianus* based grassland savannah to continuous degradation (Figs. 2 and 3).

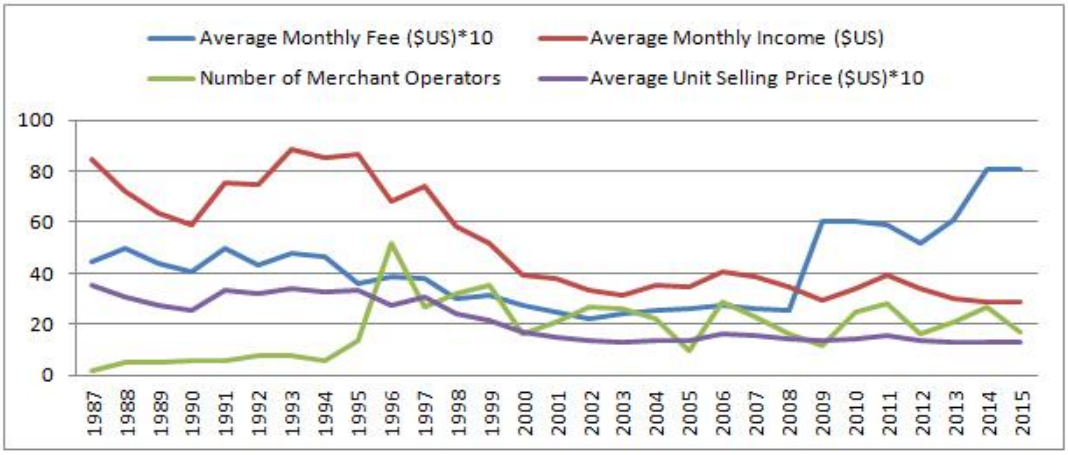
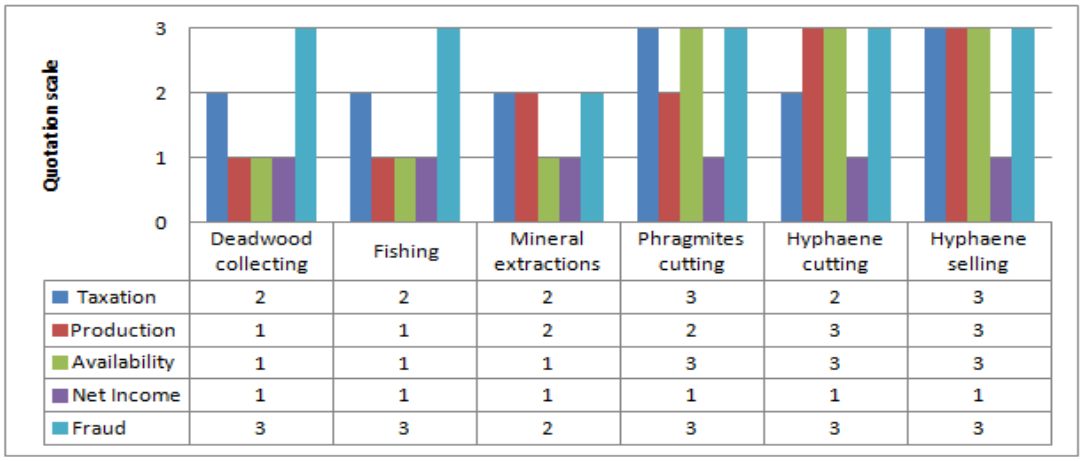


Fig. 13. Evolution of the main parameters of the resource controlled exploitations



	Deadwood collecting	Fishing	Mineral extractions	Phragmites cutting	Hyphaene cutting	Hyphaene selling
Taxation	2	2	2	3	2	3
Production	1	1	2	2	3	3
Availability	1	1	1	3	3	3
Net Income	1	1	1	1	1	1
Fraud	3	3	2	3	3	3

Fig. 14. Values of trend key indicators of the resource controlled exploitations

3.7 Resources Fraudulent Exploitation

The average annual number of offenses registered between 1988 and 2007 is 465, with a decrease rate of 60.7% during the period. Like controlled exploitation, the fraudulent exploitation is highly seasonal. It is more expressed in the dry season than in the rainy season. The results of the hierarchical classification show that the most important ten offenses are direct cuts of vegetal resources (trees, phragmites, hyphaene, grasses), vegetation-destroying operations (grazing, crop cultivation, bush fires), animal resources searches (Fishing, hunting, trapping) and mineral extractions (salts, sands, bricks) (Fig. 15). The vegetation resources cuts, poaching and cattle grazing are the most important pressures with 71%, 12% and 9% of total offenses. The impact values of the selected offenses range from 1 to 20. They correspond to high impact levels (rank 1) (Fig. 15). The ANOVA test (P-value = 0.000 <α = 0.05) shows that there are highly significant differences between resources and that the most recurring offenses are *Phragmites mauritianus* and tree cuts (Fig. 15). The χ^2 statistical test (P-value = 0.000 < α = 0.05) shows that there is a significant link between the sectors and the type and number of offenses. Offenses are more frequent in the Delta than in the Palmeraie sector (Figs. 1 and 15). At the Delta, the *Phragmites mauritianus* and tree-wood cuts are dominating while at the Palmeraie, tree-wood cuts are the most harmful offenses. Such a result seems to contradict the results of cartographic analysis showing that the Palmeraie sector is the most degraded (Figs. 4, 6 and 7). The explanation will be given below in the discussion section.

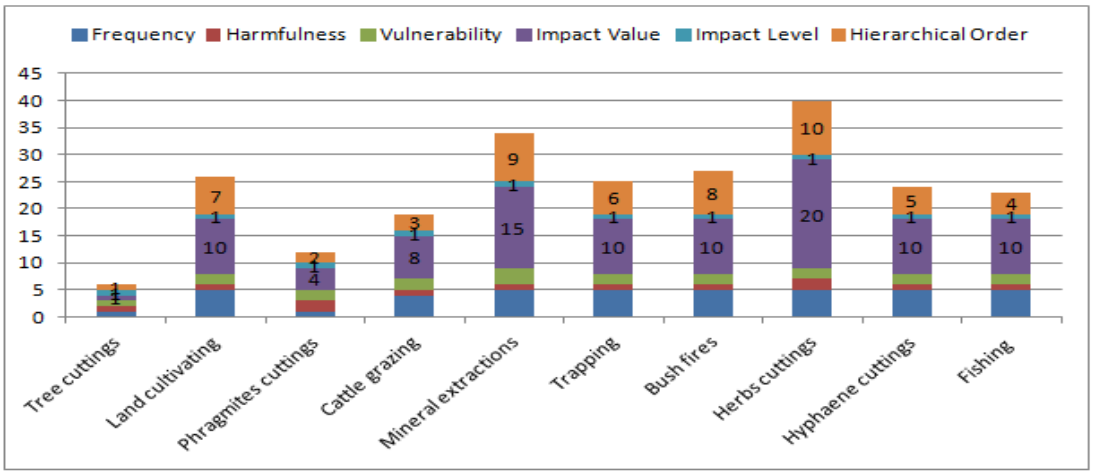


Fig. 15. Classification criteria values of the most damaging offenses (1988-2007)

Since year 2007, the number of offenses is not registered. Even though, the proliferation of fraudulent markets (Fig. 9) and the increase of the amount of penalties and seizures are indicating that the offenses have increased. Indeed, the ANOVA test (P-value = 0.001 < α = 0.05) shows that the receipts of penalties and seizures differ significantly before and after 2007. They are higher after 2007 than before. The Kolmogorov-Smirnov normality test and the Bravais Pearson coefficient correlation study indicate that the number of operators is strongly and negatively correlated with the number of offenses (R^2 = 0.79). This proves the increase of the offenses through the gradual decrease of the operators (Fig.13).

4. DISCUSSION

4.1 Land Cover Dynamics and the Rusizi Park Evolution

Between 1984 and 2015, the Rusizi Park recorded a reduction of vegetation cover of 29.9%, a regression of vegetation on 55% of the area, a reduction of water bodies of 31.2% and an extension of anthropized zones of 94.5% dominated by cultivated areas. Beside wooded savannah and dense forest relics which disappeared, all the vegetation types have regressed (Fig. 3). Farming related deforestation and wetlands farming (Figs. 4 and 5), little controlled vegetal resources exploitations, overgrazing and bush fires are mainly responsible for its degradation. The increase of peripheral offenses is justified by the demographic growth in the riparian villages due to displaced populations of the civil war in 1993, the permanence of riparian conflicts caused by the instability of the conservation status and non-participative conservation methods oriented towards centralization [12] and the lack of alternative sources for resources supply. It is strengthened by the overtaxing of resources controlled exploitation and small ratio of operators compared to the park dependent population. It appears through the increase in penalties and seizures receipts and the proliferation of fraudulent markets (Fig. 8). The riparian population has increased by 312%, bringing the park dependent population from 61% in 1984 to 76% in 2015. These results are confirmed by other studies that show the impact of population growth in land use changes [39] and the influence of socio-political conflicts on the exploitation and degradation of protected areas in Central Africa [16]. The population growth has been strategically accompanied by a proliferation of riparian villages and their rapprochement with the park for easier access to resources and security concerns (Fig. 12). The majority of the riparian villages (52%) have been created indeed between 1990 and 2000, in the context of the civil war and the population movements of 1993. They were concentrated between 0 and 3 km and between 5 and 10 km from the park boundaries because the 3-5 km space was already occupied by old rice-growing villages (Fig. 10). Such population spatial strategies for resource access are confirmed by other researches carried out in Africa [40], [1]. We realize that the most cultivated part of the park is also the most degraded (Figs. 4, 5, 6 and 7). This confirms studies which showed that agricultural conversion and deforestation of African protected areas are the greatest threats

to natural resources [39,7,41,42]. The high agricultural dependence in the park and its massive cultivation can be explained by the lack of family land [43], high rental costs and the high proportion of tenants which represents 20% population [44] Wetland farming during dry periods and the high stability of cultivated areas around water bodies reflect the use of the park as a community adaptation mechanism to climate change [23,45]. The high dependence of the riparian villages on woody, pastoral and agricultural resources justifies the important weight of resource exploitations, whether controlled or fraudulent. For instance, vegetal resources contribute to the cooking of food for 93.9% [44]. The concentration of resource controlled and offenses in the dry season due to agricultural campaign break, better physical exploitation conditions and commercial opportunities, is an additional non-climatic stress that aggravates degradation. Vegetation destructive exploitations have quite eradicated the woody cover, as evidenced by the results of cartographic analysis and assessment by operators and managers. For cooking and building wood needs, populations are now extracting strains of former giblets and non-regenerating legs of *Hyphaene benguellensis* as well as its nouts. As proved by cartographic analysis results (Fig. 7), the Palmeraie sector is the most degraded part of the park because it has few rangers and too many surrounding park dependent villages which are very close to the park. It is also the most exposed to Congolese pressures on the western border. The elongated shape and the great length of its borders reinforce the sector's vulnerability, as well as the park itself [5, 46]. The spatial inconsistency between the results from cartographic analysis and the offenses analysis can be explained by the persistent insecurity prevailing in the Palmeraie due to the presence of armed groups which did not allow sufficient evidence of offenses. The low stability values of anthropized zones (Table 2) reflect the high spatial mobility of offenses. This is one of the strategies used by populations to escape rangers as it has already been demonstrated elsewhere [18].

4.2 Resources Exploitation, Financial Repercussions and Offenses Control

The ecotourism frequenting and receipts are more important in peace time because the expatriates who are dominating the paying tourists leave the country during crisis time. Although the Rusizi Park is the most visited and the most profitable protected area in Burundi, its performances in ecotourism management remain poor. They do not allow full exploitation of its great touristic potential. The gradual shifting from free and self-consumption exploitation of resources to commercial exploitation [47] for self-financing led to increased offenses and degradation as it was demonstrated for some African countries [48]. This negative evolution is justified by the decrease of the operators' incomes due to exploitation overtaxing, weak selling prices, small production and important fraudulent exploitation (Figs. 13 and 14). The financial imbalance existing between the park and the operators, as well as the growing market resource demand, have created resource overexploitation by supervised and fraudulent operators to maximize revenues. This result is attested by operators and managers' interviews. With a month average income of US $ 51.4 and an annual decline of 2.4% since 1987, supervised operators earn less money than other African operators who realize US $ 102-172 monthly in case of Benin [49]. These results confirm research findings which showed that the participatory management gives very limited incomes compared to unsustainable exploitation activities [50, 3, 36]. The exclusively consultative role of the operators as in many protected areas in Africa [20] does not allow them to reverse these negative trends for conservation. In terms of financial capacity [6], the lack of financial planning [51], the low annual park revenues and the retrocession of the receipts to the central administration make self-financing and riparian development difficult. However, this financial weakness, which is one of the causes of the ineffectiveness of conservation policies in Central Africa [1], is common to many protected areas [34]. The weight of tourism receipts in global receipts and those from illicit exploitation in non-tourism receipts shows that participatory management is inefficient. Therefore, sustainable management of the park depends on better tourism strategies. The low involvement of the operators in conservation expressed by offenders covering and the mistrust of forest rangers proves that the conservation partnership is still feverish, as described by [3] for some African countries. Thus, in the absence of a wide and genuine partnership and basic data on exploited or exploitable resources, participatory management contributes to the degradation of the park. The largely unfavorable exploitation conditions and the low ratio of supervised operators limit the market offer and encourage offenses. Their gradual increase is proved by the

fraudulent markets proliferation and the high level of penalties and seizures receipts even if security conditions and low surveillance density (1guard/250 ha) don't allow their full realization.

5. CONCLUSION

The study shows the usefulness of integrated methods in analyzing the exploitation and evolution of protected areas in linking with spatial socio-economic interactions and dynamics. The results indicated that the participatory management based on controlled exploitation of certain resources in favor of a limited number of operators has failed in reducing the peripheral pressures and to curb the degradation of the park which has been accentuated. The shift from free controlled exploitation to overtaxed and merchant exploitation has gradually led to a decline in operators incomes, to the decrease of the operators number and finally to an amplification of fraudulent exploitations which became also commercial. Fraudulent exploitations result from many riparian villages which are highly dependent, very populated and too close to the park. They express themselves through the proliferation of forest product markets and high amount of penalties and seizures. Vegetation resources cuts, farming deforestation, overgrazing and bush fires are the main factors that cause the park degradation. The results will help decision makers to improve the protected area legislation and management methods for sustainable use of natural resources by extending the management area to all the park dependent villages. To reduce the immense human interference in the Rusizi national Park's management, appropriated strategies and actions have to be urgently developed and enhanced both at legal and operational level.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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