Canadian Journal of Tropical Geography
Revue Canadienne de Géographie Tropicale
CJTG (Online) / RCGT (En ligne)
ISSN : 2292-4108
Vol. 2 (2) : 29-42
http://laurentian.ca/cjtg

Modelling Drivers of Forest Cover Change in the Santchou Wildlife Reserve, West Cameroon using Remote Sensing and Land Use Dynamic Degree Indexes

Modélisation des Facteurs de Transformation de la Couverture Forestière dans la Réserve Faunique de Santchou, Ouest Cameroun, à l'aide de la Télédétection et d'Indices de Dynamique de Degré d'Utilisation des Terres

MELI FOKENG Reeves & MELI MELI Vivien

Abstract:

Reserves are vital tools for biodiversity conservation and management. Cameroon adopted this strategy since colonial era and the creation of new forest and wildlife reserves is on the increase. The Santchou Wildlife Reserve in the Menoua Divison is one amongst the many threaten protected areas of the division where some principal protected fauna like dwarf elephants and dwarf buffaloes have virtually disappeared because of human interferences and many other factors, including endemic birds which are currently being threatened. This study makes an assessment of forest cover changes using remotely sensed Landsat images, land use dynamic degree indexes and socio-economic data from field survey to quantify land cover changes and drivers of such changes. Forest cover was classified as montane forest, degraded montane forest, semi-deciduous lowland forest and degraded lowland forest. Market-oriented agriculture based on cocoa-coffee and anthropization of the reserve are the main driving causes of forest cover change, as cultivated land accounted for up to 43.02% of land cover/use change. Forest cover losses in 1987 and 2013 were recorded accordingly as: 12.90%, 6.3%, 10.42%, 7.33% of both montane and lowland forests, to the profit of cultivated land and built-up area respectively. Built-up area accounted for 38.09% of land cover/use change. But however, montane forest can regrow by 39.93% from a combined regrowth of degraded montane forest and abandoned farmlands, while lowland forest can sprout to 45.88% from a combined regrowth of degraded lowland forest and abandoned farmlands if arresting factors are eliminated in this secondary plant succession process. The study recommends an enforcement of laws in protection and management of the reserve in order to avert forest cover change and the destruction of wildlife habitats and a reintroduction of the pioneer fauna species; dwarf elephants and dwarf buffaloes. Sacred forests also seems to be better working as protected areas than state carved ones due to their local recognition.

Résumé:

Les réserves sont des outils essentiels pour la conservation et la gestion de la biodiversité. Le Cameroun a adopté cette stratégie depuis l'époque coloniale et la création de nouvelles réserves forestières et fauniques est à la hausse. La Réserve de faune de Santchou dans le Département de la Menoua est l'une parmi les nombreuses aires protégées menacées du département où certains principale espèces fauniques protégées telles que : les éléphants nains et buffles nains qui ont pratiquement disparu en raison des interférences humaines et de nombreux autres facteurs, notamment les oiseaux endémiques qui sont actuellement menacés. Cette étude fait une évaluation des changements du couvert forestier à partir d'images de télédétection Landsat, d'indices de dynamique de degré d'utilisation des terres et les données socio-économiques de l'enquête sur le terrain pour quantifier les changements et les facteurs de tels changements de la couverture végétale. Le couvert forestier a été classé comme forêt de montagne, forêts de montagne dégradées, forêt de plaines semi-feuillues et forêts de plaine dégradée. L'agriculture de rente basée sur la culture du cacao et du café et l'anthropisation de la réserve sont les principales causes du changement du couvert forestier. Aussi, les parcelles cultivées représentent jusqu'à 43,02% du changement de la couverture /l'utilisation des terres. Les pertes de la couverture forestière en 1987 et 2013 ont été enregistrées comme suit : 12,90%, 6,3%, 10,42%, 7,33% de forêts de montagne et de plaine au profit des parcelles cultivées et de la surface bâtie respectivement. La surface bâtie représente 38,09% du changement de la couverture/de l'utilisation des terres. Mais cependant, la forêt de montagne peut régénérer de 39,93 % à partir d'une repousse combinée de la forêt de montagne dégradée et des terres agricoles abandonnées, tandis que les forêts de plaine peuvent repousser de 45,88% grâce à une repousse combinée de forêt de plaine dégradée et des terres agricoles abandonnées si les facteurs d'arrêt sont éliminés dans le processus de succession végétale secondaire. L'étude recommande une application des lois en matière de protection et de gestion de la réserve afin d'éviter le changement du couvert forestier et la destruction des habitats fauniques et une réintroduction des espèces pionnières de la réserve: les éléphants nains et les buffles nains. Les forêts sacrées, semble-t-il, sont mieux acceptées comme aires protégées que celles créées par l'État, en raison de leur reconnaissance locale.

Keywords / Mots clés

Forest Cover Change, Remote Sensing, Wildlife Reserve, Conservation, Santchou
Changement de la couverture forestière, Télédétection, Réserve Faunique, Conservation, Santchou

INTRODUCTION

Forest reserves and wildlife habitats are presently undergoing degradation from the growing population pressures of the forest and adjacent communities. Mountain forests are threatened by uphill expansion of agriculture and human settlements, logging for timber and fuel wood and replacement by highland pastures (UNEP, 2010: 1). Mountains support about one quarter of world's terrestrial biodiversity and include nearly half of the world's biodiversity "hotspots" (UNEP, 2010). Mountains are often sanctuaries for plants and animals long-gone from the more transformed lowlands (UNEP, 2010). But nonetheless, mountains are vulnerable to several natural and anthropogenic interferences (seismic hazards, fire, land use/cover change and agricultural encroachment, urbanisation/rurbanisation, and conflicts between numerous land users). Human imprints on the landscape through the construction of roads and houses are also responsible for montane forest loss (Achankeng and Fokeng, 2015). According to Djeukam (2012), a protected area is a zone geographically demarcated and managed with a view to attaining the specific objective of conserving and realizing the sustainable harnessing of one or more given resources. Enforcing protected area boundaries is a costly and labour-intensive endeavour, particularly if the allocation of a new protected region places new restrictions on the use of resources by the native people, which may lead to their subsequent displacement (Ajonina et al., 2014). Statistics from the World Database on Protected Areas (WDPA), and other sources illustrate that 15 PAs[1] covering 1,901,739 hectares have been created and 13 others enclosing 666,026 hectares are at different stages of creation (Takem and Ngala, 2013), in Cameroon. They are 11 national parks covering 1,806,928 hectares representing 95% and 4 sanctuaries wrapping up 5% (94,811 hectares), (Takam et Ngala, 2013). According to WRI (2012) the total land use allocated for wildlife reserves in Cameroon evolved from 738,995 ha (administrative area) to 777,372 ha (GIS area[2]) and to 722,625 ha (GIS area) in 2004, 2006 and 2009 respectively.

Created by decree No 262 of 29 July 1947, the Santchou Wildlife Reserve covers an administrative surface area of 7,000 ha according to the Ministry of Forestry and Wildlife (MINFOF), (Table 1). The main objective of the creation of this reserve in 1947 was to protect/conserve the dwarf elephants and dwarf buffaloes which are now extinct because of human pressures and interferences, and a variety of endemic bird species of over 161 species that are currently present within the reserve and had suffered less threat from human presence. The reserve is also a home for a variety of monkeys and other fauna amongst which are: Gabon Viper, Python, sitatunga, Guilb herbaceous, bush pigs, porcupines, monitor lizard which are currently being threatened. According to Birdlife International (2015), the vegetation of the Santchou Wildlife Reserve is a mixture of Sterculiaceae and Ulmaceae, dominated semi-deciduous forest, shrubby savanna, sub-montane forest, periodically inundated swamp-forest and grassland and forest species include *Mitragyna ciliata*, *Lophira alata*, *Khaya ivorensis*, *Milicia (Chlorophora) excelsa*, *Mansonia altissima*, *Terminalia* spp.,*Klainedoxa gabonensis*, *Prunus africana* and a few emergent *Polyscias fulva* and grasslands comprise *Pennisetum*, *Eleusine*, *Andropogon* spp. and *Imperata cylindrica*. Some 161 species have so far been recorded from the Reserve, including the restricted-range *Hirundo fuliginosa* (*ibid.*: 1). The Santchou Wildlife Reserve is said to be one amongst the two Important Birds and Biodiversity Areas (IBAs) in Cameroon where the Guinea–Congo Forests biome species, *Phyllanthus atripennis* prevails.

The wildlife reserve is located at latitude 10°0'0'' North and longitude 5° 12'00' East (Figure 1), with seven village communities living within the Reserve and two others in the Buffer zone, Balé and Ngang. The population of several endangered species within protected areas in Cameroon are fast declining due to anthropogenic interferences (poaching, encroaching farmlands, deforestation, bush fires and grazing related activities) or better still to the migration of species linked to visual effects of humans or intruders and habitat destruction. As such, continuous update information on the status of the populations of these species and their habitat is essential for the design of effective conservation strategies within protected areas. This research is motivated on one part by the former and on another part to effectively monitor

[1] *Protected Areas*
[2] *Geographic Information System Area (That is area in a GIS framework, always slightly greater than the administrative area)*

the extent of change and destruction of this wildlife habitat (forest) that may prevent successful wildlife conservation strategies in the Santchou Wildlife Reserve and a consequent biodiversity loss.

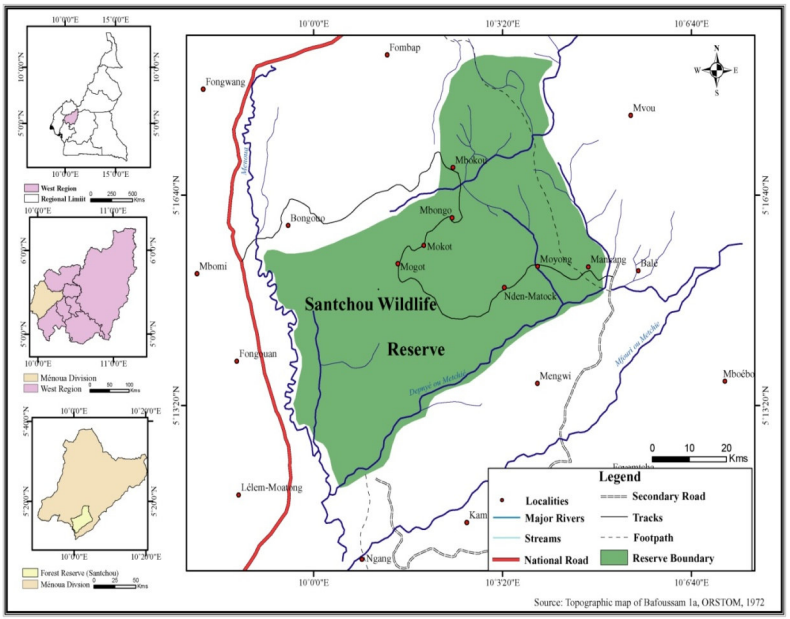

Figure 1: The Santchou Wildlife Reserve

The Santchou Wildlife Reserve over considerable distance is bordered by other national PAs, wildlife reserves and national parks. To the west and northwest, it is bordered by the Banyang Mbo Wildlife Sanctuary, to the south west by the Bakossi Mountains Wildlife Reserve and to the south south west by the Mount Manengouba National Park. Altitudes within the Reserve vary from 800-1400m above sea level (asl). Close to ¾ of the wildlife reserve is made up of faulted escarpment which forms part of the Bamileké plateau that progresses towards Bafang from past tectonic activities, including part of the Santchou depression (a paleo-continental sea or interior sea) from the same tectonic activities (Figure 2). The reserve is surrounded by four main rivers; - Alouno, Nkam, Metché and Alouo rivers to the north, west, south, and east respectively. These highlands and lowlands are areas of great endemism of biodiversity with several endemic species of birds and threaten faunal and floral.

Figure 2: Aerial view of the study area (Google earth images, 2013)

CJTG/RCJT, Laurentian University/Université Laurentienne, Geography/Géographie, Sudbury, Ontario, P3E 2C6, Canada. ISSN : 2292-4108. Vol. 2(2) : 29-42.

Biodiversity conservation in Cameroon stated since colonial times with the creation of some forest reserves, then the signing of the Convention on International Trade in Wildlife and Endangered Species in Washington, 1973; to Rio Earth Summit of 1992 and its Convention on Biological Diversity which led to the creation of the MINFOF in charge of forest and wildlife stewardship in Cameroon. Law No 81/13 of 27 November, 1981, on forest, wildlife and fisheries now replaced by law No 94/01 of 20th January, 1994, established the regime for forests, wildlife and fisheries in Cameroon. The ministerial order N°649/ MINFOF of 18/12/2006 further put wildlife in to groups (A, B and C) and the extent of hunting of each type depending on licenses. The species of class A shall be totally protected and may on no occasion be killed except as provided for in section 82 and 83 of this law (Djeukam, 2012), and those of B shall be protected but could be killed with a permit and those of C shall be partially protected and killing shall be regulated by the order laid down by the Ministry of Wildlife. Sections 155 and 158 laid down penalties for intruders in to the wildlife sector ranging from a fine of 20,000 to 50,000 CFA francs or imprisonment of twenty days to two months or both and from 3,000,000 to 10,000,000 CFA francs or imprisonment of one to three years or both respectively. The law also stipulated that any project susceptible to affect the protected area (industry, mining, and agro-sylvo-pastoral) must be accompanied by an environmental impact assessment. Decree No. 95-466-PM put in place the political and strategic framework for forest management in Cameroon. These promulgations defined the National Forest Estate (NFE) and divided it into two main land covers (Figure 3); Permanent Forest Estate (PFE), consisted of land designated as forest or wildlife habitat) and Non-Permanent Forest Estate (NPFE), made up of area that could be transformed to other land uses like agriculture) giving them specific use rights and management regimes.

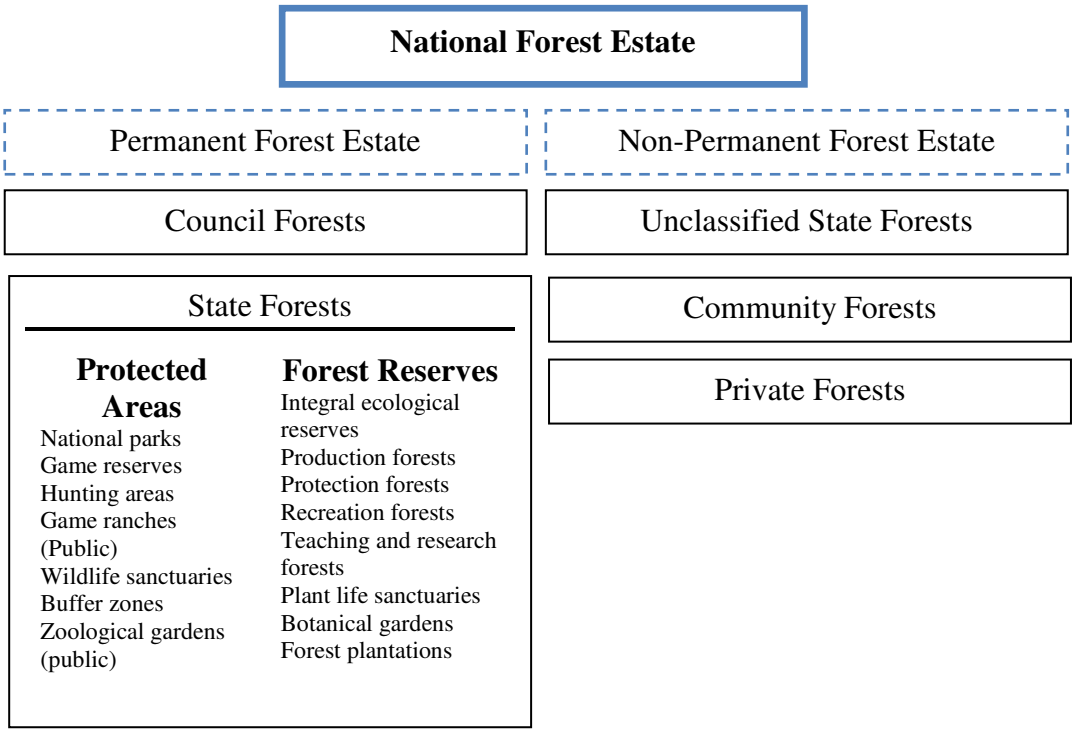

Figure 3: Forest legislation and zoning in Cameroon
Source: Forestry Law 94/01 of January 20, 1994; cited in WRI and MINFOF, 2012: 13

In terms of land cover, the NFE contains 55% dense forests and 33% mixed forests, the remaining 12% being land where forests are not the dominant vegetation and between 2006 and 2011, the PFE increased by 3% to 16.3 million ha, representing 35% of the total national land area, surpassing the 30% target stipulated by the 1994 Forestry Law (*ibid*: 8). Forest in the NPFE though small stood at 1.1 million ha in 2011 and 90% of such allocations were community forest. The country in a bit to conserve its rich biodiversity has created PAs for floral and faunal species. The creation of national faunal reserves is the cornerstone of Cameroon's wildlife conservation policy. The total surface area of PAs under wildlife reserve according to MINFOF in 2011 was 1,804,741ha with 11 faunal reserves altogether (Table 1).

Category	Name	Date of creation	Administrative area (ha)
Faunal reserves	Dja	1905	526,000
	Douala Edea	1932	160,000
	Kimbi	1964	5,625
	Lac Ossa	1968	4,000
	Santchou	1947[1]	7,000
	Benue	1968	180,000
	Bouba Ndjida	1968	220,000
	Boumba Bek	2005	238,255
	Campo Ma'an	2000	264,064
	Deng Deng	2010	58,091
	Ebo*		141,706
National Parks	Faro	1980	330,000
	Kalamaloue	1972	4,500
	Kom**		67,838
	Korup	1986	125,900
	Lobeke	2001	217,854
	Ma Mbed Mbed**		14,293[2]
	Mbam et Djerem	2000	416,512
	Mefou**		1,044
	Mont Cameroun	2009	64,677
	Monts Bakossi	2007	29,320
	Mozogo Gokoro	1968	1,400
	Mpem et Djim	2004	97,480
	Ndongere**		233,400
	Nki	2005	309,362
	Takamanda	2008	67,599
	Tchabal Mbabo**		105,251
	Vallée du Mbere	2004	77,760
	Waza	1968	170,000
	Rumpi Hills**		45,675
Santuary	Banyang-Mbo	1996	66,000
Sanctuary (Fauna)	Kilum Ijim***		1,000
Sanctuary (Flora)	Kagwene	2008	1,944
Sanctuary (Gorilla)	Mengame	2008	26,711

Tableau 1: List of PAs, date of creation and surface area in hectares (ha) in Cameroon

Source: MINFOF, 2011; cited in WRI and MINFOF, 2012: 53, 54 and reviewed by authors, 2015

[1] The right date when the reserve was created. The document mentioned 1964 instead of 1947.

[2] GIS area (ha)

*Recently proposed wildlife reserve.

**Recently proposed national parks

***Recently proposed fauna sanctuary.

The creation of PAs is a milestone towards biodiversity conservation and sustainable management in Cameroon. In recent times, the creation of new PAs is on the increase and the total national land area under PAs have significantly evolved from 2004 to 2011 according to the WRI in 2012 (Table 2).

Protected areas	2004		2006		2009		June 2011		% change (2004-2011)
	No	ADM. AREA (ha)a	No	GIS AREA (ha)	No	GIS AREA (ha)	No	GIS AREA (ha)	
National parks	17	2,910,382	15	2,733,232	24	3,433,672	24	3,459,798	+19
Wildlife reserves	6	738,995	5	777,372	5	722,625	5	715,456	-3e
Sanctuaries (floral and faunal)	4	246,368	4	254,342	5	143,909	5	143,909	-42f
Hunting zones (ZIC/ZICGC)g	57	-	52	3,078,418	52	3,078,418	52	3,078,418	0i
Total	84	-	76	6,843,364	86	7,378,624	86	7,397,581	+8i

Table 2: Evolution of PAs in Cameroon from 2004-2011

Source: Compiled from WRI and MINFOF, 2012:16, 17

a. The total PFE area for 2004 is a combination of GIS data from the Interactive Forest Atlas (version 1.0) and other MINEF data (administrative area) and therefore should only be considered as an estimate based on the best available data at the time. (*ibid.:* 18).
d. Protected areas figures for 2009 and 2011 include the recently proposed national parks (Kom, Mefou, Ebo, Tchabal Mbabo, Ndongere, and Ma Mbed Mbed) and the Rumpi Hills Sanctuary, which are still pending official classification. Together, these proposed protected areas account for 609,221 ha (*ibid.*: 18).
e. This decrease is due to a discrepancy between the administrative area of the Dja Reserve considered prior to 2011 (590,053 ha) and the GIS area (528,137 ha) (*ibid.*: 18).
f. This decrease is due to a 78% (93,936 ha) reduction in the area of the Mengame Gorilla Sanctuary and its reclassification into the Kom National Park, now 67,838 ha (*ibid.*: 18).
g. Areas overlapping other land use allocations (e.g., forest management units (FMUs), protected areas) are excluded. The total combined area (including overlaps) in 2011 was 5,230,599 ha (*ibid.*: 18).
i. Change from 2006 to 2011 (*ibid.*: 18).
ADM. Administrative area in hectares.
ZIC. Hunting zone
ZICGC. Hunting zone under community-based management

The success of conservation efforts is not without continuous law enforcement and sanctions on intruders or trespassers and illegal wildlife trafficking as well as the frequent monitoring of their habitats to prevent any human interferences that can threaten these species. MINFOF divides classified protected areas under three main categories;-1st category, 2nd category and 3rd category depending on the surface area. The Santchou Wildlife reserve is a 3rd category protected area and it is integrally protected.

MATERIALS AND METHODS

LAND COVER MAPPING ANALYSIS AND LAND USE DYNAMIC DEGREE INDEX MODELLING

According to Lambin (1999),"the lack of quantitative, spatially-explicit and statistically representative data on land cover change has left the door open to simplistic representation of forest cover change." Remote sensing techniques were used because as Lambin (1999) rightly says, these techniques have the advantage of allowing researchers to obtain synoptic and repetitive observations on the vegetation cover. The research exploits topographic map of the area to extract the exact administrative limits of the reserve and to produce a location map. Landsat 5 (1987) and 8 (2013) images of the site were acquired from the USGS Global Visualization Viewer's (GLOVIS) website at http://glovis.usgs.gov/index.shtml (Table 3) and were treated and analysed to give qualitative and quantitative data on land cover/use changes using GIS computer assisted software. The topographic map and reconnaissance field survey in 2015 also aided in the final classification of the Landsat images. Further analyses were done by simple manual calculation of percentages and percentage change in land cover/use. In excel, linear regression analysis and correlations of land cover/use changes were done and results interpreted.

S.No	Image scene	Satellite sensor	Platform	Date
1	p186r056	TM	LANDSAT_5	1987-01-06
2	p186r056	OLI_TIRS	LANDSAT_8	2013-12-15

Table 3: Landsat imagery data used for this study

Source: GLOVIS (2015)

N.B: TM=Thematic Mapper
OLI_TIRS = Operational Land Imager and Thermal Infrared Sensor

All images were taken during the dry season to prevent the effects of clouds on images and also to prevent problems of land cover classification steaming from a dominant green landscape.

Land use dynamic degree index for single land use change type, known as K1 index (Jian et al, 2008). The index is recognized as one of the most widely used indices for detecting land use change rate (equation 1).

$$K_1 = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

Where **K1** is land use dynamic degree, measuring the change rate of the target land use type; **Ua** and **Ub** are the area of the target land use type at the beginning and end of the study period respectively and **T** is the study period, which is usually measured with the unit of year. In using this index, we generally consider three land use sequences for a certain land use type in the process of land use change, that is, no conversion, conversion to other land use types, and conversion from other land use types. So the K1 index value is an integration of the three change classes for the target land use type in the study area, but K1 index cannot express information on each change type directly. So another index, the K2 index (Jian et al, 2008), for the change rate of single land use type was used (equation 2).

$$K_2 = \frac{\Delta in + \Delta out}{U_a} \times \frac{1}{T} \times 100\% \quad (2)$$

Where **K2** is land use dynamic degree, measuring the change rate of the target land use type;**Δin** and **Δout** are the area of the target land use type conversion from or to other land use types in the study period respectively; and **T** is the study period, which is usually measured with the unit of year. Focusing on the process of land use change, the index of K2 can effectively reflect the area ratio of the conversion from and to the target land use type (Jian et al, 2008). The main weakness of K2 is that it cannot compare the conversion loss rate and conversion gain rate, whereas K1 does. This notwithstanding, K1 and K2 are used to measure the change rate of single land use type. Land use dynamic degree indexes were calculated manually and Ms Excel aided in the graphical representation and interpretation of the results.

FIELD SURVEY: QUESTIONNAIRE ADMINISTRATION AND KEY INFORMANT INTERVIEWS

Sample for the study was expressed as a proportion of 1: 50 inhabitants of the total population within the study area and was applied to the total population as 2265/50 = 45 questionnaires (Table 4), then to village population as village population/50 (base). This was to have a representative proportion of each village. Only villages within/inside the wildlife reserve were sampled in order to quantify the dynamics of forest cover change within an area considered to be under protection. The field survey of sampled households made used of closely structured questionnaire in order to collect quantitative socio-economic information on the study area and to better understand and model the drivers of forest cover change using socio-economic data that complements remotely sensed data by integrating the two databases. Field checking also permitted to verify classification accuracy and to derive a final classification series for the various forest cover/land use types of the study area.

Santchou urban = 37479 inhabitants		Santchou rural = 13309 inhabitants	
Villages within the wildlife reserve	**Population**	**Sample**	**Retained***
Mankang	330	7	6
Mbokou	395	8	6
Mbongo	159	3	3
Mogot	426	9	9
Mokot	572	11	9
Moyong	113	2	2
Nden-Matock	270	5	5
Total	**2265**	45	40

Table 4: Villages within the study area and sample size for questionnaire administration

Source: Calculated from 2005 population census by BUCREP, 2010.

*88.89% of effective respondents.

Field collected data were analysed in Ms excel and interpretation was done by the authors. Key informant interview exploited an opened interview form to acquire qualitative information on the study area. The key informant interviewed was the Divisional Delegate of MINFOF, Menoua and other existing literature on the theme was also revisited to enable the construction of a concrete theoretical base.

RESULTS AND DISCUSSIONS

CHANGE DETECTION RESULTS

The climatic climax vegetation types of the Santchou Wildlife Reserve are; montane forest, sub-montane forest and semi-deciduous lowland forest. These climax vegetation have been subjected to anthropogenic interferences leaving some parts of the forests as a plagioclimax or a disclimax plant community rather than a climax natural community. These human interferences in a protected area are responsible for forest cover changes and conversions to agricultural lands and built-up area leaving the original vegetation in a more degraded form (Figure 4 and 5).

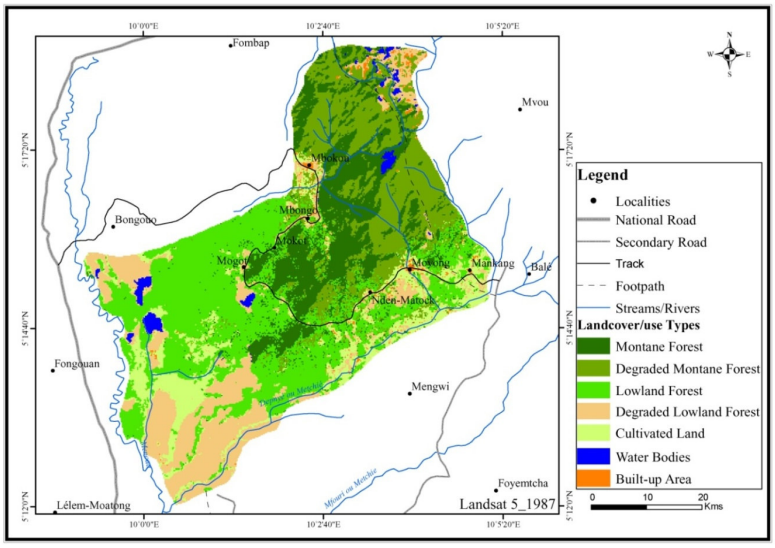

Figure 4: Land cover/use for 1987 within the reserve

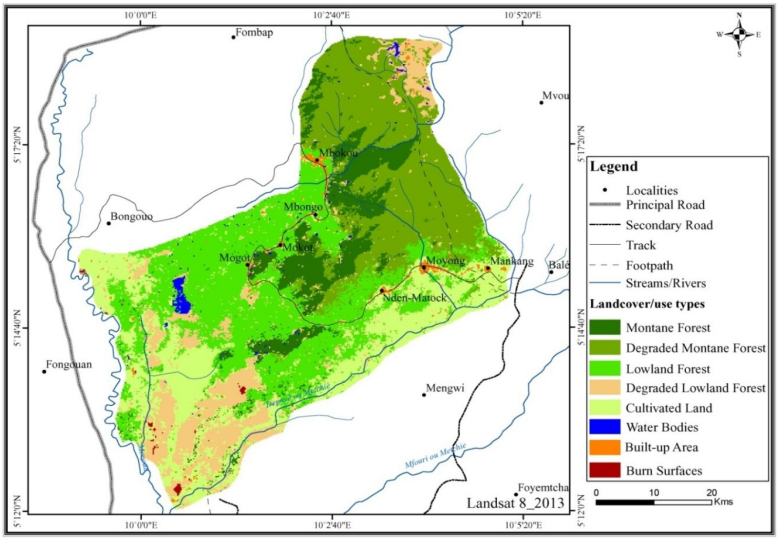

Figure 5: Land cover/use for 2013 within the reserve

Within the reserve, forest cover change is human induced as area under humanised landscapes kept increasing during the study period. The area under forests, both montane and semi-deciduous lowland forest is now experiencing a decline with negative percentage changes of -24.80% and -6.10% respectively, contrary to a progressive increase in area covered by degraded montane forest, cultivated land and built-up area (Table 5).

Land cover/use types	Surface area in hectares (ha) _1987	%	Surface area in hectares (ha)_2013	%	% change 1987-2013
Montane forest	994	17.13	599	10.17	- 24.80
Degraded montane forest	1155	20.20	1481	25.14	12.37
Lowland forest	2113	36.42	1870	31.7	- 6.10
Cultivated land	496	8.55	1245	21.13	43.02
Degraded lowland forest	954	16.45	630	10.7	- 20.45
Water bodies	76	1.31	30	0.51	- 43.40
Built-up area	13	0.22	29	0.49	38.09
Burn Surfaces	-	-	7	0.12	-

Table 5: Land cover/use change statistics from 1987-2013

For both studied periods, human induced forest cover change is from within (along the main communication axis) and from without (buffer zones). Recent human interference is aggravated by the seasonal presence of grazers in the lowlands and the occasional use of fires. Burn surfaces were detected to account for 7hectares of forest conversions in 2013 (Figure 5). There is an inverse correlation in the land cover change process. While the area under forest cover and degraded lowland forest and water bodies is declining, the area under humanised and human induced landscapes;-cultivated land, degraded montane forest, and built-up area in increasing in return (Figure 6).

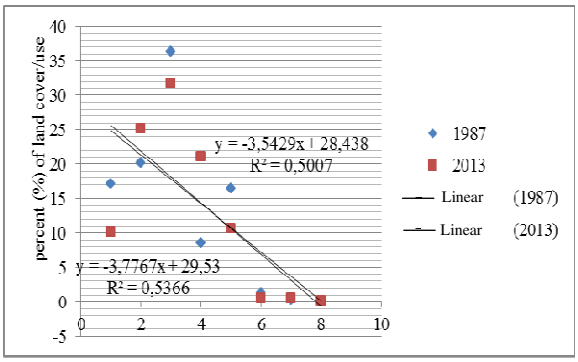

Figure 6: Linear regression curves of land cover/use changes

LAND COVER/USE DYNAMICS

The index of K2 quantifies the total "loss or gain" conversion of the target land use type; while the index of K1 reflects the algebraic summation of conversion loss and gain of the target land use type, and the absolute value of K1 measures the extent of the relative difference between conversion loss and gain, with a positive sign of the value of K1 indicating the dominance of conversion gain from other land use types to the target land use types, and a negative sign showing the precedence of conversion loss (Jian et al, 2008). Figure 7 shows on one hand the index of K1 measuring annual net increasing rate of land cover/use types and on the other hand, conversion losses and gains (K2 index). Cultivated land and built-up area scores 5.81% and 4.73% of annual increase rate (K1 value). These are the main land uses responsible for forest cover conversions and change over time. Forests accounted for negative and lowest change rates of -0.44% and -1.53% for lowland and montane forest land covers respectively (K1 value).

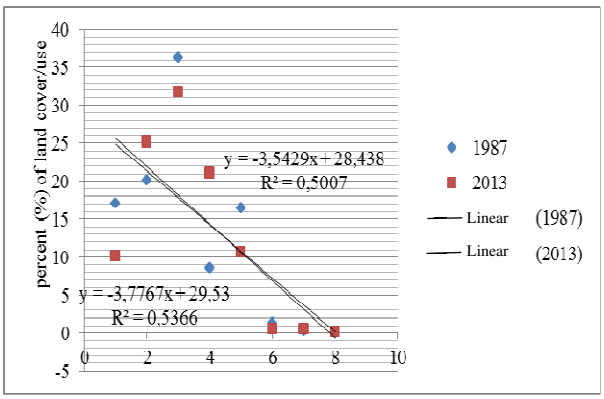

Figure 7: Forest cover conversion losses and gains

Contrarily, the index of K2 quantifies annual rates of conversion loss and gain of forest cover types. The K2 index assumes montane forest and lowland forest as the targeted land cover conversion types (that is from forest to other land uses and back to forest, that is forest regrowth). K2 indicates 16.36%, 12.90% and 6.3% of montane forest cover loss to the profit of degraded montane forest, cultivated land and built-up area (an irreversible land use) respectively (Figure 7). Lowland forest cover loss is indicated by 10.42%, 10.13%, and 7.33% for cultivated land, degraded lowland forest and built-up area respectively (Figure 7). There are however more chances of forest regrowth if arresting factors are removed in the secondary vegetation succession process as 14.08% and 25.85% of montane forest regrowth could regenerate from degraded montane forest and abandoned farmlands (Figure 7). Lowland forest was estimated to equally have high possibilities of such regrowth as 23.44% and 22.44% of regrowth could came from abandoned farmlands and degraded lowland forest (Figure 7). Thus, if human imprints are removed, the natural habitat of these faunal species will gradually evolve to a climax plant community which is in accordance with the climate and the natural conditions.

DRIVERS OF FOREST COVER CHANGE

ANTHROPIZATION OF THE WILDLIFE RESERVE

The Santchou wildlife reserve long from being a wildlife habitat is also a home for a multitude of local populations divided into two principal groups; indigenes and in-migrants (Table 6). The indigenes seem to be the original settlers of the reserve before its creation. Information on the peopling of the reserve from key informant also points out the fact that it is thought that during the Second World War of the 1940's in Cameroon, people from other parts of Bafang and Menoua migrated and took refuge within this forested area. The local population is highly agricultural; practicing a market-oriented agriculture based on cocoa-coffee. 52.5% of the sampled households were in-migrants particular from Menoua and the North West parts of Cameroon. This explains the peopling of the reserve following an external mechanism. The presence of this population, as well as their activities has not left the natural wildlife habitat intact. Forest cover changes and extinction of protected species is now the norm rather than the exception within this reserve. Human interference is aggravated by the seasonal arrival of grazers and the periodic use of fire (Figure 5). Grazing in protected areas leads to the destruction of flora, to the destruction of the habitats of fauna, attacks on animals as well as the risk of transmission of diseases like malaria (Mbanga and Gonne, 2013). This is a cause for concern.

A MARKET-ORIENTED AGRICULTURE BASED ON COCOA-COFFEE

The cultivation of cocoa-coffee interspersed with palms and food crops is becoming a dominant land use of this reserve. From the road (track) within the reserve, there is a cocoa-coffee continuum progressing inland giving an impression of a humanised space than a natural wildlife habitat. 100% of the sampled households were all cocoa-coffee cultivators with farm sizes ranging from 50m²-3ha per households (Table 6). The area is a great cocoa-coffee production zone in Santchou. This is a major problem to PAs found within cocoa producing zones in Cameroon. Ewane (2006; cited in Lambi et al: 14) refers to the Southern Bakundu Forest Reserve as a continuum of cocoa farms. This however reflects the challenges of law enforcement in protecting the wildlife reserve especially within the reserve and around the buffer zones. Buffer zones of the reserve in 2013 proved to be facing serious threats through encroachment of farmlands and related disturbances (Figure 5).

	Indicators	Frequency	Percent (%)
Local population	Indigenes	19	47.5
	in-migrants (allogenes)	21	52.5
Occupation	Farmer	40	100
Agricultural production	Coffee	3	7.5
	Cocoa-coffee	37	92.5
Average farm sizes	0-50m²	1	2.5
	50-100m²	4	10.0
	1-2ha	22	55.0
	1-3ha	10	25.0
	More than 3ha	3	7.5
Distance of farm from the defined limits of the reserve	Less than 1km	28	70.0
	More than 1km	6	15.0
	1km and above	2	5.0

Table 6: Socio- economic characteristics of the sample households

Studies by Birdlife International in 2015 when assessing IBAs revealed other human interferences or threats to the area such as agriculture and aquaculture, human intrusions and disturbances, cultivation of non-timber crops and other activities with greater degree of severity and rating (Table 7).

Threat level 1	Threat level 2	Timing	Scope	Severity	Result
Agriculture and aquaculture	annual & perennial non-timber crops, small-holder farming	happening now	whole area/population (>90%)	very rapid to severe deterioration	very high
Human intrusions and disturbance	work and other activities	happening now	whole area/population (>90%)	very rapid to severe deterioration	very high

Table 7: Threats to the site (pressure)

Source: Birdlife International (2015:6)

CHALLENGES OF LAW ENFORCEMENT IN PROTECTING THE AREA

Challenges of laws protecting the area seem to be the most driving cause of forest cover change. Even though 92.5% of the sampled households are aware that the area is under protection and confirms the frequent visit and monitoring of the Santchou Wildlife Conservation Service, conservation of the area is bisected by encroachment from inside and from the buffer zones of the reserve. The Santchou Wildlife Reserve is not an exception of threatened PAs within the Menoua Division, as invasion by intruders or trespassers, human occupation as a result of tremendous population increase and challenges of law enforcement are responsible for the conversion and destruction of most PAs of the Menoua Division created since colonial times (Table 8).

Reserve name	Act of classification	Initial surface (ha)	Estimation of occupation rate
Foréké-Dschang	arrêté No 262 of 27/07/1947	2200	more than 80%
Menoua Quinquina	arrêté No 334 of 08/11/1934	100	Totally invaded
Signal forest reserve	arrêté No 053 of 09/03/1934	42	Totally destroyed and invaded by close to 50%
Protected slopes of Foréké-Dschang	arrêté No 063 of 06/06/1956	100m in depth from one part to the other of the escarpment	Delimited by the Dschang-Melong road.

Table 8: Some humanised PAs of the Menoua Division

Source: Divisional Delegation of MINFOF, Menoua (2015)

Much monitoring and enforcement of laws on protected areas is needed to avert forest cover change and habitat destruction within the study area.

CONCLUSIONS AND RECOMMENDATIONS

PAs in Cameroon are suffering from continuous invasion by the local populations. While conservation of biodiversity becomes a more preoccupying issue, some authors advance an integrated approach in conservation that takes into consideration the local population or indigenes and not a mere protection of wildlife as Lambi et al. (2012) puts it; "When the indigenous people are denied their basic livelihoods through administrative creations that hinder them from depending on their natural resources, then there is an unresolved problem which only gets bigger as the years go by". The delimitation of PAs have deprived the indigenous population of their natural environments and resources; the basic source of their livelihoods. Solving such a problem is making sustainable development the lamp light of protected area creation and management in accordance with Brundtland Report of 1987 and Agenda 21 of Rio Earth Summit of 1992. The Divisional Delegation of MONFOF for Menoua, however identifies the human

occupation of the Santchou Wildlife Reserve as illegal and unauthorised. Presently, there is a commission termed "*Commission du Déguerpissement de la Population de la Réserve de Faune de Santchou"* in French; that is, the future removal of the present population of the reserve. According to the Divisional Delegation of MINFOF for Menoua, within such a strategy, the in-migrants shall be the first to be packed-off the reserve as the indigenes are thought to be the original settlers of the reserve before its creation. This study therefore recommends a proper wildlife and protected area law enforcement and monitoring, concerted actions in protection and conservation in integrating local populations in the sustainable management of biological diversity in order to avert forest cover change and also a reintroduction of the extinct pioneer wildlife species (dwarf elephants and dwarf buffaloes) to their natural habitat for future generations. Secret forests seems to be guarantee to flora and fauna conservation and are more sustainable forms of PAs in Cameroon, as they are well recognised and respected by the local populations than state carved PAs. The reinforcement of the status of these forests could be a better approach to conservation and protection of PAs in Cameroon since they are well recognised by the local populations.

REFERENCES

ACHANKENG, E. and FOKENG, R. (2015). "Montane Forest Loss and Watershed Degradation: Case of the Tubah Uplands of the North West Region of Cameroon". *African Journal of Special Education*, 3(1):16.

AJONINA, G. and NKWATOH, H. (2014). "Endangering the endangered: Are protected areas save havens for threatened species in Cameroon? Case of Banyang-Mbo Wildlife Sanctuary, South Western Cameroon*" Academic journals, Journal of Ecology and Natural Environment* [online], posted February 2014: http://www.academicjournals.org/J.

BIRDLIFE INTERNATIONAL. (2015). *Important Bird Areas factsheet: Santchou Faunal Reserve*. http://www.birdlife.org accessed on 26/07/2015.

BUCREP (2010). *Répertoire Actualisé des Villages du Cameroun.* Volume IV-Tome 7

COMIFAC (2011). *Directives Sous-régionales sur la Participation des Populations Locales et Autochtones et des ONG à la Gestion Durable des Forêts d'Afrique Centrale*. Série Politique No 3, Yaoundé, Cameroun.

DJEUKAM R. (2012). *The wildlife law as a tool for protecting threatened species in Cameroon*, Yaounde, Ministry of Forestry and Wildlife, Department of Wildlife and Protected Area.

FOKENG, R. (2014). *Land use change and watershed degradation: Case of the Tubah Upland Watershed, Tubah Sub-division of the Northwest Region of Cameroon.* University of Bamenda, Higher Teachers Training College Bambili, Department of Geography, DIPES II Dissertation.

JIAN, JIANSHENG, HE, ZHENGGUO, QING, TIANLONG. (2008). "Rural Land Use Change during 1986–2002 in Lijiang, China, Based on Remote Sensing and GIS Data" *Sensors* [online], posted 11 December 2008: www.mdpi.com/journal/sensors.

LAMBI., KIMENGSI., KOMETA., TATA., 2012. "The Management and Challenges of Protected Areas and the Sustenance of Local Livelihoods in Cameroon". *Environment and Natural Resources Research* [online], posted July 11, 2012: URL: http://dx.doi.org/10.5539/enrr.v2n3p1.

LAMBIN E. (1999). "Monitoring forest degradation in tropical regions by remote sensing: some methodological issues". *Global Ecology and Biogeography*, 8(3-4):191-198.

MBANGA, L. and GONNE, B. (2013). "Rethinking biodiversity conservation strategies: an analysis of transhumance and grazing in the Benue, Faro, Bouba Ndjidda Complex, (FBBNC) in the North region of Cameroon". *Annals of the Faculty of Arts*, Letters and Social Sciences 15(1): 246-292.

TAKEM M., NGALA H. (2013). "Protected Areas in Cameroon from Rio to Rio+20 (1992–2012)". *International Forestry Review* 15(4):524-533.

UNEP (2010). *Mountain Biodiversity, the Secretariat of the Convention on Biological Diversity*, [on line] www.cbd.int/mountain.

WRI, MINFOF (2012). Interactive Forest Atlas of Cameroon, *overview report,* Alex Martin eds., Washington DC, 2012, Version 3.

To cite this article

Electronic reference

Reeves Meli Fokeng & Vivien Meli Meli. « Modelling Drivers of Forest Cover Change in the Santchou Wildlife Reserve, West Cameroon using Remote Sensing and Land Use Dynamic Degree Indexes». *Canadian journal of tropical geography/Revue canadienne de géographie tropicale* [Online], Vol. (2) 2. Online in November 15, 2015, pp. 29-42. URL: http://laurentian.ca/cjtg

Authors

MELI FOKENG Reeves
Department of Geography
Faculty of Letters and Social Sciences (F.L.S.S)
University of Dschang, Cameroon
Email: rfokeng@yahoo.com

MELI MELI Vivien, Ph.D
Department of Sociology
Faculty of Letters and Social Sciences (F.L.S.S)
University of Dschang, Cameroon
Email: melvivien_03@yahoo.fr

