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An assessment and evaluation of the ecological security in a human inhabited protected area at Korup, south western Cameroon: Linking satellite, ecological and human socioeconomic indicators

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Abstract

This study attempts to identify how much understanding of ecological and human livelihood security can be gained through a binary and index model. Hereto, binary and index models of indicators of ecological security in the central zone of the Korup National Park-Cameroon are developed, taking into account the spatial variability of change in economic, social and ecological variables. Our approach is anchored in a broader conception of threats to both human well-being and ecological goods and services. The results show that, while only 1.47% of the regions cover remains unchanged, over 50% decreased barely 14 years after the creation of the park in 1986. The reasons for the decrease are mainly socioeconomic in nature. Furthermore, while the socio-economic statuses of the indigenes/villagers remain uncertain, the index of ecological security (IES) of the area has moved from slightly damaged (4.1<IES<6), to moderately damaged (2.1<IES<4) in the past decades. With increasing pressure on the land, however, sustaining livelihoods through agricultural production in the area remains a critical challenge. While community forestry, change of direction in the fight against corruption, increase finance to management of the park to step up monitoring activities could be short term remedies, we think that involuntary resettlement could be the best option for management. The results should contribute to develop and prioritize appropriate policy interventions and follow-up steps to improve the security of similar protected areas inhabited by man**.** [Journal of American Science 2009:5(2) 43-53] (ISSN: 1545-1003)

Key words: Ecological security, livelihood security, binary model, index model

1. Introduction

Healthy ecosystems are essential to the well-beings of a majority of the world's poorest societies [Smith and Scherr, 2003; Sunderlin *et al*., 2007]. Unfortunately, over the past few hundred years, humans have increased species extinction rates by as much as 1,000 times background rates that were typical over Earth's history [Millennium Ecosystem Assessment, 2005]. Biodiversity is currently being lost at rates significantly exceeding those in the fossil record [Anderson, 2001], most of the loss being reported from the tropical ecosystems. Projections and scenarios indicate that the rates of biodiversity loss will continue, or accelerate, in the future. The loss is of concern due to its widespread implications for environmental security and/or ecosystem functioning [Myers *et al.,* 2000; Loreau *et al*., 2002], human well-being for all [Diaz *et al*., 2006], ethical reasons [Agar, 2001], as well as sustainable development and poverty reduction. It is estimated that some 60 million indigenous people are completely dependent on forests, while 350 million people are highly dependent, and 1.2 billion are dependent on forests for their livelihoods [World Bank, 2004]. To the extent that humankind neglects to maintain the global life-supporting ecosystems current and future generations will be confronted with increasing severe instances of environmental induced changes.

Following continuous pressure from political regimes, many governments have responded to biodiversity conservation by creating protected areas and/or nature reserves. It is in this vein that Korup national park (KNP) Cameroon was created. In this region, the belief that ecological security became secured following the creation of the park in 1986 pervades calculations of local and national policy makers, but this belief is not based on direct observation of the situation today. The living consequences in this enclaved zone of the Park include, decline in wildlife population of plants and animals, and above all, the emission of green house gases. Such insecurity situation might in the long run further insecure the people, who cannot integrate traditional markets, but need alternatives for income generation.

Because of its short history, the concept of ecological security has no universally accepted definition, parameters, and appropriate research methods [Xiao *et al*., 2002]. As far as definitions go, Scientists have adopted both broad and narrow-sense concepts of it. The broad-sense concept [Pirages and Cousins, 2005], includes natural, economic, and social ecological security. The narrow-sense concept covers the security of natural and human influenced ecosystems.
As far as methodologies go, Scholars have proposed several measurement indices that account for different requirements from the perspectives of livelihood security, ecological risk and ecological health [Yan-Zhi et *al*., 2005]. As different ecosystems and time-space dimensions require corresponding indicator systems, there is yet to be a universally accepted, well-recognized indicator system or methodology. However, given the multi-criteria nature of ecological issues, the diversity of the stakeholders involved a systematic model that can disintegrate the component parts of such an intricate unstructured problem into well-defined parts such as the Analytical Hierarchical Process [Saaty, 1990], using the “Pressure-State-Response” model [OECD, 1993] as a foundation for an indicator system seems to be feasible. In this way, one can easily understand which variable(s) has/have mostly influenced the outcomes of the situation. The Pressure-State-Response (PSR) model on the other hand, has proven to be a logical, comprehensive tool to picture environmental issues from an anthropocentric perspective.

The purpose of this study was therefore to assess and evaluate the ecological security of the central zone of Korup national park (KNP), by linking remote sensing, human socioeconomic and ecological data.

Specifically the study aims to: (a) assess and evaluate land cover change analysis to understand the locations and degree of threats to the ecological system by using satellite remote sensing data;(b) identify the socioeconomic and ecological variables that influence ecological security of the region; (c) assess the significance of the relationships between these variables and the environment that may inform the selection of conservation prescriptions, and (d) produce an index of ecological integrity map of the area.

The results should contribute to develop and prioritize appropriate policy interventions and follow-up steps to improve the security of protected area, and seek opportunities to enhance the integrity and viability of the ecological system while maintaining or expanding the diversity of livelihood options available to poor forest dependent population.

2 Materials and Methods

2.1 Study area

The study area (1,260 km^2) is located in Ndian Division, southwestern Cameroon, between latitudes 4° 54′ and 5° 28′ north; and longitudes 8° 42′ and 9° 16′ east of the equator, at the Cameroon-Nigerian border and is contiguous with the Oban National Park-Nigeria. This area was chosen because very little or no research had been carried out there because of its enclaved nature. The mean annual rainfall is in excess of 5000mm [Zimmermann, 2000].; temperatures range from 22 to 34^{0}C, while relative humidity averages 87% throughout the year. The highest point is Mount Yuhan- a horst, reaching 1130m. Currently, four villages are located inside the Park and 31 other villages are within 3km of the park and have about 11,500 inhabitants [Schmidt, 2004]. Shifting cultivation forms the basis of the farming system. Economic activities include hunting, collection, processing and marketing of non-timber forest products.

2.2 Field investigations and variables measured

Field work took place from February to June of 2008. Both household surveys and group discussions were carried out using open-ended questionnaire. Our focus was on land-use changes, trends in crop yields, socioeconomic status of the indigenous people, factors that local people perceived as having been responsible for the land-use /cover changes, and management effectiveness.

Village chiefs and sub-chiefs were contacted for most of our recall data. Other stakeholders included government and staff of Korup national park.

Our sample size was 95 (age:20-85 years; women:60; Men:35; average household size:4 people), drawn at random from three villages that make up the central region of the park.(20 from *Ekundo-kundo*; 35 from *Erat*, and 40 from *Ekon1* villages).We adopted the probability proportional to the size-a multi-stage sampling methodology (clustering, stratification and simple random sampling).

2.3 Variables measured

Taking into consideration the biophysical characteristics of our study area, the following independent variables were measured: ecological indicators; socioeconomic indicators; and management effectiveness indicators.

Ecological indicators included soil characteristics (organic matter, available phosphorus, pH, nitrogen, etc.). A total of 100 soil samples were collected for analysis.

Socioeconomic indicators as well as statuses (decline, remain same, or increased) of wildlife including socioeconomic important plant species (medicinal plants, fruit and food plants), which are the main sources of livelihood for the villagers. Management effectiveness indicators included staffing situation, and legal security. Here, respondents were to answer either "yes", "mostly yes", "no" or "mostly no" depending on their judgments of the situation.

2.4 Data Analyses

ERDAS IMAGINE 9.0 was used for image processing and database creation; ArcGIS 9.2 for database creation and GIS analysis; and SuperDecision [Saaty 2003] software for analytical hierarchical processing. Satellite images were layer stacked, mosaicked, and a subset produced. Our classification scheme adopted four main broad classes: Forest; Farms and settlements; Water bodies; bare/exposed surfaces.

2.4.1 Framework for determining ecological indicators

Ecological sustainability or the process of development which is compatible with quality and security of food supplies [Smith and McDonald, 1998] was assessed based on three indicators: Soil fertility status, Risk and uncertainties (diversification and profitability from economic activities, farming, collection and sale of non wood forest products etc), and Land cover change.

Reduction of risk and uncertainty in agriculture production was modeled using the Herfinhahl index (HI) and the index of profitability (IP) of economic activities. The index is a function of the area allocated to a particular enterprise [Llewelyn and Williams, 1996]. Mathematically,

$$HI = \sum_{i=1}^{n} P_i^2 \ , 0 \le HI \le 1 \qquad (1)$$

where, P_i is the proportion of farm area allocated to a particular enterprise, in this case, the local farmer.

HI= 0 denotes perfect diversification, and if 1, perfect specialization.

Index of profitability (IP) was analyzed from household perspective, with household considered as a small business enterprise.

$$\mathrm{IP} = \left(1 - \frac{\mathrm{BEP}}{\mathrm{Sales}}\right) * 1000 \qquad (2)$$

Where,

$$\mathrm{BEP} = \left(\frac{\mathrm{FC}}{\mathrm{CMR}}\right) \equiv \left(\frac{\mathrm{FC} * \mathrm{Sales}}{(\mathrm{Sales} - \Delta \mathrm{C})}\right) \qquad (3)$$

BEP denotes the break even point, FC, the fixed costs; CMR, the Contribution Margin, and ΔC , the variable cost from economic activities. In arriving at this model, we assume that the household is a small business enterprise. The calculation is based on income from farming season (financial year). Costs of inputs were computed on the basis of respective local market prices.

Land cover change was modeled through supervised classification of satellite imageries (Landsat TM, 1986, and Landsat ETM+, 2000) of the area. The Normalize Difference Vegetation Index selected (NDVI) was used to identify the state of vegetation cover.

$$\text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}} \equiv \frac{\text{Band 4} - \text{Band 3}}{\text{Band 4} + \text{Band 3}} \qquad (4)$$

Where, NIR is Near-Infrared spectral band and R is red spectral band.

2.4.2 Framework for determining economic indicators

Economic sustainability requires that development be economically feasible. Therefore, economic security was measured based on four indicators: employed members in the family, annual agricultural income and, food sufficiency. Total production multiplied by the current market price within the study area was used to calculate average household income from different sources.

2.4.3 Framework for determining social indicators

Social livelihood security was assessed in terms of the following indicators: Access of safe drinking water and sanitation; and access to market, health and educational services.

These indicators are relevant both from societal and individual perspectives. For long-term livelihood security, it is necessary to provide equity in social services to reduce the vulnerability of livelihoods.

2.4.4 Framework for determining Management indicators

A protected area obtains a value for its management for example, through the sum of all the values of all the management fields, expressed as a percentage of the optimum value. The results were ranked as unsatisfactory (<=36%), marginally satisfactory (36-50%), moderately satisfactory (51-75%), satisfactory (76-90%), or very satisfactory (91-100%) depending on its score.

2.5 Development of an indicator system for assessing ecological security

We adapted the Organization for Economic Co-operation and Development “Pressure-State-Response (PSR) Framework [OECD, 1993] as the foundation of an indicator system for assessing ecological security (figure 1).

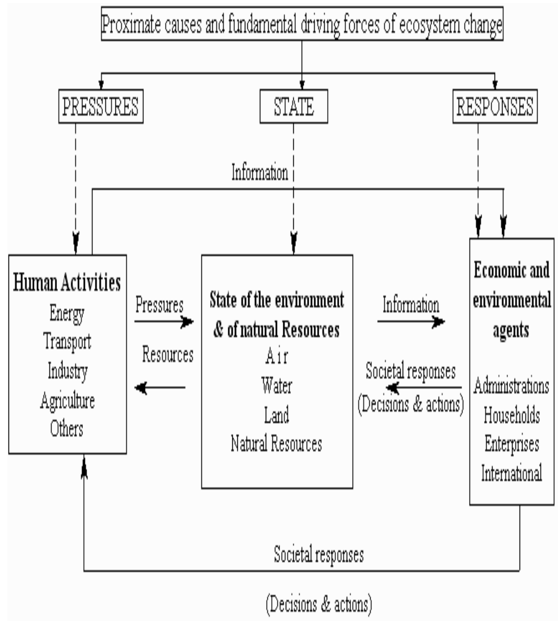

Figure 1: PSR concept model of OECD

The PSR model shows the causality between pressures on the environment and the resulting environmental degradation. The model's results thus have an obvious and intimate relationship with sustainable development. We selected three categories of factors that would be useful in assessing ecological security (natural, social, and economic factors) and that would comprehensively reflect the characteristics and situations of the regional environment.The analytic hierarchy process [Saaty, 1990] was used to decompose the factors that affect the ecosystem security into three main layers (Goal node, Criteria, and Sub-criteria node) (table 1).

Table1: Indicator system

IES=	Pressure	Population (A1)
		Hunting & collection of non timber forest products (A2)
		Farming & annual agric income (A3)
		Mean annual population growth (A4)
		Mean annual temperature (A5)
		Mean annual rainfall (A6)
	State	Soil fertility (A7)
		Land cover change (A8)
		Risk/uncertainty (A9)
		Water quality and quantity (A10)
		Access to markets & credits (A11)
		Agric diversification (A12)
		Employment (13)
		Status of fauna & non timber forest products (A14)
	Response	Staff (A15)
		Regulations (A16)
		New technology (A17)
		Behavior of households towards conservation issues (A18)
		Education & capacity building (A19)
		Research (A20)

2.5.1 Pairwise comparison

Indicators were pair-wise compared for their relative importance with respect to another element to establish priorities for the element being compared. Ratings follow the fundamental 1–9 scale [Saaty, 1997] of AHP (table 2).

Table 2. *The Fundamental Scale for Making Judgments*

1	Equal
2	Between Equal and Moderate
3	Moderate
4	Between Moderate and Strong
5	Strong
6	Between Strong and Very Strong
7	Very Strong
8	Between Very Strong and Extreme
9	Extreme
	Decimal judgments, such as 3.5, are allowed for fine tuning, and judgments greater than 9 may be entered, though it is suggested that they be avoided.

The procedure then requires that the principal eigenvector of the pair wise comparison matrix be computed to produce a best fit set of weights. These weights will sum up to one as is required by the weighted linear combination procedure. Since the complete pair wise comparison matrix contains multiple paths by which the relative importance of criteria can be assessed, it is also possible to determine the degree of consistency that has been used in developing the ratings. Saaty indicates the procedure by which an index of consistency, known as a consistency ratio (CR), can be evaluated. CR indicates the probability that the matrix ratings were randomly generated. For CR>0.1 should be re evaluated [Saaty, 1997].

2.5.2 Standardization - utility maximization mode

Ranking of alternatives is likely to be biased when attributes are measured in different units as is in our case. Hence, a multiple attribute evaluation method-utility maximization [Prato, 1999b], which involves maximizing a multiple attribute utility function, is used here:

For positive attributes or $x_{ij} \geq \min_j x_{ij}$,

$$S_{ij} = \frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} * 100 ; \quad (5)$$

For $x_{ij} \leq \min_j x_{ij}$

$$S_{ij} = 1 - \left(\frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} * 100 \right) \quad (6)$$

Where, x_{ij} is the raw value, and s_{ij} ($0 \leq s_{ij} \leq 1$), is the standardized value of the *j*th attribute for the *i*th alternative. The assumption here is that, the decision-maker is risk neutral.

It follows that, for any layer of security, the total un-security (or index of eco-security) value, IES can be estimated as:

$$IES_{ij} = \sum_{j=1}^{j=m} w_j s_{ij} ; i = 1,2,...,m \quad , \quad (7)$$

Where *m* is the number of attributes, and w_i ($0 \leq w_i \leq 1$) is the weight for the *j*th attribute, obtained by using the AHP model $\sum_{j=1}^{j=m} w_j = 1$.

3. Results

3.1 Agricultural land-use patterns and types

A large part of the population in the Korup region depends on agriculture for their livelihoods. However, crop diversification is limited to the cultivation of Cassava, yams, plantains, bananas .Of late, the increase in prices of food crops has motivated households to increase hectares seeded to some crops especially cassava and palm trees (*Elaeis guineensis*). The identified land-use/ cover types were: cultivated areas, fallow lands (characterized by fire clearing), sparse to dense tree cover, severely eroded areas, and coarse pebbles/sand rivers with outcrops of volcanic rocks in some places. Sand in most cases was still fresh signifying erosive actions. The sparse to dense, tree cover is defined as areas with more than 40% canopy cover [Lykke, 2000].

3.2 Socioeconomic threats to the ecological system

Hunting pressure is on-going and has greatly reduced the population of animals/wildlife in the area. Apart from monkeys, it is really difficult to find other species of animals we read and hear of on papers.

Demographic changes in the central zone of KNP are fundamental to the current pressure and threats on the park. The average population growth (following our investigation) puts Ekundo-*kundo* village at 2%, 4.5 % at *Erat* and 2.5% for *Ekon1* village. *Ekon1* and *Erat* villages are very close to neighboring Nigeria-Calabar and its environs. Hence, apart from natural population growth, positive fertility rates, etc., population growth in these areas can partly be explained by migration/immigration. This is posing serious threat to the Korup's ecological integrity.

3.2 Land cover Change (1986-2000)

Only 1.47% of land cover remains unchanged in the central zone of KNP from 1986 to date (table 3)

Table 3: Land cover change statistics of central korup from 1986 to 2000

From 1986 to 2000	Area (ha)	% change
Decrease	27946.70	49.54
Some decrease	9812.39	17.39
Increased	16527.80	29.30
Some increase	1300.44	2.31
Unchanged	829.68	1.47
Total	56417.01	100.00

An increase in population prompts the movement of new settlement into regions with fragile ecosystems; land under other uses is encroached upon by people seeking to find new lands to cultivate. From 1986 to 2000, land cover in the region has decreased by more than 50% and increased half as much.

3.3 Soil fertility status

Soils are acidic (4.7), mostly sandy (77%), low levels of nutrients and of organic matter (1.36-5.2%), and of high base saturation (Table 4).

Table4: Soil properties in the central zone of the Korup National Park

Soil properties		Unit	Range	Mean	Interpretation
Sand		%	70-84	76.95	Very high
Silt		%	10-30	20.9	Medium
Clay		%	6-21	12.55	Medium
Organic matter		%	1.36-5.2	2.52	Very Low
Organic Carbon		%	1.06-4.0	1.89	Very Low
Available Phosphorus		mg/Kg	2.02-4.48	2.73	Very low
pH	pH-water		4.25-5.01	4.60	Acidic
	pH-Kcl		3.74-4.06	3.90	Very acidic
Potassium		%	10.18-29.39	22.13	Medium
Saturate bases		%	24-39	31.85	High
Nitrogen		g/kg	0.6-2.38	1.23	Low
C/N ratio			10-32	16.12	Medium

Organic matter content not only influence soil productivity but also improves its texture and structure, reduce leaching of nutrients, increases water holding capacity, supports the activities of microorganisms, contributes to improve soil structure and productivity, and reduces erosion. Acidity makes it difficult for biomass to be recycled; thereby reducing global environmental services, as this negatively contributes to sequestrate carbon in soil.

3.4Socioeconomic indicators

3.4.1 The Index of crop diversification

The Herfindhal indices for both years (table 5) are respectively 0.309(309 per thousand) and 0.306 (306 per thousand). The crop diversification index revealed that both communities have significantly low crop diversification in their cropping systems.

Table 5: Crop diversification index for 1986 and 1996

	1986			1996		
i	x_i	h_i	h_i^2	x_{1i}	h_{1i}	h_{1i}^2
Cocoyams & Cassava	46	0.469	0.220	71	0.455	0.207
Plantains & Bananas	21	0.214	0.046	39	0.250	0.063
Palms	18	0.184	0.034	26	0.167	0.028
Cocoa	7	0.071	0.005	11	0.071	0.005
Others	6	0.061	0.004	9	0.058	0.003
Total	**98**	1.000	**0.309**	**156**	**1.000**	**0.306**

'Others' here refer to crops occupying less than 0.1ha of farmland. As shown, they make up about 6% of the total cropland.

3.4.2 Average annual incomes and Index of profitability (IP)

The average annual incomes are relatively low when compared to the current poverty rate in the country. The contribution margin and indices of security (88.75% and 78.29% for 1986 and 2000 respectively) are interestingly high and almost same for the period under study. However, per household average annual incomes hardly attains 150 000FCFA, an income far lower than the baseline of CFA269 400/yea r ≡ \$1.7/day, Cameroon's poverty level. This might be so because agricultural inputs are far cheaper when compared to the current rise in food prices. With current government efforts to fight against price hikes, we do not expect such a situation to be long lasting.

3.5 Pair Wise comparison of the clusters

Pairwise comparison (table 6a-c) demonstrated here was carried out using the SuperDecisions software. We pairwise compared elements of the criteria, sub-criteria and alternative decisions for assessing and evaluating ecological security of the area.

Table 6a: Pair wise comparison of main Criteria with respect to the goal

Criteria	Pressure	State	Response
Pressure	1	5	3
State	1/5	1	3
Response	1/3	1/3	1

The inconsistency value = 0.000<0.1

Table 6b: Pair wise comparison of pressure sub-criteria of the objective

Pressure sub-criteria	A1	A2	`A3	A4	A5	A6
A1	1	1	3	5	7	9
A2	½	1	2	4	6	8
A3	1/3	1/2	1	2	5	7
A4	1/5	1/4	1/2	1	2	4
A5	1/7	1/6	1/5	1/2	1	2
A6	1/9	1/2	1/7	1/4	1/2	1

Inconsistency value = 0.0181<0.1

Table 6c: Pair wise comparison for 'state' sub-criteria of the objective

State sub-criteria	A7	A8	AC9	A10	A11	A12	A13	A14
A7	1	3	2	6	4	4	5	5
A8	1/3	1	1/2	4	2	2	3	3
A9	1/2	2	1	5	3	3	4	4
A10	1/6	1/4	1/5	1	1/3	1/3	1/2	1/2
A11	1/4	1/2	1/3	3	1	1	2	2
A12	1/4	1/2	1/3	3	1	1	2	2
A13	1/5	1/3	1/4	2	1/2	1/2	1	1
A14	1/5	1/3	1/4	2	1/2	1/2	1	1

Inconsistency ratio =0.0141<0.1

The inconsistency measure is useful for identifying possible errors in judgments as well as actual inconsistencies in the judgments themselves. Inconsistency measures the logical inconsistency of your judgments.
The judgment value pointed to 3 on the third column in table 4b for example, in the first row, for example, means that A1 (population) is more important when compared to A3 (annual agricultural income), according to the decision maker. 1/3 would mean the reverse and 1 will mean equal importance. The inconsistency index, 0.0181<0.1, shows that the judgments were quite reasonable. The State, response and the other sub-criteria were compared in a similar manner. The values from the pairwise comparison were used to produce a supermatrix from which priorities of the alternatives were obtained.

3.6 Weights of the indices –weighted and Limit super matrices

The priority weights derived from the pairwise comparisons are entered in the Unweighted Supermatrix. In a hierarchical model like this, the Weighted Supermatrix is the same as the Unweighted Supermatrix because the clusters are not weighted. Raising the Weighted Supermatrix to powers yields the Limit Matrix from which the final priority options are extracted.
The sum of products of the priority weights and the standardized values of the indicators gives the weighted score, the index of ecological security for the year concerned (table 7).

Table 7 *Standardized scores of the indicators*

	Score			Weighted scores	
Indicator Name	1986	1996	Priority weight	1986	1996
Population	0.6000	0.2857	0.0728	0.0437	0.0208
Hunting & collection of NTFP's	1.0526	0.6250	0.0625	0.0658	0.0391
Annual agric income	0.6000	0.2973	0.0409	0.0245	0.0122
Mean annual population growth rate	0.5000	0.2000	0.0186	0.0093	0.0037
Mean annual temperatures	0.2308	0.2308	0.0118	0.0027	0.0027
Mean annual rainfall	0.7668	0.7668	0.0091	0.0070	0.0070
Soil fertility(organic matter)	0.9615	1.5000	0.1107	0.1065	0.1661
Land cover change	0.6250	0.8000	0.0491	0.0307	0.0393
Risks and uncertainties	0.5000	0.0909	0.0753	0.0377	0.0068
Clean water quantity& quality	0.3750	0.6667	0.0118	0.0044	0.0078
Access to markets and credits	0.0000	0.0000	0.0301	0.0000	0.0000
Crop diversification	0.6667	0.6667	0.0301	0.0201	0.0201
Employment	0.0000	0.0000	0.0181	0.0000	0.0000
status of wildlife & NTFP's	0.4000	0.5000	0.0181	0.0072	0.0090
Staff	0.3077	0.5000	0.0145	0.0045	0.0072
Legal security& International obl'gns	0.5000	0.3333	0.0240	0.0120	0.0080
New technology	0.0000	0.1818	0.0872	0.0000	0.0159
Behavior of local people-conserv'n	0.2000	0.3000	0.0313	0.0063	0.0094
Education & capacitybuilding	0.3333	0.3333	0.0501	0.0167	0.0167
Research	0.5000	0.7500	0.0340	0.0170	0.0255

Ecological security index, U, was grouped into five classes:

- ✓ (0< U_{ij} <2); moderately damaged,
- ✓ (2.1< U_{ij} <4); slightly damaged,
- ✓ (4.1< U_{ij} <6); relatively damaged, and
- ✓ (6.1< U_{ij} <8) or secured (U_{ij} >=8.1).

All values are multiplied by '1000' so as to upgrade the final weight to a whole number.

3.11 Ecological safety map of the Central zone of Korup national Park

Shape files for the ecological security indices for 1986 and 2000 were created in ArCGIS 9.2 .With other shape files (points); the ecological security map (figure 2) of the area was generated.

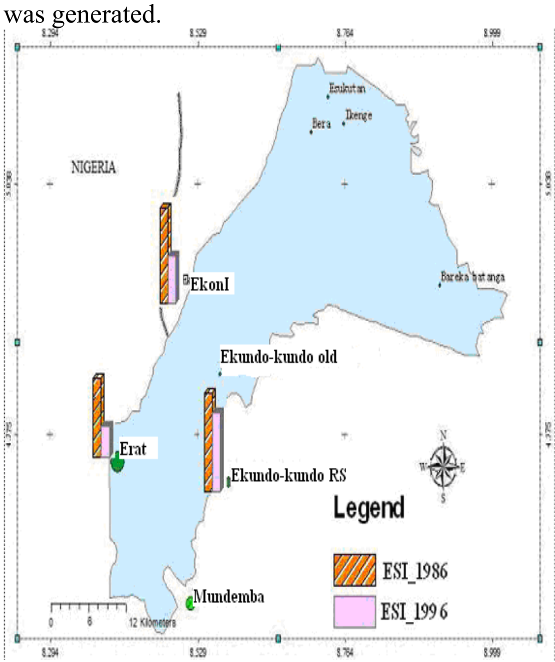

Figure 2: Index of Ecological Integrity map for the central zone of Korup national park

The taller the bar, the more secured is the ecological system and vice versa. For example, the security status of Ekundo-kundo RS (Resettlement Site), has dropped from secured (U_{ij} >=8.1) in 1986 to moderately damaged ($2.1<U_{ij}<4$).

4. Discussions

Ecological and livelihood security in the central zone of the Korup national park are the results of a variety of ecological, economic, social and changes.

The change in land cover is partly as a result of successional species from the old site (*Ekundo-Kundo*), following the involuntary resettlements of the early 2000.Also, it is the result of the recent extensification to palm and cocoa plantations in the entire central zone of the park, and the agro-climatic potentials are most important explanatory variables.

Herfindhal index reveals that there is diversification in the cropping system is not significant enough.We expected the poor soil quality to be a major set back to agricultural extensification. Though this is good for the environment, it is not good news as far as sustainable livelihoods is concerned.

4.1 Priority action for management

From the sensitivity analysis of our results, it is clear that population (A1) and annual agricultural incomes (A3) are most important priorities for management. The increasing population pressure associated with farming and homesteads activities raises some hypotheses. As many farmers now seem to specialize, this situation may fail to factor out in the long-run sustainability of the farm operation and thus creates uncertainty regarding its future. The increase in population density might render the area less suitable for agricultural extensification and thus people look for further encroachment into the park, let alone poaching activities.

4.2 Can we uncover driving forces of ecological and livelihood deterioration through our binary and index model?

Yes, the binary and index model developed in this study suggest some important underlying causes of ecological and livelihood deterioration that that can be related to some well-established frameworks. Soil is the base material required for the survival of plant ecosystems, and plays an important role in an ecosystem by means of its physical and chemical characteristics and its ability to regulate heat and water balances. The soils are generally acidic, low organic matter, low phosphorus content and of saturated basis. Soil structure is poorly developed, and their ability to preserve moisture and soil fertility is low. Taking into consideration the current property right regime in the area, and government action in meeting up with many of its international obligations, it is clear that food security in this area will be threatened in the long run.

Again, the population increase that has occurred in this region in recent decades is another important reason for the current ecological situation being experienced by central Korup. Human activities including building of mud houses, chopping down large quantities of woody vegetation to provide fuel, and so on, have also damaged the environment.

The creation of new agricultural land (which can be explained by socioeconomic and biophysical factors determining the marginality of the area) has significantly reduced the area of forestland and wild products. Such activities are the major causes of poverty and environmental degradation in watersheds [Paudyal and Thapa, 2002] and may lead to further social, political and economic problems [Seddon and Adhikari, 2003].

Like elsewhere in the tropics, there seems to be widespread public ignorance of environmental issues. Over 90% of the indigenes are ignorant of the consequences of their actions. It is imperative to convince the populace and governments officials that environmental security and/or integrity matters.

High levels of political corruption exist in the area. Like in Kalimantan-Indonesian Borneo [Smith at al., 2003], local tribal leaders, military, and police are being bribed by illegal hunters. During our survey, it was observed that forces of law and order dispatched to check illegal hunting are primary consumers of wild products especially bush meat. Special police forces could be seen with hunted species of rare animals. This demonstrates that current efforts to eradicate corruption need a change of direction to achieve tangible conservation.

Poverty and lack of funding are also seen as the major driving forces of threats to ecological security of the area. A chronic lack of funding is also threatening the integrity of the ecological system. It is read and understood that forest guards exist in the region, but during our survey, only one was seen. Lack of finance hampers management efforts threatening the opportunities of the future generations from whom we are borrowing these natural resources.

4.3 Social security

4.3.1. Access to safe drinking water supply and sanitation

There is no pipe borne water supply. Streams and rivers are the main source of portable water. Indigenes bathe and drink of the same water. An outbreak of water borne diseases may cause untold consequences to human lives.

4.3.2. Access educational services

One primary school with poor infrastructure serves each village. Furthermore, environmental education which is important for conservation is lacking in schools internal curriculum.

5. Conclusion

This paper indicates the importance of understanding the dynamics of ecological change in a spatial-explicit way, their proximate and underlying driving forces, and possible impacts on human and ecological security.

Our judgment of ecological security in this paper was based on whether human activity damages the ecosystem, and whether the resulting ecosystem threatens the existence and development of humanity. Based on the calculation model described in this paper, while the socio-economic statuses of the villagers remain uncertain, the ecological security of the area has moved from slightly, to moderately damage in the past decades.

There is need to strengthen anti-poaching and law enforcement measures, update research activities, integrating poverty alleviation issues into conservation, gain local community support through creating opportunities and benefits; capacity building and environmental education. Furthermore, agroforestry will be uniquely suited to provide ecological friendly solutions that successfully combine objectives for increased food security and biodiversity conservation gains, especially by promoting greater use of native tree species in agroforestry systems. Women and children, who are the main actors in collection of non timber forest products, hunting and farming, should be a major target. This process does not end yet and our results may be considered as a first approach.

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