Contribution of the Analytic Hierarchy Process (AHP) in Decision-Making to (RE) Define Protected Areas Boundaries – Case Study in the National Park of Campo Ma'an (South-Cameroon, Central Africa)

Alfred Homère NGANDAM MFONDOUM[1], Joachim ETOUNA[2], Mustapha HAKDAOUI[3]

[1]CRASTE-lf, Rabat – Morocco; Department of geography, University of Yaoundé I. Po Box 8381, Yaoundé – Cameroun

[2]National Institute of Cartography, Yaoundé, Cameroun

[3]Faculty of sciences of Ben M'sik, University of Casa II, Casablanca; CRASTE-lf, Rabat – Morocco

Abstract: ***In this paper, Analytic Hierarchy Process (AHP) is used as the method of criteria choice and classification for the delimitation of a protected area. Starting from the hypothesis that the space define for protected areas of Cameroon must integrate in priority wildlife, the density of spatial distribution of medium and large mammals in the Campo Ma'an National Park is used here as the main criterion analysis. Its combination in raster mode with other layers of information such as vegetation, streams, tracks, surrounding localities and areas of human activities provides a map on which the park area increased by 88.6%. This result is discussed on the basis of socio-spatial impact which is assessed in terms of three levels of relocation of the surrounding villages and their populations.***

Keywords: AHP, Cameroon, delimitation, protected area, raster mode

1. Introduction

Protected areas are some answers among others proposed to address concerns relating to the protection of the environment. In the Third World particularly, their creation attempts to address threats related to population growth, human growing needs and even political instability, with consequential flooding of areas and the destruction of natural areas increasingly important for predatory activities (hunting, agriculture, forestry) or to substantial commercial purpose [1,2, 3].

The experience of Africa in general and Cameroon in particular must be primarily related to the colonial era. Indeed, the first national park in Africa dates from the 19th century, including the Kruger National Park in South Africa erected in 1898 [1]. But when taking into account previous ancestral behavior before colonization, animals, plants or specific forest areas (principle of sacred forests in western Cameroon), were traditionally protected to respect ancestral customs or religious considerations [4].

In its advanced design, the creation of protected areas satisfies the basic need of protection and conservation of a representative sample of each species of fauna or flora threatened existing. They offer the opportunity to control plants and highly important or vulnerable animals as consequences of unsustainable practices especially for commercial purposes [5]. However, the size, shape and location of many protected areas do not offer the most appropriate conservation conditions. Those that exist are often not large enough to provide adequate habitat for some species of plant or animal. Because of their shape or location, many areas are also vulnerable to negative influences such as pollution, noise, illegal hunting and encroachment of agriculture. These multi-spaces and multifunctional [6] indeed trigger conflicts of a new type between residents and animals, especially when the basic needs of wildlife thwart those of humans with adverse consequences for both parts [7,8].

It appears indispensable to rethink the choice of areas for conservation and management approaches by reconciling conservation and perceptions of local populations [9]. On another side it is necessary to review the methodology of delimitation such a way that the largest number of elements and criteria are included. This lack of integrating multiple criteria can explain the multiple conflicts in the establishment of conservation areas because the choices and modes of zoning of protected areas have been made ambiguously [3].

This article then focuses on the contribution of the Analytic Hierarchy Process (AHP) applied to the re-delineation of Campo Ma'an National Park in southern Cameroon.

2. Methodology

2.1. Presentation of the Study Area

Located in the south-Cameroon rainforest, Campo Ma'an National Park lies between latitude °210' -2 ° 45 'N, and longitudes 9 ° 50'-10 ° 48' East (Figure 1). With an area of 264,064 ha it is classified Operational Technical Unit (UTO) of first class. It is characterized by an equatorial coastal climate with four seasons, favorable to the growth of the Guinean-Congolese dense evergreen forest vegetation [10]. Hydrography is dense and characterized by its proximity to the Atlantic Ocean. Soils are poorly developed on the mountains and troughs, waterlogged in the valleys and lowlands, yellow or red lateritic in most parts of the park. The most characteristic fauna is composed of large and medium-sized mammals that are more than 80 species, including elephant, buffalo, hippopotamus, gorilla, chimpanzee, mandrill, the panther and the giant pangolin [10, 11]. Twenty-three of these species are considered threatened with extinction [12]. The total human population was estimated at 258,275 inhabitants in the last General Census of Population and Housing [13, 14]. The economy is mainly developed around agriculture. Nevertheless, livestock, hunting, fishing, and logging are other main activities in the area.

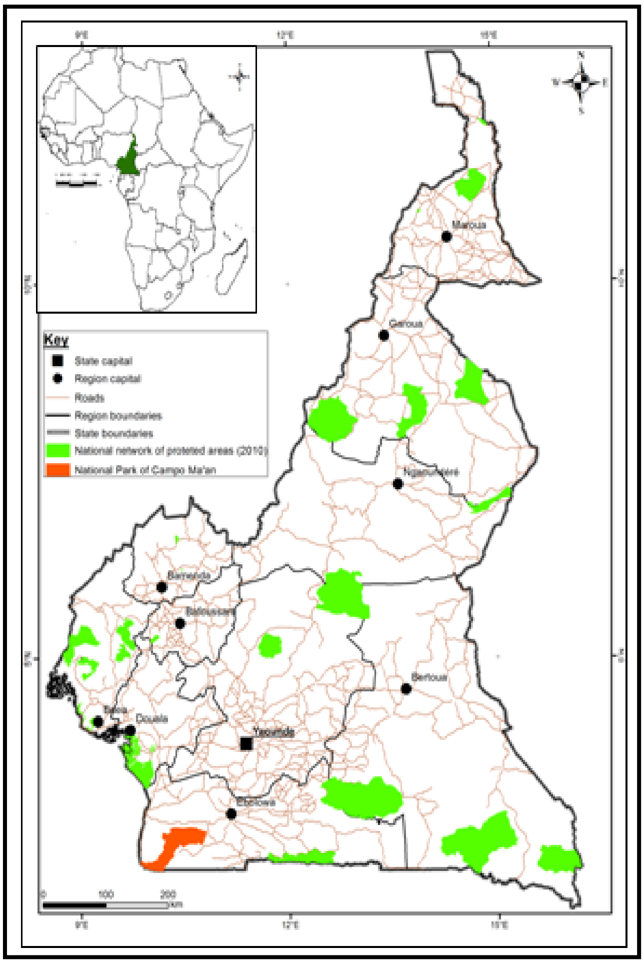


Figure 1: The study area

2.2 Overall structure of protected areas in Africa and Cameroon

The spatial structure of protected areas in Africa has the same appearance. It is a zoning system that aspires to conservation, sustainable land use and support scientific research. It helps to have one or more central areas, a core of variable size where human interference is minimal. Then follows a concentric area that serves as a buffer and where more human activities such as research, environmental education and training, as well as tourism and recreation activities are allowed (Figure 2).

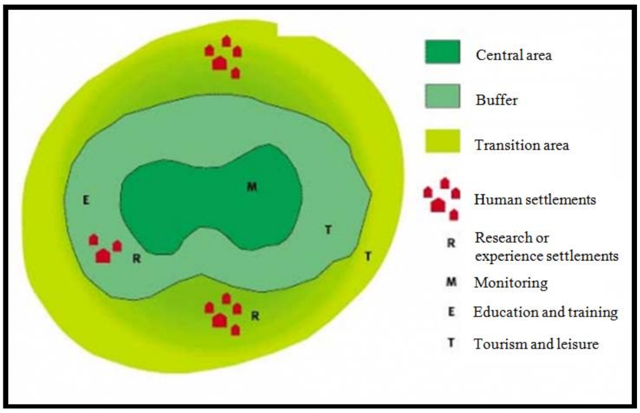


Figure 2: Schematic zoning of a protected area [3]

This structure is adapted according to country and the institutional and legislative framework.

2.3 Approach to the delimitation of Campo Ma'an National Park

The Cameroon Ministry of Forestry and Wildlife (MINFOF) is responsible of the creation and delimitation of protected areas. Its general approach to the delimitation of Campo Ma'an National Park was that described above. However special attention can be pay to the criteria taken into account according to their order of importance and integration in the delimitation process. Technically the vegetation is priority criteria characterized specifically with surrounding streams; while wildlife after qualitative characterization and counting is included as underlying vegetation. Finally, the human or humanized surrounding fields are considered in terms of their distance from the boundaries of the vegetation to be protected (Figure 3).

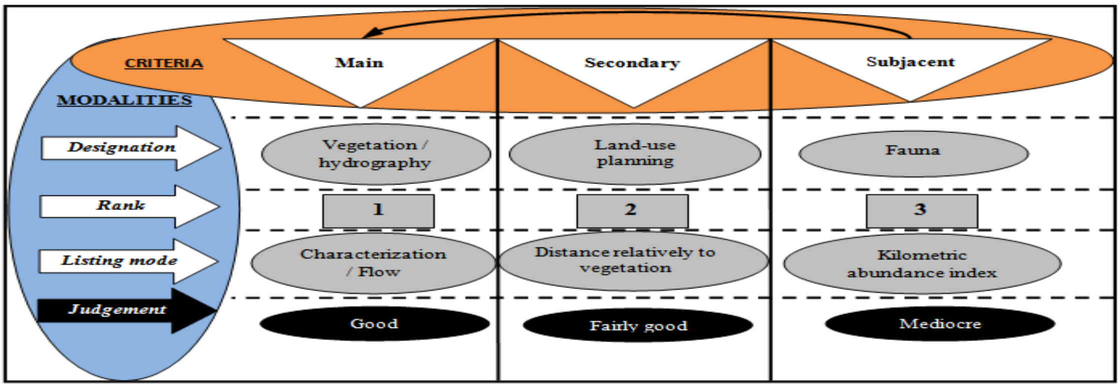


Figure 3: The summarized approach used for Campo Ma'an National Park delineation [15].

However, recurrent conflicts demonstrate the inefficiency of this approach (Figure 4). The Campo Ma'an National Park suffers from the overlap between the boundaries of industrial or family plantations and those of the park. This is particularly the case of the agro industry concession GMG HEVECAM, the Forest Planning Unit 09-025 and also village agricultural areas (fallow and burning) which affect the current boundaries of the park or beyond, with consequently the outbreak of conflict [11, 16, 17, 18]. Moreover wildlife in its natural movement or driven by human activities (forestry, agro-industry, hunting, construction of the hydroelectric dam ...) makes regular incursions across the surrounding fields during their migration to places reproduction or nutrition. For these reasons, it is important to bring this process to a model that integrates in priority the wildlife.

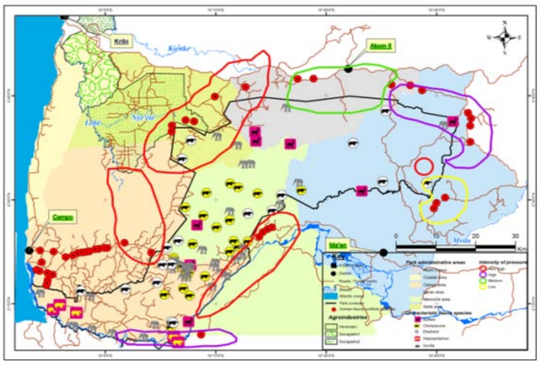


Figure 4: Anthropogenic pressures fronts around the Park [15]

2.4. Proposition of a dynamic model for delimitation of Campo Ma'an National Park based on mobile bioecological component, the Wildlife

In view of wildlife movements which are generally more distant in dry season for the needs of nutrition, it is important to consider this bioecological component as the primary criterion of protected area demarcation, including its habitat and tracks movements. Subsequently the major plant groupings determining these habitats as well as rivers most shared by wildlife in direct or distant surroundings biotopes could be integrated as secondary criteria. Human land, that is to say places of residences and farming areas are also secondary endpoints, but considered from the point of view of their exclusion from the area to build a park (Figure 5).

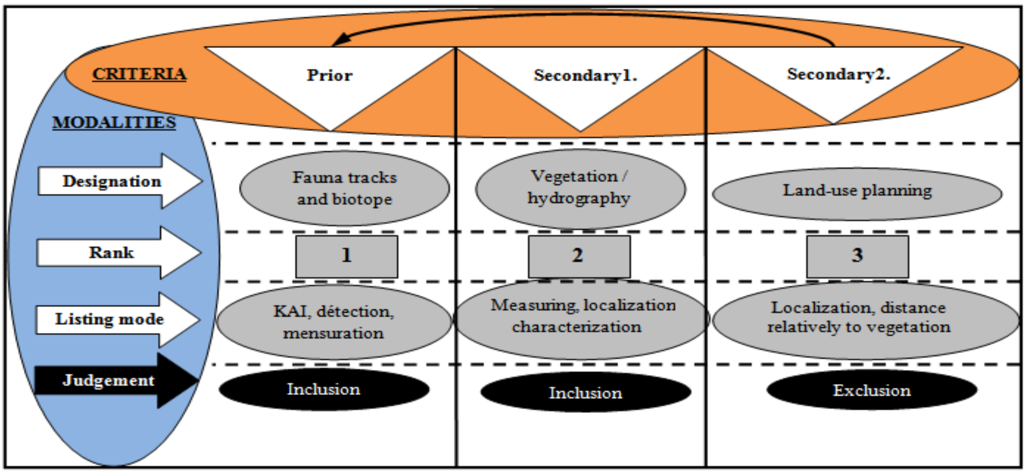


Figure 5: Schematic representation of the model proposed delimitation

3. Experimentations

3.1 Basic principles of AHP and adaptation to the context of the study

The AHP is one of many methods of multi-criteria decision support. It aims to provide tools that will enable progress in solving a decision problem where several objectives often conflicting must be taken into account. The divergence of objectives requires finding a solution the best possible compromise. Developed and tested by Thomas L. Saaty [19, 20, 21], the origin is a hierarchical tree making. Different level of the hierarchy are to be determine, criteria are to be chosen at every level before proceeding to their comparison according to their respective levels. The goal targeted by the decision maker is on top of the tree. One or many criteria are generated from it and any criterion is decomposable in sub-criteria. The method is based on three concepts:

a) Hierarchical structure: it is a decomposition of the problem into sub-problems. Every sub problem corresponds to a decision maker sub-preoccupation;
b) Structuring of priorities: some elements are proposed has hypothesis and apriorism for problem solving and classified according to their relative importance. Henceforth, any criterion or sub-criterion corresponds entirely or partially to a sub-problem;
c) Logical consistency: it is the logical grouping and ordering of the elements. This is done by joining a proposed weight to a group or a sub-group of criteria before a validation process throughout the calculation of a consistency index and a ratio of coherence;

This method is helpful to [20]:

- Formulate a representative compromise of various opinions, but not necessary consensus
- Refine a problem definition by decomposition
- Establish priority
- Consider the interdependence of elements
- Assess logical coherence of opinions used.

3.2 Adaptation of the AHP to the context of the study

In this case, the goal is the best delimitation of Campo Ma'an National Park on a suitable area and based on wildlife movement in priority. The problem has been broken down into 3 major criteria and 7 sub-criteria as follows:

- Bioecological conditions (C.1): they are divided into three sub-criteria, including the spatial distribution of mammals (C.1.1), vegetation (C.1.2) and streams (C.1.3);
- Technical and environmental conditions (C.2): they put the related environmental elements directly distinguishable by a primary source as satellite imagery and indirectly during a field trip by GPS. This is mainly tracks (C.2.1) created by animals or human being (forest trails, hunting, etc.), all included in the maximum movement radius of mammals (C.2.2);
- Social conditions (C.3): these are the areas of activities (C.3.1) and human settlements (C.3.2), which must be outside the area occupied by the park (Figure 6).

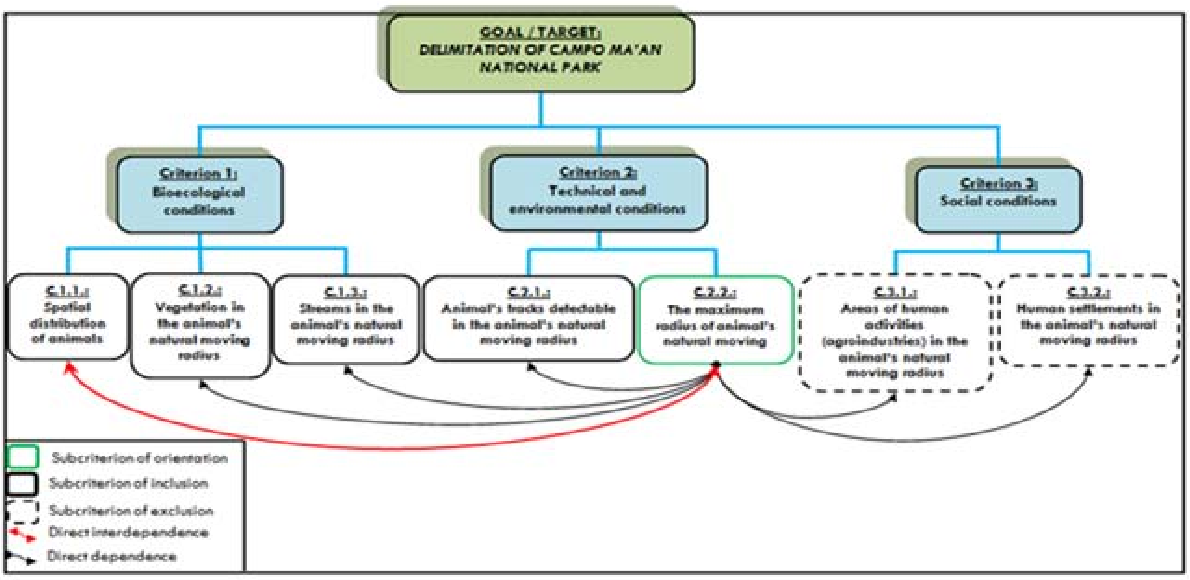


Figure 6: Hierarchy model of the problem [15].

3.3 The Weighing of Criteria

Numerical values ranging from 1 to 9 were assigned to the various sub-criteria according to their importance for the analysis. A normalization process was followed by dividing the value of each sub-criterion by the sum of the column, to facilitate the calculation of weight. The sum of all weights must be equal to 1 and the formula used for this is:

$$\text{Criterion Weight} = \frac{\text{Sum of the line}}{\text{Number of criteria}}$$

Table 1: Preference values and calculation of the weights of criteria

	C.1.1	C.1.2	C.1.3	C.2.1	C.2.2	C.3.1	C.3.2	Criterion gross Weight
C.1.1	1	2	2	2	2	3	5	0.26311
C.1.2	0.5	1	2	3	3	3	2	0.22068
C.1.3	0.5	0.5	1	2	2	3	3	0.16295
C.2.1	0.5	0.33333	0.33333	1	2	3	3	0.12795
C.2.2	0.5	0.33333	0.5	0.5	1	3	3	0.11044
C.3.1	0.33333	0.33333	0.33333	0.33333	0.33333	1	2	0.06367
C.3.2	0.2	0.5	0.33333	0.33333	0.33333	0.5	1	0.0512
								1

It has been necessary to validate these weights by a process of consistency, to minimize subjectivity in the choices made.

3.4 The numerical validation of the criteria weights

The last step of the AHP is a numerical validation of criteria or sub-criteria weights to assess their degree of consistency and minimize the subjectivity of the author. This step began by computing the average consistency multiplying each column of the matrix raw binary weight associated criterion. The sum of each row of the table was obtained and the result has been divided by the weight of the associated criterion for consistency of each criterion. The average coherence was calculated by dividing the sum of all the individual consistency by the total number of criteria, and the diagonal of the matrix obtained corresponds to the weight of different criteria. The total consistency average obtained was 7.42724. The consistency index has then been obtained as follows:

$$\text{Consistency index} = \frac{\text{Mean coherence} - \text{Number of criterion}}{\text{Number of criterion - 1}}$$

The result obtained (0.07121) was finally divided by the consistency random corresponding to the value used in an analysis with six (6) criteria,1.32, to obtain the ratio of coherence, that is 0.05394 <0.1. Thus validating the weights assigned to the different criteria for purposes of combinations.

3.5 The raster conversion of layers

The layers corresponding have been processed in raster format, based on point and linear features collected in the field and those previously digitized. Modules of ArcGIS 10.2 [22] software were used and the raster conversion methods were varied, depending on whether we had points, lines or polygons data on the one hand, and dynamic or static phenomena on the other as follows:

- Static linear (roads and rivers), surface (vegetation and agribusiness plantations) and point (locations) criteria were converted according to a geostatistic deterministic spatial interpolation method based on the Inverse Distance Weighted (IDW);
- Dynamic phenomenon meanwhile, were submitted to a splint raster conversion that best represents their spatial distribution, especially the spatial distribution of mammals.
- The combination has been performed according to the method of the weighted sum of factors. Then a consistency coefficient between 1 and 5 was introduced for each criterion based on its importance to minimize subjectivity. Calculation was computed as follows:

"ra_sp_an.asc" * 0.11044 ["d_sp_dist_an.asc" * 0.26311 * 5 + "nat_vgt" * 0.22068 * 4 + "hydro.asc" * 0.16295 * 3 + "an_tr.asc" * 0.12795 * 2 + "vil.asc" * 0.06367 * (- 1) + "agr_ind.asc" * 0.0512 * (- 1)]

ra_sp_an = radius of spatial distribution of animals; **d_sp_dist_an** = spatial distribution of animals density (here the major representatives mammals - elephants, hippos, buffalo, gorillas, chimpanzees, mandrills); **nat_vgt**= natural vegetation; **hydro** = hydrography; **an_tr** = animals tracks; **vil.** = villages and human settlements; **agr_ind** = areas of human activities; **.asc** = extension of ASCII

All this leads to a complete mapping model with convincing results for the park delineation (Figure 7).

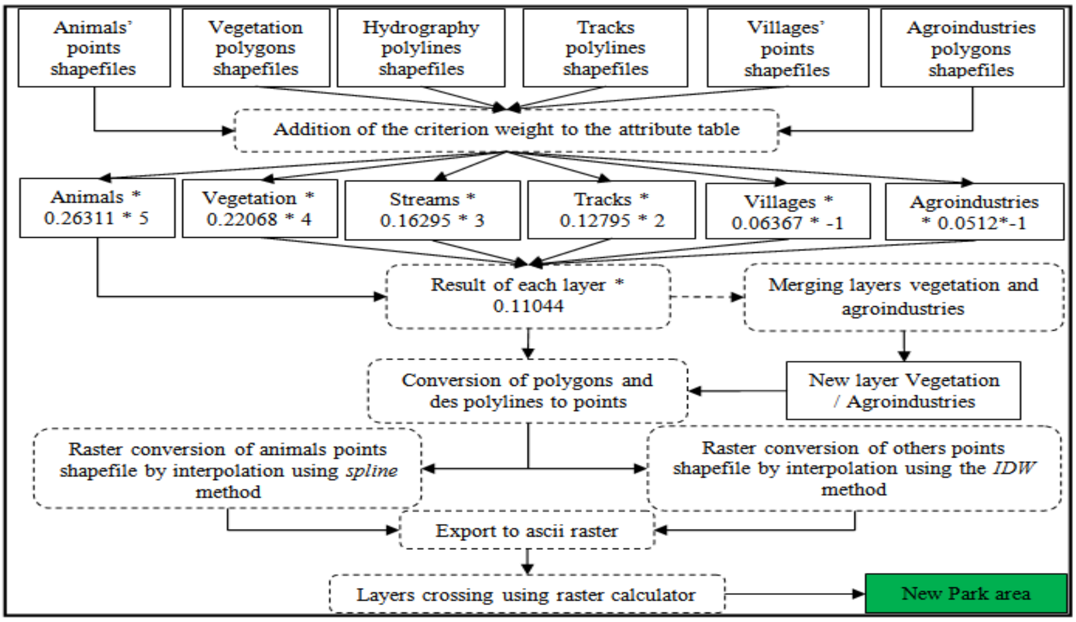
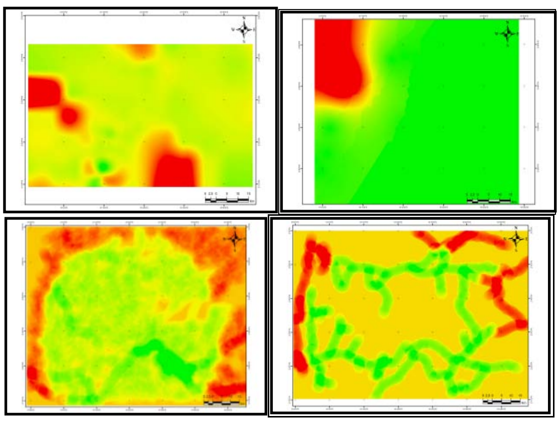


Figure 7: The general cartographic model

4. Results

Layers of useful information for the analysis have been previously derived in continuous mode intensity that is stretched (Figure 8a). Gradient contribution to the boundaries of the park is framed by green lemon color and dark orange through yellow. Thus more the color is green and more suitable the part of the relevant layer is to integrate the area of the park. On the other hand more the color tends to vivid orange and less the surfaces can be integrated to the park area.

The crossing of these layers has increased the surface of the park by 88.6%. It covers 497. 980 hectares against the current 264.064 hectares. In addition, the spatial extent of the new area is expanded in the north and narrowed in the south, taking into account the radius of the location and density of spatial distribution of all wildlife species listed. General trends can be grouped into three classes of boundary zones, a very appropriate area in green lemon, another non-suitable in dark orange, and between the two a terraced area in yellow that calls the public and administration concerns to a multi-stakeholder consensus dialogue usage (Figure 8b).



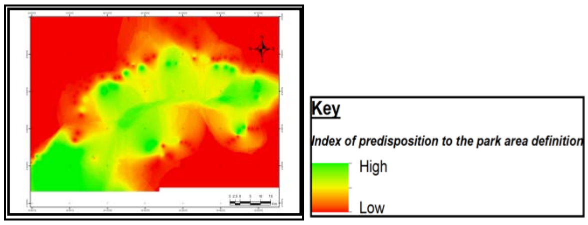


Figure 8a: Raster layers used in computation. From left to right and top to bottom, the layers: distribution of animal species, natural vegetation fused to industrial crops, hydrography, tracks, surrounding villages.

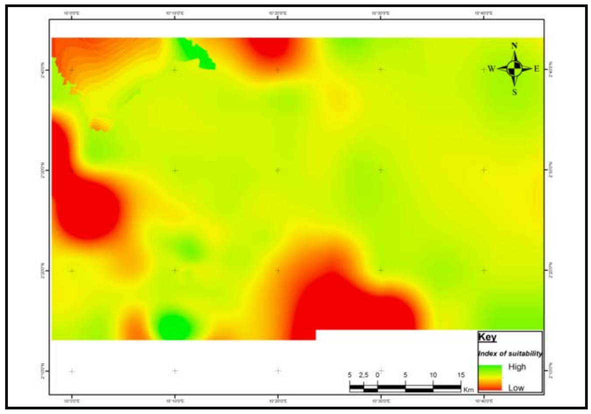


Figure 8b: Trends map of the new park area

5. Discussions

The result has features that could cause new problems despite multi criteria analysis. In fact the superposition of the new area of the park with other information layers especially with neighboring localities enable to appreciate the socio-spatial double impact. Then forty-eight (48) villages (point in vivid red) are located on the very appropriate area and should therefore be absolutely evicted. Thirty (30) other villages (in pink) are adjacent to the clearly defined park area. In total seventy-eight (78) villages are waivers on a mandatory or consensual expulsion. Other villages (green) are free because of their position external to the requested space (Figure 8c). Demographically, this would concern at least 20.597 residents. This adds to the general need for a permanent and balanced dialogue between the administration concerned and riparian communities to install and define protected areas.

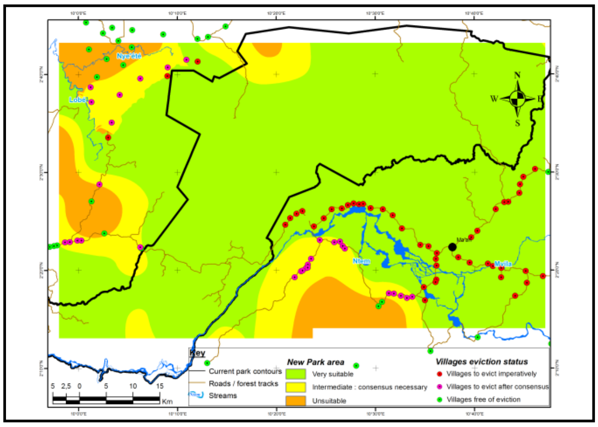


Figure 8c: The new Park area and the socio-spatial impact

6. Conclusion

In conclusion, the use of the AHP for the delineation of protected areas offers a range of solution mainly taking into account several criteria some of which are inclusion of wildlife, vegetation, hydrography, roads, and other exclusion as human activities areas and settlements. Nevertheless, it appears in the hierarchy process to prioritize the criterion of the spatial distribution of wildlife, because of their mobility that makes them go regularly beyond the actual limits; causing conflicts between park managers and residents due to various attacks and destructions.

Thus, the creation of protected areas in Cameroon especially should be based on a preliminary study based on AHP in order to take into account the population local perceptions and all the surrounding biophysical and human components. This consensual approach would avoid clashes between residents, animals and administrations, and the relocations and evictions are agreed and accepted by all for compensation. Furthermore, it is important to visually materialize the boundaries of protected areas, so they are clearly known by populations and thereby avoid any violations.

However deficiencies should be identified including the short period of observation of the movement of animals and the determination of plant species characteristics for each species in order to create suitable corridors that do not contrast with the ambient bio-ecological reality. Finally emphasis should be placed on the acquisition of satellite images of very high spatial resolution or radar to better compare the contributions of field geotracking in real time and other source of information.

References

[1] UICN, "Parks for biodiversity: policy guidance based on experience in ACP countries". Prepared par la Commission Mondiale pour les Aires Protégées pour l'UICN. Brussels et UICN, Gland, Switzerland and Cambridge, U.K., 1999.

[2] UICN, "Protected areas of the Wo rld: a review of national systems". Volume 3: Afrotropical. Prepared by World Conservation Monitoring Centre. UICN, Gland, Switzerland and Cambridge, U.K., 1992.

[3] C. Mengue-Medou,"Les aires protégées en Afrique : Perspectives pour leur conservation", VertigO, 2002, vol.3,n°1,37-44.Available : http://vertigo.revues.org/4126

[4] L. Hannah", African people, african parks: an evaluation of development initiatives as a means of improving protected conservation in Africa", USAID, Washington, D.C., 1992.

[5] E. Hakizumwami",Protected Areas Management Effectiveness Assessment system for central Africa", WWF Netherlands, (1999).

[6] A.J.Eyebe, G.P.Dkamela, D. Endamana,"Tour d'horizon des conflits Homme-faune sauvage au Cameroun", Poverty and Conservation Learning Group N° 04, 2012.

[7] UNEP/CBD, "La Convention sur la diversité biologique : texte et annexes". Montréal, Canada.

[8] Parker, G.E., Osborn, F.V., Hoara, R.E., Niskanen, L.S. (Eds), "Human-Elephant conflict mitigation: A training course for Communities-Based Approaches in Africa. Participant's Manual". Elephant Pepper Development Trust, Livingstone, Zambia, and UICN/SSC AfESG, Nairobi, Kenya.

[9] H. Synge, S. Howe, in "Parks for biodiversity: policy guidance based on experience in ACP countries". European Commission/IUCN, Gland, 1999.

[10] MINFOF "Plan d'aménagement du Parc National de Campo Ma'an et de sa Zone Périphérique – période d'exécution 2006-2010". Ministère des forêts et de la faune, Cameroun, 97 pages, 2005.

[11] MINFOF, PN Campo Ma'an,"Plan d'aménagement du Parc National de Campo Ma'an et de sa Zone Périphérique – période d'exécution 2006-2010". Ministère des forêts et de la faune, Parc National de Campo Ma'an, Cameroun, 112 pages, 2006.

[12] UICN, "Rapport de situation des éléphants d'Afrique – une actualisation de la base de données de l'éléphant d'Afrique". 320 pages, 2002.

[13] BUCREP (Bureau Central de Recensement de la Population) : "Rapport de présentation des résulta ts définitifs". Bureau Central du Recensement de la Population, Yaoundé, Cameroun, 2005.

[14] BUCREP : "La population du Cameroun en 2010", Bureau Central du Recensement de la Population, Cameroun, 2010.

[15] A.H. Ngandam Mfondoum, "Détection et intégration des pistes animalières dans le processus de délimitation des aires protégées : exemple du parc national de Campo Ma'an – Contribution de la télédétection et des SIG", Mémoire de master professionnel en Sciences et technologies de l'espace – option Télédétection et SIG, CRASTE-lf, Rabat-Maroc, 157 pages, 2014.

[16] MINFOF, "Stratégie nationale des contrôles forestiers et fauniques au Cameroun". Ministère des forêts et de la faune, Yaoundé, Cameroun, 342 pages, 2005

[17] MINFOF, "Outils néc essaires à la mise en œuvre d'un système de suivi écologique pour les aires protégées au

Cameroun – rapport final". Ministère des forêts et de la faune, Yaoundé, Cameroun, Tome 1, 2009.
[18] MINFOF, "Stratégie 2020 du sous -secteur forêts et faune", Ministère des forêts et de la faune, Yaoundé, Cameroun, 278 pages, 2012.
[19] T.L. Saâty, " How to make a decision: The Analytic Hierarchy Process", European Journal of Operational Research, 48:9-26, 1990.
[20] T.L. Saâty," Fundamentals of the Analytic Hierarchy Process". RWS Publications, 4922 Ellsworth Avenue, Pittsburgh, PA 15413, 2000.
[21] T.L. Saâty,"Decision making with the analytic hierarchy process", Int. J. Services, Vol. 1, n°1, pp. 83-98, 2008.
[22] Esri, ArcGis 10.2 Tutorials. Available : http://resources.arcgis.com/en/help/main/10.2/index.html#//002p000000t4000000

Author Profile

Alfred Homère NGANDAM MFONDOUM just received a diploma of professional master's in remote sensing and GIS at the African Regional Center for Sciences and Technologies of Space in French Language (CRASTE-lf) in Morocco, in May 2014. Before that, he received a master and an M.Phil in physical geography at the University of Yaoundé I, respectively in 2005 and 2007. He operates now as a freelance consultant while writing a Ph.D. thesis in geography.