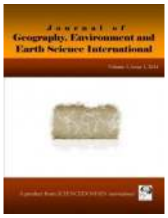

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# Participatory Spatial Multi-criteria Evaluation for Land-Use Planning and Decision Making in Mezam, Cameroon

**Ndoh Mbue Innocent[1*] and Balgah Roland Azibo[2]**

*[1]Department of Occupational Hygiene, Safety and Environment, University of Douala, P.O.Box 2071, Douala, Cameroon.*
*[2]College of Technology, University of Bamenda, P.O.Box 39, Bambili, Cameroon.*

***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

This research uses participatory spatial multi-criteria analysis for the assessment and prioritization of vulnerable ecosystems wherein, protection from anthropogenic activities could help to ensure the continued provision of ecosystem services in Mezam, Cameroon. Analytic Hierarchy Process (AHP) was used to build objective hierarchies and comparisons were made, using a scale of absolute judgments that represents how much more, one element dominates another with respect to a given attribute. Weightings were assigned to each criterion depending upon their relative importance and ratings in accordance with the relative magnitude of impact. From this, priority options for the different criteria and alternatives were calculated. Using this information and related spatial data in the decision support wizard of Idrisi GIS software, delineation of the different ecological systems was done. With an overall consistency ratio $(\mathrm{CR} \leq 0.1)$, a Pricetag criteria (0.398) was the most important criterion in the site selection process, followed by Pressure (0.299), the Response (0.218), and the State criterion (0.085). As long as experts believe that their judgments regarding

**Corresponding author: Email: dndoh2009@gmail.com;*

the importance of the criteria and their performances for the ecosystem types using each criterion are valid, the AHP priorities show that the watersheds are preferred. The resulting map can act as a tool in helping decision makers visualize choices and evaluate land-use alternatives. The results address the importance of local stakeholder participation when spatial planning and management of multifunctional cultural landscapes are realized.

*Keywords: Participatory spatial multi-criteria analysis; ecosystems; Mezam; Cameroon; analytic hierarchy process.*

## 1. INTRODUCTION

The rapid growth rates of cities and associated unsustainable human practices, combined with their huge population base, has left many cities lacking in basic infrastructure services like water supply, sanitation and sewerage, clean air, and other ecosystem system services. These changes in turn affect ecosystem's capacity to deliver important services to the human population and support human well-being, such as flood control, clean air and water provision. Against this backdrop, there is the need to devise an efficient ecosystem management system wherein decision-makers, landuse management planners and the local communities can deal with the increase in complexity, uncertainty, multi-objectivity, and subjectivity associated with this problem. Effective land-use planning includes the identification of geographical areas that are important for the support of ecosystem functions and services. Identification of these areas allows for planning uses and activities that sustain ecosystems and their services.

It is well known that local communities play a crucial role in sustainable landscape management. They possess valuable knowledge of the functions and social values attached to cultural landscapes, and this social knowledge is essential when tackling land use and land management issues for better future development. The advantages of involving them in natural resource policy-making have been well documented [1] and such participation often strives for wider community understanding and therefore sanctioning of the policies concerned. Some authors, e.g., [2], have argued that strategic spatial planning is fundamentally a ''sociospatial'' process, that must be both ''transformative'' and ''integrative'', and which by involving local people is able to ''shape and frame what a place is and what it might become'. However, as a stand-alone approach, participatory methods are lacking in rigor and in need of better structuring and analytical capabilities. This is because ecosystem management is impregnated with a number of spatial multi-criteria decision problems typically involving a set of geographically defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria.

The availability and use of geographic digital data and decision-making tools have increased the development of geographic analyses that can assist in decision making and land-use planning. Multi-criteria evaluation (MCE) analysis and GIS are two examples of tools that aid in the development of geographic data and maps for different purposes, such as conserving land for forestry or agricultural uses. Several other authors have emphasized the role of Multicriteria Decision Analysis (MCDA) as an effective tool in handling decision problems that involve a large number of different and conflicting objectives such as in multi-stakeholder evaluations [3]. MCDA was developed to help rank several alternatives from the worst to the best based on multiple, often conflicting criteria [4]. MCDA models have been used in landuse planning in regard to several objectives such as biodiversity [5], carbon sequestration [6], watershed management and land-use suitability analysis [7], and for the definition of priority areas for forest conservation [8]. However, as a stand-alone technique, MCDA has limited information on the criterion values and the geographical locations of alternatives. There is a need for broader understanding of the complex human-nature interaction in contemporary cultural landscapes especially in political decision making. Solutions for many of these management challenges lie in the actions of the people and the ways they value and use the land.

In this paper, we used participatory spatial multi-criteria analysis to develop a map that shows areas in which protection against human expansion would help to ensure the sustained provision of ecosystem services in Mezam, North western region of Cameroon. Specifically, the research aims to:

1. Use participatory spatial multi-criteria evaluation to identify priority ecosystems wherein protection from anthropogenic activities could help to ensure the continued provision of Mezam ecosystem services , and
2. Produce a map that can assist land-use planners, forest managers, and natural resources specialists, among others, in making land-use decisions around Mezam.

The approach consists in eliciting and making transparent the values and subjectivity that are applied to the more objective measurements, and understanding their implications. Perhaps MCDA's greatest strength is its ability to simultaneously consider both quantitative and qualitative criteria, as long as the latter can be represented using an ordinal or continuous scale. Uni-dimensional and top-down management approaches have been unable to capture this complexity.

## 2. MATERIALS AND METHODS

### 2.1 Description of Study Area

Mezam division is one of the seven divisions that make up the north western region of Cameroon. The capital is Bamenda. It lies between 9°58'16"N, 6°3'14"E and 10°14'16"N, 5°51'8"E. It is bounded to the North by Menchum, Boyo, to the west by Momo, to the East by Ngo-ketunjia, Bui and Donga-Mantung divisions and to the South by the West region (Fig. 1).

The department covers an area of 1745 km². As of 2001, it had a total population of 465,644 people, and is undergoing a period of rapid population growth. It is divided administratively into 5 communes: Bafut, Bali, Bamenda I, Bamenda II, Bamenda III, Santa and Tubah. The climate is temperate-like, influenced mainly by mountainous terrain and rugged topography. Average rainfall is about 2400 mm, temperature average 23°C, ranging between 15°-32°C [9]. There two main seasons: wet (March- October), and dry season (November-February). Grass covers between 60-75% of the total vegetation. Gallery forests comprising of shrubs and stunted trees typical of a savanna region dominate the area, with eucalyptus being the "bread tree". Human activities such as farming and construction are continuously exposing watersheds and wetlands. Unsustainable forestry has rendered some indigenous trees vulnerable and some extinct.

### 2.2 Methodology

This was a descriptive cross-sectional study. The participation of qualified experts and stakeholders is of paramount importance in defining and selecting regional planning objectives. Hence purposive snowball sampling [10] was used to select the participants. They consisted of men and women with varying livelihood opportunities. Based on the concept that human activities exert pressures on the environment, changing the quality and quantity of natural resources; that these changes alter the state of the environment, demanding for human responses, the pressure – state - response (PSR) framework [11,12] was employed. The PSR model provides a means for selecting and organising data and indicators in a manner useful for decision makers and the public, and ensuring that important considerations are not overlooked. The [13] four-step decision analysis phases were found plausible for this study: - (a) structure the decision problem, (b) assess possible impact of each alternative, (c) determine preference of decision – makers, and (d) evaluate and also compare decision alternative.

#### 2.2.1 Data collection

Data was collected during a participatory meeting involving all stakeholders. Two large pieces of cardboard papers (1 m x 0.4 m) and markers were used for listing and prioritizing of factors, and for participatory mapping. The following steps (Fig. 2) describe the process used.

As stated earlier, the specific objective of this analysis was to identify lands wherein protection from human activities would help to ensure the continued provision of Mezam division's ecosystem services to ensure long term ecologically integrity. From both the authors' knowledge and interviews with experts the following stakeholder groups were identified: Officers from the regional delegation of forestry and environment (local administration), people involved in Forest Research and Education, officers from municipal councils, and Conservationist Groups. The next steps are to identify the criteria that will support the stated objective and determine which criteria are more important than others in supporting that objective. Two types of criteria for MCDA analysis were used: Constraints and Factors.

Constraints here refer to criteria that exclude areas from the analysis. Since the objective of the study was to identify areas to protect from human activities (urban expansion, agriculture, hunting, deforestation…) the constraints in this case consisted of areas that were already covered by built-up land, and areas that have a formal conservation status or designation, such as nature reserves and state forests. Factors are criteria that influence the viability of the objective under consideration.

We used a group of experts (scientists and forest managers) and local people (village regents, youth leaders, and women's group representatives) to define the criteria in order to have the input of stakeholders with knowledge of forest ecosystem services and the urban effects on such services. The selected stakeholders participated in focus groups to identify and prioritize the criteria. Each focus group involved a small number of individuals in order to hold a constructive dialogue with a given stakeholder group. The sessions ranged from five participants to eight in the municipal managers meeting, with an average of seven participants per meeting. Participants decided that the following criteria (Table 1) were relevant for their site selection decision process.

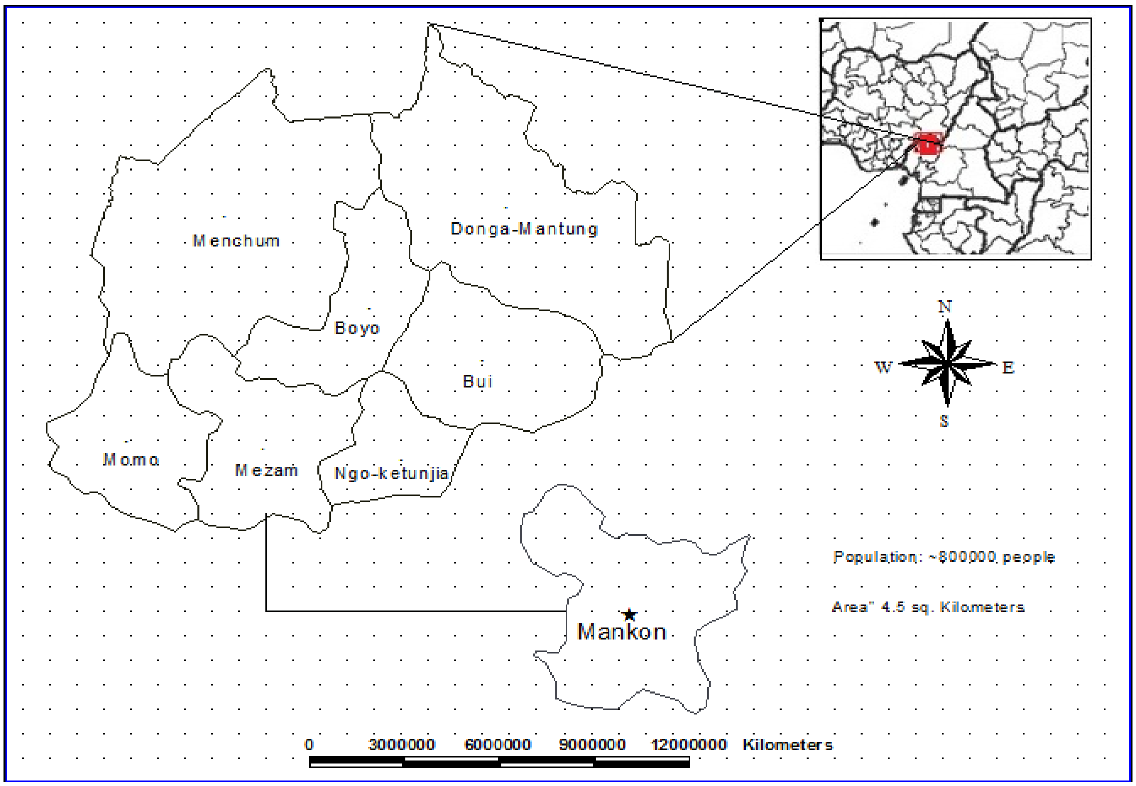


**Fig. 1. Location of study area**

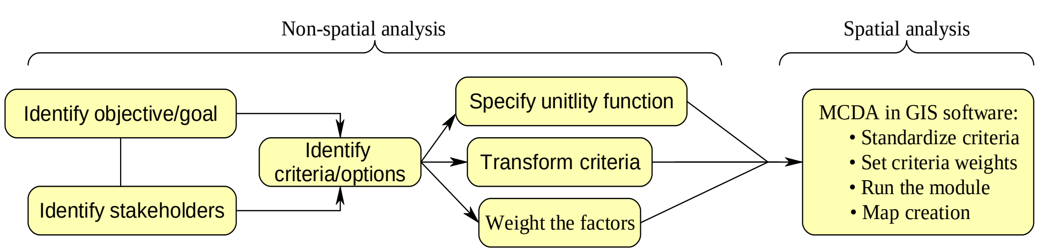


**Fig. 2. Generalized procedure for Participatory GIS based MCDA**

**Table 1. Definition and explanation of criteria, sub-criteria and alternatives**

| Criteria code | Description |
|---|---|
| Pricetag (Value)[a] | Use value (direct and Direct use value), Non-use value (Existence, Bequest and altruistic), and Option value(use in the future) |
| Pressure | Underlying factors such as population growth, consumption or poverty |
| State | Condition of the environment that results from the above pressures, e.g. the levels of air pollution, land degradation or deforestation; degree of land degradation |
| Response | Actions taken by society either individually or collectively, that are designed to ease or prevent negative environmental impacts, to correct existing damage, or to conserve natural resources e.g., environmental or research expenditure, provision of environmental information |

[a] *Ecosystem valuation (Costanza et al 1997) can be a difficult and controversial task, and economists have often been criticized for trying to put "pricetag" on nature. However, agencies in charge of protecting and managing natural resources must often make difficult spending decisions that involve tradeoffs in allocating resources*

The list of factors considered included watersheds, wetlands and Forests ecosystems. The complex problem in this study, that is, the selection sites problem for ecosystem and protection from anthropogenic activities was divided into a number of simpler problems in the form of a decision hierarchy. At the first level is the overall goal of the project. At the second level, the four criteria each contribute to the achievement of the overall goal. Finally, at the third level, each decision alternative: Wetlands, Watershed and Forest reserves contribute to each criterion in a unique way (Fig. 3).

#### 2.2.2 GIS data

GIS layer was created for each criterion, whether constraint or factor, identified in the previous steps. Factors were measured and presented as categorical, such as type of land cover. Constraints were Boolean layers (a GIS layer with only two categories, usually having values of ones and zeros), where areas to be excluded from the analysis must have a value of zero, and those to be included must have a value of one.

### 2.3 Data Analysis

A Multicriteria MCDA model, the Analytical Hierarchy Process, AHP: [14], was employed. AHP is a decision support approach designed to aid in the solution of complex multiple criteria problems in a number of application domains [15]. Pairwise comparisons were conducted among the criteria to determine the relative importance of each criterion among others. A comparison matrix among the criteria was developed, which was subsequently used to compute an eigenvector, which ultimately represented the ranking of the criteria. For the calculation of ratings associated with each criterion, a pair wise comparison of alternatives on the basis of each criterion was conducted. The following decision making steps were employed:

(1) Given $i$ = 1, …, m objectives, their respective weights $w_i$, were determined;
(2) For each objective $i$, the j = 1, …, n alternatives were compared and their weights, $w_{ij}$ , determined with respect to objective 1; and
(3) Priorities (the final/global alternative), $w_j$, are determined where $w_j$ is a normalized weight, so that $\Sigma w_j = 1$.

The alternatives were then ordered by the $W_j$, the most preferred alternative having the largest $W_j$. The relative ratio scale derived from a pairwise comparison reciprocal matrix of judgments is derived by solving:

$$\sum_{j=1}^{n} a_{ij}\, w_j = \lambda_{\max} w_i \ ; \ \sum_{i=1}^{n} w_i = 1 \qquad (1)$$

with $a_{ji}=1/a_{ij}$ or $a_{ij}\, a_{ji}=1$ (the reciprocal property), $a_{ij} > 0$ (thus $A$ is known as a positive matrix) whose solution, known as the principal right eigenvector, is normalized as in equation (2). A relative ratio scale does not need a unit of measurement.

When $a_{ij}\, a_{jk} = a_{ik}$, the matrix $A=(a_{ij})$ is said to be consistent and its principal eigenvalue is equal to $n$. Otherwise, it is simply reciprocal. The general eigenvalue formulation is obtained by perturbation of the following consistent formulation:

$$Aw = \begin{matrix} & \begin{matrix} A_1 & \cdots & A_n \end{matrix} \\ \begin{matrix} A_1 \\ \vdots \\ A_n \end{matrix} & \begin{bmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_n} \\ \vdots & & \vdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \end{matrix} \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = nw. \quad (2)$$

where $A$ has been multiplied on the right by the transpose of the vector of weights $w = (w_{1,\ldots,}w_n)$. The result of this multiplication is $nw$. Thus, to recover the scale from the matrix of ratios, one must solve the problem:

$$Aw = nw \text{ or } (A - nI)w = 0. \quad (3)$$

This is system of homogeneous linear equations has a nontrivial solution if and only if

$|(A - nI)| = 0$ (i.e., $n$ is an eigenvalue of $A$). (4)

Now $A$ has unit rank since every row is a constant multiple of the first row. Thus all its eigenvalues except one are zero. The sum of the eigenvalues of a matrix is equal to its trace, that is, the sum of its diagonal elements. In this case the trace of $A$ is equal to $n$. Thus $n$ is an eigenvalue of $A$, and one has a nontrivial solution. The solution consists of positive entries and is unique to within a multiplicative constant.

Using the comparison matrix among the alternatives and the information on the ranking of the criteria, AHP generated an overall ranking of the solutions. The alternative with the highest eigenvector value was considered to be the first choice. In establishing the priorities for the four criteria, AHP required land administrators to state how important each criterion is relative to each other criterion when the criteria are compared two at a time (pairwise).

In a focused group workshop, the facilitator explained the objective of the analysis to the participants. The first step consisted in producing a map that would identify lands wherein protection from anthropogenic activities would help to ensure the continuous provision of ecosystem services. In a second step, the participants were asked to collectively make a list of the factors to be incorporated into a GIS analysis to produce the map. The facilitator:

- wrote all the factors on a large sheet of paper for the participants to review and add to if necessary,
- drew a matrix on the large sheet of cardboard paper with all the factors listed on top (columns) and the same factors listed on the left side (rows) of that matrix. Such pair-wise matrices provide a means of prioritizing lists of elements when a simple consensus is difficult to attain. The purpose of the matrix in this project was to assist in the factors' prioritization process, and
- From (1) and (2), a participatory pairwise comparison is developed.

The facilitator, for example, would ask, "*With respect to Pricetag how do you compare the effects of Pressure vs. State vs Response*?" For each pair-wise comparison, time was given for the participants to discuss and decide each factor's importance. To decide how much more important a factor was when compared to others, we adopted the AHP scale of 1 to 9 (Table 2).

**Table 2. The AHP pair-wise comparison scale**

| Numerical rating | Verbal judgment |
|---|---|
| 1 | Equally important preferred or preferred |
| 3 | Moderately more important or preferred |
| 5 | Strongly more important or preferred |
| 7 | Very strongly more important or preferred |
| 9 | Extremely more important or preferred |
| 2, 4, 6 and 8 | Intermediate values between two adjacent judgements |

*Source: Adapted from [14]*

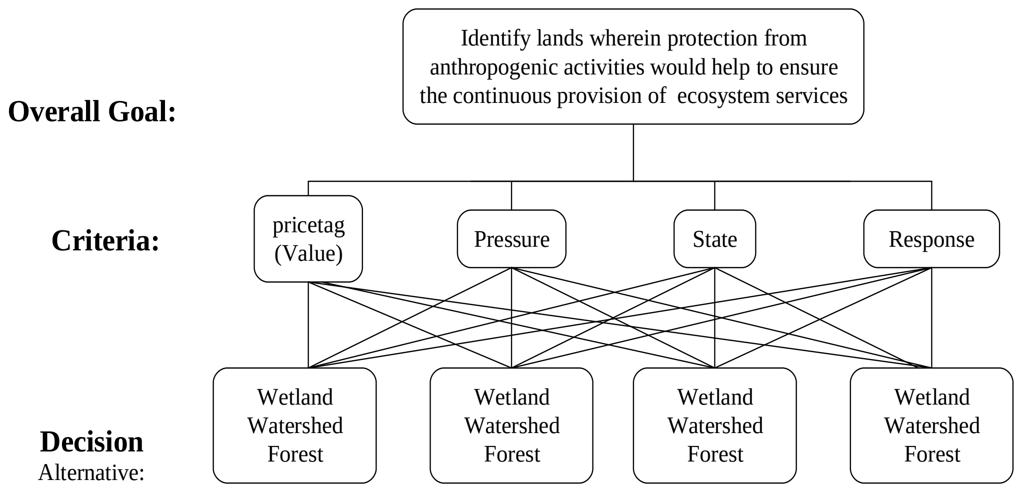


**Fig. 3. Development of hierarchy for assessing lands for protection from anthropogenic activities**

A consistency ratio was used to measure how consistent the judgements have been relative to large samples of purely random judgements. A comparison matrix A (equation 3) is said to be consistent if,

$$a_{ij} = a_{ik}\, a_{ij};\ \forall i, j, k \quad (6)$$

A consistency ratio for the pairwise comparison is given by:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}},\ \mathrm{RI} \neq 0 \quad (7)$$

Where,

$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1}$ is the consistency index; and

RI = the consistency index of a randomly generated pairwise comparison matrix. The value of RI depends on the number of items being compared [14].

#### 2.3.1 Decision rule

If CR is such that:

$$\begin{cases} \mathrm{CR} \leq 0.1;\ \text{consistency in pairwise comparison} \\ \mathrm{CR} > 0.1;\ \textit{inconsistency in pairwise comparison} \end{cases}$$

The overall score for alternative j; sj, is given by:

$$S_j = \sum_i w_i . r_{ij} \quad (8)$$

Where,

$w_i$ = The weight for criterion I, and
$r_{ij}$ = The rating for criterion *i* and decision alternative *j*

### 2.4 Mapping the Criteria

A three-step process was employed in the mapping process: In a first step, a GIS layer was generated for each criterion (constrain or factor) earlier identified, Factors variables were either expressed as nominal or ordinal level variables, while constraints were expressed as Boolean layers:

$$f(x) = \begin{cases} 0, & \text{areas to be excluded from the analysis} \\ 1, & \text{areas to be included from the analysis} \end{cases} \quad (9)$$

Shapefiles were also generated representing the two constraints for the MCDA analysis: one of the areas with urban land cover in the year 2008 (year with the most recent free Landsat ETM image for the area) and another one of the two areas already having a kind of conservation status (Bali-Ngemba forest and Bafut-Ngemba forest reserve). GIS layers were also created for the whole area covered by the six municipalities that make up the division (Mezam) within their boundaries.

In a second step, GIS vector and raster layers were created for all three factors identified by stakeholders: watershed, Wetland Cover, and Forest reserve. Since the software used is raster-based GIS, all vector layers were converted to raster format.

In a third stage, the MCDA was applied into a GIS:

a) Using the decision support wizard of Idrisi GIS software [16], the objective of the analysis was specified and the file names for the GIS layers representing the constraints and factors indicated. Each factor was standardized by the program to a common measurement scale of 0 to 255, where a value of 0 indicates that the factor does not suit the analysis's objective and a value of 255 indicates that it does perfectly
b) Using the option "user-defined weight" in the decision wizard, the various criteria were identified and the already calculated weights assigned.
c) After all the parameters of steps (1) and (2) are entered in the wizard, the program runs the MCE module to create the final map.

## 3. RESULTS AND DISCUSSION

Watersheds, wetlands and forests are key ecological systems a region can never afford to lose because of the numerous ecosystem services they jointly provide. Their benefits and uses range from both tangible and intangible psychological and aesthetic benefits to amelioration of climate and mitigation of air pollution. The importance of these services to human livelihoods and existence cannot be over emphasized though overlooked by decision makers.

### 3.1 Weights Calculation: Pairwise Comparison Matrix

The complete pairwise comparison matrix for the site selection criteria is shown (Table 3).

Following this, AHP synthesization procedure provides the priority for each criterion in terms of its contribution to the overall goal of selecting the best site for protection (Fig. 4).

Pricetag with a priority of 0.398 is the most important criterion in the site selection process. Pressure with a priority of 0.299 ranks second in importance and is closely followed by Response with a priority of 0.218. State is the least important criterion with a priority of 0.085.

**Table 3. Pairwise comparison matrix for the site selection criteria**

| | Pricetag | Status | Response | Pressure |
|---|---|---|---|---|
| Pricetag | 1 | 3 | 2 | 2 |
| Status | 1/3 | 1 | 1/4 | ¼ |
| Response | ½ | 4 | 1 | ½ |
| Pressure | 1/2 | 4 | 2 | 1 |


**Fig. 4. Priority of the different criteria**

**Table 4. Pairwise comparison showing preferences for the ecosystems using each criterion**

| Pricetag | Wetland | Watershed | Forest |
|---|---|---|---|
| Wetland | 1 | 1/3 | ¼ |
| Watershed | 3 | 1 | 1/3 |
| Forest | 4 | 2 | 1 |

| Pressure | Wetland | Watershed | Forest |
|---|---|---|---|
| Wetland | 1 | ¼ | 1/6 |
| Watershed | 4 | 1 | 1/3 |
| Forest | 6 | 3 | 1 |

| State | Wetland | Watershed | Forest |
|---|---|---|---|
| Wetland | 1 | 2 | 8 |
| Watershed | ½ | 1 | 6 |
| Forest | 1/8 | 1/6 | 1 |

| Response | Wetland | Watershed | Forest |
|---|---|---|---|
| Wetland | 1 | 1/3 | 4 |
| Watershed | 3 | 1 | 7 |
| Forest | 1/4 | 1/7 | 1 |

### 3.2 Consistency

The step by step procedure for estimating the consistency ratio for the criteria of the car selection problem follows:

- In the first step, a linear combination of the priorities with the column vectors of the pairwise comparison matrix is established to obtain the weighted sum vector:

$$0.398\begin{bmatrix}1\\ \frac{1}{3}\\ \frac{1}{2}\\ \frac{1}{2}\end{bmatrix} + 0.085\begin{bmatrix}1\\ \frac{1}{3}\\ \frac{1}{2}\\ \frac{1}{2}\end{bmatrix} + 0.218\begin{bmatrix}1\\ \frac{1}{3}\\ \frac{1}{2}\\ \frac{1}{2}\end{bmatrix} + 0.299\begin{bmatrix}1\\ \frac{1}{3}\\ \frac{1}{2}\\ \frac{1}{2}\end{bmatrix} = \begin{bmatrix}1.687\\ 0.347\\ 0.907\\ 1.274\end{bmatrix}$$

- In a second step, the elements of the weighted sum vector were divided by the corresponding priority for each criterion to obtain the variance explained by each of the criterion:

$$\text{Pricatag (Value)} = \frac{1.67}{0.398} = 4.236$$

$$\text{Status} = \frac{0.347}{0.3980.085} = 4.077$$

$$\text{Response} = \frac{0.907}{0.218} = 4.163$$

$$\text{Pressure} = \frac{1.274}{0.299} = 4.264$$

- In a third step the average variance, explained by the four criteria is established:

$$\lambda_{max} = \frac{(4.236 + 4.077 + 4.163 + 4.264}{4} = 4.185$$

- In a final step, the consistency ratio was computed:

- consistency index:

$$\text{CI} = \frac{\lambda_{\text{max}} - \text{n}}{\text{n} - 1} = \frac{4.185 - 4}{4 - 1} = 0.0616$$

- Hence, consistency ratio (n = 4):

$$\text{CR} = \frac{0.0616}{0.90} = 0.068$$

A significant CR (CR < 0.10) as such shows that the degree of consistency in the pairwise comparisons is acceptable.

### 3.3 Other Pairwise Comparison for Ecosystem Selection Problem

Continuing with the AHP analysis of the land selection problem, we need to use the pair wise comparison procedure to determine the priorities for the three land uses using each of the criteria: Pricetag, Pressure, State and Response. Determining these priorities requires experts (land Administrators) to express pairwise comparison preference for the landuses using each criterion one at a time. For example, using the price criterion, experts took the following pairwise comparisons:

the Pricetag compared to the Wetlands
the Pricetag compared to the Watersheds
the Wetlands compared to the Forest

In each comparison, experts must select the most preferred landuse and then express a judgement of how much more preferred the selected land is:

- In terms of value (Pricetag), the Watersheds are moderately to strongly more preferred than the Wetlands.
- In terms of Pressure, Forest ecosystems are moderately more preferred than the Watershed,
- In terms of State, Wetlands ecosystems are very strongly to extremely more preferred than the Forest, and
- In terms of Response, Watersheds ecosystems are moderately more preferred the Wetland.

Following this, a synthesization was conducted for each pairwise comparison matrix in order to determine the priority of each landuse type (Table 5) using each criterion.

Forest covers are the preferred alternative based on Pricetag (0.557), and on pressure (0.639); the wetland is the preferred alternative based on state (0.593), and the watersheds are the preferred alternative based on response (0.656). At this point, no site is clear overall best and so we proceed to an overall priority ranking.

### 3.4 Overall Priority Ranking

The procedure consists in weighting each site's priority with the corresponding criterion priority:

For the Wetlands:

$$0.398*0.123 + 0.085*0.087 + 0.218*0.593 + 0.299*0.265 = 0.265$$

For Watersheds:

$$0.398*0.320 + 0.085*0.274 + 0.218*0.341 + 0.299*0.656 = 0.421$$

For Forests:

$$0.398*0.557 + 0.085*0.639 + 0.218*0.065 + 0.299*0.080 = 0.314$$

Ranking these priorities we have the AHP ranking of the decision alternatives (Fig. 3).

These results provide a basis for experts to make a decision regarding the prioritization of ecosystem types. As long as experts believe that their judgments regarding the importance of the criteria and their performances for the ecosystem types using each criterion are valid, the AHP priorities show that the watersheds are preferred. In addition to the recommendation of the watersheds as priority ecosystems for protection, the AHP analysis helped experts gain a better understanding of the trade-offs in the decision-making process and a clearer understanding of why the watersheds are the AHP recommended alternative.

#### 3.4.1 Watershed ecosystems

A watershed is a drainage basin in which all land and water areas drain or flow toward a central collector such as a river, stream, lake, or estuary. These water bodies supply our drinking water, water for agriculture and manufacturing, offer opportunities for recreation and provide habitat to numerous plants and animals. Water systems are life supporting, and a healthy water system is essential for a robust economy and a good quality of life. This is no longer the case in Mezam division. The main stream flowing through the capital, Bamenda is impregnated with all sorts of particles ranging from faeces to iron sheets. At some points, especially during the dry seasons, eutrophication is common. The story is same with other water bodies. The reason is simple, watersheds supplying these water bodies are being impaired by a combination of human activities including agriculture and human settlement all leading to the pollution of waterways.

The leading causes of pollution of these waterways are sediments, bacteria (such as *E. coli*) and excess nutrients (such as nitrogen and phosphorus). Erosion, runoff of animal waste and overflowing of combined sewers are just a few ways these pollutants reach our waters. As a result of pollution, water bodies do not support one or more of their intended uses: not suitable to drink, swim in or to consume the fish caught there. Should these watersheds not be protected, the current water crises plaguing the entire region will aggravate in the coming decades, leaving the future generation with a life hard to live. Protecting these watersheds means protecting the lakes, rivers, or streams by managing the entire watershed that drain into them.

**Table 5. Pairwise comparison matrix for prioritization of landuse type**

| | *Criterion* | | | |
|---|---|---|---|---|
| | **Pricetag** | **Pressure** | **State** | **Response** |
| Wetland | 0.123 | 0.087 | 0.593 | 0.265 |
| Watershed | 0.320 | 0.274 | 0.341 | 0.656 |
| Forest | 0.557 | 0.639 | 0.065 | 0.080 |


**Fig. 5. Overall priority of different places for ecosystem site ranking**

#### 3.4.2 Forest ecosystems

With 0.314, the forest ecosystems ranked second in priority. A complementary and even more disturbing fact is that every year many hundreds of hectares of precious forest continue to be lost to (or seriously degraded by) alternative land uses. The value of forest services (such as carbon sequestration, biodiversity conservation and soil and water protection) could reach many thousands of dollars per hectare. Generally, forests influence rainfall interception, evapotranspiration, water infiltration, and groundwater recharge. They contribute to regulating base flows during dry seasons and peak flows during rainfall events, both of which are services of utmost importance for the adaptation of people to climate variability and change. Unfortunately, forest management practices, though on paper, are totally inapplicable in the entire region and markets to remunerate such services, are either non-functional or remain in their infancy. In the face of economic and social pressure to convert forest land to other purposes, it is essential that all the values of forests are recognized and compensated to promote their retention and sustainable management.

#### 3.4.3 Wetlands

With 0.265, the wetland ecosystems ranked third in priority. Wetlands are vital for human survival. They are among the world's most productive environments; cradles of biological diversity that provide the water and productivity upon which countless species of plants. The wetlands also help to reduce the impacts from storm damage and flooding, maintain good water quality in streams and rivers, recharge groundwater, store carbon, help stabilise climatic conditions and control pests. A variety of wetland plant communities and soil types have developed in the Bamenda highlands because of regional differences in hydrologic regimes, climate, soil-forming processes, and geologic settings. Consequently, many terms, such as "marsh," "river bottom," "lowland," and others are applied to different types of wetlands across the region. These are found mostly in the raffia bushes which dominate the lowland vegetation. These raffia palms have high water holding capacities, evident from their continuous wetness even during the worst droughts. Even wetlands that appear dry at times for significant parts of the year such as vernal pools often provide critical habitat for wildlife adapted to breeding exclusively in these areas.

### 3.5 Maps resulting from GIS analysis

As indicated in the methodology section, before the AHP analysis, the three factors used in this study were standardized to the byte level range of 0–255. These factors were thereby standardized to a continuous scale of suitability from 0 (the least suitable) to 255 (the most suitable). Rescaling the factors to a standard continuous scale allows us to compare and combine them. The 0–255 range provides the maximum differentiation possible with the byte data type. In other words, 0 denotes the least effective areas in forest ecosystem system protection, whereas 255 indicate the most effective areas in forest (Fig. 6).

For non-forest reserves, as the values increase (darker greens in the map), the more critical it becomes to protect the areas from human activities and plan for uses that ensure the provision of the forest's ecosystem services. Hence, a zonal map (Fig. 7) based on place-specific values, in which the zones indicate the type of management that should be applied to the ecosystem was defined.

It should be noted, however, that the map cannot be used as a stand-alone tool for decision making. This mapping process is rather just one among many tools available to aid in the decision-making process regarding land use. It can be inferred that the areas of the scenario at extremely low risk would be quite small because it is a case that only the areas with high density of all the ecosystem services can be regarded as priority areas. Again, the spatial correlation between ecosystem services and priority areas also influenced the efficiency. As some parcels with higher density of ecosystem services improvement were not laid within priority areas, the conservation efficiency were low even in the areas with a high threshold.

The map resulting from the multi-criteria evaluation (MCDA) and GIS analyses provides geographic information that can be used by decision makers, who must make many, and sometimes conflicting, land-use decisions. The resulting map can act as a tool in helping decision makers visualize choices and evaluate land-use alternatives. An authority each of the forestry sector, the ministry of the environment and the selected municipalities were each asked to analyze land-cover maps, maps that show critical habitats for endangered species, and the map produced in this study, among others to evaluate potential construction sites for potential projects in the division.

The use of maps during the interviews supported the process of identifying values. Stakeholders used the maps for marking areas, FGDs with stakeholders were used to identify and rank place-specific values, in contrast to the questionnaires by authors like [17] and [18]. This allowed a dialogue where the analyst could answer questions from and explain unclear points directly to the respondents, e.g., regarding the different management classes, so that uncertainties in the data due to misunderstandings were decreased. With a few exceptions, the approach seemed to work well,

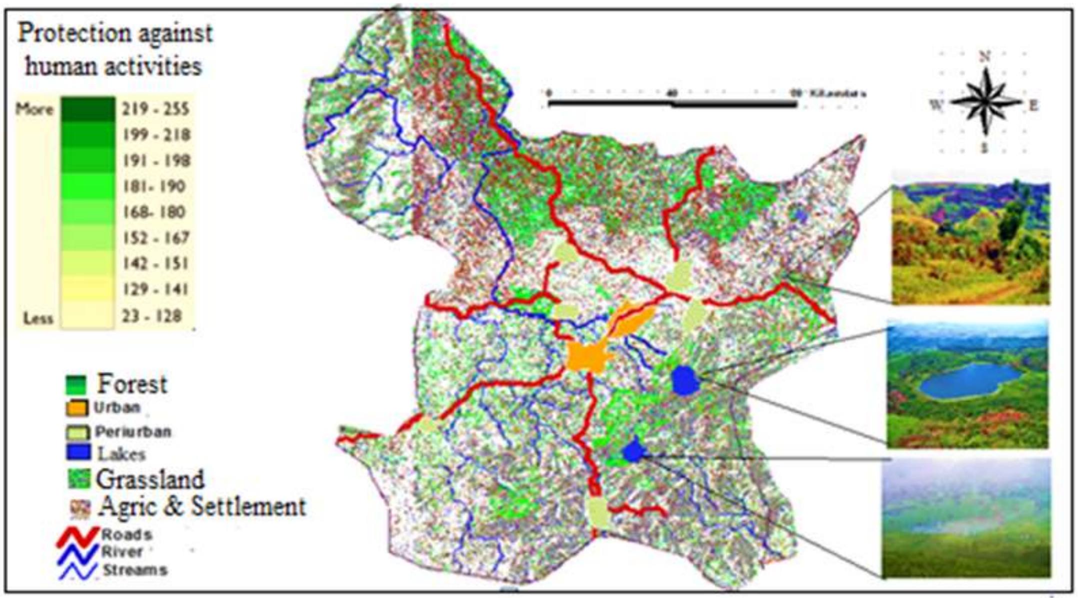


**Fig. 6. Output map from the multi-criteria evaluation and GIS analysis around Mezam**

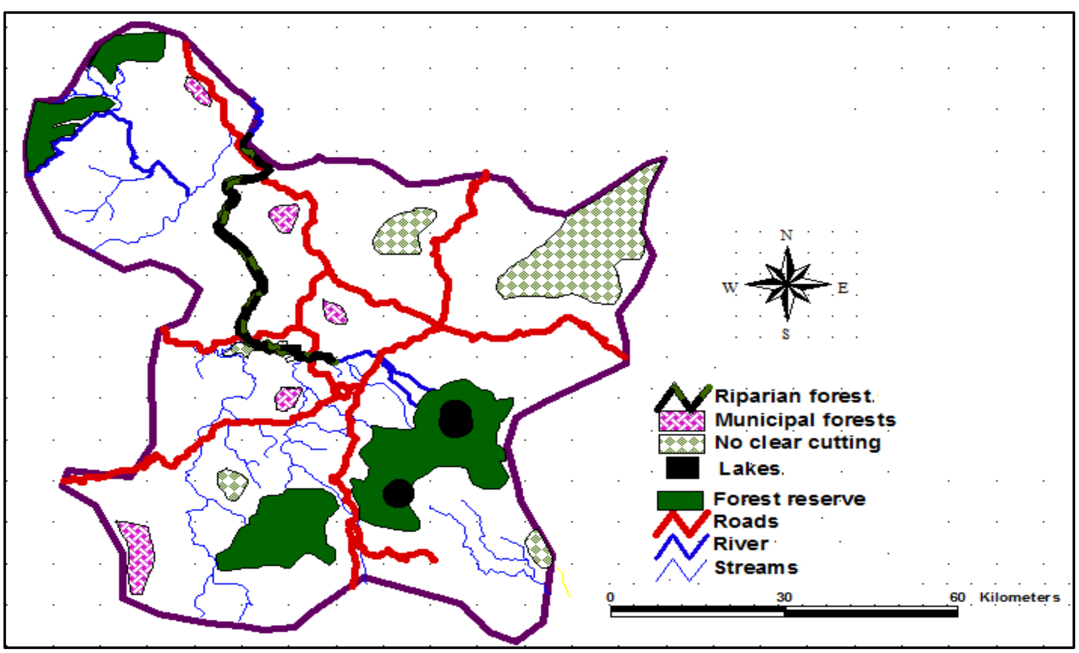


**Fig. 7. Proposed zonal planning map for Mezam based on place-specific values**

only a few stakeholders seemed unsure because they were not accustomed to using maps or because the scale or general layout of the maps was a novelty to them.

## 4. CONCLUSIONS AND RECOMMENDATIONS

Participatory spatial multi-criteria methodology allowed us to identify the priorities of stakeholders from different population sectors and to design some potential restoration sites. At the end, a tangible result, the map of priority areas, represents the most consensual sites to implement a sustainability restoration plan at the regional scale based on participants' judgment. A number of geographic and environmental factors were identified for use in the generation of the map. The value of the ecological system (Pricetag), pressure, state and response data of the study area, were important factors for identifying areas in need of protection against human expansion, and were consequently used to generate the map. The resulting map can be used as a tool for aiding in the decision-making process regarding landuse planning and management around Mezam. We also found that some stakeholders think in terms of specific areas when they articulate their criteria and preferences. Our approach therefore seem to improve the possibilities of capturing stakeholder values more fully. As long as land cover information is available, this method can be easily adapted to different regions for the participatory planning and restoration of degraded ecosystems. Nonetheless there is still need for developing and testing other approaches for assisting stakeholders in expressing and communicating place-specific values and formal approaches for incorporating these place-specific values in the planning process. We hope that the approach presented here will find its way into the ecosystem manager's tool box for spatial participatory environmental planning. There is, however, still a need for developing and testing both approaches for assisting stakeholders in expressing and communicating place-specific values and formal approaches for incorporating these place-specific values in the planning process.

The following recommendations focus on ways that the division could improve upon current practices, and thus strengthen the role that watershed management plays in protecting the long-term security of drinking water supplies:

- The protection of drinking water sources should be recognized as a permanent and integral part of a long-term, secure water supply strategy. Source protection represents the first layer in a multiple defense system for ensuring that clean water is available to all water users. Source protection is especially vital to water users, such as rural residents and businesses, whose geographic location and low water usage afford them few alternative drinking water supply options and may limit the economic viability of employing end of-pipe treatment measures.
- There is a need for a divisional integrated water policy that recognizes the principles of watershed management and deals with all aspects of water. The division should expand its interests in watershed management beyond flood and erosion control operations to achieve maintenance and enhancement of ground and surface water (both quality and quantity) for all users. Watershed management is based upon an understanding of the watershed, its water cycle and its interrelationship with human activities. It includes identification, protection and enhancement of significant natural features including, headwaters, groundwater recharge and discharge areas, wetlands, vegetated stream buffers and forest areas, while considering historical and current human activities impacting the system; promotes research into water issues and development of decision support tools to ensure the best science, technology and management practices are shared and available for local application; and supports an adequate monitoring program to measure change and adapt policies and programs accordingly (i.e., adaptive environmental management). A commitment must be made to the long-term support of state-of-the-art monitoring networks.

Further research and practical applications could point to the implementation of MCDA techniques for the management of adaptive policies for regional and local scale restoration.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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