The Classification of the Environmental Indicators using ELECTRE TRI Method for Loukkos Basin in Morocco

Layla Aziz, Samira Achki, and Ridouane Chalh
Laboratory LAMAI, University Cadi Ayyad,
Laboratory GIESI, University Cadi Ayyad,
Laboratory AMIPS, University Mohammed V
E-mail: layla.az1@gmail.com

Abstract. Multi-Criteria Analysis (MCA) has found many applications in both technical and research sectors. MCA is a way to break the problem into more practicable elements, to permit data and decisions to be judgements to support the elements, and make the right decision. The aim of this paper is to analyze, compare, and make decisions of various current, and future scenarios of different quantifiable indicators for different considerations and various socio-economic aspects. Furthermore, this analysis is used to improve or at least to preserve the environment and natural resources in the basin. In this study an application by a real data set is made, these data are evaluated and extracted from classified satellite images of Loukkos basin, the classification of this satellite images regroups several classes of the data set such as agglomeration, dams, watercourses, croplands, bare soils and forests...etc. In reality, these data come from different sources like watershed information system (drinking water supply, irrigation system), transportation infrastructures (roads, dams), natural resources (Water, soils, and vegetation), human activities (agriculture, urbanization, and industry) and different socio-economic factors (demography). The main objective of this work is sorting the environmental indicators using the ELECTRE TRI tool, where ten alternatives are considered. We focus the classification of the real data set into the altitude, and the combined surface area factors. The obtained results prove that the classification is stable and the multi-criteria approach ELECTRE-TRI is suitable to a better sorting of the environmental indicators for the Loukkos Basin located in Morocco.

1. Introduction
This work refers to our previous papers entitled "Hypsometrical Technique Automated as a Decision Support System, Assessment of Environmental Indicators in Loukkos Basin in Morocco" [1], and "Big Data Open Platform for Water Resources Management” [2], where the assessment and evaluation of environmental indicators used for supporting and managing water resources and help in decision making. This work attempts to overcome some functionalities, it provides an environment that permits acquisition of data from different sources, integration of databases, using GIS technology. Also, it includes decision tools and models as well as multi-criteria analysis and hypsometrical approach; furthermore, it permits to use hydraulic and hydrological models, high-performance computing (HPC), grid computing and simulation models. Technically a special effort has been granted to multi-criteria analysis. As mentioned above the aim of this paper is to estimate parameters of environmental indicators cover/use
surface in the Loukkos basin, using an optimization method represented by ELECTRE TRI method. In regards to our study case, we have used data set up to 4.5 million lines of environmental indicators analyzed and extracted from the satellite image of the Loukkos basin. The data includes various studied parameters such as pixel id, position X, position Y, altitude (position Z), combined surface area. In our case study, we limit the parameter to study, using multi-criteria analysis, in two variables which are the altitude and the combined surface area to apply the ELECTRE TRI method (Figure 1). Data sciences in domain of environmental 

![Figure 1. The proposed method](image)

particularly water resources discipline, very importing and interesting employment is to analyze, extract, classifications, and visualize knowledge from a big rule data sets. The different aspects of environmental, economic, and social are amongst the difficulties that influence the level of basin sustainability. The development of these aspects’ growth disadvantage of natural resources in the basin and use limitations on environmental indicators as though: vegetation, soils, watershed, croplands, and dams. To expedite the managing of these different natural resources it needs to progress the implementation of novel scientific and technological solutions. Recently there are many works and various scientific researches proposed many strategies and approaches in this area to reach the objective. Amongst these strategies: the creation of efficient decision to enhance the socio-economic level and improve supportable progress using hypsometrical strategies[3], the objective of this approach as a decision support system, assimilating environmental indicators, improvement of distribution semi-arid zones covered by vegetation and soil[4]. The authors[5] create novel opportunities for data concentrated science in the multi-disciplinary agro-environmental domain. A theoretical framework is offered to structure and analyses data-intensive cases and are practical to three case studies, collected covering a broad range of technologies, and features related to Big Data usage. In [6], [7] study the method for analyzing big data of the water supply and sanitation systems. Based on the assessment of scientific publications and their analysis, a model for analyzing large data were projected. It includes several parameters such as information sources, data collection, and storage platforms and suggests additional parameters for the programming model. The authors in [8] useful the latent Dirichlet allocation (LDA) method, which is a propagative probabilistic topic model that classifies topics based on the frequency of words from a collection of documents, the LDA method is usually used for unsupervised document classification when correct to a set of documents, the topics are construed as themes in the collection. In this paper, we proposed a method to classify the environmental indicators using the ELECTRE TRI method. The parameters to be explained in our real data set are represented by Altitude, and one or
more parameters represented by the combined surface area. The structure of this paper is organized as follows: we start with the introduction and related work section, which gives a brief literature review. The second following section of this paper concerns methodology and materials it provides an overview of the theoretical Background of Applied modeling technique represented by the ELECTRE TRI method, an overview of the study area. The third section presents results and discussion. The last section concludes this work and gives perspectives.

2. MCA

MCA has found great attention from the research community. It is widely exploited, for resolving complex problems in several fields, including economics, mathematics, and engineering [9]. Roy [10] categorizes the decision problems in three main kinds: choice, sorting, and ranking (Figure 2). Our purpose is sorting the environmental indicators for Loukous basin in Morocco. Consequently, our problem belongs to the sorting category.

![Figure 2. Types of the decision problems](image)

2.1. The ELECTRE TRI method

ELECTRE TRI is a multi-criteria approach, which has been proposed to resolve the problems based on the third category. Its main objective is affecting the evaluated alternatives to pre-defined categories, where each class has to be limited by a lower and upper profile. Figure 3 describes the categories and the profiles for a sorting problem. The main aim of this work is sorting the environmental indicators using the ELECTRE TRI approach.

![Figure 3. Categories](image)

Let $A=\{a_1, a_2, a_3, \ldots, a_m\}$ denotes the set of the alternatives, where each alternative has to be sorted among the categories denoted as $C=\{C_1, C_2, C_3, \ldots, C_h\}$. Each category has a lower and upper limits that represent the set of profiles denoted as $B=b_1, b_2, b_3, \ldots, b_h$. The process of classification is mainly composed of two steps [11]:
Step1: Determining an outranking relation $S$ by the validation of the assertion $aSb$, which means that “the $a$ is at least as good as $b$”, then construct the degree of credibility $\sigma(a, b)$. $aSb$ is considered as a valid value only if its value is higher than $\lambda$ (a cutting value that belongs to $[0.5, 1]$). This step consists of computing the partial concordance indices $C_j(a, b)$ using the following equation:

$$C_j(a, b) = \begin{cases} 
0 & \text{if } g_j(b) - g_j(a) \geq p_j(b) \\
1 & \text{if } g_j(b) - g_j(a) \leq q_j(b) \\
\frac{p_j(b)+g_j(a)-g_j(b)}{p_j(b)-q_j(b)} & \text{otherwise}
\end{cases} \quad (1)$$

Calculation of the concordance index $C(a, b)$:

$$C(a, b) = \frac{\sum_{j \in F} C_j(a, b)}{\prod_{j \in \bar{F}} C_j(a, b)} \quad (2)$$

Calculation of the discordance indices $d_j(a, b)$:

$$d_j(a, b) = \begin{cases} 
0 & \text{if } g_j(b) - g_j(a) \leq p_j(b) \\
1 & \text{if } g_j(b) - g_j(a) > q_j(b) \\
\frac{p_j(b)+g_j(a)-g_j(b)}{v_j(b)-p_j(b)} & \text{otherwise}
\end{cases} \quad (3)$$

Calculation of the credibility index $\sigma(a, b)$ [12]:

$$\sigma(a, b) = C(a, b) \prod_{j \in F} \frac{1 - d_j(a, b)}{1 - C_j(a, b)} \quad (4)$$

where:
- $K_j$ represents the weights of criteria $j$.
- $C_j(a, b)$ represents the partial concordance index of criteria $j$.
- $F := \{ j \in F : d_j(a, b) > C(a, b) \}$

The outranking relation is determined based on the values of the index of credibility $\sigma(a, b)$ and $\lambda$-cut with respect to the following rules:

- $\sigma(a, b) \geq \lambda$ and $\sigma(b, a) \geq \lambda \Rightarrow aSbh$ and $\sigma(b, a) \geq \lambda \Rightarrow aSb_h$ and $bhSa \rightarrow aIb_h$.
- $\sigma(a, b) < \lambda$ and $\sigma(b, a) < \lambda \Rightarrow adoesnotoutrankbh$ and $bh$ doas not outrank $a$.

The preference between the action $a$ and the profile $b_h$ is defined by the values of the credibility index and $\lambda$. The alternatives are compared taking into account the thresholds determining the boundaries between $h$ categories. We distinguish between three cases: $aIb_h$ that reflects the indifferent comparison, $aR$ means that $a$ and $b_h$ are incomparable, and $aoutranksb_h$ which reflects the outranking case.
Table 1. The weights of criteria

| Criterion   | Weight |
|-------------|--------|
| C1 (area)   | 0.7    |
| C2 (altitude)| 0.3    |

Table 2. The decision matrix

|    | C1   | C2   |
|----|------|------|
| A1 | 163.149 | 916  |
| A2 | 163.158 | 918  |
| A3 | 163.227 | 932  |
| A4 | 163.173 | 921  |
| A5 | 153.577 | 545  |
| A6 | 154.263 | 555  |
| A7 | 159.555 | 670  |
| A8 | 163.153 | 917  |
| A9 | 163.182 | 923  |
| A10| 157.98  | 627  |

Step 2: Assignment Procedures
We distinguish between two assignment procedures: pessimistic and optimistic. The first type consists of comparing the alternative a to the profiles $b_i$, for $i$ in $[1,....,h]$, then assign the alternative a to category $C_h(a \rightarrow c_h)$.

The second type is based on comparing the alternative a to the profiles $b_i$, for $i$ in $[h, h-1, ........,0]$ then assign the alternative to the category $C_{h+1}(a \rightarrow c_{h+1})$.

3. Results and Discussion
In this section, we present our illustrative example. This case study aims at making an efficient classification of ten alternatives using the ELECTRE TRI tool, taking into account two essential criteria: the area and the altitude. The process of this tool is based on the following steps: Step 1: Determine the value of the weights corresponding to each criterion. Step 2: Define the decision matrix, where we attribute the value of each criterion for each alternative. Step 3: Determine the profiles for the study, including the values of the essential thresholds. Step 4: Making the classification of the available alternatives using the predefined profiles. Table 1 shows the different criteria and their values of preference.

In Table 2, we give the decision matrix, exploited for achieving the current study. In Table 3, we give the profiles of this study. Table 4 depicts the values of the parameters for the ELECTRE TRI method.

The last step consists of making the classification of the alternatives. Table 5 shows the classification obtained. The main objective of this work is to make an efficient classification of the environmental indicators; We have chosen the ELECTRE-TRI method due to its efficiency for performing the classification of the alternatives. Our goal is sorting the alternatives into three different categories: C1, C2, C3. To make this classification, we have considered two
Table 3. Initial profiles defining the category limits

| Profiles | C1   | C2   |
|----------|------|------|
| b₁       | 162  | 870  |
| b₂       | 155  | 555  |

Table 4. Parameters for ELECTRE TRI

| Threshold | C1   | C2   |
|-----------|------|------|
| Weight(Kₖ) | 0.7  | 0.3  |
| qⱼ(b₁)    | 0.2  | 0.2  |
| pⱼ(b₁)    | 1    | 1    |
| vⱼ(b₁)    | 0.5  | 0.5  |
| qⱼ(b₂)    | 0.2  | 0.2  |
| pⱼ(b₂)    | 1    | 1    |
| vⱼ(b₂)    | 0.5  | 0.5  |

Table 5. The classification results for $\lambda=0.76$

| Alternatives | Class 1 | Class 2 | Class 3 |
|--------------|---------|---------|---------|
| A1           | x       |         |         |
| A2           | x       |         |         |
| A3           | x       |         |         |
| A4           | x       |         |         |
| A5           |         | x       |         |
| A6           |         | x       |         |
| A7           | x       |         |         |
| A8           | x       |         |         |
| A9           | x       |         |         |
| A10          |         |         | x       |

profiles (Table 3). Hence, we have three different classes where C1 represents the best category. As seen in Table 2, the best alternatives are those of the most relevant class(C1) that have the highest values for the area criterion and the lowest values for the altitude criterion. From these results, it is visually clear that the alternatives A1 and A2 and A3 and A4 and A8 and A9 are classified into the best class(C1). However, the alternatives A7 and A10 belong to the second class(C2), while A5 and A6 are sorted into the last category(C3). To prove this classification, we have studied the sensibility analysis according to the cut-value $\lambda$. Hence, we have studied the classification of the considered data set using two different values $\lambda = 0.65$ and $\lambda = 0.85$. Table 6 shows the classification of the alternatives considering $\lambda = 0.65$ and Table 7 shows the results of the classification for $\lambda = 0.85$.

From the obtained results, we observe that the alternatives are affected to the same classes even if we consider different values of $\lambda$. Therefore, we can conclude that the classification of the considered alternatives is stable and insensitive to the variation of the value of $\lambda$. Hence, the ELECTRE-TRI approach has successfully classified the different alternatives considered for the current study.
Table 6. The classification results for $\lambda=0.65$

| Alternatives | Class 1 | Class 2 | Class 3 |
|--------------|---------|---------|---------|
| A1           |   x     |     |         |
| A2           |   |   |         |
| A3           |   x     |     |         |
| A4           |   x     |     |         |
| A5           |   x     |   x  |         |
| A6           |   |   |         |
| A7           |   x     |     |         |
| A8           |   x     |     |         |
| A9           |   |   |         |
| A10          |   x     |     |         |

Table 7. The classification results for $\lambda=0.85$

| Alternatives | Class 1 | Class 2 | Class 3 |
|--------------|---------|---------|---------|
| A1           |   x     |     |         |
| A2           |   |   |         |
| A3           |   x     |     |         |
| A4           |   x     |     |         |
| A5           |   x     |   x  |         |
| A6           |   |   |         |
| A7           |   x     |     |         |
| A8           |   x     |     |         |
| A9           |   |   |         |
| A10          |   x     |     |         |

4. Conclusion and perspectives

MCA has been widely exploited for resolving different decision problems including those of economics and engineering fields. Decision problems have been categorized into three major categories: choice problems, sorting problems, and ranking problems. In this study, we are interested in the sorting category. Our objective is to make an effective classification of the environmental indicators using the well-known multi-criteria method ELECTRE-TRI. We have considered two essential criteria for this study: the area and the altitude factors. In this work, we have presented an illustrative example using ten alternatives. Moreover, the sensibility analysis has been studied according to the cut-value $\lambda$ to confirm the validity of the classification of our dataset. From the obtained results, we have obtained a stable classification. Hence, it is visually clear that the ELECTRE-TRI approach has assisted in making the classification of the alternatives considered for the current study. In summary, The integration of the multi-criteria method ELECTRE-TRI serves its purpose by contributing to a better sorting of the environmental indicators for Loukkos Basin in Morocco. Hence, ELECTRE-TRI can be considered as an efficient tool for making a meaningful classification of the alternatives. The main advantages of this method are the consideration of the decision-makers’ preferences and different criteria. As future work, we intend to use another classification tool for sorting the environmental indicators.
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