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JOINT USE OF THE ELECTRE TRI AND KEMIRA-SORT MULTI CRITERIA DECISION MAKING METHODS TO PRIORITIZE THE EXPLOITATION OF NON TIMBER FOREST PRODUCTS PROVIDING SPECIES

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Abstract

The exploitation of non timber forest products (NTFPs), are the main source of income for rural populations in the Pô region of Burkina Faso. However, the potential of NTFP-providing species is not always exploited in a way that provides greater profitability for rural populations. This is mainly due to the fact that several criteria must be taken into account and aggregated in agreement with the various stakeholders. The aim of this work is to propose a prioritization of NTFP-providing species based on their ability to provide greater profitability for local populations. To this end, a proposition of a methodology based on the joint use of the KEMIRA-sort and ELECTRE Tri multi-criteria sorting methods to assign NTFP-providing species to ordered categories of profitability is made. The application of this methodology enabled to identify a median categorization made up of three categories of NTFP-providing species according to their profitability in the Pô area. The best category is made up of one specie (tamarind), while the second best category is made up of four species (shea, baobab, moringa, mango) and the last of five species (nere, detarium, jujube, resin and liana). The concordance of these results with the estimate

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of the expert, playing the role of decision maker, at the very start of our study, validate empirically the proposed approach, prefiguring its successful application to other context of multiple criteria sorting problems in the future (e.g. prioritizing areas at risk of the spread of a given disease in public health). Our approach also shows the complementary use of a total aggregation method (KEMIRA-sort) and an outranking method (ELECTRE Tri) in solving a multi-criteria sorting problem.

Math. Subject Classification: 90B50 , 90B90

Key Words and Phrases: MCDM,ELECTRE Tri, KEMIRA-Sort, Median categorization, Prioritization, Non Timber Forest Products

1. Introduction

Non-Timber Forest Products (NTFPs) are defined in [1, 2] as "all goods of biological origin other than wood and fauna, with the exception of insects, derived from forests and trees outside forests, consisting of spontaneous or domesticated plants, and those intended for reforestation". 70% of Burkina Faso's national territory, i.e., approximately 19 048 352 ha, contain a wide variety of non-timber forest products (NTFPs). There are 52 woody species providing edible fruits and seeds, 16 woody species pro- viding edible leaves, 13 woody species supplying gums and resins, 2 woody species supplying sap and latex, 6 woody species providing tubers, rhizomes and roots for various uses, 24 woody species providing barks and stems for various uses, 21 species of edible mushrooms, 7 species of straw, 76 species of woody fodder crops. Despite this great diversity of species of exploitable non-timber forest products (NTFPs) in Burkina Faso, rural populations collect these NTFPs without really having a clear idea of the advantages that one or other of these NTFP-providing species can bring to their farming areas. It is in response to this concern that our work aims to prioritize NTFP-providing species to enable rural populations in the Pô area to better benefit from NTFP exploitation. To characterize a woody species as a whole, it is necessary to take into account all its natural, technical and economic aspects, which are often conflicting. This is why the use of an adapted Multiple Criteria Decision Making (MCDM) method is necessary to take into account this complexity [3, 4]. To the best of our knowledge, we have yet to find a case study in the literature dealing with the prioritization of non-timber forest product species through the combined use of MCDM methods. The rest of our paper is structured as follows. In section 2 we justify the choice of the MCDM methods KEMIRA-Sort introduced by [5] and ELECTRE Tri first presented by [6] and [7], for assessing NTFP-providing species. We then present the two MCDM methods in section 3 and 4. Section 5 is dedicated to the application of the KEMIRA-Sort and ELECTRE Tri methods to our case study. Finally, we conclude our work and propose several prospects for the future.

2. Choice of KEMIRA-Sort and ELECTRE Tri methods

In the present work, we aimed to prioritize NTFP-providing species. From this point of view, multiple criteria sorting methods seem to us to be the most suitable. The literature on

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multiple criteria sorting methods shows that they are generally designed according to two main principles: total aggregation and partial aggregation [3]. Total aggregation methods, e.g. AHP [8] and UTADIS [9], are generally criticized for their blind compensation between heterogeneous criteria. By heterogeneous criteria we mean criteria between which natural compensation is generally not possible. This is the case, for instance, between an economic criterion and an environmental criterion or between an economic criterion and a social criterion. Conversely, two criteria are said to be homogeneous if a natural compensation is possible between them. This is the case, for example, between two criteria that are both economic, social or environmental. In the context of multiple criteria choice, the KEMIRA method, which is based on the principles of total aggregation and enables compensation between heterogeneous criteria to be mitigated, was proposed [10]. KEMIRA method divides criteria into homogeneous groups. For an alternative to be selected as the best, it must satisfy a certain level of performance within each homogeneous group. This method enables to determine the best alternatives and the weighting of criteria within each homogeneous group. An extension of this method for multi criteria sorting problem, KEMIRA-Sort, has been successfully proposed [5, 11]. We first used the KEMIRA-Sort method for our case study. As a multiple criteria sorting method using the principle of partial aggregation or outranking, we opted for the ELECTRE Tri [6, 12] method because of its good handling of environmental issues [7, 13]. We can then compare the results of the two methods, KEMIRA-Sort and ELECTRE Tri when applying them to our case study to ensure their validity.

3. Presentation of the KEMIRA-Sort Method

In what follows we briefly present the KEMIRA-Sort method [5]. For this purpose, we introduce the following notations:

- $x^k, k \in \{1,2,\dots,P\}$ designates an alternative.
- We assume that Q criteria are divided into G groups $G_1, G_2, \dots, G_G$. $|G_i|$ denoting the number of elements of the set G_i relation (1) holds:

$$\sum_{i=1}^{G} |G_i| = Q. \quad (1)$$

- The couple (i,j) denotes the criterion g_j inside the group G_i and $\boldsymbol{w_{i,j}}$ its corresponding weight.
- We assume that within each group of criteria G_i, the decision-maker is able to rank the criteria from best to worst. Therefore, relations (2), (3) and (4) hold:

$$(i,1) \gtrsim (i,2) \gtrsim \dots \gtrsim (i,|G_i|), \qquad \forall\, i \in \{1,\dots,G\}, \quad (2)$$

$$w_{i,1} \geq w_{i,2} \geq \cdots \geq w_{i,|G_i|}\ \forall\, i \in \{1,\dots,G\}, \quad (3)$$

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$$\sum_{j=1}^{|G_i|} w_{i,j} = 1, \ \ \forall\, i \in \{1, \dots, G\}, \tag{4}$$

where $(i,j) \gtrsim (i,l)$ means that criterion (i,j) is at least as important as criterion (i,l).

- The variable $X_{i,j}^k$ denotes the performance of alternative x^k with respect to criterion (i,j) and its normalized performance, $x_{i,j}^k$, is given by relation (5)

$$x_{i,j}^k = \frac{X_{i,j}^k - \min\limits_k X_{i,j}^k}{\max\limits_k X_{i,j}^k - \min\limits_k X_{i,j}^k}. \tag{5}$$

- The variables $C_1, C_2, \dots, C_M$ denote the ordered categories of alternative assignment, with C_1 being the worst and C_M being the best.
- The variables $\alpha_i^l, l \in \{1, \dots, M-1\}, i \in \{1, \dots, G\}$ denote the performance thresholds associated with each group of criteria $G_1, G_2, \dots, G_G$.

In order to apply the KEMIRA-Sort method, the following main steps must be followed:

(i) Computing the increasing functions, W_i (average performance) according to each group of criteria G_i, by applying the formula (6):

$$W_i(X^k) = \sum_{j=1}^{n_i} w_{i,j} \times x_{i,j}^k. \tag{6}$$

(ii) The performance thresholds α_i^l associated with each group of criteria are specified via relation (7):

$$\begin{gathered} \alpha_i^l(p) = p \times \max_k W_i(X^k), \\ 0 < \alpha_i^1(p) < \cdots < \alpha_i^{M-1}(p) < 1, \end{gathered} \tag{7}$$

where p denotes a percentage. In each group G_i, the $\alpha_i^l(p)$ threshold value is chosen as a percentage p of the maximum average performance.

(iii) The assignment process of alternatives to categories (8) is as follows:

$$\begin{aligned} &\text{step 1: if } \exists\, i \in \{1,2,\dots,G\}, W_i(X^k) \le \alpha_i^1(p), \text{assign } X^k \text{ to } C_1; \\ &\text{step 2: if } \exists\, i \in \{1,2,\dots,G\}, W_i(X^k) \le \alpha_i^2(p), \text{and } (X^k \notin C_1), \\ &\text{assign } X^k \text{ to } C_2 \\ &\text{step 3: if } \exists\, i \in \{1,2,\dots,G\}, W_i(X^k) \le \alpha_i^3(p), \text{and } (X^k \notin C_1) \\ &\text{and } (X^k \notin C_2), \text{assign } X^k \text{ to } C_3 \end{aligned} \tag{8}$$

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$$\vdots$$

step M: if X^k does not satisfy the step 1 to step $M-1$,
assign X^k to C_M

(iv) Solve the mathematical programming problem (9):

$$\max_{w_{i,j}} f_{opt} = \sum_{l=1}^{M} l \times |C_l|$$

$$\text{subject to} \begin{cases} w_{i,1} \geq w_{i,2} \geq \cdots \geq w_{i,|G_i|} \; \forall\, i \in \{1, \dots, G\}, \\ \sum_{j=1}^{|G_i|} w_{i,j} = 1, \;\; \forall\, i \in \{1, \dots, G\}, \\ assignment\ process \;\; (8). \end{cases} \tag{9}$$

The mathematical programming problem (9) is solved iteratively via the KEMIRA-Sort algorithm [5]. At the optimum, each alternative is assigned to its best category, and within each group G_i, the weights of the criteria are determined.

4. Presentation of the ELECTRE Tri method

Considering the previous notations, we begin by specifying a few new notations and conventions which are used in the definitions we give below, and which will help us to understand the presentation of the ELECTRE Tri method in its original version [6,7].

- $F = \{1,2, \dots, m\}$ denotes the set of criteria indices and w_j, denotes the weight associated with the criterion $g_j, j \in F$. The evaluation of alternative x^k according to criterion g_j, is denoted as $g_j(x^k)$.
- $B = \{1,2, \dots, M-1\}$ denotes the set of indices of limit profiles or reference alternatives defining M categories. The profile b^l is the upper limit of category C_l and the lower limit of category $C_{l+1}, l = 1,2, \dots, M-1$. The evaluation of profile b^l with respect to criterion g_j is $g_j(b^l)$. We assume that the categories are ordered in ascending order of their index, with category C_M being the best.
- Without loss of generality, we assume that the direction of preferences increases for each criterion.
- We consider only the case of true criteria; consequently, the preference and indifference thresholds are considered to be all zero. We also assume that there is no veto on the criteria. Under these conditions, the degree of outranking between two alternatives, $\sigma(x^i, x^k)$, is simply defined by the relation (10):

$$\sigma(x^i, x^k) = \sum_{\{j:\, g_j(x^i) \geq g_j(x^k)\}} w_j. \tag{10}$$

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The ELECTRE Tri method requires the prior selection of perfectly comparable alternatives. Each of these alternatives outranks or is outranked by others. These alternatives serve as reference alternatives or limit profiles. ELECTRE Tri constructs an outranking relation S between an alternative x^k and a limit profile b^l, i.e., validates or invalidates the assertion $x^k S b^l$ (or $b^l S x^k$). The $x^k S b^l$ outranking is based on the determination of its degree of credibility $\sigma(x^k, b^l)$. The proposition $x^k S b^l$ ($b^l S x^k$) is considered true if $\sigma(x^k, b^l) \geq \lambda$ ($\sigma(b^l, x^k) \geq \lambda$), where $\lambda \in [0.5; 1]$ is a "cutting threshold". The values of $\sigma(x^k, b^l)$, $\sigma(b^l, x^k)$ and λ determine the different preference situations between x^k and b^l:

- ($\sigma(x^k, b^l) \geq \lambda$ and $\sigma(b^l, x^k) \geq \lambda$), *i.e.*, ($x^k S b^l$ and $b^l S x^k$), *i.e.*, x^k is indifferent to b^l, which we denote by $b^l I x^k$ or $x^k I b^l$.;
- ($\sigma(x^k, b^l) \geq \lambda$ and $\sigma(b^l, x^k) < \lambda$), *i.e.*, ($x^k S b^l$ and $not(b^l S x^k)$), *i.e.*, x^k is preferred to b^l, which we denote by $x^k \succ b^l$;
- ($\sigma(x^k, b^l) < \lambda$ and $\sigma(b^l, x^k) \geq \lambda$), *i.e.*, ($not(x^k S b^l)$ and $b^l S x^k$), *i.e.*, b^l is preferred to X^k, that we denote by $b^l \succ x^k$;
- ($\sigma(x^k, b^l) < \lambda$ and $\sigma(b^l, x^k) < \lambda$), *i.e.*, ($not(x^k S b^l)$ and $not(b^l S x^k)$), *i.e.*, b^l is incomparable to x^k, which we denote by $b^l R x^k$ or $x^k R b^l$.

To be able to assign each alternative to exactly one of the predefined categories, it is necessary to define two particular reference alternatives b^0 (anti-ideal alternative) and b^M (ideal alternative) as follows:

$$\forall\, x^k \in A\ x^k \succ b^0 \text{ and } b^M \succ x^k, k \in \{1, \dots, P\}, \tag{11}$$

where A denotes the set of alternatives.

We can then assign the alternatives of the set A to one of the C_l categories via two procedures:

The pessimistic procedure

(i) Compare x^k successively to b^i, for $i = M, M-1, \dots, 2, 1$;

(ii) If b^h is the first profile such that $x^k S b^h$, then x^k is assigned to category C_{h+1}.

The optimistic procedure

(i) Compare b^l successively to x^k, for $i = 1, 2, \dots, M-1$;

(ii) If b^h is the first profile such that $b^h \succ x^k$, then x^k is assigned to category C_h.

For each alternative, the optimistic procedure yields a ranking that is at least as good as that of the pessimistic procedure.

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5. Results and Discussion

5.1. Identification of species providing non timber forest products (NTFP)

The species supplying non timber forest products identified in the Pô rural area by a study conducted by [14] were as follows:

- The shea (*vitellaria paradox*) (x^1)
- The nere (*parkia biglobosa*) (x^2)
- The baobab (*adansonia digitata*) (x^3)
- The moringa (*moringa oleifera*) (x^4)
- The tamarind (*tamarindus indica*) (x^5)
- The detarium (*detarium senegalense*) (x^6)
- The Jujube (*ziziphus jujuba*) (x^7)
- The mango (*mangifera indica*) (x^8)
- The resin (*lannea microcarpa*) (x^9)
- The liana (*saba senegalensis*) (x^{10})

These different species represented all our alternatives

5.2. Identification of evaluation criteria

Eight (08) criteria were identified from the analysis of studies conducted by [15, 16], and were divided into three (03) groups of homogeneous criteria.

- Group 1 reflects the economic aspects related to other parts of the species other than the fruit. The three criteria belonging to this group are as follows:
    - the price of a kilogram of leaf (1, 1) is the purchase price (in CFA francs) on the Pô market of a kilogram of leaf of the species;
    - the price of a kilogram of bark (1, 2) is the purchase price (in CFA francs) on the Pô market of a kilogram of bark of the species;
    - the price of a kilogram of roots (1, 3) is the purchase price (in CFA francs) on the Pô market of a kilogram of roots of the species.
- Group 2 translates the economic aspects of fruits; the two criteria belonging to this group are as follows:
    - the purchase price per hectare before fruit treatment (2, 1) is the amount (in CFA francs) sold on one hectare immediately after harvest;
    - the purchase price per hectare of fruit after processing (2, 2) is the

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amount (in CFA francs) set for processors.

- Group 3 translates technical aspects related to demand in different markets; the two criteria belonging to this group are as follows:
  - The national market demand (3, 1) is the rating from 0 to 10 of the species in relation to the national market demand for the NTFP from the species;
  - International market demand (3, 2) is the rating from 0 to 10 of the species in relation to the national market demand for the NTFP from the species.

5.3. Evaluation matrix

Data collection in the area of Pô was carried out with the help of an expert in biology and natural resources, who also acted as decision-maker. Each alternative was then evaluated w.r.t. the criteria, and the results are recorded in Table 1.

Table 1: Evaluation matrix

	(1, 1)	(1, 2)	(1, 3)	(2, 1)	(2, 2)	(3,	(3,
Shea x^1	00	400	00	350000	375000	08	09
Nere x^2	00	350	00	135000	216000	03	00
Baobab x^3	600	400	00	27000	99000	09	09
moringa X^4	1000	500	1000	234000	1350000	10	10
Tamarind$\boldsymbol{x}^5$	800	400	500	450000	252000	10	08
Detarium$\boldsymbol{x}^6$	00	300	200	135000	72000	04	00
Jujube $\boldsymbol{x}$	400	200	00	25200	72000	04	00
Mango $\boldsymbol{x}^8$	200	400	00	2400000	140000	04	00
Resin $\boldsymbol{x}^9$	300	200	350	22500	600	05	00
Liana $\boldsymbol{x}^{10}$	350	00	500	120000	1750	05	00
Objective	max	max	max	max	max	max	max

The normalized evaluation matrix obtained when using relation (5) is shown in Table 2

Table 2:Normalized evaluation matrix

	(1, 1)	(1, 2)	(1, 3)	(2, 1)	(2, 2)	(3, 1)	(3, 2)
Shea x^1	0	0.8	0	0.1377	0.129	0.714	0.9
Nere x^2	0	0.7	0	0.0473	0.0547	0.125	0
Baobab x^3	0.6	0.8	0	0.0019	0.001	0.875	0.9
moringa X^4	1	1	1	0.089	0.1033	1	1
Tamarind $\boldsymbol{x}^5$	0.8	0.8	0.5	0.1798	0.1697	1	0.8
Detarium $\boldsymbol{x}^6$	0	0.6	0.2	0.0473	0.0441	0.25	0
Jujube $\boldsymbol{x}^7$	0.4	0.4	0	0.0011	0.0007	0.25	0
Mango $\boldsymbol{x}^8$	0.2	0.8	0	1	1	0.25	0
Resin $\boldsymbol{x}^9$	0.3	0.4	0.35	0	0	0.375	0
Liana $\boldsymbol{x}^{10}$	0.35	0	0.50	0.041	0.0393	0.375	0
Objective	max	max	max	max	max	max	max

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5.4. Empirical assignment of alternatives

We have chosen to assign NTFP-providing species according to three categories: a C_3 category, where the best species will be assigned, a C_1 category, where the worst species will be assigned; and an intermediate C_2 category, where species that do not belong to either the C_1 or C_3 categories will be assigned. To guide us in the choice of parameters for implementing the KEMIRA-Sort and ELECTRE Tri algorithms, we asked the decision-maker to provide examples of category assignments on the basis of his experience. Empirically, the decision-maker was able to provide assignment examples as summarized in Table 3.

Table 3: Examples of empirical assignment

Alternatives	Assignment categories
Nere x^2	C_1
Mango x^8	C_2
Tamarind x^5	C_3

5.5. Running the KEMIRA-Sort algorithm

We implemented the KEMIRA-Sort algorithm in the Python language. The parameters of the KEMIRA-Sort algorithm chosen in such a way as to match the results in Table 3 as closely as possible. This enabled us to set the performance threshold values $\alpha_i^l(p)$ as presented in Table 4.

Table 4: KEMIRA-sort algorithm results

	$W_1(X^j$	$W_2(X^j$	$W_3(X^j$	C_1	C_2	C_3	$\sum^M$	$W_1(X^j$	$W_2(X^j$	$W_3(X^j$	C_1	C_2	C_3	$\sum^M$
X^1	0.22	0.13	0.78	0	1	0	2	0.24	0.13	0.74	0	1	0	2
X^2	0.19	0.04	0.	1	0	0	1	0.21	0.04	0.	1	0	0	1
X^3	0.54	0.00	0.87	1	0	0	1	0.50	0.00	0.86	1	0	0	1
X^4	1.	0.02	1.	1	0	0	1	1.	0.09	1.	1	0	0	1
X^5	0.74	0.17	0.92	0	0	1	3	0.72	0.17	0.96	0	0	1	3
X^6	0.20	0.04	0.08	1	0	0	1	0.23	0.04	0.11	1	0	0	1
X^7	0.32	0.00	0.08	1	0	0	1	0.29	0.00	0.11	1	0	0	1
X^8	0.33	1.	0.08	1	0	0	1	0.33	1.	0.11	0	1	0	2
X^9	0.33	0.	0.17	1	0	0	1	0.34	0.	0.23	1	0	0	1
X^{10}	0.28	0.04	0.17	1	0	0	1	0.28	0.04	0.23	1	0	0	1
$\alpha_i^1(p)$	0.10	0.10	0.10					0.10	0.10	0.10				
$\alpha_i^2(p)$	0.15	0.15	0.15					0.15	0.15	0.15				
f_{opt}							13							14

The KEMIRA-Sort algorithm begin by randomly choosing

$w^0 = (w_{1,1}^0, \cdots, w_{1,|G_1|}^0; w_{2,1}^0, \cdots, w_{2,|G_2|}^0; \cdots; w_{G,1}^0, \cdots, w_{G,|G_G|}^0)$ a vector satisfying relations (3) and (4): here, w^0 = (0.53, 0.28, 0.19; 0.72, 0.28; 0.6, 0.4) is the initial weight vector for starting iteration. The first part of Table 4 (columns 1 to 7) shows the associated alternatives assigned

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to categories.

Additionally, in Table 4, considering the columns for C_1, C_2 and C_3 categories the number 1 (0) means that the alternative is (not) assigned to the corresponding category.

At each iteration, the KEMIRA-Sort algorithm modifies the value of the weight vector W^0 to assign each alternative to its best category, following the optimization of mathematical programming problem (9). We stop the algorithm when the assignment categories of each alternative no longer change. We have therefore reached the optimum of the economic function of problem (9).

In our case, after two hundred thousand iterations (200000) of the KEMIRA-Sort algorithm corresponding to a running time of approximatively 14.0 seconds, the optimum value of the economic function was $f_{opt} = 14$. The corresponding optimal assignments of the alternatives to categories are shown in the second part of Table 4 (columns 9 to 15) and the final weight vector determined by the algorithm was

$w^{200000} = (0.4444, 0.3030, 0.2525;\ 0.9009, 0.0990;\ 0.8265, 0.1734)$. Table 5 highlights this categorization.

Table 5: Best categorization via the KEMIRA-Sort method

Categories	Alternatives
C_1	nere $(\boldsymbol{x^2})$, baobab$(\boldsymbol{x^3})$, moringa $(\boldsymbol{x^4})$, detarium $(\boldsymbol{x^6})$, jujube $(\boldsymbol{x^7})$, resin $(\boldsymbol{x^9})$, liana $(\boldsymbol{x^{10}})$,
C_2	shea $(\boldsymbol{x^1})$, mango $(\boldsymbol{x^8})$
C_3	tamarind $(\boldsymbol{x^5})$

As shown by the results of the KEMIRA-Sort method presented in Table 5, the best choices of our parameters allowed us to have alternatives assigned to categories such a way to respect all the empirical assignment examples given by the decision-maker (see Table 3). More specifically, the final assignment given by the KEMIRA-Sort method showed that:

- nere (x^2), baobab(x^3), moringa (x^4), detarium (x^6), jujube (x^7), resin (x^9), liana (x^{10}) are assigned to the worst category C_1;
- shea (x^1), mango (x^8) are assigned to the C_2 category;
- tamarind (x^5) is assigned to the best category C_3.

5.6. Running the ELECTRE Tri algorithm

To run the ELECTRE Tri algorithm, the weights of the criteria must first be determined. To do this, we used Simos' revised card method implemented in the SRF software [17] to find the weights of the criteria presented in Table 6.

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Table 6: Weighting of criteria using SRF sofware

Criteria	weight
National market demand (3, 1)	26.65
International market demand (3, 2)	24.37
Purchase price per hectare before fruit treatment	19.26
Purchase price per hectare after processing (2,2)	17.14
Price of a kilogram of leaf (1, 1)	9.76
Price of a kilogram of bark (1, 2)	4.49
Price of a kilogram of roots (1, 3)	1.33

We have implemented the ELECTRE Tri algorithm in MATLAB. As with the KEMIRA-Sort algorithm, the examples of alternatives assigned to the predefined categories provided by the decision-maker (see Table 3) guided us in our choice of parameters: the majority threshold or cutting threshold, $\lambda \in [0.74; 0.78]$, the limit profiles or reference alternatives. Specifically, this limit profiles were obtained by setting their values following relations (12) and (13) and are presented in Table 7.

$$b_j^1 = 0.6 \times \max_k g_j(X^k), \ \forall j \in F, \tag{12}$$

$$b_j^2 = 0.6 \times \max_k g_j(X^k), \ \forall j \in F. \tag{13}$$

Table 7: Limit profiles

	(1, 1) g_1	(1, 2) g_2	(1, 3) g_3	(2, 1) g_4	(2, 2) g_5	(3, 1) g_6	(3, 2) g_7
b^1	600	300	600	1440000	1591800	6	6
b^2	800	400	800	1920000	2122400	8	8

After a running time of approximately 13.5 seconds we obtained the assignment of alternatives to predefined categories as shown in Table 8. Additionally, in Table 8, we noted that the best choices of our parameters did not allow us to have alternative mango (x^8) assigned to the C_2 category while respecting all the empirical assignment examples given by the decision-maker (see Table 3). In the final assignment given by the ELECTRI Tri method, we find the nere (x^2) assigned to the worst category C_1, and the tamarind (x^5) to the best category C_3, as for the empirical assignment examples. The mango (x^8), empirically assigned to the C_2 category, is assigned to the best category C_3 via ELECTRE Tri method. More specifically, the final assignment given by the ELECTRE Tri method is as follows:

- nere (x^2), detarium (x^6), jujube (x^7), resin (x^9), liana (x^{10}) are assigned to are assigned to the worst category C_1;
- shea (x^1) is assigned to the C_2 category;
- baobab(x^3), moringa (x^4), tamarind (x^5) , and mango (x^8) are assigned to the best

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category C_3.

Note that we have considered the result obtained with the optimistic procedure of the ELECTRE Tri method. The pessimistic procedure assigned all the alternatives to the worst category C_1.

Table 8: Best categorization via the ELECTRE Tri method

Categories	**Alternatives**
C_1	nere $(\boldsymbol{X^2})$, detarium $(\boldsymbol{X^6})$, jujube $(\boldsymbol{X^7})$, resin $(\boldsymbol{X^9})$,
C_2	shea $(\boldsymbol{X^1})$
C_3	baobab$(\boldsymbol{X^3})$, moringa $(\boldsymbol{X^4})$, tamarind $(\boldsymbol{X^5})$**,**

5.7. Discussion

The results of the two categorizations given by the KEMIRA-Sort method (see Table 5) and the ELECTRE Tri method (see Table 8) showed that the KEMIRA Sort method was stricter than the ELECTRE Tri method with the optimistic procedure (and less strict than ELECTRE Tri method with the pessimistic procedure). While the KEMIRA-Sort method assigns the alternative mango (x^8) to the C_2 category, the ELECTRE Tri method with the optimistic procedure assigns it to the C_3 (the C_1 category). While KEMIRA-Sort assigns the alternatives baobab (x^3) and moringa (x^4), to the C_1 category, the ELECTRE Tri method with the optimistic procedure assigns them to the C_3 category. To obtain a median categorization, it seems logical to keep in the median category C_1 (respectively C_3) the alternatives belonging to the intersection of the categories C_1 (respectively C_3) given by the KEMIRA-Sort and ELECTRE Tri methods. Consequently, the remaining alternatives would logically be assigned to the median category C_2. The resulting median categorization is shown in Table 9. This median categorization respected the empirical examples of assignment to categories (see Table 3) given by the decision-maker. Even better, the median categorization, which is based on the assignment examples provided by the decision-maker, provided the latter with a categorization of all NTFP-providing species according to the benefit they would bring to the population.

Table 9

Median categorization

Categories	**Alternatives**
C_1	nere $(\boldsymbol{x^2})$, detarium $(\boldsymbol{x^6})$, jujube $(\boldsymbol{x^7})$, resin $(\boldsymbol{x^9})$,
C_2	shea $(\boldsymbol{x^1})$, baobab$(\boldsymbol{x^3})$, moringa $(\boldsymbol{x^4})$, mango $(\boldsymbol{x^8})$
C_3	tamarind $(\boldsymbol{x^5})$

6. Conclusion

The exploitation of non timber forest products (NTFP) is a booming sector in sub-Saharan Africa, particularly in Burkina Faso. To better guide the exploitation of NTFPs in the rural area of Pô in Burkina Faso, we developed a process for prioritizing NTFP-providing species on the

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basis of the combined use of the KEMIRA-Sort and ELECTRE Tri methods. This joint use of the KEMIRA-Sort and ELECTRE Tri methods enabled us to produce a median categorization of NTFP-providing species in line with the decision-maker's empirical knowledge. Tamarind has emerged as the preferred NTFP-producing species. The second group consisted of species such as shea, baobab, moringa and mango. These results also demonstrate the effectiveness of the KEMIRA-Sort and ELECTRE Tri methods in solving agricultural problems. In our case study, we did not consider the possible interactions between the different NTFP-providing species. It would be interesting to see how this aspect could be taken into account, and what the repercussions would be on the median categorization. In addition, our approach could also be applied in the context of prioritizing areas at risk of the spread of a given disease in public health.

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