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Research Article

Multi-criteria Decision Making Using KEMIRA-Sort Method for Assessing the Suitability of Wild Animals to Promote Sustainable Management of a Wildlife Farm

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Abstract

In Burkina Faso, most of the wildlife farms hosting touristic visits, which started out with great enthusiasm, are now closed, highlighting the need for sustainable wildlife farm management. Although also of interest for wildlife farming, most of the study dealing with sustainable animal farm management are focus on livestock farming. This study was motivated by the need to provide an answer to the question of sustainable management of wildlife farming in Burkina Faso. To this end, our aim is to assess the suitability of wild animals to promote sustainable management of an ex-situ wildlife farm, hosting touristic visits. The implementation of a Multi-Criteria Decision Making (MCDM) process enabled us, among other things, to identify the wild animals and the criteria against which their suitability to promote sustainable management has been assessed. Our concern, on the one hand, to enable the stakeholders to easily express their preferences and thus fully adhere to the decision-making process, and on the other hand, to respect the heterogeneous dimensions implied by sustainability led us to choose the KEmeny Median Indicator Ranks Accordance-Sort (KEMIRA-Sort) multi-criteria sorting method. The evaluation phase was guided by the consideration of decision-maker's preferences for ranking criteria and empirical examples of assigning wild animals to ordered categories of suitability to sustainable management. The complete implementation of the decision-making process enabled us to identify the categories of wild animals according to their suitability to promote sustainable management in the case study of the Wédbila wildlife farm (WWF) in Burkina Faso. More specifically, we showed that the group of wild animals most likely to promote WWF sustainable management was made up of *pork-spicy*, *aulacodes*, and *red-necked ostrich*. These results obtained was in line with empirically estimation of the principle stakeholder playing the role of Decision maker. These relevant results obtained thus validate the effectiveness of the KEMIRA-Sort multi-criteria sorting method. In addition, the flexibility of the proposed approach predisposes it, subject to adaptation, to be used in other sustainable management wildlife farm contexts.

Keywords

MCDM, Shorting Method, KEMIRA-Sort, Sustainable Management, Wildlife Farm

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1. Introduction

Animal breeding farm has more often than not been coupled with tourist visits, which generally entails complex management. To be sustainable, this system combining animal breeding and tourist visits must respect economic, environmental, social and animal reproduction principles. Multi-criteria decision-aid methods are the ideal tools for taking into account the conflicting aspects inherent in decision-making. Also, in the context of agriculture we find successful work combining deterministic and/or uncertain multi-criteria decision making methods [1, 2] to address the sustainability of its management. Particularly in the context of the sustainability of livestock farms, we can note work carried out on several aspects linked to the search for sustainability in the management of the said livestock farm. In contrast to traditional livestock farm management, which focuses on economic profitability alone, thereby generating conflicts with stakeholders given the failure to take into account the environmental components (water, soil, gas emissions, etc.) affected by livestock farm operations, [3] propose a model for the sustainable management of a livestock farm based on a multi-criteria decision making approach to achieve economic, social and environmental objectives. [4] looked at the risks associated with the livestock supply chain. Seventeen risks were identified and ranked according to their importance, using the AHP multi-criteria decision making method, in order to plan and guarantee sustainable management of a livestock farm. Virtual technologies (Artificial Intelligence, Big Data, etc.) and connected objects are known to have a leverage effect in all the business sectors in which they are applied. The sustainable management of animal farms is no exception. [5] point out that the adoption of these new technologies would enable traditional animal breeding farms to become precision breeding farms, where animal health and behavior, among other parameters, would be monitored in real time, thus fostering sustainable animal farm management. On a larger scale, Genovese et al [6] investigate the characteristics of a sustainable business model based on the coexistence of livestock farming and tourism activities. They show that the sustainability and success of such a business model in a mountainous context depends on the proactive intervention of a supra-agricultural dimension, while retaining the specific features of individual farms. It should be noted that the last two works do not mention the use of multi-criteria decision support tools, which could certainly contribute more to giving them a solid theoretical framework that would promote their application to other contexts or study regions of sustainable animal farm management. However, it should be noted that these works, although also of interest for wildlife farming, are more focused on livestock farming. Indeed, as pointed out by [7], speaking specifically of the sustainable management of wild animal farms, an essential element in ensuring sustainable management is the suitability of wild animals to promote sustainable management of the farm in question.

In Burkina Faso, most of the wildlife farms hosting touristic visits, which started out with great enthusiasm, are now closed. This situation highlights the need for sustainable wildlife farm management in Burkina Faso and other countries suffering from this problem.

For a given ex-situ wildlife farm hosting tourist visits, in order to ensure its sustainable management, we propose a methodology for assessing the suitability of wild animals to promote its sustainable management. Specifically, we propose to find orderly categories of the best animals that can promote this sustainable management. Setting up an ex-situ wildlife farm with a view to sustainability requires taking into account criteria relating to profit, reproduction and investment, which are different and conflicting in nature. Concerning the conflicting nature of criteria, note that two criteria are said to be homogeneous when a natural compensation is possible between them (e.g. two economic criteria or two social criteria), otherwise the two criteria are said to be heterogeneous (e.g. a social criterion and an economic criterion or an economic criterion and an environmental criterion). Multiple Criteria Decision Making Methods (MCDM) are better suited to take into account the complexity inherent in a problem. In the context of our sorting problem, several MCDM methods are available (ELECTRE Tri [8, 9], UTADIS [10, 11], KEMIRA-Sort [12]). Choosing an MCDM sorting method means finding the most efficient one:

1. Achieving a good balance with respect to the number of parameters required for its operation,
2. Respecting the heterogeneity of criteria,
3. Easy to apply.

Looking these criteria for choosing an MCDM method in our context, KEMIRA-Sort method [12] seems the most appropriate for the problem of sustainable wildlife farm management. Unlike the total aggregation method UTADIS [10, 11], KEMIRA-Sort is a multiple criteria sorting method, avoiding blind compensation between heterogeneous criteria. In addition, it requires few parameters for its implementation, compared with outranking based method as ELECTRE Tri [8, 9]. KEMIRA Sort method is an extension of the multiple criteria choosing method KEMIRA [13]. KEMIRA-Sort method has been successfully used for landscape degradation management problems [12].

In the rest of our paper, we describe the case study of the Wédbila wildlife farm, and briefly present the KEMIRA-Sort method. We then apply the KEMIRA-Sort method to categorize the wild animals of the Wédbila wildlife farm according to their suitability to ensure sustainable wildlife farm management. Finally, we conclude our paper with suggestions for future work.

2. Materials and Methods

2.1. Materials

The Wédbila wildlife Farm (WWF), is a project conceived and developed by Lungren [14] since 1954. It is a wildlife farm covering some sixty hectares, where wild animal visits, research and training activities take place, activities to perfect the breeding of wild animals on several parameters such as sexual maturity, gestation time, interval between litters, commercial age, life expectancy, mortality rate, number of pups per litter, cost of care, cost of feed, commercial value and so on. The WWF is located southwest of Ouagadougou, in the commune of Koubri, between latitude 12 °03'30.7" North and longitude 1 °25'18.7" West.

In this study, we propose to assign wild animals to the following ordered categories C_1, C_2, C_3, C_4 in order to evaluate their suitability to promote the sustainable management of an ex-situ wildlife farm like that of Wédbila (Burkina Faso). Thus, animals in category C_1 will be considered as having the lowest suitability to promote sustainable farm management, and those in category C_4 will be considered as having the highest suitability to promote the sustainable management of the wildlife farm. We consider that the more an animal is assigned to a better category, the better it can promote the sustainable management of the wildlife farm.

Table 1 presents the wild animals of the WWF each assigned to a category. In section 3, a justification of the categorization provided by Table 1 is given. Figure 1 presents a plaque of the Wédbila wild farm showing the animals in their habitat.

Table 1. *Categorization.*

Categories	Alternatives
C1	“ephalophus rufilatus” (X^6)
	“Sylvicapra grimmia” (X^7)
	“Geochelone sulcata” (X^9)
	“Kobus ellipsiprymnus” (X^{12}) psiprymnus” (X^{12})
	“Alcelaphus buselaphus” (X^{13})
	“Hippotragus niger” (X^{14})
	“Lupulella adusta” (X^{15})
C2	
C3	“Phacochoerus africanus” (X^2)
	“Gazella dorcas” (X^3)
	“Tragelaphus Seriptus” (X^4)
	“cricetomys” (X^8)
	“Gazella rufifrons” (X^{10})
C4	“Hystrix Cristata” (X^1)
	“Thryonomys swinderianus” (X^5)
	“Struthio camelus” (X^{11})

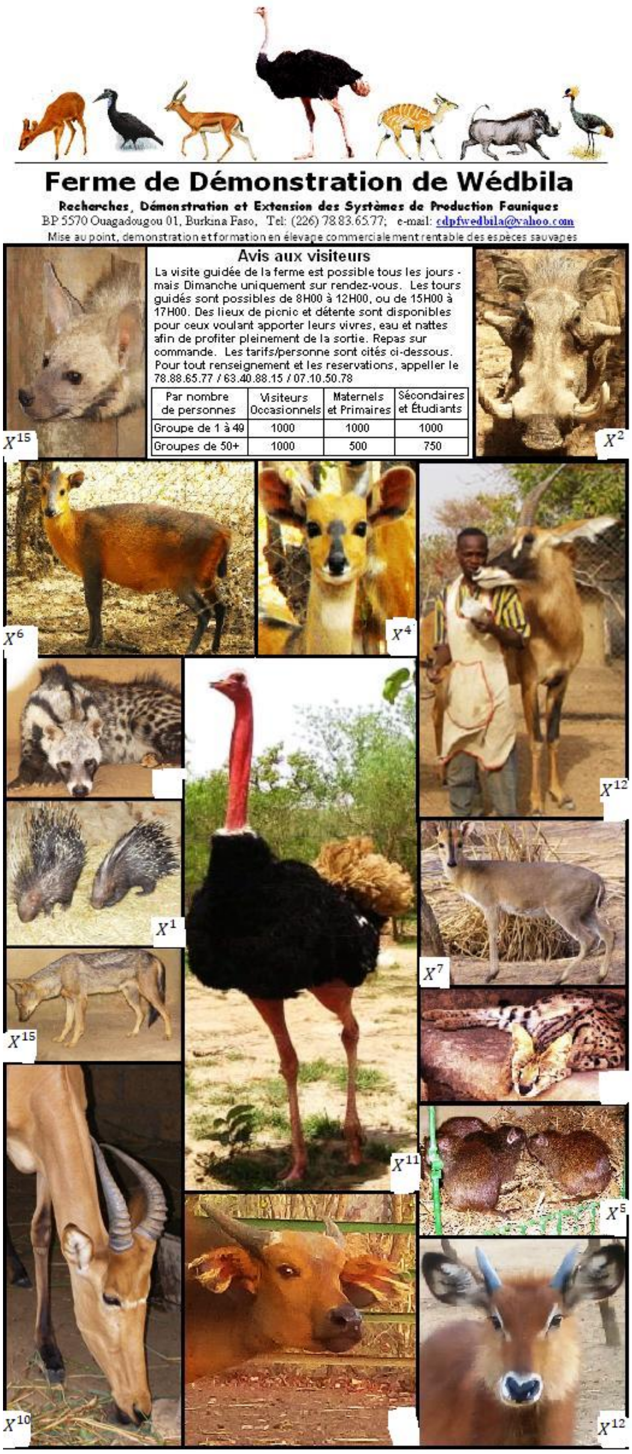

Figure 1. *Plaque of Wédbila wild farm.*

2.2. Methods

2.2.1. Keys Steps of KEMIRA-Sort Method

In what follows, we adopt the following notations [12]:

1. $X^k, k \in \{1,2,\dots,P\}$ designates an alternative.
2. We assume that have Q criteria divided into G groups $G_1, G_2, \dots, G_G$. Of Course the relation (1) holds:

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

Where $|G_i|$ represents the cardinal of G_i.

1. The pair (i, j) designates the criterion j of the group G_i.
2. The variable $X_{i,j}^k$ denotes the performance of the alternative X^k with respect to the criteria j of the group G_i.
3. The variable $x_{i,j}^k$ denotes the normalized performance of X^k obtained by using the relation (2):

$$X_{i,j}^k = \frac{x_{i,j}^k - \min_k x_{i,j}^k}{\max_k x_{i,j}^k - \min_k x_{i,j}^k}. \quad (2)$$

1. The variable $w_{i,j}$ denotes the weight of criterion (i, j).
2. The variable $C_1, C_2, \ldots, C_M$ represent the ordered categories of alternative assignment, with C_1 being the worst and C_M being the best.
3. The variables $\alpha_i^l, l \in \{1, \ldots, M-1\}, i \in \{1, \ldots, G\}$ denotes the performance thresholds associated respect to group of criteria $G_1, G_2, \ldots, G_G$

The main steps in implementing the KEMIRA Sort method are described below.

1. Identification of alternatives.
2. Developing relevant criteria to evaluate the alternatives.
3. Grouping criteria into homogeneous groups.
4. Ranking of criteria by the decision-maker in each sub-group G_i in descending order from the most preferred to the least preferred. So the relations (3), (4) and (5) hold:

$$(i, 1) \gtrsim (1,2) \gtrsim \ldots \gtrsim (i, |G_i|), \ \forall i \in \{1, \ldots, G\}, \quad (3)$$

$$w_{i,1} \geq w_{i,2} \geq \cdots \geq w_{i,|G_i|} \qquad \forall i \in \{1, \ldots, G\}, \quad (4)$$

$$\sum_{j=1}^{|G_i|} w_{i,j} = 1, \ \forall i \in \{1, \ldots, G\}, \quad (5)$$

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

1. Increasing functions. W_i (weighted averages) are calculated by applying the formula (6):

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

2. Ask the Decision Maker (DM) to give the parameters p (a percentage) of the formula (7) to calculate the thresholds α_i^l of increasing functions W_i:

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

3. Apply the assignment process (8) to the categories, following the steps below ($step$ 1 to $step$ M):

$$\begin{cases} \text{step 1: if } \exists\ i \in \{1,2, \ldots, G\}, W_i(X^k)\ \alpha_i^1(p), \text{assign } X^k \text{ to } C_1; \\ \text{step 2: if } \exists\ i \in \{1,2, \ldots, G\}, W_i(X^k) \leq \alpha_i^2(p), \text{ and } not(X^k \in C_1), \text{assign } X^k \text{ to } C_2; \\ \text{tep 3: if } \exists\ i \in \{1,2, \ldots, G\}, W_i(X^k) \leq \alpha_i^3(p), \text{ and } not(X^k\ C_1) \text{ and } not(X^k\ C_2), \text{assign } X^k \text{ to } C_3 \\ \vdots \\ \text{step } M\text{: if } X^k \text{ does not satisfy the step 1 to step M} - 1, \text{ assign } X^k \text{ to } C_M \end{cases} \quad (8)$$

4. Solving the mathematical programming problem (9):

$$\max_{w_{i,j}} f_{opt} = \sum_{l=1}^{M} l \times |C_l|$$
$$\text{s.t.} \begin{cases} w_{i,1} \geq w_{i,2} \geq \cdots \geq w_{i,|G_i|}\ \forall\ i \in \{1, \ldots, G\}, \\ \sum_{j=1}^{|G_i|} w_{i,j} = 1, \ \forall\ i \in \{1, \ldots, G\}, \\ assignment\ process\ (8). \end{cases} \quad (9)$$

At the optimum, alternatives or actions are assigned to their best categories.

2.2.2. KEMIRA-Sort Algorithm

Table 2 describes the KEMIRA-Sort algorithm used to solve mathematical programming problem (9).

Table 2. *KEMIRA-Sort algorithm.*

1: Fix algorithm parameters:

2: $10^{-3} \leq \epsilon \leq 10^{-1}$, the initial iteration $t = 0$, the maximum of iterations $\max_{iter}$,

3: Thresholds: $0 < \alpha_i^1(p) < \cdots < \alpha_i^{M-1}(p) < 1$.

4: Randomly choose an initial weights vector satisfying the conditions (5) and (4):

5: $w^0 = (w_{1,1}^0, \cdots, w_{1,|G_1|}^0; w_{2,1}^0, \cdots, w_{2,|G_2|}^0; \cdots; w_{G,1}^0, \cdots, w_{G,|G_G|}^0)$

6: Randomly choose a vector direction Δw:

7: Increment the number of iterations: $t = t + 1$

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8: Compute the vector w^t = w^0 + ϵ × Δw
9: if w^1 does not meet the restrictions (5) and (4) then
10:    apply the corrections proposed by Krylovas et al. [13]:
11:       for i, j
12:          if w^t_{i,j} < 0 then
13:             change: w^t_{i,j} = 0.
14:          end if
15:          if w^t_{i,j} < w^t_{i,j+1} then
16:             change: w^t_{i,j} = w^t_{i,j+1}
17:          end if
18:          if s_i = ∑_{j=1}^{|G_i|} w^t_{i,j} ≠ 1 then
19:             change: w^1_{i,j} = w^1_{i,j} / s_i
20:          end if
21:       end for
22: end if
23: Compute the W_i(X^k) as in (6) using w^0 values and run the condition (8).
24: Compute the value of the objective function f^0_opt as indicated in (9)
25: if t > max_iter then
26:    stop the algorithm
27: else
28:    Compute W_i(X^k) as in (6) using w^t values and execute the condition (8).
29:    Compute the value of the current objective function f^t_opt as indicated in (9).
30:    if f^t_opt > f^0_opt then
31:       change: f^0_opt = f^t_opt, w^0 = w^t and go to step 7 of the algorithm
32:    else
33:       go to step 4 of the algorithm.
34:    end if
35: end if
```

3. Results

3.1. Wild Animals Selected for the Wédbila Wildlfe Farm (WWF)

The structuring phase allows us to identified fifteen (15) wild animals (alternatives) listed as follows:

1. A couple of pork - spicy (Hystrix Cristata: X^1)
2. A couple of warthogs (Phacochoerus africanus: X^2)
3. A couple of dorcas gazelle (Gazella Dorcas: X^3)
4. A couple of Guib Harnache ´(Tragelaphus Seriptus: X^4)
5. A family of aulacodes (Thryonomys swinderianus: X^5)
6. A couple of flanked duiker (cephalophus rufilatus: X^6)
7. A couple of Grimm's duiker (Sylvicapra grimmia: X^7)
8. A family of Gambia rats (cricetomys: X^8)
9. A couple of ring-necked tortoise (Geochelone sulcate: X^9)
10. A couple of red-fronted gazelle (Gazella rufifrons: X^{10})
11. A couple of red-necked ostrich (Struthio camelus: X^{11})
12. A couple of defassa cobe (ellipsiprymnus: X^{12})
13. A couple of hartebeest major (Alcelaphus buselaphus:

X^{13})

14. A couple of black hippotrague (Hippotragus niger: X^{14})
15. A couple of striped jackal (Lupulella adusta: X^{15})

Figure 1 give some pictures of these wild animals.

3.2. Choice of Evaluation Criteria

The criteria for evaluating the alternatives were identified in common agreement with the manager of the WWF, who has long experience in farm management and who also played the role of decision- maker. This enabled us to select fourteen criteria divided into three groups summarized in Table 3.

1. The group 1, named aspects of reproduction is made up of seven criteria.
2. The group 2, named investment aspects is made up of four criteria.
3. The group 3, called economic aspects, is made up of three criteria.

In each group, the criteria were ranked from best to worst

Table 3. *Group 1, Group 2 and Group 3 of criteria*.

Criteria	Indicators	Objective
(1, 1)	life expectancy (in years)	maximize
(1, 2)	the number of babies per year	maximize
(1, 3)	sexual maturity (in days)	minimize
(1, 4)	commercial age (in days)	minimize
(1, 5)	gestation time (in days)	minimize
(1, 6)	interval between litters (in days)	minimize
(1, 7)	mortality rate (as a percentage)	minimize
(2, 1)	annual feed cost (in CFA)	minimize
(2, 2)	annual cost of care (in CFA)	minimize
(2, 3)	housing construction costs (in CFA)	minimize
(2, 4)	cost of materials for daily use (in CFA)	minimize
(3, 1)	3-year rate of return (in CFA) maximize	maximize
(3, 2)	training demand (scale from 1 to 15) maximize	maximize
(3, 3)	gains on visits per year (scale from 1 to 15) maximize	maximize

3.3. WWF Evaluation Matrix

The evaluation of each alternative w.r.t. the 14 criteria (see Table 4) was carried out using documents from the literature review on wild animals [15-20], data from daily animal monitoring and the WWF archives.

Table 4. *Evaluation matrix.*

Alternatives	Criteria													
	(1, 1)	(1, 2)	(1, 3)	(1, 4)	(1, 5)	(1, 6)	(1, 7)	(2, 1)	(2, 2)	(2, 3)	(2, 4)	(3, 1)	(3, 2)	(3, 3)
X^1	20	3.6	720	150	48	150	0.03	111600	4800	500000	60000	3600000	15	8
X^2	21	2	1260	180	175	360	0.05	257000	24590	450000	75000	1250000	15	7
X^3	12	1	720	180	180	360	0.03	60000	16990	600000	35500	3000000	10	10
X^4	12	1.5	720	180	180	240	0.05	65000	3865	600000	41500	4800000	10	8
X^5	6	24	180	90	90	180	0.05	174960	2100	137750	58000	10800000	15	6

Alterna-tives	Criteria													
	(1, 1)	(1, 2)	(1, 3)	(1, 4)	(1, 5)	(1, 6)	(1, 7)	(2, 1)	(2, 2)	(2, 3)	(2, 4)	(3, 1)	(3, 2)	(3, 3)
X^6	15	1	720	180	210	360	0.03	45000	3090	600000	43500	2700000	5	9
X^7	14	2	480	180	210	270	0.03	239040	3090	1568500	43500	2700000	5	9
X^8	8	96	180	180	32	60	0.05	4363200	2100	100000	44000	10800000	10	5
X^9	50	24	180	180	32	360	0.05	900000	5400	1066500	43500	4500000	5	4
X^{10}	14	1	540	180	189	360	0.03	14400	16990	1568500	35500	3000000	10	10
X^{11}	40	8	1440	45	42	360	0.01	219000	10000	838250	35500	74000000	5	15
X^{12}	18	1	1050	270	240	360	0.05	720000	60000	802750	42500	7500000	5	14
X^{13}	19	1	810	720	245	360	0.03	720000	60000	802750	42500	15000000	5	11
X^{14}	20	1	1800	270	270	360	0.03	912500	80000	802750	42500	25000000	5	13
X^{15}	16	6	240	60	60	365	0.05	146000	6000	1022750	42500	4800000	5	12
objective	max	max	min	min	min	min	min	min	min	min	min	max	max	max

The data were then normalized using relation (*2*) and the normalized evaluation matrix presented in Table 5 (with all the criteria to be maximized).

Table 5. *Normalized evaluation matrix.*

Alterna-tives	Criteria													
	(1, 1)	(1, 2)	(1, 3)	(1, 4)	(1, 5)	(1, 6)	(1, 7)	(2, 1)	(2, 2)	(2, 3)	(2, 4)	(3, 1)	(3, 2)	(3, 3)
X^1	0.318	0.027	0.666	0.844	0.932	0.704	0.5	0.977	0.965	0.7276	0.379	0.032	1.	0.363
X^2	0.340	0.010	0.333	0.8	0.399	0.016	0.	0.944	0.711	0.761	0	0.	1.	0.272
X^3	0.136	0.	0.666	0.8	0.378	0.016	0.5	0.989	0.808	0.659	1	0.024	0.5	0.545
X^4	0.136	0.005	0.666	0.8	0.378	0.409	0.	0.988	0.977	0.659	0.848	0.048	0.5	0.363
X^5	0.	0.242	1.	0.933	0.756	0.606	0.	0.963	1.	0.974	0.430	0.131	1.	0.181
X^6	0.204	0.	0.666	0.8	0.252	0.016	0.5	0.992	0.987	0.659	0.797	0.019	0.	0.454
X^7	0.181	0.010	0.814	0.8	0.252	0.311	0.5	0.992	0.987	0.659	0.797	0.019	0.	0.454
X^8	0.045	1.	1.	0.8	1.	1.	0.	0.	1.	1.	0.784	0.131	0.5	0.090
X^9	1	0.242	1.	0.8	1.	0.016	0.	0.796	0.957	0.341	0.797	0.044	0.	0.
X^{10}	0.181	0.	0.777	0.8	0.340	0.016	0.5	1.	0.808	0.	1.	0.024	0.5	0.545
X^{11}	0.772	0.073	0.222	1.	0.957	0.016	1.	0.952	0.898	0.497	1.	1.	0.	1.
X^{12}	0.272	0.	0.462	0.666	0.126	0.016	0.	0.837	0.256	0.521	0.822	0.085	0.	0.909
X^{13}	0.295	0.	0.611	0.	0.105	0.016	0.5	0.837	0.256	0.521	0.822	0.189	0.	0.636
X^{14}	0.318	0.	0.	0.666	0.	0.016	0.5	0.793	0.	0.521	0.822	0.326	0.	0.818
X^{15}	0.227	0.052	0.962	0.977	0.882	0.	0.	0.969	0.949	0.371	0.822	0.048	0.	0.727
objective	max	max	max	max	max	max	max	max	max	max	max	max	max	max

3.4. Empirical Assignment of Alternatives

Recall that we wanted to assign the wild animals (alternatives) according to four ordered categories: the C_4 category for the best wild animals promoting sustainable management of the wildlife farm; the C_1category for the worst animals; and two intermediate C_2 and C_3 categories for animals that do not belong to either the C_1 or C_4 categories. In order to guide the analyst in the choice of parameters for implementing KEMIRA-Sort method, we (playing the role of analyst) asked the decision-maker to give us examples of category assignments based on his experience. Empirically, the decision-maker was able to provide us with assignment examples as summarized in Table 6. Note that while the decision-maker was sure about his examples of assignment to the best category C_4 and to the worst category C_1, he was more hesitant about assigning alternatives to the intermediate categories C_2 and C_3. Consequently, according to the decision-maker, the examples of assignment to category C_2 could just as well correspond to those of category C_3.

Table 6. *Examples of empirical assignment.*

Alternatives	Assignment categories
X^6, X^7, X^9	C_1
	C_2
X^3, X^8, X^{10}	C_3
X^1, X^2, X^5	C_4

3.5. Running KEMIRA-sort Algorithm

3.5.1. Setting Parameters

We have implemented KEMIRA-Sort algorithm in python language. The parameters of the KEMIRA-Sort algorithm have been chosen in such a way as to match the results in Table 6 as closely as possible. This enabled us to set the performance threshold values $\alpha_i^l(p)$ as presented in Table 7 and Table 8, and the following parameters:

The maximum number of iterations is set at 100000 ($\max_{iter}$ = 100000).

The parameter p varies over the set $p \in \{40\%; 45\%; 60\%\}$ and can be used to create tiers of three (03) thresholds as a function of p as stated in relation (*7*).

The value of ϵ is set to ϵ = 0.01

KEMIRA-Sort algorithm begins by randomly choose a vector:

$$w^0 = (w_{1,1}^0, \cdots, w_{1,|G_1|}^0; w_{2,1}^0, \cdots, w_{2,|G_2|}^0; \cdots; w_{G,1}^0, \cdots, w_{G,|G_G|}^0)$$

satisfying relations (4) and (5).

Here w^0 = (0.19, 0.17, 0.17, 0.16, 0.14, 0.1, 0.07; 0.4, 0.35, 0.14, 0.11; 0.61, 0.35, 0.04) is the initial weights vector for starting iteration.

3.5.2. Results with the Initial Values of Parameters

With the values of parameters as set in section 3.5.1, KEMIRA-sort algorithm implemented in python gave the result summarized in the Table 7 and Table 8.

In the first part of Table 7:

The columns $W_i(X^k) = \sum_{j=1}^{n_i} w_{i,j} \times x_{i,j}^k, i \in \{1,2,\cdots,G\}$ give us the average performance of the alternatives in relation to each group of criteria;

Considering columns C_1, C_2, C_3, C_4, the number 1 (respectively 0) in the Table 6 indicates that the alternative is assigned (respectively not assigned) to the corresponding category.

In the second part of the Table 7:

the different performance thresholds for the different criteria groups are represented. Each group of criteria G_i, is assigned three thresholds $\alpha_1^l(p), \alpha_2^l(p), \alpha_3^l(p), l \in \{1,2,3\}$.

The initial weights vector w^0 satisfying the relations (4) and (5) allowed the algorithm to find the first assignment of alternatives to categories and the value of the objective function $f_{opt}^0 = 26$.

Table 7. *Result with the initial values.*

	$W_1(X^k)$	$W_2(X^k)$	$W_3(X^k)$	C_1	C_2	C_3	C_4
X^1	0.549	0.872	0.384	0	0	1	0
X^2	0.308	0.733	0.360	0	1	0	0
X^3	0.356	0.881	0.211	0	0	0	1
X^4	0.362	0.923	0.219	0	0	0	1
X^5	0.527	0.918	0.437	0	0	0	1
X^6	0.352	0.922	0.030	1	0	0	0

	$W_1(X^k)$	$W_2(X^k)$	$W_3(X^k)$	C_1	C_2	C_3	C_4
X^7	0.404	0.812	0.030	1	0	0	0
X^8	0.716	0.576	0.258	1	0	0	0
X^9	0.670	0.789	0.027	1	0	0	0
X^{10}	0.379	0.793	0.211	1	0	0	0
X^{11}	0.562	0.875	0.65	0	0	0	1
X^{12}	0.256	0.588	0.088	1	0	0	0
X^{13}	0.211	0.588	0.140	1	0	0	0
X^{14}	0.203	0.480	0.231	1	0	0	0
X^{15}	0.495	0.862	0.058	1	0	0	0
$\alpha_1^l(40\%)$,	0.2864	0.3692	0.26				
$\alpha_2^l(45\%)$,	0.3222	0.4153	0.2925				
$\alpha_3^l(60\%)$,	0.4296	0.5538	0.39				

3.5.3. Final Iteration Results

The results become stable at the hundred thousandth iteration, with the optimum of the objective function, f_{opt}^{100000}, always equal to 34 and an execution time of around 65 seconds.

The final weights vector

$$w^{100000} = \begin{pmatrix} 0.21, 0.2, 0.19, 0.18, 0.14, 0.06, 0.02;\ 0.375, 0.365, \\ 0.230, 0.028;\ 0.530, 0.448, 0.020 \end{pmatrix}$$

satisfying the relations (4) and (5) computed by the algorithm allowed to find the final assignment of alternatives to categories and the value of the objective function $f_{opt}^{100000} = 34$.

So after the hundred thousandth iterations, the categorization results no longer change, giving the result summarized in Table 8.

Table 8. *Final iteration Results.*

	$W_1(X^k)$	$W_2(X^k)$	$W_3(X^k)$	C_1	C_2	C_3	C_4
X^1	0.533	0.898	0.473	0	0	0	1
X^2	0.337	0.789	0.454	0	0	1	0
X^3	0.363	0.847	0.248	0	0	1	0
X^4	0.377	0.904	0.257	0	0	1	0
X^5	0.548	0.963	0.522	0	0	0	1
X^6	0.359	0.908	0.019	1	0	0	0
X^7	0.403	0.739	0.019	1	0	0	0
X^8	0.743	0.618	0.295	0	0	1	0
X^9	0.733	0.750	0.023	1	0	0	0
X^{10}	0.388	0.699	0.248	0	0	1	0
X^{11}	0.554	0.829	0.551	0	0	0	1
X^{12}	0.283	0.552	0.064	1	0	0	0
X^{13}	0.203	0.552	0.113	1	0	0	0

	$W_1(X^k)$	$W_2(X^k)$	$W_3(X^k)$	C_1	C_2	C_3	C_4
X^{14}	0.197	0.441	0.189	1	0	0	0
X^{15}	0.540	0.820	0.040	1	0	0	0
$\alpha_1^l(40\%)$,	0.2972	0.3852	0.2204				
$\alpha_2^l(45\%)$,	0.3343	0.4333	0.2479				
$\alpha_3^l(60\%)$,	0.4458	0.5778	0.3306				

4. Discussion

We find that, among the feasible solution of our mathematical programming problem (9), the ones with the best economic function value is given by the objective function value $f_{opt}^{100000} = 34$. The optimal value of the economic function thus identified, is the one enables us to obtain a best categorization, presented in Table 8, associated to the set of weights

$$w^{100000} = \begin{pmatrix} 0.21, 0.2, 0.19, 0.18, 0.14, 0.06, 0.02;\ 0.375, 0.365, 0.230, \\ 0.028;\ 0.530, 0.448, 0.020 \end{pmatrix}$$

which is a solution of the mathematical programming problem (9).

As shown the results presented in Table 1, a best choices of the KEMIRA-Sort algorithm parameters allows us to have alternatives assigned to categories such a way to respect as much as possible all the empirical assignment examples given by the decision-maker (see Table 6). More specifically, the final assignment given by KEMIRA-Sort method, showed that:

"Ephalophus rufilatus" (X^6), "Sylvicapra grimmia" (X^7), "Geochelone sulcata" (X^9), "Kobus

Ellipsiprymnus" (X^{12}), "Alcelaphus buselaphus" (X^{13}), "Hippotragus niger" (X^{14}), "Lupulella adusta" (X^{15}) are assigned to the worst category C_1;

No alternatives assigned to category C_2;

"Phacochoerus africanus" (X^2), "Gazella dorcas" (X^3), "Tragelaphus Seriptus" (X^4), "cricetomys" (X^8), "Gazella rufifrons" (X^{10}), are assigned to C_3 category;

"Hystrix Cristata" (X^1), "Thryonomys swinderianus" (X^5), "Struthio camelus" (X^{11}) are assigned to the best category C_4;

Two animals have been added among the best categoties C_3 and C_4 (comparing with examples of empirical assignment to categories of Table 6) which are respectively the "Tragelaphus Seriptus" (X^4) and the "Struthio camelus"(X^{11}).

Empirically:

Most of this result reflects the estimate given by the manager (playing the role of decision- maker) of the Wédbila Demonstration Farm (WDF) at the very start of our study, and this validate our findings. Note that using examples of empirical assignment to categories allowed us to elicit indirectly the performance thresholds, $\alpha_1^l(p)$, $\alpha_2^l(p)$, $\alpha_3^l(p), l \in \{1,2,3\}$, of KEMIRA-Sort method. This way of eliciting parameters has already been successfully tested by Zheng et al. [21], Kadziński and Ciomek [22].

The information given by the decision-maker relative to weights elicitation was not rich (i.e. imprecise). Indeed, in each group, he had to give a ranking of criteria according to their importance $(i,1) \gtrsim (1,2) \gtrsim \ldots \gtrsim (i,|G_i|),\ \forall\, i \in \{1,\ldots,G\}$; i.e. we only have information on the ranking order of the criteria in each group, which is usually an information easy to provide by the DM. As a result, the set of weights to be investigated as a solution for the mathematical programming problem (9) was very large. This can result in a long algorithm execution time in case of large data dimension to find a suitable weights vector as solution for the mathematical programming problem (9).

Assessing the suitability of wild animal species for sustainable farm management is a new concept, as reported in [7]. To the best of our knowledge, we have yet to see such an evaluation carried out by any other method. In the future, we plan to carry out such an evaluation using other methods, and compare the results in order to consolidate the evaluation approach we have proposed.

5. Conclusions

For sustainable management of a wildlife farm, the choice of animals is of prime importance. Evaluating alternatives (animals) based on criteria, using the KEMIRA-Sort method, enabled us to identify "Phacochoerus africanus" (X^2), "Gazella dorcas" (X^3), "Tragelaphus Seriptus" (X^4), "cricetomys" (X^8), "Gazella rufifrons" (X^{10}), "Hystrix Cristata" (X^1), "Thryonomys swinderianus" (X^5), "Struthio camelus" (X^{11}) as the most appropriate for the sustainable management of the Wédbila Wildlife Farm (WWF). Most of this result reflects the estimate given by the manager of the WWF at the very start of our study, and this supports our findings. Furthermore, to demonstrate the credibility of our results, we plan to apply the KEMIRA-Sort method to other contexts of sustainable livestock farm management, and to compare it with other multiple criteria sorting methods.

Abbreviations

CDPF	Centre de Développement et de Production Faunique
KEMIRA	KEmeny Median Indicator Ranks Accordance
MCDM	Multi-Criteria Decision Making
WWF	Wédbila wildlfe farm

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Author Contributions

Gilbert Tapsoba: Data curation, Software, Writing – original draft

Stéphane Aimé Metchebon Takougang: Conceptualization, Data curation, Methodology, Supervision, Writing – original draft

Désiré Ouédraogo: Data curation, Validation

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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