

Comparison of Brans Promethee multicriteria decision method and Promethee modified by authors for the optimization of an erosion control integral plan in Chaco area in Salta province (Argentina)

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Abstract- Chaco area is situated in the Province of Salta at North West of Argentina. The desertification is a big problem. In order to mitigate the problem it is necessary to take into account not only pedologic criteria but the economical, environmental, cultural and sociological criteria. Six sub zones have been established following previous studies. Eight criteria and six alternatives have been introduced in the model. Following the results of the study carried out by a collaborative project between UPM and UCS financed by AECID (1) were established several initial matrix. Brans Promethee Multicriteria Decision Method (MCDM) was applied and the authors modified that method introducing weights like in Electre Method.

I. INTRODUCTION

The Salta Province has 155.000 km² and 1 million population, it is at NW of Argentina (NOA) having latitudes around 25°S, it has rain from 400 to 800 mm/year. It has a low density of population in small cities and Indian places "puestos" or "colonias". It has low standards for roads and it has an environment that is "deteriorating progressively". Water is the most critical factor, as much for human and animal consumption, as for the production system in general and for the flooding and lack of appropriated infrastructures. Besides the water, other factors have an important influence in the erosion and progressive desertification of this region and environment degradation. Historically the human exploitation of natural forest to use in the railway and other activities produced an environment degradation process. Later on the autochthonous population followed the irrational wood extraction an over pasture as "modus vivendi" contributing to make the situation worse. Actually the farms and big single-crop exploitations in some locations do not give solution to the desertification problem. Only one integral plan considering all factors involved and the differences among sub zones will be an initial point to change the direction of the desertification process.

A. Criteria, alternatives and Sub zones

The following eight criteria were defined:

Water erosion (WE): The water erosion is important. The relative water erosion indexes figures in the decisional matrix.

Eolian erosion (EE): Winds erode, transport and deposit

materials and are effective agents in several areas of this region.

Implementation Facility (IF): They have been established taking into account actors' opinions.

Water Resources (WR): By each alternative have been considered and the relative results have been taken into this criterion.

Economical benefits (EB): The relative economical benefits using each alternative in a period of 25 years have been obtained as shown in the matrix with figures from 1 to 10.

Hand power (HP): We have considered that would be satisfactory to give employment to the majority of it population. For that, we have considered this criterion as of "more is better" kind.

Environmental Impacts (EI): They have been considered in each sub zone the environmental impacts according with the alternative adopted.

Social Acceptance (SA): The figures included in this criterion have been obtained from the results of different forums and meeting with institutions, organizations and native people.

Five alternatives have been retained:

A) **Autochthonous forest:** mainly "Quebracho Blanco" and "Quebracho Colorado" forest species.

B) **High value forest:** mainly teak, ebony, walnut tree, cherry tree, lignum vitae, eucalyptus, etc

C) **Traditional farms** with extensive agriculture and livestock mixed with autochthonous forest modified and several foraging plants.

D) **Erosion control Crop with agriculture use.**

E) **Erosion control crop with industrial use (biomass).**

Following the experience and the local acknowledge, the area has been divided in 6 **sub zones**: Las Lajitas, La Estrella, Pichanal, Martin Hickmann, Rivadavia banda sur and Joaquín V. Gonzalez.

II. METHODOLOGY

We have used the Preference Ranking Organization Method (The PROMETHEE Method for Multiple Criteria Decision-Making) by Ref. [4, 13, 14]. This is an outranking method, as

ELECTRE due to Roy [11, 12] or A.H.P. due to Saaty [15, 16, 17]. Following Ref. [4, 13, 14] two possibilities are offered, PROMETHEE I provides a partial preorder and PROMETHEE II a total preorder on the set of possible alternatives. Different types of criteria have been adopted.

Type I and Type III with different threshold (m). Type I is the usual Criterion. With this criterion if $f(a) = f(b)$ this is indifference between a and b. If this is not the case the decision-maker has a strict preference for the action having greatest value. Type III is the Criterion with Linear Preference. Such an extension of the notion of criterion allows the decision-maker to prefer progressively a to b for progressively larger deviations between $f(a)$ and $f(b)$. The preference increases linearly until deviation equals m, after this value the preference is strict. For m the values 2, 4 and 6 have been taken.

The authors have modified the PROMETHEE method using the weights of the criteria following the ELECTRE I Method [6, 1, 2, 3, 7, 8, 9, 10]. In the case I have been adopted the same weights for all sub zones and in the case II different weights

Besides, some modifications have been considered in the data of the initial matrixes.

Finally, MathCad has been used to program the calculus.

We show below, like example, the application to sub zone "La Estrella".

EROSION AND DESERTIFICATION INTEGRAL CONTROL PLAN USING PROMETHEE

SUB ZONE LA ESTRELLA (1)

ORIGIN:=1

CRITERION: 1.-water erosion index 2.- eolian erosion index, 3.- Implementation facility 4.-Water Resources, 5.- Economical Benefits, 6.- Hand power, 7.-Environmental Impacts, 8.- Social Acceptance

alternatives i
1 2 3 4 5

$$t := \begin{bmatrix} 7 & 7 & 3 & 2 & 3 \\ 6 & 6 & 3 & 2 & 2 \\ 1 & 5 & 6 & 6 & 8 \\ 8 & 4 & 4 & 4 & 5 \\ 5 & 5 & 8 & 5 & 8 \\ 2 & 9 & 9 & 6 & 6 \\ 8 & 6 & 3 & 5 & 4 \\ 6 & 5 & 9 & 6 & 8 \end{bmatrix}$$

Alternatives:
i = 15.

Indice lsubj:
más es mejor lsubj = 1
más es peor lsubj = -1

$$I := \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad W := \begin{bmatrix} 0.20 \\ 0.15 \\ 0.15 \\ 0.10 \\ 0.10 \\ 0.10 \\ 0.10 \\ 0.10 \\ 0.10 \end{bmatrix}$$

with $x >= 0$, if not with $|x|$

A- functions of criterion-parameter and type elected for each criterion j: following Ref. [4]
j = 1 type III, m=2, j = 2 type III, m=4, j=3 type III, m=4, j=4 type I j = 5 type I, j = 6 type III, m=6, j=7 type III, m=6 j=8 type III, m=2

$$p1(x) := \text{if} \left(x \leq 2, \frac{x}{2}, 1 \right)$$

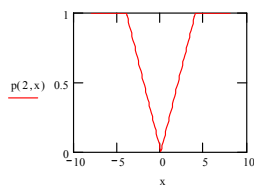
$$p4(x) := \text{if} (x=0, 0, 1)$$

$$p3(x) := \text{if} \left(x \leq 6, \frac{x}{6}, 1 \right)$$

$$p2(x) := \text{if} \left(x \leq 4, \frac{x}{4}, 1 \right)$$

$$p(j, x) := \begin{cases} y \leftarrow |x| \\ z \leftarrow p1(y) & \text{if } j=1 \\ z \leftarrow p2(y) & \text{if } j=2 \\ z \leftarrow p2(y) & \text{if } j=3 \\ z \leftarrow p4(y) & \text{if } j=4 \\ z \leftarrow p4(y) & \text{if } j=5 \\ z \leftarrow p3(y) & \text{if } j=6 \\ z \leftarrow p3(y) & \text{if } j=7 \\ z \leftarrow p1(y) & \text{if } j=8 \\ z \end{cases}$$

x := -8, -7.9, 8



With this outranking graph, función de preference adopted:

$$P(i, ii, j) := \text{if} \left[1; \left(t_{j,i} - t_{j,ii} \right) \leq 0, 0, P \left(j, \left| t_{j,i} - t_{j,ii} \right| \right) \right]$$

A.- Results following initial methods of Ref [4]:

Indices q(i,ii) of preferences (pi(ii) Brans&Vincke), giving outranking graphs according with values

$$i := 1..5 \quad ii := 1..5 \quad qq_{i,ii} := q(i, ii)$$

$$qq = \begin{bmatrix} 0 & 0.229 & 0.448 & 0.438 & 0.458 \\ 0.25 & 0 & 0.281 & 0.333 & 0.354 \\ 0.5 & 0.281 & 0 & 0.406 & 0.156 \\ 0.208 & 0.094 & 0.042 & 0 & 0.021 \\ 0.458 & 0.469 & 0.208 & 0.5 & 0 \end{bmatrix}$$

$$q(i, ii) := \frac{\sum_{j=1}^8 P(i, ii, j)}{8}$$

$$\begin{aligned} \text{Outgoing flow: } fp(i) &:= \sum_{ii=1}^5 q(i, ii) & fpp_i &:= fp(i) \\ \text{Incoming flow: } fm(i) &:= \sum_{ii=1}^5 q(ii, i) & fmm_i &:= fm(i) \end{aligned} \quad fpp = \begin{bmatrix} 1.417 \\ 1.073 \\ 0.979 \\ 1.677 \\ 0.99 \end{bmatrix} \quad fmm = \begin{bmatrix} 1.573 \\ 1.219 \\ 1.344 \\ 0.365 \\ 1.635 \end{bmatrix}$$

PROMETHEE II (classification of alternatives by Total Preorder, Each alternative obtain one value(more is better):

$$fd(i) := fp(i) - fm(i) \quad fdd_i := fd(i) \quad fdd = \begin{bmatrix} 0.156 \\ 0.146 \\ 0.365 \\ -1.313 \\ 0.646 \end{bmatrix}$$

PROMETHEE I (classification of alternatives by Partial Preorden):

$$pr(i, ii) := \begin{cases} z \leftarrow -1 \\ z \leftarrow 0 & \text{if } (fp(i)=fp(ii)) \wedge (fm(i)=fm(ii)) \\ z \leftarrow 1 & \text{if } ((fp(i) > fp(ii)) \wedge (fm(i) < fm(ii))) \vee ((fp(i) > fp(ii)) \wedge (fm(i)=fm(ii))) \vee ((fp(i)=fp(ii)) \wedge (fm(i) < fm(ii))) \end{cases}$$

pr_{i,ii} := pr(i, ii)

$$pr = \begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 \end{bmatrix}$$

Alternative E is preferred (E C A B D).

B Results following the method modified by Ref [6] in order to weigh comparativment the criteria with similar weights to ELECTRE-I:

q Preference Index (pi Ref. [4]), gives outranking graph by values

$$i := 1..5 \quad ii := 1..5 \quad qq_{i,ii} := q(i, ii) \cdot 5 \quad q(i, ii) := \sum_{j=1}^8 P(i, ii, j) \cdot W_j$$

$$qq = \begin{bmatrix} 0 & 0.917 & 2.479 & 2.5 & 2.583 \\ 1.25 & 0 & 1.813 & 2.083 & 2.167 \\ 2.25 & 1.188 & 0 & 1.938 & 0.688 \\ 1.083 & 0.438 & 0.167 & 0 & 0.083 \\ 2.083 & 2.063 & 0.958 & 2.375 & 0 \end{bmatrix}$$

$$\begin{aligned} \text{Outgoing flow: } fp(i) &:= \sum_{ii=1}^5 q(i, ii) & fpp_i &:= fp(i) \\ \text{Incoming flow: } fm(i) &:= \sum_{ii=1}^5 q(ii, i) & fmm_i &:= fm(i) \end{aligned} \quad fpp = \begin{bmatrix} 1.696 \\ 1.463 \\ 1.213 \\ 0.354 \\ 1.496 \end{bmatrix} \quad fmm = \begin{bmatrix} 1.333 \\ 0.921 \\ 1.083 \\ 1.779 \\ 1.104 \end{bmatrix}$$

PROMETHEE II (classification of alternatives by Total Preorder)

$$fd(i) := fp(i) - fm(i) \quad fdd_i := fd(i) \quad fdd = \begin{bmatrix} 0.363 \\ 0.542 \\ 0.129 \\ -1.425 \\ 0.392 \end{bmatrix}$$

PROMETHEE I (classification of alternatives by Partial Preorden):

$$pr(i, ii) := \begin{cases} z \leftarrow -1 \\ z \leftarrow 0 & \text{if } (fp(i)=fp(ii)) \wedge (fm(i)=fm(ii)) \\ z \leftarrow 1 & \text{if } ((fp(i) > fp(ii)) \wedge (fm(i) < fm(ii))) \vee ((fp(i) > fp(ii)) \wedge (fm(i)=fm(ii))) \vee ((fp(i)=fp(ii)) \wedge (fm(i) < fm(ii))) \end{cases}$$

where, pr(i,ii) = 1 tell us that alternative i is preference (outranks) to alternative j, pr(i,ii) = 0 is indifference, y pr(i,ii) = -1 are incomparable, that may be obtained by pr(ii, i).

$$pr_{i,ii} := pr(i, ii) \quad pr = \begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix}$$

Alternative B is preferred (B E A C D).

III. RESULTS

1. Sub zone Martin Hickman

1.1. ALTERNATIVE 1:

Table I shows the values to Martin Hickman sub-zone. It has been included the type of pseudo-criteria used and the threshold (m) for the type III [4].

TABLE I
DECISIONAL MATRIX FOR MARTIN HICKMAN, ALTERNATIVE 1

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	9	8	5	8	7	2	8	2
B	7	5	7	5	6	8	6	5
C	4	2	8	4	8	8	1	9
D	3	3	6	4	6	7	5	6
E	3	3	2	6	8	6	5	8
Weight	0.2	0.2	0.05	0.1	0.1	0.1	0.15	0.1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			2	2	4

Two procedures have been applied in order to obtain alternative preorder:

- A: Initial method of Ref. [4].
- B: Method modified by Ref. [6].

1.1.A. Results by Ref. [4] method. The preorder is shown in Fig. 1.

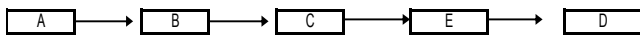


Fig. 1 Graph sub zone Martin Hickman, alternative 1.1A, Promethee II.

1.1. B Results following Ref. [9] method are shown in Fig. 2.



Fig. 2: Graphs sub zone Martin Hickman 1.1B Promethee II, modified.

1.2 ALTERNATIVE 2: Other value of criteria, same weight, pseudocriteria and thresholds (Table II and Fig. 3 and 4).

TABLE II
DECISIONAL MATRIX FOR MARTIN HICKMAN, ALTERNATIVE 2.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	9	8	5	8	7	7	8	2
B	7	5	7	5	8	8	6	5
C	7	5	8	4	8	8	6	9
D	3	3	6	4	6	7	5	6
E	3	3	8	6	8	6	5	8
Weight	0.2	0.2	0.05	0.1	0.1	0.1	0.15	0.1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			2	2	4

1.2. A. Results by method of Ref. [4] method. The preorder is shown in Fig. 3.

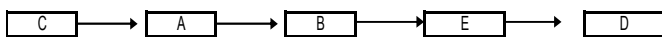


Fig. 3: Graphs sub zone Martin Hickman, alternative 1.2.A . Promethee II

1.2. B. Results following Ref [9] method are shown in Fig. 4.

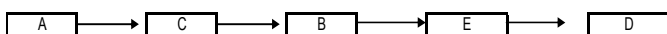
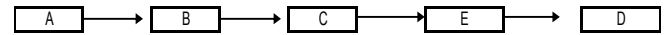


Fig. 4: Graphs sub zone Martin Hickman, alternative 1.2.B. Promethee II, modified.

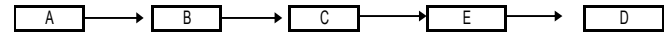
Changing the weights (0,2 – 0,15 – 0,15 – 0,10 – 0,10 – 0,10

– 0,10 – 0,10), the results are:

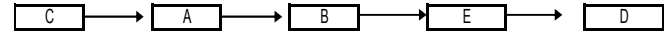
1.1.A



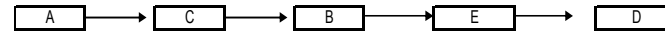
1.1.B



1.2.A



1.2.B



2. Sub zone LA ESTRELLA

2.1. ALTERNATIVE 1: Decisional matrix is shown in Table III.

TABLE III
DECISIONAL MATRIX FOR LA ESTRELLA, ALTERNATIVE 1.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	7	6	1	8	5	2	8	6
B	7	6	5	4	5	9	6	5
C	3	3	6	4	8	9	3	9
D	2	2	6	4	5	6	5	6
E	3	2	8	5	8	6	4	8
Weight	0.15	0.15	0.15	0.1	0.15	0.1	0.1	0.1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			6	6	2

2.1A. Results by Ref [4] method. The preorder is shown in Fig. 5.

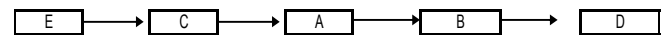


Fig. 5: Graph sub zone La Estrella alternative 2.1A Promethee II

2.1B. Results following Ref [6] method are shown in Fig. 6.

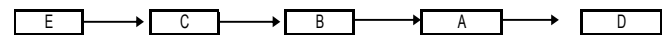


Fig. 6: Graphs sub zone La Estrella alternative 2.1B Promethee II, modified.

2.2. ALTERNATIVE 2: Changing some criteria values and maintaining weights (Table IV).

TABLE IV
DECISIONAL MATRIX FOR LA ESTRELLA, ALTERNATIVE 2.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	7	6	5	8	5	6	8	6
B	7	6	5	4	5	9	6	5
C	3	3	6	4	8	9	3	9
D	2	2	6	4	5	6	5	6
E	3	2	8	5	8	6	4	8
Weight	0.15	0.15	0.15	0.1	0.15	0.1	0.1	0.1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			6	6	2

2.2A. Results by Ref. [4] method. The preorder is shown in Fig. 7.

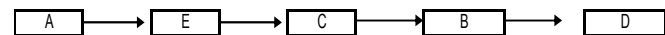


Fig. 7: Graph sub zone La Estrella, alternative 2.2A, Promethee II.

2.2B. Results following Ref [6] method is shown in Fig. 8.

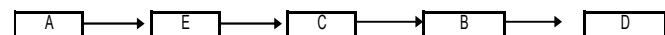
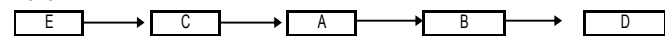
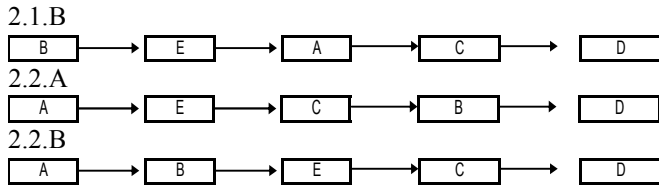


Fig. 8: Graph sub zone La Estrella alternativa 2.2B, Promethee II modified.

Changing weights (0,20 – 0,15 – 0,15 – 0,10 – 0,10 – 0,10 – 0,10 – 0,10) the results are:

2.1.A





3. Sub zone RIVADAVIA SUR

3.1. ALTERNATIVA 1: Initial matrix is shown in Table V.

TABLE V
DECISIONAL MATRIX FOR RIVADAVIA SUR, ALTERNATIVE 1.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	8	5	1	9	5	7	9	6
B	6	6	6	5	5	8	6	5
C	3	2	2	4	8	9	1	9
D	2	2	5	4	6	7	5	6
E	3	3	8	5	8	6	4	8
Weight	0.25	0.1	0.1	0.05	0.1	0.1	0.2	0.1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			2	2	4

3.1A. Results following Ref [4] method is shown in Fig. 9.

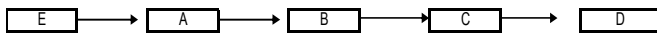


Fig. 9: Graph sub zone Rivadavia Sur, alternative 3.1A, Promethee II.

3.1B. Results following Ref. [6] method in Fig. 10.

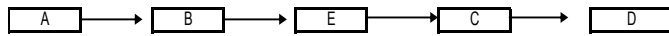


Fig. 10: Graph sub zone Rivadavia Sur, alternative 3.1B, Promethee II, modified.

3.2. ALTERNATIVE 2: Changing some criteria values and maintaining weights (Table VI).

TABLE VI
DECISIONAL MATRIX FOR RIVADAVIA SUR, ALTERNATIVE 2.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	8	5	6	9	5	7	9	6
B	6	6	6	5	5	8	6	5
C	3	2	2	4	8	9	1	9
D	2	2	5	4	6	7	5	6
E	3	3	8	5	8	6	4	8
Weight	0.25	0.1	0.1	0.05	0.1	0.1	0.2	0.1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			2	2	4

3.2A. Results following Ref. [4] method in shown in Fig. 11.

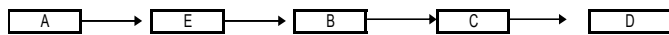


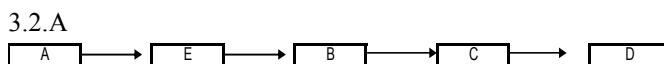
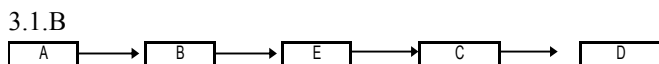
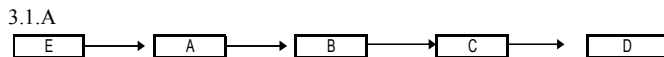
Fig. 11: Graph sub zone Rivadavia Sur, alternative 3.2A, Promethee II.

3.2B. Results following Ref. [6] is in Fig. 12.



Fig. 12: Graph sub zone Rivadavia Sur, alternative 3.2B, Promethee II, modified.

Changing weights (0,2 – 0,15 – 0,15 – 0,10 – 0,10 – 0,10 – 0,10 – 0,10) the results are:



3.2.B



4. Sub zone PICHANAL

4.1. ALTERNATIVE 1: Initial matrix is shown in Table VII.

TABLE VII
DECISIONAL MATRIX FOR PICHANAL, ALTERNATIVE 1.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	6	6	1	7	5	2	8	2
B	6	5	4	4	5	8	6	5
C	3	2	9	4	8	9	1	9
D	2	2	6	4	5	7	5	6
E	3	2	8	5	8	6	4	8
Weight	0.20	0.15	0.10	0.10	0.20	0.05	0.05	0.15
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	2	4	4		2	2	4

4.1A. Results following Ref. [4] is shown in Fig. 13.

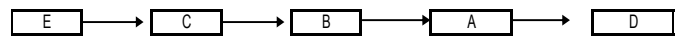


Fig. 13: Graph sub zone Pichanal, alternative 4.1A, Promethee II.

4.1B. Results following Ref [6] is shown in Fig. 14.



Fig. 14: Graph sub zone Pichanal, alternative 4.1B, Promethee II, modified.

4.2. ALTERNATIVE 2: With other values same weights (Table VIII).

TABLE VIII
DECISIONAL MATRIX FOR PICHANAL, ALTERNATIVE 2.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	6	6	5	7	5	7	8	2
B	6	5	4	4	5	8	6	5
C	5	2	9	4	8	9	1	9
D	2	2	6	4	5	7	5	6
E	3	2	8	5	8	6	4	8
Weight	0.20	0.15	0.10	0.10	0.20	0.05	0.05	0.15
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	2	4	4		2	2	4

4.2A. Results following Ref [4] is in Fig. 15.



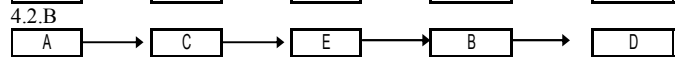
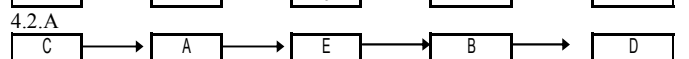
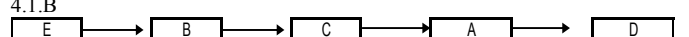
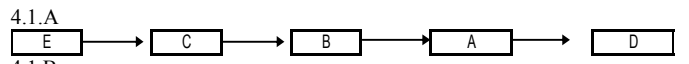
Fig. 15: Graph sub zone Pichanal, alternative 4.2A, Promethee II.

4.2B. Results following Ref [4] is shown in Fig. 16.



Fig. 16: Graph sub zone Pichanal, alternative 4.2B, Promethee II, modified.

With other weights (0,2 – 0,15 – 0,15 – 0,10 – 0,10 – 0,10 – 0,10 – 0,10) the results are:



5. Sub zone JOAQUIN V. GONZALEZ

5.1. ALTERNATIVE 1: Initial matrix is shown in Table IX.

TABLE IX
DECISIONAL MATRIX FOR JOAQUIN V. GONZÁLEZ, ALTERNATIVE 1.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	6	6	1	7	7	2	9	2
B	6	5	6	4	7	8	6	5
C	3	4	9	4	8	9	4	9
D	2	2	7	4	5	7	5	6
E	3	2	8	4	8	6	4	8
Weight	0,2	0,15	0,1	0,1	0,15	0,1	0,1	0,1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			2	2	4

5.1.A. Results following Ref. [4] is shown in Fig. 17.

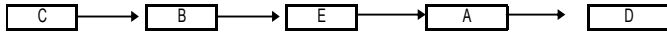


Fig. 17: Graph sub zone Joaquin V. Gonzalez, alternative 5.1A, Promethee II.

5.1.B. Results following Ref. [6] is in Fig. 18.

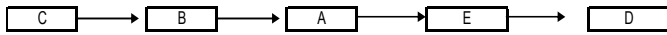


Fig. 18: Graph sub zone Joaquin V. Gonzalez, alternative 5.1B, Promethee II, modified.

5.2. ALTERNATIVE 2: Other values and same weights (Table X).

TABLE X
DECISIONAL MATRIX FOR JOAQUIN V. GONZÁLEZ, ALTERNATIVE 2.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	6	6	3	7	7	4	9	2
B	6	5	6	4	7	8	6	5
C	5	4	9	4	8	9	4	9
D	2	2	7	4	5	7	5	6
E	3	2	8	4	8	6	4	8
Weight	0,2	0,15	0,1	0,1	0,15	0,1	0,1	0,1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			2	2	4

5.2.A. Results following Ref. [4] is shown in Fig. 19.



Fig. 19: Graph sub zone Joaquin V. Gonzalez, alternative 5.2A, Promethee II.

5.2.B. Results following Ref. [6] is in Fig. 20.

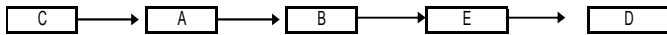
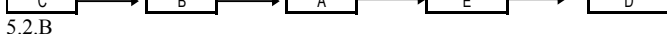
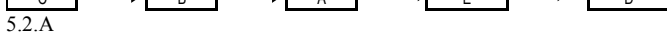
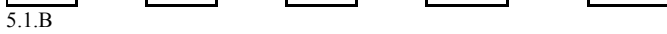


Fig. 20: Graph sub zone Joaquin V. Gonzalez, alternative 5.2B, Promethee II, modified.

With other weights (0,2 – 0,15 – 0,15 – 0,10 – 0,10 – 0,10 – 0,10 – 0,10) the results are:



6. Sub zone LAS LAJITAS:

6.1. ALTERNATIVE 1: Initial matrix is shown in Table XI.

TABLE XI
DECISIONAL MATRIX FOR LAS LAJITAS, ALTERNATIVE 1.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	3	6	1	3	3	3	4	2
B	3	4	3	3	5	8	3	5
C	2	3	9	4	8	9	1	9
D	2	2	6	4	5	7	1	6
E	2	2	8	4	8	6	1	8
Weight	0,2	0,05	0,1	0,2	0,2	0,15	0,05	0,1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			6	6	2

6.1.A. Results following Ref. [4] method is in Fig. 21.

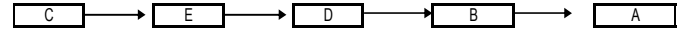


Fig. 21: Graph sub zone Las Lajitas, alternative 6.1A, Promethee II.

6.1.B. Results following Ref. [6] method is shown in Fig. 22.



Fig. 22: Graph sub zone Las Lajitas, alternative 6.1B, Promethee II, modified.

6.2. ALTERNATIVE 2: Other values and same weights (Table XII).

TABLE XII
DECISIONAL MATRIX FOR LAS LAJITAS, ALTERNATIVE 2.

Alternative	WE	EE	IF	WR	EB	HP	EI	SA
A	3	6	1	3	3	2	4	2
B	3	4	3	3	5	8	3	5
C	2	3	9	4	8	9	1	9
D	2	2	6	4	5	7	1	6
E	2	2	8	4	8	6	1	8
Weight	0,2	0,05	0,1	0,2	0,2	0,15	0,05	0,1
Type of criterion	III	III	III	I	I	III	III	III
Thresholds	2	4	4			6	6	2

6.2.A. Results following Ref. [4] method is shown in Fig. 23.



Fig. 23: Graph sub zone Las Lajitas, alternative 6.2A, Promethee II.

6.2.B. Results following Ref. [6] method is in Fig. 24.

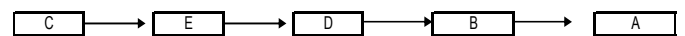
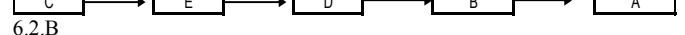
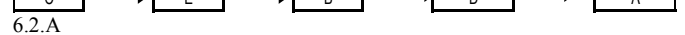
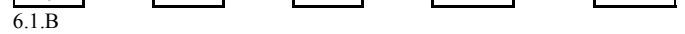


Fig. 24: Graph sub zone Las Lajitas, alternative 6.2B, Promethee II, modified.

Changing weights (0,2 – 0,15 – 0,15 – 0,10 – 0,10 – 0,10 – 0,10 – 0,10) the results are:



IV. CONCLUSIONS

Following the results mentioned above (Table XIII), we can obtain as conclusions that the PROMETHEE method is a very useful tool to elaborate a erosion control integral Plan. It is robust as we have confirmed changing a little the relative preference. Besides, with both methods similar results have been obtained.

TABLE XIII

SUMMARY RESULTS OF PROMETHEE METHODS APPLICATION TO EROSION CONTROL PLANS IN SALTA PROVINCE (ARGENTINE).

Subzone Method	Martin Hickman	La Estrella	Rivadavia Banda Sur	Pichanal	J. V. González	Las Lajitas
PROMETHEE, applying variable weights in each sub zone						
1.A	A	E	E	E	C	C
1.B	A	E	A	E	C	C
2.A	C	A	A	C	C	C
2.B	A	A	A	C	C	C
PROMETHEE, applying the same weights in each sub zone						
1.A	A	E	E	E	C	C
1.B	A	B	A	E	C	C
2.A	C	A	A	C	C	C
2.B	A	A	A	A	C	C

Note: 1.A and 2.A : Following the initial method of Ref. [4], 1.B and 2.B: Following method modified by the authors [6].

For this purposes, we would recommend to use Promethee II modified using the ELECTRE I weights. Besides, with usual criterion and type III pseudocriterion have been obtained the best results. We could recommend to Salta Government the following actions:

Las Lajitas: extensive farming and livestock. If it is only farming it could be with crop rotation. The livestock should be with natural forestry and foraging plants.

La Estrella: We can combine Autochthonous and high value forestry with biomass production.

Pichanal: Similar to Las Lajitas.

Martin Hickman: Autochthonous forestry, combined with some crop rotation and livestock like Las Lajitas.

Rivadavia Banda Sur: Similar to La Estrella.

Joaquin V. Gonzalez: Similar to Las Lajitas combined in some areas with high value forestry.

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