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STRATEGOS

Need for a Regional Summit to prevent Environmental Modification Operations in South Eastern Europe

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ABSTRACT

The „Convention on the prohibition of military or any other hostile use of environmental modification technique" (referred lately in this paper as "Convention"), effective since 5 October 1978, strictly forbade military usage of Environmental Modification Techniques (ENMOD). The Convention protects signatory nations more broadly; against any other hostile use of the ENMOD technologies, and to advocate cooperation, trust and scientific knowledge exchange between the signatory nations. The Convention also offers UN role in consultation, protection and the determined protocol for a possible issue caused by the application of the ENMOD technologies. Since the dissolution of Yugoslavia, in the early nineties, only one country; the Republic of Slovenia, ratified the Convention. Due to this fact, a large area in Southeast Europe has no proper international regulation of this matter. Regardless of the minor possibility of military ENMOD application in the region, there is an increasing expectancy of unilateral ENMOD applications as a response to economic losses caused by climate change (impacts on hydrology cycle, agriculture, forestry etc.). The main goal of this work is to apply an objective multi-criterion decision analyse, in the form of combined Analytic Hierarchy Process and Analytic Network Process, to suggest a course of action for decision-makers in the ENMOD regulation. Besides ranked alternatives, many latent and side suggestions arose from the results helping to determine the next best alternative in the case of inability to realize the best option: assembling a regional summit to promote Convention ratification.

KEYWORDS

Environmental Modification Techniques, ENMOD, multi-criteria decision analysis, Analytic Hierarchy Process, Analytic Network Process

INTRODUCTION

One of the most influential modern challenges is climate change. It is far beyond the scope of the paper to discuss all the impact and consequences of climate change to modern societies, but the public and especially relevant experts are well aware of them. This work is about one of the aspects of the climatic change; ENvironmental MODification (ENMOD) by artificial means and about its international regulation. There are many initiatives for slowing down and even reverse climate change effects. However, only the "Convention on the prohibition of military or any other hostile use of environmental modification technique" (United Nations, 1976), referred in this paper as the "Convention", offers clear and defined protocols, procedures and services of appropriate international organizations, as well as a permanent Consultative Committee of Experts. The main purpose of the Convention is the abandonment of military use of the ENMOD, cooperation and peaceful conflict resolving. However, the Convention explicitly states, in the Article I of the Convention: "Each State Party to this Convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party". The statement "any other hostile use" applies to ENMOD techniques of one country to counter the climatic change when this activity causes damages to neighbouring countries. It is expected that ENMOD techniques will be widely used to preserve current agricultural, forestry or transportation condition as an answer to the climate change consequences. For example, application of silver iodide, aerosols, salt water, ions etc. could affect the water cycle for watering own agriculture and forest areas or to preserve water level on inland waterways. In fact, such praxis is present in some countries (e.g. China, United Arab Emirates, United States of America, and

India) for years. It is not possible to limit the ENMOD inside state borders, so a good formulated and wide accepted regulation is necessary.

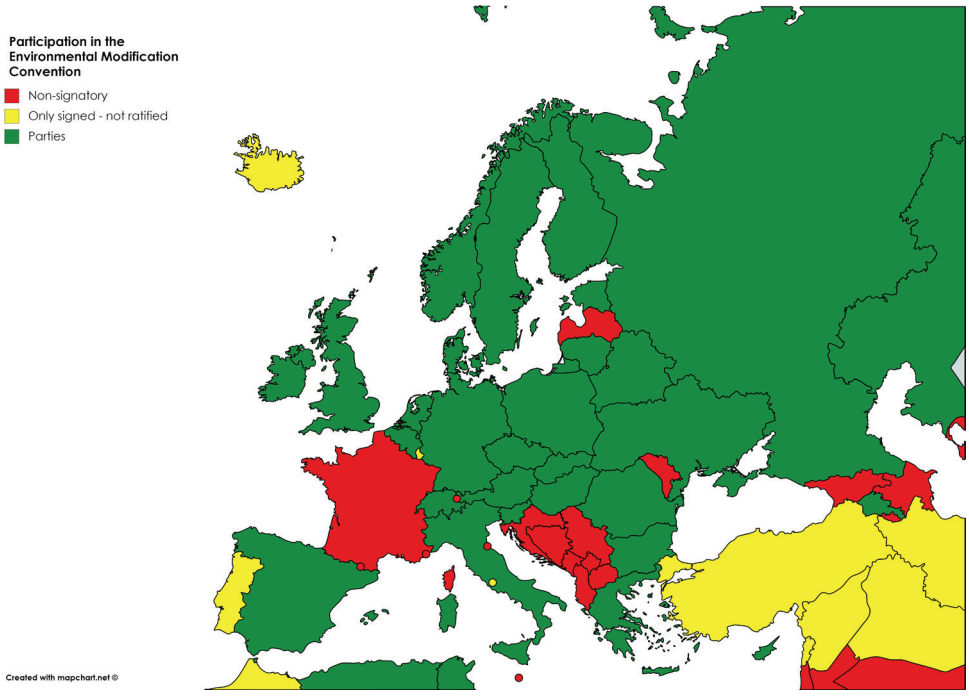

Figure 1. Participation in the Convention for the European and Mediterranean states; Albania, Bosnia and Hercegovina, Croatia, Montenegro, Kosovo, North Macedonia and Serbia are all non-signatory countries. Source: own, created with Mapchart.net

After the dissolution of Yugoslavia, succession states did not sign or ratify the Declaration, except the Republic of Slovenia. The consequence is a large area in South Eastern Europe with non-signatory countries, without proper international ENMOD regulation (Figure 1). Purpose of the Convention is not a total ban of ENMOD techniques, but application in a controlled way and in cooperation with all surrounding states that are influenced, in hope for mutual benefits. Collective signatory of the Convention should have a significant political gain for participating countries as well as avoidance of substantial economic losses. Having that in mind, we proposed several

courses of action, and we computed their relative ranks using a mixed Analytical Hierarchy / Analytical Network Process (AHP/ANP). The main purpose of the following results is a suggestion to decision makers for appropriate international political actions and their immediate alternatives.

METHOD

Once, when the unfavourable situation in the region had been noticed and after the existing and proved solutions had been studied, an objective methodology has been sought that will result in a recommendation in the sense of future policy towards the Convention. The Republic of Croatia can have a political role as an initiator in broadening the circle of states, which ratified the Convention. Alternatives represent directions of political action aimed at improving the existing state of affairs, the accession of the remaining countries of the former Yugoslavia (except the Republic of Slovenia) to the signatories of the Convention (Figure 1). The alternatives are in the range from "not taking any action" to "seeking patronage from the UN". A mixed hierarchy/network model has been developed (Figure 2) to evaluate the rank of each of the alternatives, which provided the consistency of their judgment, and gives a ranked list of the priorities derived from the matrix comparison. There are two basic criteria: "Political gains" and "Avoidance of economic damage". Both main criteria; "Political gains" and "Avoidance of economic damage" were deliberately disconnected because of imposed fair solution; maximizing both criteria instead of opening up the possibility of increasing political gains through the exploitation of the consequences of intentional damages that an external factor would commit to our economy. Unlike the hierarchy of criteria, all sub-criteria are linked to the network structure since they interact and do not exclude one another.

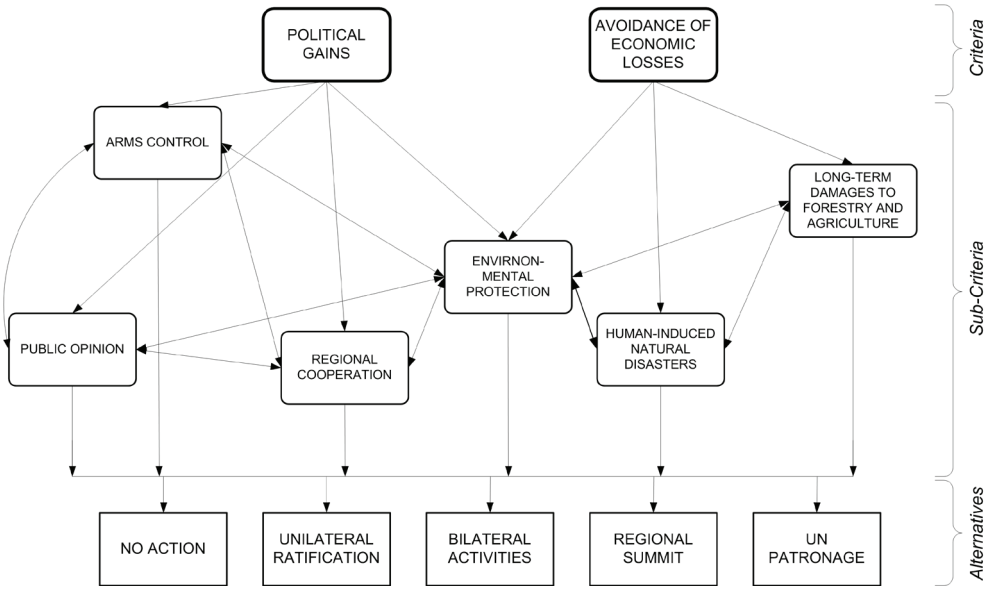

Figure 2 Mixed Analytic Hierarchy Process and Analytic Network Process model used in this study; all sub-criteria are networks connected while both criteria and alternatives are dependent hierarchically.

The political alternatives need to be ranked according to political and economic criteria. Given that, through restriction of the weather modification techniques, we do not see any economic gain, we have decided on the following two main goals:

- political gain
- avoidance of economic damage.

Under political gains, we mean what the Republic of Croatia can improve in relations with neighbouring states, but also within our own country. The sub-criteria of political gain is divided into internal politics and foreign policy. Foreign policy sub-criteria are:

- regional co-operation
- armaments control.

Regional cooperation in the sense of sharing scientific knowledge as well as timely mutual information exchange on the directions of research and the

intentions of technology development will contribute to regional cooperation in the wider context. Mutual armament control is an act of good intentions by observing the status and plans of the development of national armed systems and giving a statement of weather modification technologies denial for any kind of military advantage. On the other hand, internal political sub-criteria are:

- public opinion
- constant environmental protection.

Public opinion is manifested in widespread support or denial of policy support to the signing of the Convention. Permanent environmental protection is a widespread action and signing the Convention is just one of the actions in that direction. In the sub-criteria structure, permanent environmental protection is recognized as a common criterion for both major criteria.

On the other side, avoiding economic damage is seen in two ways:

- long-term action to limit and ban all weather modifications that can cause damages to agriculture and forestry
- preventing individual natural disasters caused by human activity
- constant environmental protection.

The long-term damages to the environment are caused by an artificial modification in annual temperature and precipitation cycle and the use of harmful chemical compounds. Climate change, in addition, affects soil and soil composition and also initiates animal migrations, which can indirectly affect the balance of the existing ecosystem. Unlike long-term damage to forest and agricultural areas, artificial modification of weather conditions could cause short-term but catastrophic consequences, primarily due to the impact on the circulation of water in nature, which could cause flooding or drought.

For the evaluation of the criteria, a fundamental gradation scale of 1 to 9 was used, developed from the comparison of all sub-criteria pairs according to the stimulus-responsive theory (Saaty, 1993). There are more comprehensive studies of the comparison scales (Ji and Jiang, 2003), and proposals for a balanced scale (Pöhjönen, 1997). However, for this work, please note that

differences between ranks are not equidistant; differences at lower intensities of importance are more subtle (Table 1):

Table 1: Ranks and definitions for sub-criteria pair comparisons

The intensity of importance (Saaty)	**Verbal definition of the importance**	Balanced scale (Pöhjönen)
1	**Equal importance**	1.00
2		1.22
3	**Somewhat higher importance**	1.50
4		1.86
5	**Higher importance**	2.33
6		3.00
7	**Markedly higher importance**	4.00
8		5.67
9	**Dominating importance**	9.00

According to intensities of importance, comparing between all sub-criteria pairs shown in the Fig.1, a symmetrical matrix of weights **A** was constructed. To evaluate ranks of the sub-criteria ranks the eigenvector **w** and eigenvalue λ were computed.

$$\mathbf{Aw} = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_1} \end{pmatrix} \begin{pmatrix} w_1 \\ w_1 \\ \vdots \\ w_1 \end{pmatrix} = \begin{pmatrix} \lambda w_1 \\ \lambda w_1 \\ \vdots \\ \lambda w_1 \end{pmatrix} = \lambda \mathbf{w} \tag{1}$$

To confirm consistency in the subjective comparison of the intensities of importance, there must be a high level of accord between consecutive comparisons. In the ideal condition, comparisons should satisfy conditions (2) to (4). If a particular comparison is

$$a_{ij} = \frac{w_i}{w_j} \quad \forall\, i, j \tag{2}$$

then consecutive comparisons are, in ideal conditions

$$a_{ij} a_{jk} = \frac{w_i}{w_j} \frac{w_j}{w_k} = \frac{w_i}{w_k} = a_{ik} \tag{3}$$

so, we can conclude that, in ideal conditions

$$a_{ik} = a_{ij} a_{jk} \quad \forall\, i, j, k \tag{4}$$

Consistencies were checked for every comparison matrix using eigenvalue λ and maximum eigenvalue λ_{max} and consistency indices CI(A) were computed (Saaty, 1977):

$$CI(\mathbf{A}) = \frac{\lambda_{\max} - \lambda_n}{\lambda_n - 1} \tag{5}$$

for perfect consistency $\lambda = \lambda max$ so CI(A) = 0. In real, subjective, comparisons an inconsistency up to 0.1 is allowed (Saaty, 1980). In the next step, a rescaled value of the CI(A) was computed to obtain consistency ratios CR(A) (Saaty, 1980):

$$CR(\mathbf{A}) = \frac{CI(A)}{RI_n} > 0.1 \tag{6}$$

where random indices RIn are estimations of the average CI precomputed from a very large set of matrices of size n, which are randomly generated. A table for the comparison matrices up to size n is presented here (Saaty, 1980):

Table 2: Random indices for matrices with size up to n = 10

n	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI_n	0.5247	0.8816	1.1086	1.2479	1.3417	1.4057	1.4499	1.4854

For every comparison matrix $CR(\mathbf{A})$ have to be less than 0.1, if these conditions are not satisfied, then rations in intensities of importance (1) have to be checked and corrected to satisfy the condition in Equation (6).

RESULTS AND DISCUSSION

Political Gains

According to the comparisons in Table 3, normalized local priorities for the criterion "Political Gains" were computed (two rightmost columns of the table) using maximal eigenvalues in Eq. (1) and almost perfect inconsistency, less than 0.00005 was obtained, Eq. (6). Meanings are following; comparing pair of sub-criteria "Arms control" with "Environmental protection" 1/2 means that the "Environmental protection" has greater importance, between "Equal importance" and "Somewhat higher importance" (according to the intensities of importance in Table 1). In another example from the same Table 3; when comparing "Environmental protection" with "Regional cooperation" value of 4 means that importance of the "Environmental protection" is more important, between "Somewhat higher importance" and "Higher importance" (according to the rank definitions in Table 1). Please note that, due to the symmetrical nature of the comparison matrices, redundant values at the bottom left side of the matrix are not present. Maximum values of eigenvectors for the four sub-criteria, computed by Eq. (1) were normalized (original value of the maximal eigenvalue divided by sum of all maximum eigenvectors, "Normal" in order to obtain sum of all "Normal" values equal

1.00000), and compared with the most important sub-criteria. The actual "Normal" value was divided by the largest "Normal" value in the same eigenvector, presented as "Ideal" to obtain value of 1.00000 for the first ranked sub-criteria or alternative and to produce ranks of the criteria or alternatives with their relative importance in the column "Ideal".

Identifying the most important influences to the political gains the decision makers should pay attention to the most important sub-criteria; "Environmental protection" and "Public opinion". Twice less important is sub-criterion "Arms control" while sub-criterion "Regional cooperation" is four times less important than two dominant sub-criteria "Environmental protection" and "Public opinion".

Table 3: Importance comparisons for the sub-criteria under criterion "Political Gains"

Inconsistency < 0.00005	Environmental protection	Public opinion	Regional cooperation	Normal	Ideal
Arms control	1/2	1/2	2	0.18182	0.50000
Environmental protection		1	4	0.36364	1.00000
Public opinion			4	0.36364	1.00000
Regional cooperation				0.09090	0.25000

Importance of sub-criteria under main criterion "Avoidance of economic losses" are presented in Table 4. By our judgement, dangers to the "Agriculture and forestry damage" have equal importance to the permanent "Environmental protection". "Human-induced natural disasters" are estimated with a low probability of occurrence so the precedent sub-criteria of "Agriculture and forestry damage" and "Environment protection" have

higher importance than the risk of the "Human-induced natural disasters". All judgements in Table 4, computed using Eq. (6) have acceptable inconsistency of 0.00532.

Avoidance of Economic Losses

Local priorities for the criterion "Avoidance of Economic Losses" are quantized in Table 4, in two rightmost columns; the importance of "Environmental protection" is just 7.2% less than the importance of the dominant sub-criterion "Agriculture and forestry damage". On the other side, the importance of "Human-induced natural disasters" is just about 21.5 % of the dominant sub-criterion. The common sub-criterion "Environmental protection" has 15 between sub-criteria comparison pairs at all (Table 5); all comparisons are conformed in intensities to the same pair comparisons in Table 3 and Table 4. Acceptable inconsistency, computed by Eq. (6), is 0.06063.

Table 4: Importance comparisons for the sub-criteria under criterion "Avoidance of Economic Losses"

Inconsistency 0.00532	**Environmental protection**	**Human-induced natural disasters**	**Normal**	**Ideal**
Agriculture and forestry damage	1	5	0.46647	1.00000
Environmental protection		4	0.43303	0.92832
Human-induced natural disasters			0.10050	0.21544

Environmental protection

Maximum values of eigenvectors for the "Environmental protection" sub-criterion, computed by Eq. (1) were normalized and presented in the rightmost columns of Table 5. To fulfil the "Environment protection" decision makers should pay attention to "Public opinion" as the most important sub-criterion than to the long-term losses induced by the "Agriculture and forestry damage" (about 6.7 % less important than the dominant "Public opinion" sub-criterion) and the "Environment protection" (14.6 % less important than the dominant sub-criterion). Remaining three sub-criteria; "Arms control", "Human-induced natural disasters" and broad sense "Regional cooperation" are all much less important.

Table 5: Importance comparisons for the common sub-criteria "Environmental Protection"

Inconsist. 0.06063	Arms control	Environmental protection	Human-induced natural disasters	Public opinion	Regional cooperation	Normal	Ideal
Agriculture and forestry damage	5	1	5	1/2	3	0.25846	0.93305
Arms control		1/2	1/2	1/2	2	0.08781	0.31699
Environmental protection			4	1	4	0.23649	0.85373
Human-induced natural disasters				1/4	1	0.07774	0.28066

Public opinion	4	0.27700	1.00000
Regional cooperation		0.06250	0.22562

Alternatives

All six alternatives are connected in a hierarchical structure with all of the sub-criteria. Following six tables (Tables A1 – A5) show importance comparisons for all possible alternative pairs for all of the criteria. Inconsistency levels in the comparisons of the alternatives are at an acceptable level, less than 0.1. The two rightmost columns in Tables A1 – A5 show local priorities for alternatives according to one by one sub-criterion. All of them indicate the same ranks of priority, indicated in the "Ideal" column; "Regional summit" is the best alternative, following by "UN patronage", then "Bilateral activities", "Immediate (unilateral) ratification" of the Convention and "No action" as the worst alternative.

CONCLUSION

The model synthesis produces an overall priority, eigenvector with the final ranks of the alternatives with the least error in the decision, concerning the importance comparisons for sub-criteria (Tables 3 - 5), and the importance for the alternatives (Tables A1 – A5).

Table 6: Model synthesis, alternatives according to their rank

Rank	Alternative	Raw	Normal	Ideal
1st	Regional summit	0.248940	0.497879	1.00000
2nd	UN patronage	0.579044	0.288294	0.579044
3rd	Bilateral activities	0.057983	0.115966	0.232922
4th	Immediate ratification	0.033585	0.067171	0.134914
5th	No action	0.015345	0.030690	0.061641

The result is presented in Table 6 as the six alternatives according to their rank, their relative comparisons with the best alternative ("Regional summit") are presented in the column "Ideal". A mixed ANP/AHP model with two main criteria, six sub-criteria (with one common sub-criterion) and six alternatives (Fig. 2), with consistent comparisons of all pairs criteria, sub-criteria and alternatives shows that the best alternative is initiative for a regional summit to initiate the process of signature and ratification of the Convention.

This solution ensures the smallest error in the decision regarding "Political gains" and "Avoidance of economic losses" criteria with all correspondent sub-criteria discussed above. The second-best alternative is "UN Patronage" with 57.9 % of the best value (Table 6, column "Ideal", row "UN patronage").

The third-ranked alternative is "Bilateral activities" with just 23.3 % of the best value, but still better than "Immediate (unilateral) ratification" suggesting decision maker that in the case of impossibility for the realization of the first two alternatives. An attempt to approach to neighbouring countries with bilateral action for mutual ratification or signature of the Convention is much better (23.3 % to 13.5 % of the best solution, respectively, Table 6, column 'Ideal') that our own, unilateral, unconditional and immediate ratification of the Convention in hope that the countries in our region will follow our example. At last, the worst alternative is 'No action', leaving the present state of affairs as about 6.2% of the best solution.

REFERENCES

Ji, P. and Jiang, R. (2003) Scale transitivity in the AHP. *Journal of the Operational Research Society*, 54(8), 896–905.

Pöhjönen, M. A., Hämäläinen, R. P. and Salo, A. A. (1997) An experiment on the numerical modelling of verbal ratio statements. *Journal of Multi-Criteria Decision Analysis*, 6(1), 1–10.

Saaty, T. L. (1977) A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*. 15(3), 234–281.

Saaty, T. L. (1980) *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. New York, McGraw-Hill.

Saaty, T. L. (1993) What is relative measurement? The ratio scale phantom. *Mathematical and Computer Modelling*. 17(4-5), 1–12.

United Nations. (1976) Convention on the prohibition of military or any other hostile use of environmental modification technique. New York, United Nations. Available from: https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVI-1&chapter=26&lang=en

APPENDIX A

Table A1: Importance of the alternatives according to sub-criteria "Public opinion"

Inconsistency 0.06754	Immediate ratification	No action	Regional summit	UN patronage	Normal	Ideal
Bilateral activities	3	5	1/6	1/5	0.11462	0.24085
Immediate ratification		3	1/7	1/5	0.06222	0.13072
No action			1/9	1/7	0.03288	0.06907
Regional summit				2	0.47596	1.00000
UN patronage					0.31432	0.66039

Table A2: Importance of the alternatives according to sub-criteria "Arms control"

Inconsistency 0.07036	Immediate ratification	No action	Regional summit	UN patronage	Normal	Ideal
Bilateral activities	2	5	1/5	1/4	0.11392	0.23268
Immediate ratification		5	1/5	1/4	0.08686	0.17741
No action			1/9	1/8	0.03002	0.06130
Regional summit				3	0.48962	1.00000
UN patronage					0.27958	0.57102

Table A3: Importance of the alternatives according to sub-criteria "Regional cooperation"

Inconsistency 0.05988	Immediate ratification	No action	Regional summit	UN patronage	Normal	Ideal
Bilateral activities	2	5	1/5	1/4	0.10573	0.20789
Immediate ratification		3	1/8	1/7	0.05926	0.11653
No action			1/9	1/8	0.03146	0.06186
Regional summit				3	0.50859	1.00000
UN patronage					0.29496	0.57996

Table A4: Importance of the alternatives according to sub-criteria "Environmental protection"

Inconsistency 0.08486	Immediate ratification	No action	Regional summit	UN patronage	Normal	Ideal
Bilateral activities	3	5	1/6	1/4	0.11294	0.22105
Immediate ratification		4	1/7	1/6	0.06325	0.12379
No action			1/9	1/8	0.02981	0.05834
Regional summit				3	0.51091	1.00000
UN patronage					0.28309	0.55409

Table A5: Importance of the alternatives according to sub-criteria "Human-induced natural disasters"

Inconsistency 0.06882	Immediate ratification	No action	Regional summit	UN patronage	Normal	Ideal
Bilateral activities	3	6	1/6	1/4	0.12109	0.23725
Immediate ratification		2	1/6	1/5	0.05717	0.11202
No action			1/9	1/8	0.03257	0.06381
Regional summit				3	0.51041	1.00000
UN patronage					0.27876	0.54613

Table A6: Importance of the alternatives according to sub-criteria "Long term damages to forestry and agriculture"

Inconsistency 0.08968	Immediate ratification	No action	Regional summit	UN patronage	Normal	Ideal
Bilateral activities	3	6	1/6	1/4	0.12486	0.24986
Immediate ratification		4	1/5	1/4	0.07421	0.14851
No action			1/9	1/8	0.02928	0.05859
Regional summit				3	0.49970	1.00000
UN patronage					0.27195	0.54423

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