Multiple impact assessment of forest projects in the context of sustainable development: a cross-country application of forest projects in mountain Mediterranean forest areas

V. Kazana[1], A. Kazaklis[2]
[1]Technological Education Institute of Kavala, Department of Forestry and Natural Environment Management, 1st km Drama - Mikrohori, 66100 Drama, GREECE
[2]Centre for Integrated Environmental Management, 39 Androutsou Str., 55132 Kalamaria, Thessaloniki, GREECE

INTRODUCTION

Forest planners, managers and policy makers are often confronted with difficulties when they attempt to evaluate *ex-ante*, *ex-post* or *ongoing* forest projects in the context of sustainability. This is due to the fact that either appropriate impact evaluation tools are missing, or the existing ones fail to incorporate all of the different types of project impacts, such as environmental, social and economic, as these are usually different at different spatial scales, time scales and levels of aggregation. In addition, most of the attributes related to the forest project impacts are vague, subjective, intangible or uncertain.

This paper presents the MEDMONT fuzzy multi-criteria rule-based model, which can use spatially referenced natural, socio-economic, green accounting and institutional impact indicators at different scales and levels of aggregation to assess the contribution of the forest projects to sustainability in the mountain Mediterranean areas. The model is tested with real forest projects at the landscape system level and high level of aggegation in Mediterranean forest areas of Greece, France and Spain.

METHODOLOGY- THE MEDMONT FUZZY MULTI-CRITERIA FOREST PROJECT IMPACT ASSESSMENT MODEL

The MEDMONT multi-criteria fuzzy model is part of the MEDMONT integrated evaluation framework for project sustainability assessments in the mountain Mediterranean areas (Kazana *et. al.* 2005).

MEDMONT interrelates the target groups with the project evaluation and monitoring processes and tools by integrating three dimensions: spatial scale, level of aggregation (or level of detail) and method of approach (top-down and bottom up) and it involves:

a natural resource base and capability evaluation, ii) a socio-economic evaluation, iii) an institutional evaluation, iv) a green accounting evaluation, v) a social preference evaluation and vi) an integrated evaluation based on Multiple Criteria Analysis and Fuzzy Logic.

The MEDMONT fuzzy multi-criteria evaluation model provides project sustainability impact assessments by considering the dynamics of two subsystems, the natural resource impact changes and the human impact changes (Figure 1).

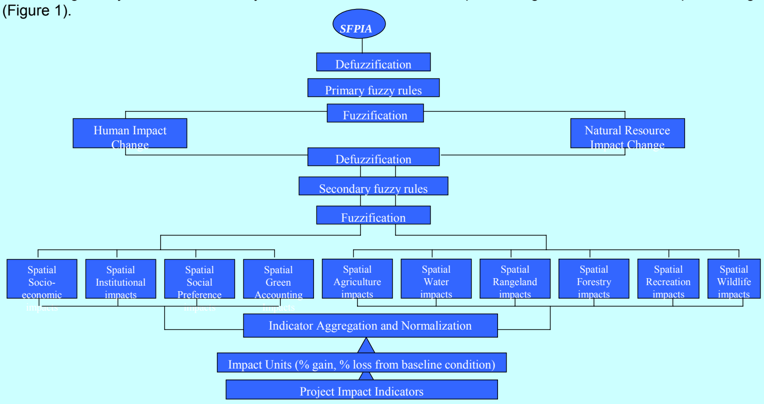


Figure 1. The MEDMONT fuzzy model for sustainability assessment of forest project impacts

The overall forest project contribution to sustainability is considered as a nonlinear function of the individual sustainabilities and it is constructed logically by using fuzzy logic. Specialist experts using the MEDMONT spatially referenced impact indicator models evaluate each subsystem. Natural resource impact changes are estimated with the NREM and the human impact changes are estimated with the HRIEM. Indicator impact units are assessed as % loss or % gain from a baseline condition, which is always the no project option. The combination of the impact loss and impact gain by means of fuzzy logic provides a measurement of sustainability for each subsystem. Therefore, in the model's general form, 8 secondary linguistic variables (AGRimp, FORimp, RANGEimp, WATERimp, RECimp, WLIFEimp, SECONimp, INSTimp) are considered to obtain the two primary linguistic variables, the natural resource impact change (NRESimp) and the human resource impact change (HRESimp).

NRES HUMAN	VL	L	M	H	VH
VL	VL	L	M	H	VH
L	L	L	M	H	VH
M	M	M	M	H	VH
H	H	H	M	H	VH
VH	VH	VH	VH	VH	VH

NRES HUMAN	VL	L	M	H	VH
VL	VL	VL	VL	VL	VL
L	VL	L	L	L	L
M	VL	L	M	M	M
H	VL	L	M	H	H
VH	VL	L	M	H	VH

(VL: very low, L: low, M: medium, H: high, VH: very high)

Table 1. Linguistic rule base_ max

Table 2. Linguistic rule base_ min

Triangular membership functions are used for the secondary variables and trapezoidal functions are used for the primary variables to represent an increased uncertainty involved in the computation.

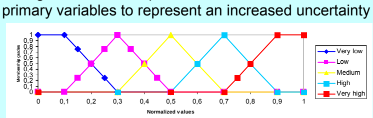


Figure 2. Membership functions for AGRimp, FORimp, RANGEimp, WATERimp, WLIFEimp and RECimp variables.

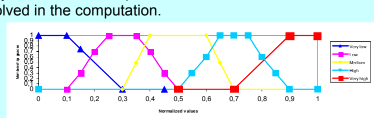


Figure 3. Membership functions for SFPIA, NRES and HUMAN variables

To fuzzify the Estimated Impact Unit (EIU) value, in the Gain case, the land parcel area affected by the project multiplies the maximum possible value, which could be obtained. By applying the following formula the max EIUs are estimated, which correspond to the value of 1. The EIU value is then fuzzified by deduction. In the Loss case, the min value, that is, 0 is taken.

$$\frac{(\text{EIUs-max for alternative Pi}) - (\text{EIUs for baseline condition})}{(\text{EIUs for baseline condition})} \times 100$$

The value of each primary linguistic variable is given by the average aggregation of the estimated values of the secondary linguistic variables.

Simulation of the evolution of the system is represented by rules of the form of "IF (antecedents) – THEN (consequent)", where the implication operator "THEN" and the connectives "AND" among antecedents are fuzzy. The rules are expressions of the role of interdependencies among different kinds of project impact changes. To determine the contribution of the project to sustainable development, PSIA, the rule base needs 52= 25 rules, because there are 5 linguistic values and 2 variables. Different linguistic rule bases can be built according to knowledge acquisition.

To express quantitatively the fuzzy rules the "AND", "OR", or "IF-THEN" connectives may be used. The connective "OR" is expressed by the max-max operator, while the "AND" connective by the γ-operator defined as γ-operator = γ-minimum + (1-γ) maximum, where γ є [0,1]. If γ=0.5, equal weight on the maximal and minimal values is assigned. Smaller values of γ emphasize the maximum and larger values emphasize the minimum. Finally, defuzzification, which is the final operation to convert membership grades into a single crisp value, is done with the center-of gravity formula, as it complies with the averaging process used before fuzzification of the input. So, the crisp value for project contribution to sustainable development is given by

$$Def(T_{PSIA}) = \frac{\sum_j y_j \cdot \mu_{T_{PSIA}}(y_j)}{\sum_j \mu_{T_{PSIA}}(y_j)}$$

Where, y_j is the value of the jth element of the fuzzy set T_{PSIA}, and $\mu_{T(PSIA)}(y_j)$ is the membership grade of the j^{th} element of the fuzzy set T_{PSIA}.

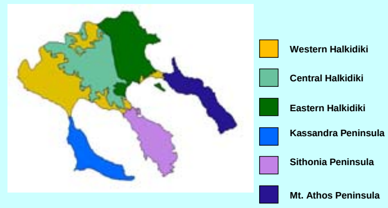
The fuzzy MEDMONT model runs with the MATLAB fuzzy toolbox.

RESULTS – CASE STUDIES

FOREST PROJECT IMPACT EVALUATION TOOL

Spatial Entities Concept
specific
generic
thematic mapping (suitability / impact severity)

A/A	LANDSCAPE SYSTEMS
1	Alluvia 0-300m
2	Alluvia 300-800m
3	Alluvia 800-1800m
4	Alluvia >1800m
5	Soft Sedimentary Rocks 0-300m
6	Soft Sedimentary Rocks 300-800m
7	Soft Sedimentary Rocks 800-1800m
8	Soft Sedimentary Rocks >1800m
9	Hard Sedimentary Rocks 0-300m
10	Hard Sedimentary Rocks 300-800m
11	Hard Sedimentary Rocks 800-1800m
12	Hard Sedimentary Rocks >1800m
13	Igneous Rocks 0-300m
14	Igneous Rocks 300-800m
15	Igneous Rocks 800-1800m
16	Igneous Rocks >1800m
17	Foliated Metamorphic Rocks 0-300m
18	Foliated Metamorphic Rocks 300-800m
19	Foliated Metamorphic Rocks 800-1800m
20	Foliated Metamorphic Rocks >1800m



Landscape Systems Map of Halkidiki study area, Greece

Forestry resource suitability/ capability indicators (MEDMONT, NREM)

A/A	Indicators
1	Conservation of soil/moisture
2	Conservation of landscape aesthetic value
3	Conservation of water quality
4	Prevention of air quality
5	Prevention of soil erosion
6	Prevention of catastrophic floods
7	Prevention of wildfires
8	Prevention of landslides and avalanches
9	Wood production
10	Production of nuts and other food types (for human and wild fauna consumption)
11	Production of seeds (collection or nurseries)

Forestry resource suitability/ capability indicators (MEDMONT, NREM)

A/A	Indicators
1	External investment* /ha
2	Intermediate consumption*/ha
3	Ordinary output* /ha
4	Local varieties or breeds/ha
5	New technology
6	Quality of products /ha
7	Number of jobs /ha
8	Training of the residents /ha
9	Building of new houses /ha
10	Increase of local population /ha
11	Outdoor activities /ha
12	Cultural or historical heritage /ha
13	Road traffic /ha

GREECE - Restoration of the Agia Paraskevi-Pefkohori Burnt Forest area, Kassandra, Halkidiki

This project aims at restoring the Agia Paraskevi - Pefkohori burnt forest area, located in Halkidiki- Greece on 1735 ha. The project involves the following operations: a) removal of the burnt and damaged wood b) construction of brush and bole dams in sites of high fire risk and soil erosion, with lifetime of 5 years, c) construction of small wooden dams for flood protection, with lifetime of 5 years and small concrete dams with lifetime of 20 years and d) natural regeneration of the pine forest through silvicultural practices, such as wide sowing or sowing in rectangles and supplementary planting with broadleaf seedlings. The total investment cost is about 1 million €, publicly granted through national policies programs.

FRANCE- Frassigna forest road (la Haute Corse, Corsica)

The project involves building a 5.2 km road passing through the Bonifatu forest. This forest was severely damaged by fires and the road mainly aims at facilitating forest regeneration by allowing removals of burnt wood. It does however respond to other socio-environmental concerns, such as protection against other subsequent fires, improvement of accessibility for recreation and environmental education. It directly affects a forest area of 264 ha, which is publicly owned (Corsica Region). The total investment cost reaches 270,500 €, fully financed through national policy programmes. The only stakeholder is the National Forest Service (ONF), acting both as institution and beneficiary, responsible for all project activities.

SPAIN- Forest Regeneration of the Alcornocales (cork oak) Natural Park (CONP)

This RDP involves improvement of natural regeneration of the Alcornocales (cork oak) Natural Park (CONP) through silvicultural sustainable management practices and protection of the local oak tree species, which is unique in the Mediterranean type of forests. The *Alcornocales* (cork oak) Natural Park (CONP), which stretches over 170,025 ha, is located in the Cádiz and Málaga provinces in southwestern Spain. The CONP is publicly owned and consists of a mosaic of uses and vegetation. Vegetation includes 48.5 % cork oak (*Quercus suber*), 3.7 % Algerian oak (*Quercus canariensis*), 1.8 % wild olive (*Olea europaea, var. sylvestris*), 2.3 % conifer plantations, 22.8 % shrub land, 15.7 % grassland, 3.2 % crops and 2.0 % other uses.The project favours an increase in the production of firewood and different types of cork, such as curruca, bornizo and segundero.

Project sustainability impacts in each country case study were assessed in comparison to the no-project alternative (baseline condition).

The natural resource impacted indicators and the socioeconomic, green accounting and institutional impacted indicators were selected by specialist experts in each country using the MEDMONT NREM and HRIEM models at the landscape spatial scale. These ware weighted with the social preference models of the MEDMONT system. Tables 3 and 4 show the overall project sustainability assessments in the three country case studies.

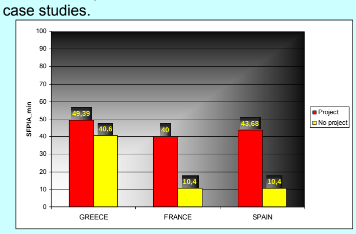


Table 4. Cross-country Forest Project contribution to sustainability -Rule base_min

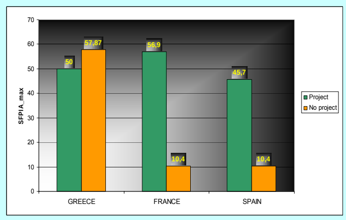


Table 5. Cross-country Forest Project contribution to sustainability -Rule base_max

The final SFPIA value implies that the project option after balancing the natural resource and the human resource impacts is more preferable in sustainability terms. In other words, a rational decision maker should select the project option, since this contributes more to the sustainable development of the area than the no project option.

CONCLUSIONS

The MEDMONT fuzzy multi-criteria model is a tool, which can be used to balance and integrate environmental, socio-economic and institutional project impacts in the context of sustainable development of mountain Mediterranean areas. The model structure is based on fuzzy logic and therefore, the model can successfully deal with attributes related to project impacts that are vague, subjective, intangible or uncertain.

The constituents of the project sustainability draw upon the Natural Resource Evaluation Models (NREM) and the Human Resource Impact Evaluation Models (HRIEM) of the MEDMONT integrated project evaluation framework. As a result of this, the model is consistent with mountain sustainable development, is applicable to a variety of project categories and it can be uniformly applied to all levels of decision- making. The model also incorporates social preferences in the evaluation process to balance natural resource and human resource impacts, expressed through its linguistic rule base.

ACKNOWLEDGMENTS

Work presented in this paper was funded by the EU Vth Framework DG- Research Project " MEDMONT- Tools for evaluating investment in the Mediterranean mountain areas. An integrated framework for sustainable development ", QLK5 – CT-2000-01031.

REFERENCES

Kazana, V., Bonnieux, F., Campos-Palacin, P., Croitorou, L., Gatto, P., Kazaklis, A., Merlo, M., Paoli, J.C. and Zadnik, L. (2005). MEDMONT: Tools for evaluating investment in the mountain Mediterranean areas – An integrated framework for sustainable development. Final Report, EU DG-Research, Brussels, pp 255, http://www.maich.gr/medmont