MULTI-DISCIPLINARY ASSESSMENTS OF PEAT SWAMP FORESTS AND ASSOCIATED WETLANDS ECOSYSTEMS FOR THE LOAGAN BUNUT NATIONAL PARK (SARAWAK) AND THE KLIAS PENINSULA (SABAH)

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ABSTRACT

Tropical peat swamp forests are unique and diverse ecosystems with a variety and abundance of often highly adapted fauna and flora. It is a "dual ecosystem" of tropical rain forest and tropical peatland found only within specific areas of the humid tropics characterised by low-lying flat land with limited seasonality and poor drainage. Many peat swamp forest plants are endemic and much of its characteristic fauna is severely threatened. Besides its critical role in providing habitat for wildlife, tropical PSFs also acts as a gene bank, harbouring potentially useful varieties of plant species.

The present project is part of *The Conservation and Sustainable Use of Tropical Peat Swamp Forests and Associated Wetland Ecosystems Project*, which is co-funded by UNDP, the Global Environment Facility (GEF), the Government of Malaysia, and the Governments of Netherlands and Denmark. Under this project, a separate task is to undertake Multi-Disciplinary Assessments (MDAs) of peat swamp forests. Three sites to be covered by the overall GEF Project have been identified by the states of Pahang, Sabah and Sarawak.

The term 'Multi-Disciplinary Assessment', however, is not clearly defined, and the paper will discuss various aspects of how to make MDA operational in protected area management and design/implementation of monitoring programmes. The present project operates with four disciplines: (1) socio-economy; (2) hydrology; (3) vegetation; and (4) wildlife, each of them subdivided into a number of indicators/properties that in concert describe the state of the ecosystem, the management variables and monitoring indicators. A Generic Evaluation Model for Inter-disciplinary Management Interventions (GEMIMI) is suggested to illustrate how relationships between the various indicators can be quantified to support overall management of forests and protected areas.

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1 INTRODUCTION

1.1 Context

Multi-Disciplinary Assessment (MDA) is an approach used in planning development strategies and projects for evaluation of effects in one discipline of various management interventions in other disciplines – and vice versa. Some tools for Environmental Impact Assessment have been broadly used for introductory evaluation of impacts on a number of sectors/disciplines for a set of management/project scenarios, e.g. RIAM (1998). These tools are typically used by a number of consultants, national and multilateral agencies in their effort to include all relevant/significant considerations in various sectors into the decision procedure for larger projects/management interventions, e.g. in management of protected areas (PA), water and forests (e.g. CEQ 1978; CEU 1997; World Bank 1988; Danida 1994).

These tools, however, separately assess the impacts on different sectors from a planned protect or a set of development strategies and management actions. The inter-sectoral (or multi-disciplinary) relationships are seldom addressed quantitatively due to the complexity of the procedure and lack of data/information. Yet, for protected area management these multi-disciplinary links have proven to be of major importance – often in the retrospective when undesired and unexpected results/effects appears.

It is necessary to ensure some degree of transparency and systematic approach in the generally qualitative assessment and evaluation of impacts where the cause-effect relationships are interdependent. MDAs need to be re-assessed with the passage of time and the data therein should be open to scrutiny and revision as new data become available. Therefore, there should be a direct link between any MDA-tool and the monitoring/data collection programme for the particular protected area.

1.2 Background

The background of the proposed MDA-tool (GEMIMI – A Generic Evaluation Model for Inter-disciplinary Management Interventions) originates from the principles of Agenda 21 and international policies on sustainable natural resources management. Natural resources are central to human activities and essential for poverty alleviation and economic and social development. Agenda 21 also outlined the principle of Integrated Water Resources/Coastal Zone Management (IWRM/ICZM) as an approach to action, which aims to ensure the co-ordinated development and management of water, land and related resources by maximising economic and social welfare without compromising the sustainability of vital ecosystems.

Sector thinking and approaches to management of natural resources have lead to fragmented and uncoordinated development and management. Natural resources management are traditionally positioned within specific sectors (e.g. forestry, environment, water, agriculture, industry, fishery and recreation) and managed by sector-based institutions. As a consequence, the management of natural resources tends to become lost within short-term rationalisation and sector interests.

The methodology presented in this paper is based on experiences and developments made during the Sungai Skudai Rehabilitation Action Plan Study, Johor State (AWE 2002). Rehabilitation of rivers includes interventions in a number of disciplines (wastewater, agriculture, water supply, forestry, etc.) and most of the planned interventions are correlated with the other disciplines. This approach, however, is general and can with few moderations be extended to function also for protected area management. Based on these experiences, we would like to propose the idea of Integrated Protected Area Management (IPAM) as an extension to the more consolidated (policy, institutional organisation, technical) concepts of IRBM and ICZM.

1.3 MDA Preliminary Report from Klias Forest Reserve, Sabah, and Loagan Bunut National Park, Sarawak (UNDP-GEF funded project)

During June and July 2003, a consultant team has carried out multi-disciplinary assessments of the two protected areas, Klias Forest Reserve (KFR) and Loagan Bunut National Park (LBNP). The purpose of the MDA is to provide a landscape level baseline assessment covering the following disciplines (examples of monitoring/management indicators shown in brackets):

- Socio-economy (Tourism, Logging, Hunting/fishing, Agriculture/development, …)
- Hydrology/infrastructure (Flooding, Drainage, Pollution, Fire, …)
- Vegetation (D. Rappa, Nepenthes spp, Pandanus spp, Gonystylus bancanus ….)
- Wildlife (Sooty-capped babbler, Flying fox, Proboscis monkey, Samba deer, ….)

The findings of the field surveys have been presented in a preliminary report to UNDP Malaysia on 15 August, and the data is presently being scrutinised and evaluated. Application of the present quantitative approach is not part of the project; however, IPAM can at a later state when sufficient information is available be formulated for the two sites and implemented into a decision support system based on the GEMIMI approach.

2 MATERIAL AND METHODS

This paper describes a procedure of scoring within a correlation matrix that has been designed to allow multi-disciplinary relationships to quantitative recorded – and later linked to a monitoring programme. Hence, the procedure provides inter-disciplinary evaluation and a record of knowledge that can be re-assessed and updated in the future. This chapter describes the methodology and the calculation procedures included in the GEMIMI tool (or MIMI in short) for IPAM.

2.1 Definitions

The basic assumption is that a protected area can be said to be in an optimal situation or state of balance for all of the disciplines engaged in the assessment. It should be noted that not all disciplines necessarily applies to all protected areas. Due the individual characters of the protected areas, the varying hydrological and socio-economic settings will determine the state and issues to be addressed. In general, though, socio-economy and secondly hydrology are the factors/disciplines that can be manipulated/managed – and which therefore also generally exercise the most severe threats to a given protected area.

Firstly, it is requisite to establish a baseline description of the actual protected area. In case of KRF and LBNP, the present MDA-study will give such a baseline description that can be used to plan future management interventions (action/management plans) and later function as a basis for monitoring and comparison of the temporal development in the selected indicators. The baseline state is assessed and given a character for each of the indicators under consideration.

For the present purpose, the baseline state for each of the indicators is given a value (numeric or alpha-numeric) according to where the resource lies in relation to a so-called balance state – or preferred state (see Figure 1). Preferred state is interpreted as a management characteristic that describes the overall objective of the protected area.

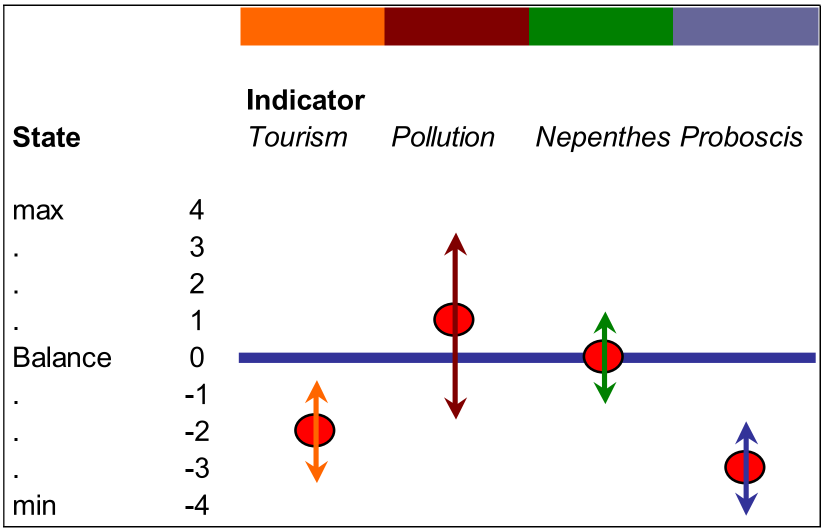

Figure 1: Definition of baseline and changes in indicators (example)

According to the baseline, for example *tourism* is recorded as being utilised below the carrying capacity (the balance state) of the protected area. This is the case for both KRF and LBNP. Consequently there is a potential of increasing tourism in the areas. On the other hand, pollution is on the 'wrong' side of the balance state, that is, the carrying capacity of the area is exceeded as far concerns pollution. These two factors usually counteract each other (pollution keeps tourists away and tourists generate pollution). How to analyse and quantify these interactions will be illustrated in the following chapter.

2.2 Overall approach

The Generic Evaluation Model for Inter-disciplinary Management Interventions (GEMIMI) is based on a set of indicators categorised in disciplines and a standard definition of the important assessment criteria as well as the means by which quantitative values for each criteria can be collated to provide a score for each indicator. The MIMI-matrix (Model for Inter-disciplinary Management Interventions) contains the cause-effect relationships between the indicators.

The impacts of management interventions are evaluated for the selected indicators in such a way the a score is given to each indicator as a measure of the direct impact of the intervention – and a score that measures the indirect impact caused by the cross-correlation between indicators. If the indicators are independent, then the score evaluation degenerates to standard single-disciplinary impact assessment methods such as the RIAM.

2.2.1 Evaluation criteria

Formulation of the evaluation criteria course of action is in the main based on the RIAM methodology, however, extended to operate on pairs of indicators (conditions) instead of single independent conditions. One important difference, therefore, is the use of 2-dimensional criteria in the MIMI describing the relationships between changes in one indicator on all indicators. The evaluation criteria fall into two groups:

(A) Criteria that are of importance to the indicator, and which can individually change the score obtained
(B) Criteria that are of value to the situation, but individually should not be capable of changing the score obtained

Interdisciplinary impact *magnitude* of indicator (**A**$_1$) (matrix). Magnitude is defined as a 2-dimensional measure of the scale of benefit/dis-benefit of change in one indicator on another indicator. The scales are defined:

+3 = strong positive impact (sp)
+2 = moderate positive impact (mp)
+3 = weak positive impact (wp)
0 = no change/neutral (n)
+3 = weak negative impact (wn)
+3 = moderate negative impact (mn)
+3 = strong negative impact (sn)

Importance (political priority) of indicator (**A**$_2$) (vector). A measure of the importance of the indicator, which is evaluated against the political priorities/interests or spatial scale changes will affect:

3 = Very important/high priority
2 = Moderately important/normal priority
1 = Less important/low priority
0 = Not important

Box 1: Group (A) criteria

Timing of indicator (**B**$_1$) (matrix). Timing describes whether an change in one indicator will have an immediate, delayed or neutral impact on the other indicator:

3 = Immediate
2 = Delayed
1 = None/NA

Reversibility of indicator (**B**$_2$) (matrix). This measure defines whether the indicator change will affect irreversible changes in other indicators:

3 = Irreversible
2 = Reversible
1 = Neutral/NA

Box 2: Group (B) criteria

Four criteria, two in each group, have been selected for the present MIMI. These criteria, together with their evaluation scores are defined in Box 1 and 2. Previously, RIAM has been applied to a number of projects and the method has demonstrated that the selected criteria represent the most fundamental assessment conditions, and satisfies the universality principle that allows them to be used in different EIAs.

The scoring system requires simple multiplication of the scores given to each of the criteria in group (A). The use of multiplier for group (A) is important to ensure that the weight of each score is expressed, whereas simple summation of scores could provide identical results for different conditions. Scores for the value criteria group (B) are added to provide a single sum. This ensures that the individual value scores cannot influence the overall score, but that the collective importance of all values in group (B) is fully taken into account. The sum of the group (B) scores is then multiplied by the result of the group A scores to provide a final evaluation score (**E**) for the indicator – also denoted the MIME-matrix in the following. This process can be mathematically expressed:

$$\begin{aligned} \mathbf{A}_m &= \mathbf{A}_1 \cdot \mathbf{A}_2 \\ \mathbf{B}_s &= \mathbf{B}_1 + \mathbf{B}_2 \\ \mathbf{E} &= \mathbf{A}_m \cdot \mathbf{B}_s \end{aligned} \quad (1.)$$

where the dot-operator denotes element multiplication.

2.2.2 Evaluation procedure

The MIMI-matrix calculation procedure is presented in the following:

1. Identify the indicators for each discipline (x_j)
2. Identify the baseline state for each of the indicators (**b**)
3. Identify/estimate the impact correlation between changes in the indicators (the *Magnitude*-matrix – $\mathbf{A}_1 = \rho(\Delta x_i, \Delta x_j)$)
4. Assign priorities to the indicators (The *Priority*-vector – $\mathbf{a}_2$ and $\mathbf{A}_2 = [\mathbf{a}_2\ \mathbf{a}_2\ \mathbf{a}_2\ \mathbf{a}_2]$)

5. Assign values to the *Timing*-matrix - $\mathbf{B}_1$
6. Assign values to the *Reversibility*-matrix – $\mathbf{B}_2$
7. Calculate the MIMI-matrix based on the input matrices – **E**
8. Assign values to the management vector – **m**
9. Calculate the direct impacts, indirect impacts and the total impacts – $\mathbf{i}_d$, $\mathbf{i}_i$ and $\mathbf{i}_t$

This is the basic procedure. For management purposes a number of further activities will be part of the IPAM plan:

10. Evaluate and optionally define alternative management vectors or calculate the optimal impact vector using linear programming technique
11. Formulate policies/measures that reflect the suggested interventions
12. Follow-up from regular monitoring programme (adjust the input matrices)

IPAM is, as the term expresses, based on integration of the relevant disciplines (inter-disciplinary) and close interaction between planning and the indicator monitoring programme. Monitoring and data assessment will link the effects as recorded in the real world to the management interventions and to their assumptions and relationships.

2.3 Calculation procedure

Having prepared the input data the direct as well as the indirect impacts of the management interventions can be calculated (step 9). Calculation of the total impact vector is in actual fact simple and straightforward once formulated in a matrix-notation. The direct impact ($\mathbf{i}_d$) from the management interventions quantified in the management vector (**m**) is calculated as:

$$\mathbf{i}_d = \mathbf{m}^T \times \mathbf{E} \qquad (2.)$$

where the x-operator denotes matrix multiplication and the superscript ^{T} denotes matrix transpose. The indirect impact vector ($\mathbf{i}_i$) is calculated by multiplying the cross-correlation terms in the MIME-matrix (**E**) and sum over each indicator:

$$\mathbf{i}_i = \sum_{row} (-1)(\mathbf{D} - \mathbf{U})(\mathbf{E} \cdot \mathbf{E}^T) \qquad (3.)$$

where **D** is a diagonal matrix and **U** is the unity-matrix. The dot-operator denotes multiplication element by element. The total impact vector is found as the sum of the two vectors:

$$\mathbf{i}_t = \mathbf{i}_d + \mathbf{i}_i \qquad (4.)$$

This corresponds to step 9 in the procedure outlined in the previous section. Having obtained the impact vector from one set of management interventions, other management scenarios can be evaluated and results compared in order to achieve the most optimal solution – and illustration of those mitigation measures that have to be implemented for the dependent indicators (typically flora and wildlife) in order to mitigate any negative impacts arising from indirect effects when introducing interventions in the independent indicators (typically socio-economy and hydrology).

3 RESULTS/EXAMPLE

The methodology is demonstrated using the example that was introduced in section 3.1. We have the four indicators (in more realistic applications the number is bigger, e.g. 4-5 indicators per discipline):

1. Socio-economy → Tourism
2. Hydrology → Pollution
3. Vegetation → Nepenthes spp
4. Wildlife → Proboscis monkey

The indicators are selected for demonstration purpose only and the numbers/assessments assigned to the indicators have no bearing whatsoever to KRF or LBNP.

3.1.1 Baseline vector

The balance situation is defined qualitatively or quantitatively for each of the four indicators:

1. Tourism → carrying capacity (e.g. 5,000 cap/year)
2. Pollution → water quality (e.g. WQI >= 70)
3. Nepenthes → number of species (e.g. 5 species)
4. Proboscis → number of groups/families groups (e.g. 3 groups of approximately 30 individuals each)

It should be noted that specific carrying capacity assessments should be made for each of the indicators for each site. Tourism, vegetation and wildlife are principally dependent on the size of the protected area. The PA must have a certain size to accommodate a certain level of biodiversity. If the boundary effects dominate to large part of the PA, there is no basis for wildlife or for tourism. Following the methodology shown in Chapter 2, the baseline vector **b** is given as:

Indicator	Value
Tourism	-2
Pollution	1
Nepenthes	0
Proboscis	-3

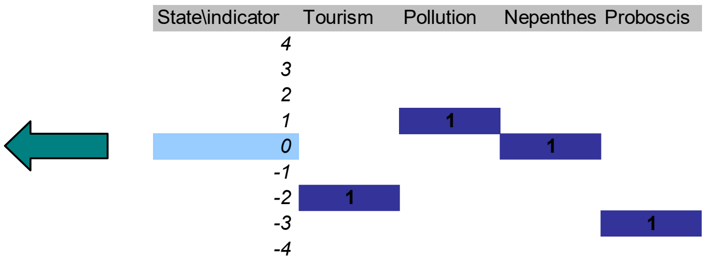

Table 1: Baseline vector describing the present state of the four indicators relative to the optimal balance state. State is given a character between –4 and 4 as shown in the graphical representation.

The baseline vector specifies that tourism in the actual area is developed below its potential. The pollution level is somewhat higher than the carrying capacity, the Nepenthes species are in balance and the Proboscis monkeys are essentially not found in the area.

3.1.2 Assessment matrices

The assessment variables are organised in the two groups defined in Chapter 2, and exemplified in the following. It should be noted that values entered are only for the purpose of illustration.

Change (increase) in / Effect on	Tourism	Pollution	Nepenthes	Proboscis
Tourism	1.00	0.67	-0.67	-0.33
Pollution	-0.33	1.00	-0.67	-0.33
Nepenthes	0.67	0.00	1.00	0.33
Proboscis	0.67	0.00	-0.33	1.00

*Table 2: Interaction magnitude (correlation) between indicators. (**A**$_1$ matrix)*

The correlation matrix indicates the interaction between the indicators, that is, it describes the effect that changes in one indicator will have on the others. The correlation matrix takes values between –1 and 1 indicating strong negative impact and strong positive impact, respectively. A value of 0 is given when changes in two indicators are independent.

Indicator	Priority
Tourism	2
Pollution	2
Nepenthes	2
Proboscis	2

*Table 3: Overall importance/political priority. (**a**$_2$ vector)*

The *Importance* criteria vector can be used to assign particular interests in the management planning. It may be that tourism for a number of reasons that are not covered by the MIME evaluation method is advocated strongly in a particular area within the influence zone of the actual protected area.

Change (increase) in / Effect on	Tourism	Pollution	Nepenthes	Proboscis
Tourism	2	3	2	3
Pollution	2	3	2	2
Nepenthes	3	1	2	2
Proboscis	3	1	2	2

*Table 4: Timing (**B**$_1$ matrix)*

Change (increase) in / Effect on	Tourism	Pollution	Nepenthes	Proboscis
Tourism	1	2	2	2
Pollution	2	1	3	2
Nepenthes	2	1	1	2
Proboscis	2	1	3	1

*Table 5: Reversibility (**B**$_2$ matrix)*

Effects of indicator interventions can be immediate, delayed or neutral – within and between indicators (Table 4). Any change in *Tourism*, for example, could have a delayed effect on itself meaning that even though measures are taken to increase tourism, the effect will be delayed because there is an inherent inertia in tourist preferences. Interventions may also have a tendency to result in irreversible effects on some indicators (Table 5), whereas changes in other indicators can be reversed later. Generally, negative changes in biological systems are essentially irreversible on a generation time scale.

Finally, the Evaluation Score matrix (**E**) is calculated based on the procedure given previously. The MIME-matrix contains the effective scores (scaled between –1 and 1) for the indicators including their interdependence. A positive number indicates a positive impact.

Effect on Change (increase) in	Tourism	Pollution	Nepenthes	Proboscis
Tourism	0.50	0.56	-0.44	-0.28
Pollution	-0.11	0.33	-0.28	-0.11
Nepenthes	0.28	0.00	0.25	0.11
Proboscis	0.28	0.00	-0.14	0.25

*Table 6: MIME-matrix (***E*** matrix)*

3.1.3 Management vector

The main purpose of the MIME-approach is to relate monitoring to management and further to follow-up and introduction of corrective measures (indicator monitoring programme). The management vector is used to include various management options formulated by the responsible authority/agency. Based on the baseline situation, the authorities can specify a set of management interventions for one or all indicators that have the purpose of correcting unwanted developments.

Indicator	Value
Tourism	1
Pollution	-1
Nepenthes	0
Proboscis	2

Table 7: The management vector (example). A minor increase in tourism, minor reduction of pollution, no actions on flora and moderate actions to support Proboscis habitats

In fact, the management vector can be established via mathematical optimisation (e.g. linear programming) by seeking solutions that minimise the variation of baseline state plus total impact around the balance state (the preferred optimal state).

3.1.4 Calculation of the impact vectors

The impact vectors for the example data are shown in Table 8.

Impact	Tourism	Pollution	Nepenthes	Proboscis
Direct ($\mathbf{i}_d$)	1.83	-0.11	-0.44	0.94
Indirect ($\mathbf{i}_i$)	-0.52	0.12	0.00	-0.43
Total ($\mathbf{i}_t$)	**1.31**	**0.01**	**-0.44**	**0.51**

Table 8: The calculated impact vectors

The direct impact vector ($\mathbf{i}_d$) says that from a management intervention described in Table 7, the direct effect is a further increase in **Tourism**, a reduction in the **Pollution** level, decrease in **Flora** diversity and increase in **Proboscis** populations. The indirect effects, however, counteract these direct effects to a certain extent except for the **Flora** indicator. The total impact scores are obtained by adding the direct and the indirect impact scores, and the result of the example management interventions is a net increase in **Tourism**, no change in **Pollution**, net decrease in **Flora** and an increase in **Proboscis** populations. Other management interventions can be tested in order to find an optimal/satisfying overall impact level, and to identify indicators where certain levels of mitigating measures must be taken in order to avoid undesired indirect effects.

4 DISCUSSION OF THE EXAMPLE

A general pattern can be deducted by presenting the MIMI-matrix itself without taking into account the management interventions. Figure 2 shows the MIMI-matrix for the example data presented earlier. For each indicator the direct effect on all indicators can be quantified relative to each other. For **Tourism**, for example, an intervention increasing tourism in the area by 1 unit (relative on a –4 to 4 scale) will have a direct impact (taking into account *Importance*, *Timing* and *Reversibility*) of approximately 0.5. It will have a net numerically positive effect on hydrology (increase of **Pollution**), and a negative impact on vegetation and wildlife. An increase in **Pollution** will generate negative impacts on the other three indicators, whereas a positive increase in number of species/population of **Nepenthes** will have a positive effect on the other indicators.

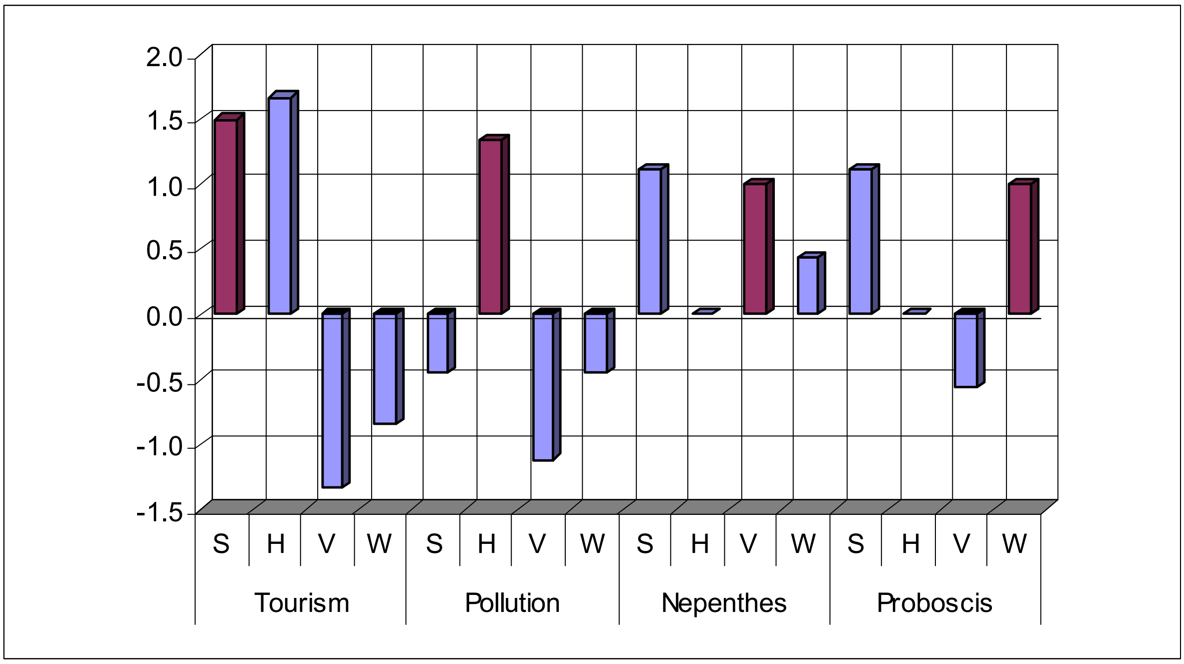

Figure 2: Influence factors for the selected indicators. (S = Socio-economy, H = Hydrology, V = Vegetation, W = Wildlife). Purple colour indicates the indicator that is changed and blue colour designates the resulting effects on the other indicators.

Hence, the influence factors are weights that measure the impact from any management interventions (changes in indicators) on all indicators. These weights transform the indicator changes (the management vector) into direct and indirect impacts. The management impacts given in Table 8 are shown in Figure 3. Here the manager can evaluate the effect of various activities (quantified/translated into matrix-notation) and design appropriate mitigating measures for undesired indirect effects.

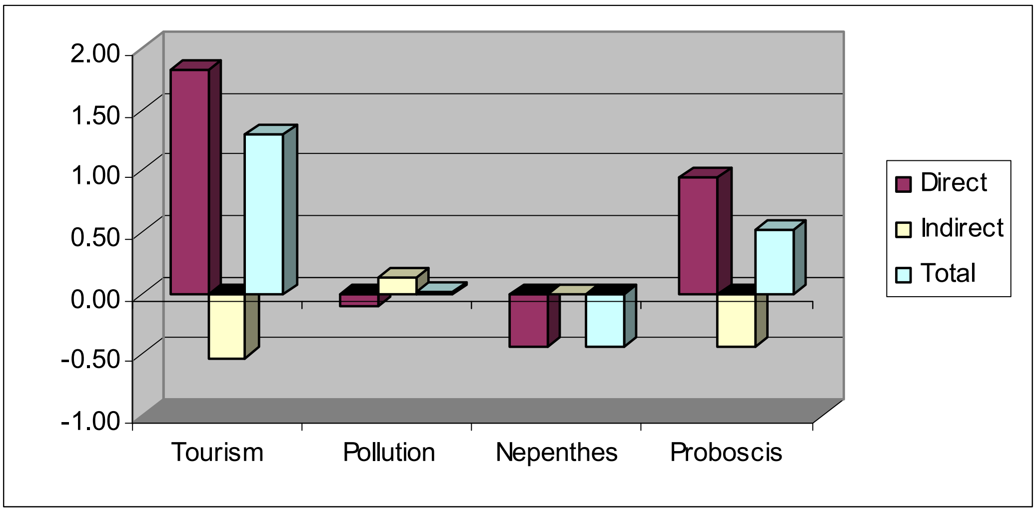

Figure 3: Management impacts for the selected indicators

Having calculated the total impacts of a set of management interventions, the management impacts can be added to the baseline evaluation in order to obtain a situation in the PA that conforms as good as possible to the preferred/optimal state. The result of this calculation is presented in Figure 4.

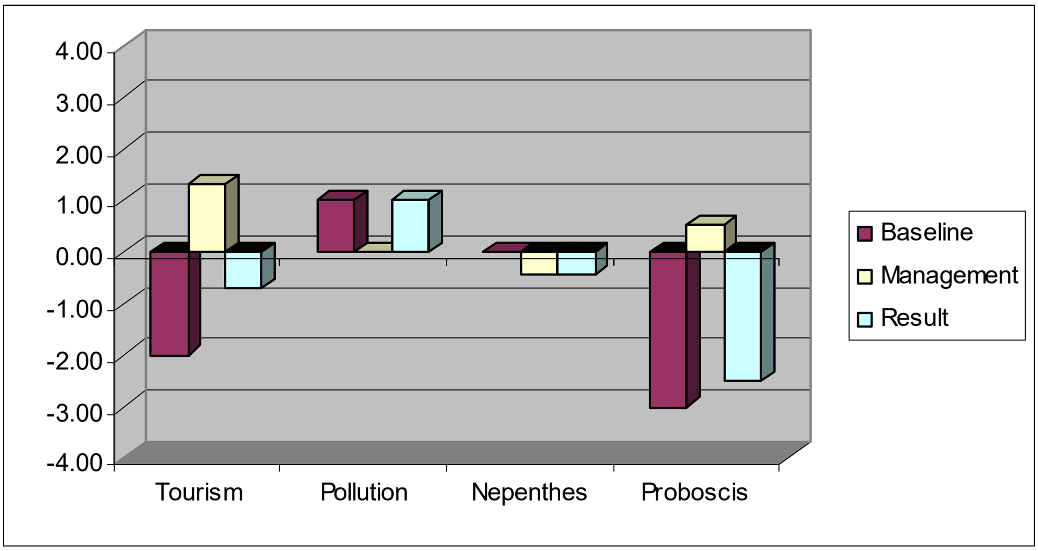

Figure 4: Influence factors for the selected indicators

The resulting PA evaluation shows that in spite of the planned interventions, the tourism potential is still below its balance level, pollution is essentially unchanged, flora diversity/population is slightly decreased and the Proboscis population still significantly below the preferred number. A mathematical optimisation procedure can be formulated in order to estimate the management vector in such a way that the total sum of the results over the indicators is equal to 0 – meaning that the PA is in balance on average.

5 CONCLUSION

The MDA-tool (GEMIMI) is described here on a purely theoretical basis, though development and testing is continuing to assess the use of the methodology in the complex world of protected area management. One strong argument for following a stringent mathematical procedure is to eventually establish objective documentation for decisions made as to the future management and protection of natural resources, e.g. protected areas.

The GEMINI approach links closely together baseline evaluation, data collection/monitoring and decisions in an adaptive and transparent environment. The MIME-matrix can be established based on general experience and information from general research and other practical PA management plans. Based on the selected indicators, the monitoring programme should then be designed to verify or refute the inter-relationships stipulated in the correlation matrix, e.g. relationships between hunting and animal populations for various species, between drainage and vegetation, between agricultural or tourist development and pollution.

Hence, the GEMIMI can assist decision makers in making proper use of the increasing amount of data and information that is collected in connection with protected areas. Generally, it is not possible to get the picture of all data and synthesise the complex relationships without proper analysis and decision support tools. By setting up the matrix-system described in this paper, it is possible to compare a number of management scenarios and make comparisons between them in order to find a satisfying solution and also to identify measures that can mitigate indirect and unwanted effects.

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