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Landscape Ecological Indicators - Application to the monitoring system of sete cidades special land use plan

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Abstract

The village of Sete Cidades and its surrounding landscape are considered to be the most important tourist attraction of the Azores archipelago. However, the landscape and its values are at risk. The lakes show an advanced state of eutrophication, due to an increasing agricultural use of the basin as pastureland for milk production. A Special Land Use Plan for this area (POBHLSC) was prepared and within the framework of a INTERREG-IIIB program, a Pilot Study on the Integrated Management of Sete Cidades Landscape is being carried out. This aims at the definition of a monitoring system that will enable the periodic evaluation of future landscape dynamics within the context of the plan. After its approval, the plan will regulate the future land uses, and therefore it may have a considerable impact on the landscape features.
Even though there is not much experience available on landscape monitoring and development of landscape indicators systems in Portugal, this pilot study aims at providing an approach as a basis to a future systematic use.
The approach is built on a recently produced landscape unit map and the formulation of a suitable set of landscape indicators, structured according to the OECD Agri-environmental indicator model.
This paper presents the adopted methodological approach by focusing on the landscape indicators development and its integration in a monitoring system, which is based on a GIS.

Introduction

The definition of landscape is outlined by an ambiguous concept as far as the subject, contents and coverage are concerned (Ramos, 1998). However, its dynamics in time and space is consensually recognized, especially within the context of a particular cultural landscape as it is the case of Portugal and Europe in general: each landscape has its own specificities which are given by the relationship between the current society and the environmental components (Andresen, 1992, Saraiva, 1999, Telles, 1994), being them the political and spatial framing in which the societies develop and to which they are subordinated.

The European Landscape Convention (2000) is the latest international policy-guiding document as far as the landscape is concerned. It appeals to the definition of national landscape policies, a process that comprises the identification of landscape units, the definition of landscape goals and monitoring the policies performance against the outlined goals, involving a periodic application of landscape indicators too.

The landscape monitoring process is extremely important (a) to understand the transformations, (b) and the transformation processes in order (c) to identify the performance of the set objectives. Also, (d) in order to evaluate the efficacy of the political measures that may directly aim the evolution of the landscape (d), which should originate adjustment responses to these instruments, and/or the re-definition of the objectives. This becomes extremely important when dealing with very dynamic landscapes which are subjected to pressures that cause their transformation, or in cases of highly fragile landscapes. This fragility may have not only environmental but also social origins. The pressure factors may also be of

different natures, being those predominantly related to decisions that may cause a change in the patterns of the human activities, and as a result, in the land uses.

The Sete Cidades Watercatchment landscape is undoubtedly a landmark when it comes to recognize the Azores archipelago in Portugal and abroad. Owing to its landscape framing given by the Sete Cidades Lake, this landscape unit is truly worthy of its epithet: the *ex libris* of the Azores. The lake is located on the island of São Miguel, within the area of Ponta Delgada municipality. Its surface reaches 19,34 Km^2. The ridgeline is limited by the edge of the Sete Cidades volcano crater. It is indeed, an almost perfect circular huge depression with 17,8 Km of perimeter. There are four water bodies in the watercatchment, showing each one of them different characteristics. They are the Blue, the Green, the Santiago and the Rasa Lakes and altogether they correspond to 24% of the lacustrine area of the watercatchment.

The Blue Lake is the largest water body and also the largest superficial hydric reservoir in the Azores archipelago. Therefore, it is a strategic water reserve to several uses, including the water supply to the populations. The smaller Green Lake (0,83 Km^2) is connected to the Blue Lake by a narrow, shallow channel (Figure 1).

Figure 1 – View of Sete Cidades Watercatchment

The current landscape of Sete Cidades is a historical testimony of the evolution of the different economic and social circumstances that have marked the territory throughout the productive specialization cycles of the Azores economy (Calado, 2000). This landscape is also the support of the cattle-breeding activity, specifically for the production of milk, which is the main economic activity of the inhabitants (about 800). Thus, the Sete Cidades landscape reflects the adaptation of the man to the pre-existing environmental conditions throughout the time.

The landscape is dominated by the glittering waters of the Green and Blue lakes, but it is also possible to enjoy other unique details such as the segmented structure of the pastureland included in a forest matrix of *Criptomeria japonica* and the singular built area which is also a remarkable feature in the landscape.

There are also other structuring elements in this landscape, such as the streams and the road network. The hydrographic structure, deeply rooted in the surrounding relief, defines outstanding visual units. Owing to its unique nature, the whole watercatchment results in an arranged, although contrasting, exceptional landscape value in which the relations between the biophysical and cultural components express the geomorphological, ecological and economic complexity. As a consequence of these unique characteristics Sete Cidades has become a tourist attraction which contributes to the dynamics of several economic activities in the region.

Nevertheless, the lakes are currently in an advanced state of eutrophication due to the increase of the cattle breeding activity and use of fertilizers (Porteiro, 2000). The reduction in the transparency of the water, the change in its colour and the rapid growing of algae are some of the most visible phenomena (Figure 2). The degradation in the quality of this resource has determined the need to elaborate the Special Land Use Plan for the Sete Cidades Watercatchment (POBHLSC), which is already being implemented.

Figure 2 – Eutrophication phenomenon in the Sete Cidades Lake

The adopted development scenario and management model will lead to continuous changes to the current land uses in some areas of the watercatchment and to the implementation of vegetation corridors and galleries. The proposals of the plan will inevitably bring impacts to the landscape. Therefore, monitoring is necessary so that the previewed effects of the plan on the landscape may be evaluated *in continuum* in order to enable acting upon the planning process in time in case any unexpected or unsatisfying situation is detected. According to this presumption and within the scope of the Pilot Programme for the Protection, Integrated Management, Rehabilitation and Sustainable Valorisation of the Macaronesic Islands Landscape, it has been decided to elaborate the Pilot Study for the Integrated Management of Sete Cidades Landscape Unit. The respective financing comes from the Community funds FEDER and Interreg IIIB Açores-Madeira-Canárias (Azores-Madeira-Canary Islands). The main goal of this pilot study consists in the definition of a supporting methodology to create a monitoring system which may allow to evaluate and determine the landscape dynamics after the implementation of the POBHLSC, using landscape indicators and a geographic information system (GIS).

Pressures upon the landscape dynamics

The existence of multiple definitions of landscape reflects the diversity of perspectives that approach the subject. Beyond the objective component, they also include perceptive, artistic and subjective components (Ramos, 1998). In an attempt to

summarise these perspectives, Saraiva (1999) proposes a three dimension structure for the components which contribute to the formation of the landscape: (a) biophysical and ecological, (b) social, cultural and economic and, finally (c) perceptive, aesthetic and emotional.

From this structure stands out the fact that beyond the natural dimension in the landscape, and particularly in the cultural landscape, which has been changing throughout the time, there is a very strong human component, not only at the level of the physical construction factors, materialized through the economic activities and social relations which are established in the territory, but also at the level of mental constructions that each individual activates before a landscape.

In the rural landscape the land uses are an indicator of the human activities, some of them closely connected with the natural components such as agriculture and sylviculture. These uses deeply mark the landscape due to the vast area they occupy, contributing significantly to its visual and aesthetic quality and can also affect the quality of the environment.

All the activities that may cause environmental damages in the lacustrine ecosystems are present in this watercatchment, except for the industry. Nevertheless, the rural character of the human activities practiced in this territory reflects a clear evidence of non-urban uses. (Table 1). Owing to this fact, more attention is paid to the environmental and landscape pressures linked to cattle breeding, sylviculture and agriculture.

Table 1 – Land Uses in the Sete Cidades Watercatchment

Land Use Categories	Watercatchment Area	
	(ha)	(%)
Forest	841,4	57,3
Agriculture	41,0	2,8
Cattle Breeding	463,2	31,5
Social	84,8	5,8
Other Uses	38,3	2,6
Total	1468,7	100,0

Source: Calado, 2000.

Besides the cattle breeding, potential impacts arising from tourism have also been considered, since there has been an increase in the use of the water body and its surroundings for leisure activities. It is important to stand out that all the factors that contribute to the degradation of the water quality are indirect activators of the landscape dynamics.

However, the spatial planning instruments also change the landscape by regulating the occupation and transformation of the land uses. Several of these instruments, as well as instruments for nature protection and preservation converge in the Sete Cidades watercatchment. Whether they are of legal or strategic nature, their significant number brings some complexity to the management of this area. The Study of Characterization and Identification of the landscapes of the Azores, the Ponta Delgada Municipal Master Plan (in force), the regulations the Sete Cidades Protected Landscape (in force), the POBHLSC (in force) and the Operational Plan for the Environmental Re-qualification of the Azores Autonomous Region Lakes (in force) are the most relevant instruments.

Within these instruments, the POBHLSC stands out since it binds the remaining ones (except for the urban area of the watercatchment), including specific dispositions that will regulate the interventions in this landscape. Its goals are framed by the figure of Special Spatial Plan for the Lake Watercatchment, as well as, on the objectives resulting from the European Community guidelines (Water Directive 2000/60/CE and Agenda 21). Besides these, there are also the general goals included in the building/specifications agreement of the plan and those resulting from the specificities of the intervention area. Indeed, all these objectives cross and complement themselves due to the transversal nature of the resource water. Nevertheless, the specific goals of the POBHLSC are of a great importance:

- to make the lake viable as a strategic water reserve,
- to create a sustainable management model to fight the eutrophication process;
- to value the water body as a resource and to expand the leisure use areas;
- to diversify the economic basis by promoting new activities and the participation of the local agents.

The POBHLSC foresees a set of indicators that will allow the evaluation *in continuum* of its performance throughout the validity period. The plan includes two landscape indicators, namely *Lake Transparency* and *Variation in the Built Area*. However, and given the relevance of this territory unit, there was the need to develop a monitoring system to support the landscape impact assessment.

Landscape Monitoring System of the Sete Cidades Watercatchment

Creating a monitoring system based on indicators allows to determine the landscape dynamics in the watercatchment as a supporting tool to its integrated management was the main goal of the pilot study. Nevertheless, knowing that the implementation of the POBHLSC will directly condition the landscape has influenced the way this monitoring system was developed. In fact, it is senseless to start monitoring the Sete Cidades landscape without taking into account that the main element which will regulate its transformation is the POBHLSC. Therefore, the evaluation of its implementation and impacts reveals itself as being of extreme importance.

However, considering the focus and the specific goals of the pilot study, it has been decided to give priority to the landscape monitoring. Based on these presumptions the Landscape Monitoring System of the Sete cidades Watercatchment has been created and will be forward referred to as SMP SETE CIDADES. Nevertheless, and in sequence of what has been mentioned above, it is composed of two monitoring subsystems, which are:

a) the Monitoring and Management System of the POBHLSC;

b) the Landscape Monitoring System.

Still, both monitoring systems are complementary and inter connected in some of their components. In fact, they act as a database, with the possibility of being up dated, which allows the user to visualize and consult all the graphic and written components of each system.

The **Monitoring and Management System of the POBHLSC** aims to supervise its implementation and support and the licensing process (housing and other activities). By having access to this system, the user may consult the

fundamental elements of the plan – Future Land Use Map; Constraints Map and Regulations, as well as some of its complementary information, such as the proposed programmes/ projects/actions and the Monitoring Report. In this scope, it is also possible to view all information related to the monitoring indicators. In order to support the urban and licensing management in the Sete Cidedades watercatchment, the cadastre of the properties map has been also incorporated in this system. Thus, the user selects a certain parcel in the cartography and has the opportunity to consult all the related information collected. Since the limit of intervention of the POBHLSC is restricted to the non-urban area of the watercatchment, the graphic and written fundamental pieces of others legal existent instruments for this territory are also made available.

The Landscape Monitoring System aims to supervise the transformations which will occur in that territory during the time of the implementation of the POBHLSC. The Landscape Units Map is the basis of this system (Figure 3).

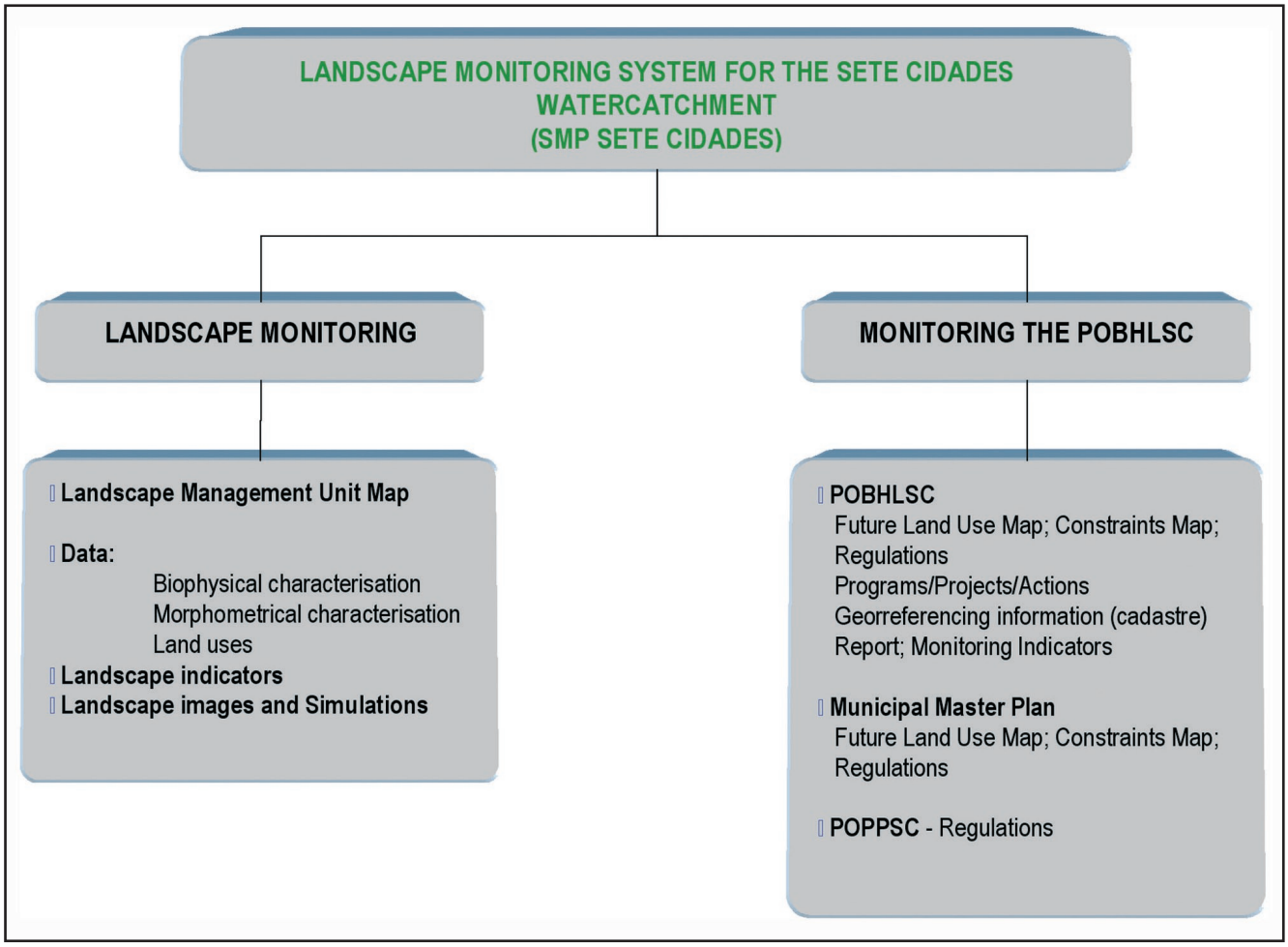

Figure 3 – Structure of the Landscape Monitoring System for the Sete Cidades Watercatchment

Landscape indicators

As it has been mentioned before, indicators are important elements in a landscape monitoring system. However, landscape indicators have begun to be developed very recently and included in agro-environmental indicators systems. The debate on the definition of landscape indicators and their structured formulation dates to the end of the nineties. Thus, the discussion on how to improve them is still going on, mainly the aspects concerning their operationalization, being the experience in this scope very limited.

The OCDE plays a fundamental role in the development of landscape indicators within the context of the agro-environmental indicators and proposes their organization according to the landscape structure: - those which inform how the landscape is managed, that is; the political measures that actively contribute to the protection/conservation of a given landscape and those which reflect the value that the society attributes to the landscape.

As far as the landscape structure is concerned, there is a large theoretical field within the scope of landscape ecology where several mathematic indexes have been developed aiming to objectively quantify different aspects of the landscape structure (i.e. Forman, 1995; Turner and Cardille, 2002; Eiden et al., 2002). In this context, it is necessary to identify the components or elements of the landscape and to be able to detect their spatial organization afterwards.

The OCDE has proposed two indicators for monitoring the landscape value - *Public Evaluation of the Landscape* and *Public Expenditures in Landscape Conservation*. The public evaluation of the landscape is generally evaluated by carrying out surveys to different segments of the public about their preferences. The public expenditures in landscape conservation refers to the amount that the government spends in studies, plans, measures or training sessions aiming specifically the landscape conservation, bearing in mind the assumption that the budget priorities reflect the concern of the society and thus, its social value.

Since the experiences concerning bringing into practice the indicators are quite few, there is no consensus regarding which are the "best" indicators. Thus, the proposed set of indicators for the landscape monitoring of the Sete Cidades Watercatchment follows the model mentioned above, but it takes into account the characteristics of this territory and the purpose for which the indicators were created. In fact, the goal is not to establish comparisons, but to follow the evolution of this landscape throughout the time (until the year 2015), being irrelevant some parameters for which it is not previewed that in normal conditions, and in this period of time, may suffer alterations.

Thus, the adopted methodology for the construction of the indicators system, which aim to reflect what is important in this landscape, has been based on three stages:

(a) research on the landscape indicators already applied in others landscape monitoring systems;
(b) discussion on the indicators that were coherent to be applied to the Sete Cidades landscape, given its specific characteristics;
(c) final filtration of the indicators, considering the ones that are theoretically valid and simultaneously operational and possible of being implemented within the monitoring system, given the existent data and the resources available.

Thus, a set of indicators was proposed but also an optional one, which is considered to enrich the former, but as it is more resource-consumer it can be subsequently executed, according to the availability of the competent authority.

Landscape Structure Indicators

Generally, the spatial structures of the landscapes are associated with the composition and configuration of the elements that constitute them. The composition refers to the number and occurrence of different types of landscape elements, whereas the configuration comprehends the distribution or spatial character within the landscape. The quantification is related to the biodiversity measurement, homogeneity and heterogeneity. In this scope, a preliminary exercise was carried out in order to identify the dominant pattern of the landscape and the fundamental elements of its composition. The more relevant are the following:

(d) the vast water body made up by the lakes;
(e) the dense and continuous forest occupation of the sloppiest hills and ridges;
(f) the pastureland in less slope areas divided by forest fences or stone walls;
(g) the housing agglomeration in the Sete Cidades village;
(h) the existence of cultural elements such as the lava stone walls, built area and the bridge over the lake.

Following the systematisation of the structure indicators that may be applied to landscape monitoring systems, it has been an option to adopt a set of indicators which may be supported by the information of the POBHLSC (e.g. classes of areas) and by the frequency of collection recommended in the respective monitoring plan so as to reduce the use of other resources (Table 2).

Table 2 – Landscape structure indicators for the Sete Cidades Watercatchment

Code	Indicator
IE.1	Land use
IE.2	Rate of Land use transformation
IE.3	Patch Density
IE.4	Edge Density
IE.5	Core Area Density
IE.6	Cultural Features
IE.7	Lakes transparency

Nevertheless, it has been thought that beyond the organization of the elements, indicators that may inform about the quality of the elements (matrix parcels and corridors) should also be included. That is, the indicators that may reveal their specific composition, namely those concerning the flora. The necessary information in order to calculate these diversity indicators demands a survey of species in terms of abundance and frequency based on aerial photography and fieldwork.

Landscape Value indicators

The indicators proposed by the OCDE (2001) suggest the use of two indicators as shown in Table 3.

Code	Indicator
IV.1	The public valuation of the landscape
IV.2	Public cost of maintaining or enhancing the landscape

Table 3 - Landscape value indicators for the Sete Cidades watercatchment

As far as the indicator "*Public valuation of the landscape*" is concerned, its definition is based on the importance that the perception aspect assumes within the context of landscape monitoring. It is a fact that the perception of the landscape by the inhabitants of the watercatchment and those who visit it may be currently different from the one they will have throughout the time of the implementation of the POBHLSC. In a comparative perspective, it would be interesting to investigate about the current and the future perception of that landscape. Carrying out a survey at half time or near the end of the plan horizon, will allow the quantification of this indicator. The results of this inquiry may help the reviewing process of the POBHLSC.

Landscape Management Indicators

The management indicators proposed for the monitoring of the Sete Cidades Watercatchment are some of the ones proposed in the POBHLSC, namely the ones that are considered to be relevant to supervise the transformation in that landscape (Table 4).

Code	Indicator
IG.1	Strategic objectives of the POBHLSC that have been achieved (%)
IG.2	Specific objectives of the POBHLSC that have been achieved (%)
IG.3	Public-private partnership actions that fit the objectives of the POBHLSC (%)
IG.4	Projects in which the previewed goals are achieved (%)
IG.5	Achieved previewed actions in the plan, per item (%)
IG.6	Actions/projects of POBHLSC whose costs of execution have been exceeded, per item and amount (%)
IG.7	Annual execution of the financing plan (%)
IG.8	Actions/projects of the POBHLSC whose financing agenda was not fulfilled

Table 4 - Landscape management indicators for the Sete Cidades watercatchment

Complementary information is associated to each indicator: units, methodology for calculation, source of information, local of sampling, periodicity, bibliographic reference and commentaries. In the landscape indicators database there is a cell dedicated to the calculation of the indicator where the user of the system may, throughout the time, and in accordance with the established periodicity, fill the value of each indicator, keeping the database updated.

Final considerations

The growing political significance given to the landscape, its valorisation as a natural and economic resource, results in the increasing need to protect it, and therefore to monitor its transformations due to the pressures it suffers.

The Spatial Plans are by themselves an important pressure factor upon the landscape that needs to be evaluated throughout the time, using indicators systems able to reflect the significance of those transformations.

The value of the Sete Cidades watercatchment, associated to the elaboration of a Special Spatial Plan, has created a window of opportunity to include a system specifically aimed to monitoring its landscape. It is within this context that the proposal herein presented has been conceived, taking into account the specificities of this landscape and the objectives of the respective monitoring process. However, and due to the lack of experience in applying landscape indicators to monitoring systems, this pilot study can be considered as a first approach, susceptible of being validated in other case- studies.

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