Environmental Engineering and Management Journal *July 2016, Vol.15, No. 7, 1593-1602*
http://omicron.ch.tuiasi.ro/EEMJ/

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MAPPING THE ECOLOGICAL STRUCTURE IN OCEANIC ISLANDS - THE CASE-STUDY OF S. MIGUEL ISLAND (PORTUGAL)

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Abstract

Oceanic islands face very serious environmental issues such as climate change, environmental degradation, loss of biodiversity and proliferation of invasive alien species. The delimitation of the IES shall consider the many inter-relationships between all biophysical and cultural variables, contributing therefore to a better understanding of the socio-ecological system. The Island Ecological Structure (IES) includes the key natural resources, biophysical functions and ecological processes within this territorial unit, in order to ensure the existence of a *continuum naturale* across the island. This paper presents a methodological proposal of mapping IES. A case-study based on consistent biophysical and land policy criteria was conducted for S. Miguel Island (Archipelago of the Azores, Portugal). The results have showed that the Island Ecological Structure covers about 75% of its total area. The land use conflictive areas within the Island Ecological Structure (21%) have also been identified and should be addressed by Land Management Plans in order to minimize the conflict effects.

Key words: Azores, ecological structure, environmental planning, island, land management

Received: January, 2012; Revised final: April, 2013; Accepted: April, 2013

1. Introduction

The importance of island ecosystems has been formally recognized by many pieces of legislation and European Policy by both the European Union (EU) and the Council of Europe. Oceanic islands host a high proportion of endemic species, many of which are in danger as a consequence of recent human habitation (Whittaker and Fernández-Palacios, 2007). There are very few places where the "biodiversity crisis" is as apparent and in need of urgent action (Triantis et al., 2010). These characteristics associated with remoteness, isolation, smallness, and particularly closed systems, make planning and management on small islands more challenging in scientific and technical terms (Calado et al., 2007; Gil et al., 2012). Moreover, the biodiversity within island ecosystems is fundamental to ecosystem functioning that underpins services on which human well-being largely depends (Borges et al., 2010). Climate variability and changes, the proliferation of invasive exotic species, the increasing growth of tourist activity, natural catastrophes, the overexploitation of natural resources, as well as the pollution and residue management are the main threats to sustainable development, nature conservation and small island biodiversity maintainability (CBD, 2006). Anthropogenic pressures, such as land use changes, are one of the main threats to biodiversity conservation especially for island ecosystems, inherently vulnerable systems (Lagabrielle et al., 2009). Therefore, the planning and

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management systems of protected areas need to be adjusted to the specific context of small islands, so that they can ensure maximum effectiveness in space organization, and fulfillment of inherent conservation and sustainable development objectives (Fonseca et al., 2011).

The Island Ecological Structure (IES) includes the key natural resources, biophysical functions and ecological processes that have to be preserved in order to maintain their integrity and to ensure the existence of a *continuum naturale* across the island. It should constitute a strategic and core instrument for land planning and sustainable development policies support at island scale (Vieira, 2007). The concept of Ecological Structure (ES) as land planning decision support element has been introduced in Portugal by the Decree-Law 380/99 of September 22nd 1999, which states that Municipal Master Plans should map the ecological structure through the identification of the key natural, cultural, forest and agricultural resources as well as the biophysical functions and ecological processes that are associated with them.

Nevertheless, this legal diploma does not define which type of resources should be identified and described, and which type of methodological approach should be applied during this core mapping process. The National Nature Conservation Strategy of Portugal published in 2001 through the legal diploma RCM 152/2001 of October 11th 2001 states that the ES identification and mapping procedures would be mandatory for all land management instruments, at every territorial scale (local, municipal and regional). Although the mandatory nature of this process, neither ES components neither methodological approaches have been legally defined since then.

Consequently, many different methodological approaches have been applied to identify and map the municipal, inter-municipal and regional ES in mainland Portugal on the behalf of land planning instruments development processes. The degree of complexity and factors prioritization strategy applied on this mapping process varies considerably in each master plan (CM Arruda dos Vinhos, 2006; CM Cascais, 2005; CM Coimbra, 2009; Machado et al., 2005; Magalhães et al., 2002; Neto, 2010; Quental et al., 2004; UTAD, 2001). In general, most approaches have defined the territory covered by classified sites (mostly Protected Areas and Natura 2000), by the National Ecological Reserve (REN) and by the National Agricultural Reserve (RAN) as core areas of the Ecological Structure.

The main goal of REN is to regulate land-use in both areas with high susceptibility to natural hazards, and areas essential for aquifer recharge, protecting them also from contamination (Laranjeira and Teles, 2005). The RAN main purpose was to defend and preserve all the areas with better soils and higher agricultural aptitude and productivity.

Because of their geographical (archipelago of 9 small islands) and political (autonomous region) framing, as well as their singular morphological and ecological characteristics, both REN and RAN national diplomas never were fully transposed and applied in Azores islands. Instead, both diplomas applications were interpreted and adapted to local biophysical and socio-economic reality because of the huge existing differences between these territories and those in mainland Portugal for which they were originally created.

Therefore, the Regional Agricultural Reserve (RAR) focuses its soil protection measures on the mitigation of superficial erosion due to the mountainous and steep nature of Azores islands morphology, by classifying as arable soils those located in larger flatter areas (Gil, 2007). REN has never been formally adapted and legally transposed into a coherent Regional Ecological Reserve (RER).

Azorean local and regional administration technicians and policy makers have been mapping this reserve by identifying all the REN features that can be observed in these islands and entitling them as Municipal Ecological Reserve (REM). Nevertheless, some typical morphological features as "fajãs" (supratidal talus-platforms with hummocky surfaces resulting from landslides along Azores islands cliffed coasts) are not included for protection in the REN diploma but have been integrated into REM.

The Azorean Regional Network of Protected Areas (RRAP) is defined by two basic units: the Islands Natural Parks (PNI for terrestrial and coastal areas) and the Azores Marine Park (PMA for marine areas). There are nine PNI, as much as islands in the Azores Archipelago (Calado et al., 2009). All existing classified areas for nature conservation such as Natura 2000 sites (Special Protected Areas and Special Conservation Zones), Ramsar sites, UNESCO Biosphere Reserves, Important Bird Areas (IBA) and Natural Forest Reserves have been reclassified using IUCN classification system and integrated into the RRAP in order to perform a more effective and coherent conservation planning and management. These areas include most of the Azores Archipelago's terrestrial, coastal and marine ecological value (fauna, flora and habitats).

This paper aims to propose a methodology and present a case-study application of an Island Ecological Structure mapping process based on consistent island-scaled biophysical and land policy criteria fully adapted to Azores Islands (Portugal). The main goal of this GIS-based approach is to support on a coherent and objective way the elaboration, implementation and monitoring of regional and municipal master plans and further land management tools (protected areas, basins and lakes, coastal areas). This methodology shall be able to be applied to further small volcanic islands from Macaronesia (Azores, Canary and Madeira archipelagos) and European Outermost Regions.

2. Experimental

2.1. The case-study of S. Miguel Island (Archipelago of the Azores, Portugal)

Azores Islands, located in the North Atlantic, are an archipelago consisting of nine volcanic islands with stunning coasts, forests, and year-round mild weather. S. Miguel, the largest and most populated island within the Azores archipelago, is located about 1500 km from Europe (Fig. 1). This island with 74677 hectares is part of the Eastern group together with Santa Maria, the oldest and easternmost island. São Miguel Island extends along an E-W axis which starts in the old solid mass of Povoação and Nordeste, the oldest of the island (dated about 4 Mys ago), which holds the highest peak of the island (Pico da Vara, 1103 m a.s.l.). The island continues towards the west by the connected and progressively younger stratovolcanoes and *caldeiras* of Furnas, Fogo and Sete Cidades. Climate is temperate oceanic with a mean annual temperature of 17ºC at sea level. Relative humidity is high and rainfall is topographically determined, ranging from 1,000 mm/yr in the coast to well above 3000 mm/yr in the highest altitudes of the Sete Cidades, Lagoa do Fogo and Graminhais volcanic buildings. Human settlement in the Azores began in the 15th century (Hortal et al., 2010; Silva, 2001). Most people live and work around the coast resulting in significant development pressure on the environment. In the last 20 years this trend has even increased considerably. The narrow littoral fringe of the Azores islands is one of the few land areas that offers potential for settlement, and Azoreans are strongly dependent upon the sea for income, communication, and trade. This explains the coastal location of major commercial facilities and employment opportunities, together with economic activities and population (Andrade et al., 2006; Rodrigues et al., 2012).

2.2. Phase 1 - IES GIS model organization

The first step consists of identifying the core geographic variables to be inputted into our GIS procedure flowchart (Fig. 2). A cultural variable (Landscape) and five core biophysical variables (Flora and Fauna, Water, Soils, Landforms, and Geology) support the GIS process organization. All three basic land protection instruments applied in the Azores Autonomous Region (Municipal Ecological Reserve; Regional Agricultural Reserve; Regional Protected Areas Network) have been analyzed in order to understand and extract the GIS variables that would represent their full integration within this model:

- Municipal Ecological Reserve (REM): areas of superficial erosion by water flowing; hydrological network (streams and margins); maximum infiltration areas, areas of flood risk, headwaters areas, wetlands, ponds, springs, steep areas with slopes over 30%, beaches and coastal dunes, cliffs and islets.
- Regional Agricultural Reserve (RAR): Arable Soils (A, B and C types).
- New Regional Protected Areas Network (RRAP): besides former standard protected areas, the reorganization of this network implied a reclassification according to IUCN categories and the inclusion of new areas showing high geological ("Azores Geopark") and ecological interest (Natura 2000 sites: Special Protected Areas and Special Conservation Zones, UNESCO Biosphere Reserves, Ramsar Sites and IBA- Important Bird Areas) (Calado et al., 2009).

As a core physical feature type of the Azorean insular morphology that is not included in the REN diploma, "fajãs" (supratidal talus-platforms with hummocky surfaces resulting from landslides along Azores islands cliffed coasts) have been included as a "Landforms" variable.

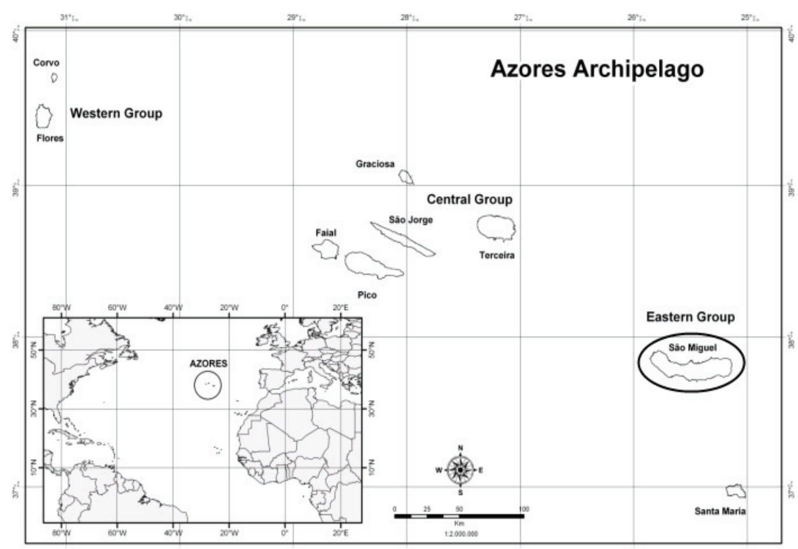

Fig. 1. Location of Archipelago of the Azores and S. Miguel Island

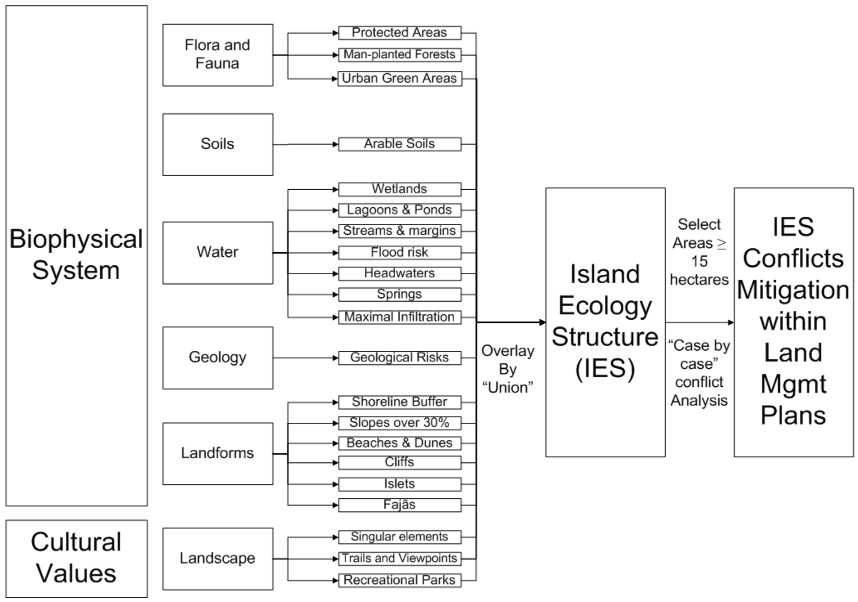

Fig. 2. Methodological flowchart for obtaining the Island Ecological Structure (IES)

Regarding "Flora and Fauna" variables, besides protected areas, some basic but fundamental IES land cover features such as man-planted/production forests (mostly *Cryptomeria japonica*) and urban green areas have to be identified and mapped.

At the cultural level, three landscape features have to be inputted in our IES model: "singular landscape features" (Cancela D'Abreu et al., 2005), pedestrian trails and viewpoints (both including a respective protection/influence area), and the existing forest-based recreational parks. The promotion of environmental values and the growing importance of ecotourism related activities imply an effective protection and management of such places and infrastructures. Therefore, they shall be included in the IES.

In this first phase, all 21 thematic variables will be overlaid by "union" geoprocessing operation in GIS. Therefore, every resulting feature will be individually defined by the combination of these 21 spatial database's fields (a field for each overlaid variable). The resulted area will be the Island Ecological Structure (IES), which represents the island areas that possess at least one biophysical or cultural value that has to be protected and/or managed in order to ensure the IES integrity and functioning.

2.3. Phase 2 - IES conflict analysis

Some land uses and physical natural features exclude or impose restrictions to further types of uses or activities development in the same area. Whenever this situation occurs, we may consider it as a conflict. In this phase, each different area of the IES larger than 15 hectares (0.02% of S. Miguel Island) resulting from the overlay (by "union") of all 21 thematic variables is analyzed in order to identify hypothetical status conflicts that could threat either the ecosystem integrity or the human use safety. This minimal area of 15 hectares has been judged as the most appropriate for planning and management purposes for the specific case of S. Miguel Island. Before every IES conflict analysis, this minimal area size shall be discussed between multidisciplinary experts, this decision depending on the dimension of the analyzed island and on its most relevant environmental issues and sustainable development challenges. Those areas shall be especially addressed by Land Management instruments being currently applied in the Azores Autonomous Region (Table 1) in order to mitigate or eliminate the existing conflict. Although there are hundreds of possible conflictive combinations, some of them will require special attention by acting through both planning and management measures.

2.4. Data

Table 2 presents all the geographic information used for the S. Miguel IES mapping process, indicating the source dataset and owner of each GIS variable inputted into the cartographic model.

3. Results and discussion

3.1. Phase 1 - IES GIS model implementation

The application of this methodological approach to S. Miguel Island has resulted in an Island Ecological Structure with 55410 hectares (Fig. 3), covering about 75% of the island (Table 3). The morphology of the island and the remoteness of some core natural areas are key factors to explain these results. The regional interpretation of REN delimitation rules and their strict application done by municipalities so far in the Azores Autonomous Region has resulted in the fact that about half of the island (45.3%) could be considered as Municipal Ecological Reserve (REM). Almost half of this area shows a relevant geological risk (21.1%), due to abrupt relief differences coupled with changing weather and soil moisture conditions throughout the year.

On the other hand, the strong economical livestock sector of S.Miguel has been decisive for the classification of the soils with higher agricultural potential located in lower altitudes and flatter areas as RAR – Regional Agricultural Reserve (23% of the island territory). The fact that 18.6% of S. Miguel is classified as protected area highlights the ecological value of this island and reinforces the need of a strong and coherent conservation management policy at the whole island scale. The area occupied by man-planted forests (mostly *Cryptomeria japonica*) constitutes 21.2% of the IES and 15.8% of S. Miguel territory (11730 hectares). This fact underlines the importance of this important land use at both economic and scenic levels.

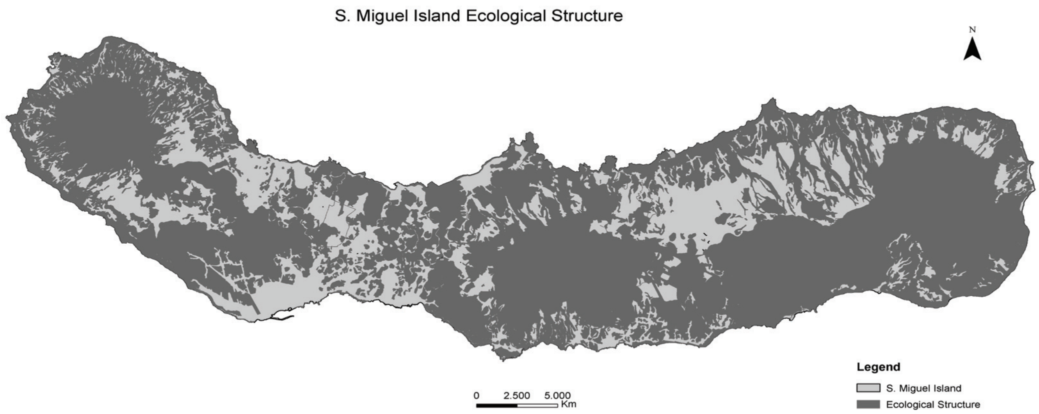

Fig. 3. S. Miguel Island Ecological Structure spatial distribution

Table 1. Existing Land Management instruments in the Azores

Legal Instrument	***Main Goals***
Special Land Management Plans (**PEOT** – "Planos Especiais de Ordenamento do Território")	Regulates the land planning and management in specific geographical features: basins and lagoons; Protected Areas; coastal zones
Municipal Master Plans (**PMOT** – "Planos Municipais de Ordenamento do Território")	Regulates the land planning and management in municipalities

Table 2. Geographic information used for the S. Miguel IES mapping process

IES Variable	***Source Dataset***	***Data Producer***
Protected Areas	Azorean Regional Network of Protected Areas	Azorean Regional Direction of Environment
Man-planted Forests	S. Miguel Island Forest Inventory	Azorean Regional Direction of Forestry
Urban Green Areas	Municipal Master Plans of S. Miguel Island municipalities	Ponta Delgada, Ribeira Grande, Lagoa, Vila Franca do Campo, Nordeste and Povoação municipalities
Arable Soils	Regional Agricultural Reserve (RAR)	Azorean Regional Institute of Agricultural Planning (IROA)
Wetlands	Municipal Ecological Reserve Maps included in Municipal Master Plans	S. Miguel Island Municipalities
Lagoons and Ponds	Municipal Ecological Reserve Maps included in Municipal Master Plans	S. Miguel Island Municipalities
Streams and margins	Municipal Ecological Reserve Maps included in Municipal Master Plans	S. Miguel Island Municipalities
Flood risk	Municipal Ecological Reserve Maps included in Municipal Master Plans	S. Miguel Island Municipalities
Headwaters	Municipal Ecological Reserve Maps included in Municipal Master Plans	S. Miguel Island Municipalities
Springs	Municipal Ecological Reserve Maps included in Municipal Master Plans	S. Miguel Island Municipalities
Maximal Infiltration	Municipal Ecological Reserve Maps included in Municipal Master Plans	S. Miguel Island Municipalities
Geological Risks	Regional Plan of the Azores Autonomous Region	Azorean Regional Direction of Environment
Singular elements	"Azorean Landscapes Characterization" Research Project (Cancela D'Abreu et al., 2005)	Azorean Regional Direction of Environment
Trails and Viewpoints	S. Miguel Island Pedestrian Trails Inventory	"Amigos dos Açores" Environmental Association
Forest-Based Recreational Parks	S. Miguel Island Forest Inventory	Azorean Regional Direction of Forestry

Geographic References: UTM projection; International Ellipsoid; S.Braz Datum; UTM Coordinate System - Zone 26

3.2. Phase 2 - IES conflict analysis

S. Miguel IES is spatially constituted by areas resulting from 172 different combinations of attributes (IES variables). After selecting all areas occupying at least 15 hectares (about 0.02% of the total area of the island), the 12 most representative combinations have been obtained in order to perform the conflict analysis phase (Table 3) and the IES conflictive areas spatial distribution (Fig. 4). About 21% (11751 hectares) of S. Miguel IES area is potentially conflictive. These identified areas (Fig. 4) shall be especially addressed and carefully planned and managed by responsible public bodies and associated stakeholders. Some land-use conflicts mitigation policies have to be undertaken on the scope of municipal and special land management master plans (see Table 1: PMOT and PEOT) in order to ensure the preservation and the integrity of key natural resources, biophysical functions and ecological processes within this territorial unit. The most representative combinations include the REM and the "Man-Planted Forest" as main conflictive components, therefore water resources and sensitive landforms integrity could be especially threatened by this land-use (10067 hectares) and also by intensive agricultural practices induced by the overlapping with the RAR (1115 hectares). Protected Areas present more than 5000 hectares showing a relevant level of potential conflicts with further land-use within its limits that should induce serious restrictions and changes in the way those activities are carried (agriculture, forest production, ecotourism).

Some conflicts cannot be mitigate, thus the status of at least one of the components must change, as for instance the presence of hiking trails, man-planted forests and intensive agricultural activity in geological risk areas (hiking trails and RAR must be declassified; production forestry should be forbidden). Therefore, the land-use conflict is a very negative synergy in those cases that needs to be urgently addressed by land management tools. Undertaken mitigation measures in these areas have to be specially prioritized in the strategic, temporal and financial points of view.

Table 5 shows most relevant land-use compatibility issues and land management guidelines for conflict mitigation within S. Miguel IES. Although Table 4 evidences and characterizes bilateral conflicts, 7 of 12 most relevant land-use conflicts within S. Miguel IES involve more than two conflictive variables.

Table 3. Quantitative relationship between IES and S. Miguel Island areas

IES Variables Dataset	*Total Area (hectares)*	*Percentage of total IES Area (%)*	*Percentage of S. Miguel Island Area (%)*
Protected Areas	13865	25	18.6
Man-planted Forests	11730	21.2	15.8
Urban Green Areas	33	0.1	<0.1
Regional Agricultural Reserve	17041	30.8	22.9
Municipal Ecological Reserve	33701	60.8	45.3
Geological Risks	15728	28.4	21.1
Singular elements	35	0.1	<0.1
Trails and Viewpoints	415	0.8	0.6
Forest-Based Recreational Parks	125	0.2	0.2
S. Miguel IES	**55410**	**-**	**74.42**

Table 4. S. Miguel IES most relevant conflicts

IES Conflicts	*Area (hectares)*	*Land-use compatibility issues*
Regional Network of Protected Areas + Municipal Ecological Reserve + Man-Planted Forest + Geological Risk Area	2964	F, NC, R, LW
Municipal Ecological Reserve + Man-Planted Forest + Geological Risk Area	2584	F, R, LW
Regional Network of Protected Areas + Municipal Ecological Reserve + Man-Planted Forest	2296	F, NC, LW
Municipal Ecological Reserve + Man-Planted Forest	1830	F, LW
Regional Agricultural Reserve + Municipal Ecological Reserve	1115	A, LW
Man-Planted Forest + Geological Risk Area	489	F, R
Regional Network of Protected Areas + Man-Planted Forest	177	F, NC
Regional Network of Protected Areas + Man-Planted Forest + Geological Risk Area	158	F, NC, R
Regional Network of Protected Areas + Regional Agricultural Reserve	72	A, NC
Regional Network of Protected Areas + Regional Agricultural Reserve + Geological Risk Area	27	A, NC, R
Hiking Trails Area + Municipal Ecological Reserve + Geological Risk Area	23	R, T, LW
Hiking Trails Area + Municipal Ecological Reserve + Man-Planted Forest + Geological Risk Area	16	F, R, T, LW
Total	**11751**	

Legend: A – Agriculture and Livestock; F – Production Forest; NC - Nature Conservation; R - Risk Area; T - Ecotourism; LW – Sensitive Landforms and Water Resources.

Table 5. S. Miguel IES most relevant land-use compatibility issues and generic land management orientations for conflicts mitigation, to be included in existing Land Management Plans (PEOT and PMOT)

	Agriculture and Livestock	*Production Forest*	*Nature Conservation*	*Risk Area*	*Ecotourism*	*Sensitive Landforms and Water Resources*
Agriculture and Livestock	-	-	**Soil erosion and contamination by fertilizers, herbicides and pesticides; Increased loss of biodiversity; Land clearance**	**Increased Soil erosion**	-	**Increased Soil erosion; Water and Soil contamination by fertilizers, herbicides and pesticides; Lagoons Eutrophication**
Production Forest	-	-	**Loss of Biodiversity; Land clearance; Invasion by exotic vegetation after harvesting**	**Increased landslide risk in areas with thinner soils**	**Land clearance favoring invasion by exotic vegetation**	**Increased Soil erosion after harvesting**
Nature Conservation	*Prohibition of intensive and non-organic farming; Benefits derived from the strict use of local agricultural species and from the reconversion to forest*	*Benefits derived from the strict use of native species for reforestation; obligation of reforestation just after harvesting*	-	**Increased loss of biodiversity by landslide**	**Land clearance favoring invasion by exotic vegetation; Illegal collection of native plants**	-
Risk Area	*Declassification as RAR; Prohibition of agricultural activity; Benefits derived from the reconversion to native forest*	*Prohibition of production forestry activity; Benefits derived from the strict use of native shrubby species for reforestation*	*No intervention; very restricted access*	-	**Increased accident risk due to landslide occurrence or pavement degradation**	**Increased landslide occurrence and water contamination risks;**
Ecotourism	-	*Prohibition of walking outside the marked trail; Prohibition of collecting forest specimen*	*Prohibition of walking outside the marked trail; Prohibition of collecting any biological (flora and fauna) or geological material; Determination of each hiking trail carrying capacity and consequent strict limitation of daily hikers*	*Declassifica-tion as Hiking Trail Area; very restricted access*	-	**Sensitive landforms degradation**
Sensitive Landforms and Water Resources	*Prohibition of using fertilizers, herbicides and pesticides; No tillage allowed; benefits derived from using very conservative techniques and from promoting the reconversion to shrubby native forest*	*Obligation of reforestation just after harvesting; benefits derived from using very conservative techniques and from promoting the reconversion to shrubby native forest*	-	*Very restricted access*	*Prohibition of walking outside the marked trail; Determination of each hiking trail carrying capacity and consequent strict limitation of daily hikers*	-

Legend: Land-use compatibility issues (bold) and land management orientations for conflicts mitigation (italics)

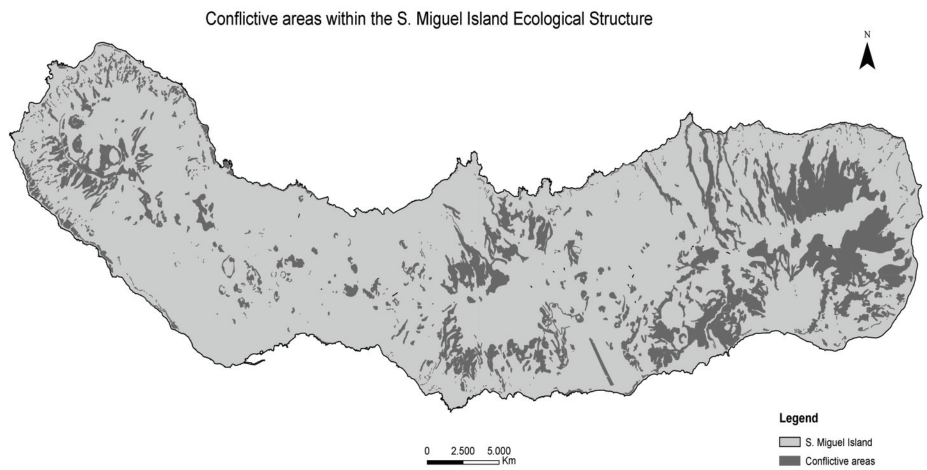

Fig. 4. S. Miguel Island Ecological Structure's conflictive areas spatial distribution

4. Conclusions

The main scientific novelty of this research paper is to propose a methodological approach for the Island Ecological Structure mapping process based on consistent island-scaled biophysical and land policy criteria which is fully adapted to Small Oceanic Islands, using S. Miguel Island (Archipelago of the Azores, an European Outermost Region), as case-study. The main goal of this GIS-based approach is to support on a coherent and objective way the definition, protection and monitoring of the Island Ecological Structure, by also identifying the most sensitive and relevant conflictive areas within IES, in order to be especially planned and managed by responsible public bodies and associated stakeholders in the scope of existing land management tools (at municipal, protected areas, coastal areas, basins and lakes level). This methodology shall be able to be applied to further small oceanic islands from Macaronesia (Azores, Canary and Madeira archipelagos) and European Outermost Regions.

4.1. How to manage and island which 75% of its area is classified as IES?

The fact that a large part of an island is defined as IES (e.g. S. Miguel IES occupies about 75% of the whole island) shall not be considered as an obstacle to social and economic development in these territories; on the contrary, it shall be regarded as an opportunity to potentiate a more effective and balanced development. In order to reach this sustainable development, it is fundamental to ensure the full applicability and effectiveness of municipal and sectorial (protected areas; coastal zones; basins and lagoons) land management and planning instruments. Although "island-scaled" environmental planning and land management instruments shall be a more realistic and effective solution for IES management (following an ecosystem approach), those existing municipal and sectorial plans can be equally efficient by prioritizing and promoting at the strategic, temporal and financial levels a rigorous planning and an active management of the most sensitive and conflictive IES areas. Stakeholder involvement can be crucial in order to reach a cost-effective IES management.

4.2. GIS data quality is mandatory for IES accurate mapping

The delimitation of the IES shall consider the many inter-relationships between all biophysical and cultural variables, contributing therefore to understand the whole system. The reliability and accuracy of the proposed methodology and its results depend directly on the quality, consistency and accuracy of all the inputted GIS information. That's why it is vital that, before initiating any process of delimitation of the Island Ecological Structure, existing cartographic and GIS databases shall be processed and validated using the most accurate geoprocessing techniques (Digital Terrain Modeling and intensive use of groundtruth data, for instance).

4.3. Ecological Reserve mapping accuracy is the key factor for IES definition

The most relevant component of the IES - resulting from the merging of the 6 REM (Ponta Delgada, Ribeira Grande, Lagoa, Vila Franca do Campo, Povoação and Nordeste municipalities) of S. Miguel Island - was produced and mapped at the municipal scale in an individual context, without taking into account each adjacent municipality or even the whole island. Each REM was delimited by identifying all the REN features that can be observed in these municipalities and by adding some local morphological features as "fajãs" that are not included for protection in the REN diploma. Therefore, in order to define a more coherent and consistent IES, it is fundamental to map and to input into the IES GIS Model an Ecological Reserve produced at the island scale, using the exactly same criteria (fully adequate to these insular ecosystems), types of data and geoprocessing techniques, as it has be done for the mapping processes of further IES components data sources (RAR, Regional Network of Protected Areas, Geological Risk Areas, Regional Forest Inventory and Landscape Singular Elements).

4.5. Integration of detailed and accurate GIS ecological data will improve the accuracy and usefulness of IES mapping

The integration into this model of accurate and detailed ecological data such as vegetation (distinguishing native from exotic invasive vegetation patches at the species or structural level) and habitat spatial distribution shall contribute to a more effective IES definition. The use, processing and posterior integration of satellite and airborne remote sensing data shall be considered as the most relevant and promising factor in order to improve this IES mapping model.

Acknowledgements
This research has been developed on the behalf of a Doctoral (M3.1.2/F/025/2007) and a Post-Doctoral (M3.1.7/F/005/2011) Research Project, both supported by the Regional Fund for Science (FRC) of the Azorean Regional Government. This work was partially funded by Portuguese National Funds through FCT – Fundação para a Ciência e Tecnologia (Foundation for Science and Technology), under the project "PTDC/AAC-AMB/098786/2008".

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