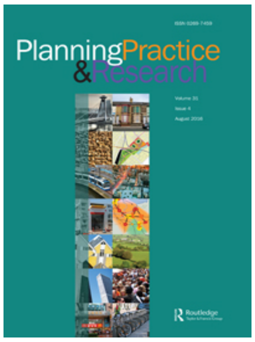

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Spatial planning in small islands: the need to discuss the concept of ecological structure

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PRACTICE REVIEW

Spatial planning in small islands: the need to discuss the concept of ecological structure

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ABSTRACT

The concepts of green infrastructure and ecological structure (ES) are current topics of discussion among the scientific community and spatial planners. ES is mandatory in Portugal in land-planning, such as municipal master plans, but no consensus has been reached on how to implement it. The concept has not yet been implemented in the Azores, a Portuguese autonomous region, even though the Region has the responsibility of adapting legislation or accomplishing the Portuguese legislature. This study presents a critical analysis of the available literature about ES and proposes a conceptual framework to define ES for small islands, which have unique characteristics, focusing on the Azorean archipelago. The conceptual framework meets the requirements of local legislation and uses an ecological function approach that is increasingly advocated in recent European recommendations. This framework is presented as a strategic and flexible way to identify both the important elements (recognized in current legislation) in a territory and the remaining potential of the territory. The framework also supports decision-making by allowing the identification of integrated solutions, decreasing trade-offs as much as possible and reconciling the needs of nature conservation and socioeconomic development. This framework could be applied to other small islands and other territories, with local adaptations.

KEYWORDS

Ecological structure; green infrastructure; small islands; spatial planning; ecosystem functions and services

1. Introduction

The concept of ecological structure (ES) is not a new idea (Benedict & McMahon, 2002) but is being increasingly discussed both in scientific and political debates (Naumann *et al.*, 2011; Wright, 2011; Albert & Von Haaren, 2014). Several similar terms have been proposed (see Table 1), such as ecological networks, habitat networks, and ecological infrastructure (Ahern, 1995), and ES may correspond to what has recently often been referred to as green infrastructure (GI) (Lucius *et al.*, 2011). Different meanings and interpretations have been applied to these terms, as well as different levels of their components, features, and definitions of associated functions and services (Benedict & McMahon, 2002; Naumann *et al.*, 2011). Wright (2011) argues the difficulty of adopting a single GI definition due to the

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involvement of environmental theory and socioeconomic policy, but this lack of consensus obscures the use of the ES concept, with several interpretations depending on the sector and context and on the user's involvement in GI theory or policy. The GI debate has not yet been settled in local planning practices (Albert & Von Haaren, 2014).

One disadvantage of developing a new GI concept, as suggested by Albert and Von Haaren (2014), is the competition with other well-established and used concepts (e.g. greenbelts) and planning categories, which can lead to confusion and can hamper the justification of adding GI to the list of terms. New concepts also require a long time to be understood, accepted and disseminated. The European Commission (COM, 2013), however, advocates that GI will promote coherence in decision-making for the integration of ecological and sustainable goals into spatial planning, because GI requires an integrated view of ecosystem services and consequently emphasizes the multifunctionality of rural areas.

Small islands, such as the Azores, face particular challenges not applicable to mainland territories (e.g. small size, remoteness, isolation, low capacity to maintain critical ecological functions, predisposition to natural disasters and extreme events, and fragile economies dependent on mainland or larger countries) (Mulongoy *et al.*, 2006; Mimura *et al.*, 2007), when implementing their spatial planning and management systems. Natural resources are limited and scarce, and their balance is particularly sensitive. The well-defined territorial boundaries, however, hinder the search for alternative activities and locations for economic development. The negative impacts of spatial planning from conflicts of sectoral interests (Hauck *et al.*, 2013) and a higher susceptibility to global environmental, economic and societal changes (Mulongoy *et al.*, 2006; Rietbergen *et al.*, 2007) are even more important on small islands due to their closed nature (Calado *et al.*, 2007). The resilience of insular ecosystems is limited by the combined and cumulative effects of environmental, socio-economic and cultural pressures, and balancing conservational targets and constraints is especially challenging (Mulongoy & Chape, 2004). Integrating the GI concept into local and regional policies on small islands should be especially advantageous for integrating the several naturally limited ecosystem functions and resources.

The Azores archipelago is one of the Outermost Regions of the European Union (EU) and is an autonomous region of Portugal, with political and administrative autonomy and governmental agencies with the power to create regional legislation or adapt national legislation to region-specific interests. The Azores, however, must comply with or adapt both European and Portuguese legislation. The European Commission and the Portuguese government have already published communications (COM, 2013) and national legislation (Decree-Law No. 46/2009, 2009), respectively, endorsing the creation of GI. The Azorean government has already adapted the legislation for determining the creation of ES for the regional legal system (Regional Legislative Decree No. 35/2012/A, 2012) but which has not yet been implemented, with only one study conducted (Gil *et al.*, 2011). Some examples of ES have already been applied on the Portuguese mainland (e.g. PMAB, 2005; Magalhães, 2013), but no consensual and standardized methodology to implement ES in spatial planning in Portugal and its autonomous regions has yet been adopted. The Portuguese legislature has adopted the term ES, and that's how it will be used from now on.

Our aim is to present the current status of the application of the concept of ecological systems/networks in the Azores by a logical and coherent review of the literature and to discuss the integration of ES in spatial planning on small islands, especially the Macaronesian islands and particularly the Azores archipelago.

2. ES background

ES has been variably defined (Table 1), but most definitions focus on some common topics that have persisted over time. The connection of areas, mainly natural or semi-natural areas, is one of the spatial features of ES. Its main objectives are to maintain natural processes and the balance of healthy ecosystems, ensuring the preservation of their functions and services that ultimately enhance the quality of life for communities and people.

The topic of ecosystem functions and services is common in documents involving ES, even if the methodologies to implement it differ (Table 2). Benedict and McMahon (2002) identified a system of hubs and links, where hubs 'anchor green infrastructure networks and provide an origin or destination for wildlife and ecological processes moving to or through it' and where links 'are the connections that tie the system together and enable green infrastructure networks to work'. EC (2010) and other projects addressed by Naumann *et al.* (2011) identified various potential areas to integrate ES, both in rural and urban areas, with references to multifunctionality and connectivity. Gil *et al.* (2011) proposed a methodological framework to map ES at an island scale, mainly based on biophysical features and geographical variables identified in other land policies.

EC (2012) also advocated the multifunctionality of ES and identified areas by the services they provide. For example, protected areas (PAs) (functioning as cores and hubs)

Table 1. Definitions of green infrastructure/ecological structure.

Source	Definition
Benedict and McMahon (2002, p. 6)	'Green infrastructure is our nation's natural life support system – an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for America's communities and people.'
Ahern (2007, p. 267)	Green infrastructure is an emerging planning and design concept that is principally structured by a hybrid hydrological/drainage network, complementing and linking relict green areas with built infrastructure that provides ecological functions.
Nauman *et al*. (2011, p. 14)	'Green infrastructure is the network of natural and semi-natural areas, features and green spaces in rural and urban, and terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services.'
(Azorean) Regional LegislativeDecree No. 35/2012/A, p. 4542	'The municipal ecological structure is the set of areas that, due to their biophysical or cultural features and their ecological continuity and planning, have as their main function contributing to the ecological balance and to the protection, conservation and improvement of the environment, landscape and natural heritage of rural and urban spaces.'
COM (2013, p. 3)	'GI (green infrastructure): a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.'
Magalhães (2013, p. 4)	A spatial concept, understood as a planned structure, designed and managed for various purposes, based on ecological components that provide the physical and biological conditions necessary for the maintenance or conservation of ecological functions, favoring the biological and landscape diversity and promoting sustainable use of natural resources.

Table 2. Elements constituting green infrastructure/ecological structure.

Source	Elements
Benedict and McMahon (2002, pp. 7, 8)	System of hubs and links: • Hubs include reserves, managed native landscapes, working lands, regional and community parks, and natural areas • Links include landscape links, conservation corridors, greenways, greenbelts and ecobelts
EC (2010, p. 3)	• Protected areas • Healthy ecosystems and areas of high natural value outside protected areas • Natural landscape features • Restored habitat patches created for specific species • Artificial features (e.g. eco-ducts or eco-bridges) • Multifunctional zones where land uses that help maintain or restore healthy biodiverse ecosystems are favored over other incompatible activities • Areas where measures are implemented to improve the general ecological quality and permeability of the landscape • Urban elements hosting biodiversity and allowing for ecosystems to function and deliver their services by connecting urban, peri-urban and rural areas • Features for adaptation to and mitigation of climate change
Nauman *et al.* (2011, p. 18)	• Protected areas • Restoration zones • Sustainable-use areas • Green urban features • Natural connectivity features • Artificial connectivity features • Multifunctional zones
Gil *et al.* (2011, p. 26)	• Protected areas • Planted forests • Urban green areas • Arable soils • Wetlands • Lagoons and ponds • Streams and margins • Flood risk • Headwaters • Springs • Maximal infiltration • Geological risks • Shoreline buffer • Slopes >30% • Beaches and dunes • Cliffs • Islets • 'Fajãs' • Landscape singular elements • Trails and viewpoints • Recreational parks
EC (2012, pp. 6, 15, and 22)	*Protecting ecosystem state and biodiversity:* • Nature-rich areas • Wildlife and natural areas • Areas of high value for biodiversity and ecosystem health outside protected areas • Ecological corridors or strips of vegetation used by wildlife (including linear corridors, stepping-stone corridors, and landscape corridors of diverse, uninterrupted landscape elements) • Greenways and greenbelts • Ecoducts or green bridges • Fish ladders, fishways, or fish passes • Ecological buffer areas • Restoration of landscapes and ecosystems • Urban elements, such as parks, gardens, churchyards, sports fields, allotments, urban ponds and canals, green roofs and green walls • Agricultural land *Improving ecosystem functioning and promoting ecosystem services:* • Areas of high natural value outside protected areas • Restored habitats for specific functions and/or species • Ponds and wetlands • Urban trees, vegetation, and soils • Vegetated landscapes (including green vegetated roofs or ecoroofs, rain/infiltration gardens and trenches) • Pervious or permeable pavements made from porous materials

(*Continued*)

Table 2. (*Continued*).

Source	Elements
	Promoting societal health and well-being: • Public parks, pathways, playing fields, cycle paths and jogging tracks • Urban vegetation • Wetlands, grassed areas and urban forests • Communal parks, village greens and town squares • Green spaces in residential communities
COM (2013, p. 3)	This European Communication recommends that ES incorporates green spaces (or blue spaces in aquatic ecosystems) and other physical features in terrestrial zones (including coastal zones) and marine zones. ES in terrestrial areas is present in rural and urban areas
Magalhães (2013, pp. 9 – 12)	*Two main systems, physical and biological:* • Physical system includes geology, lithology, geomorphology, soil, water, landforms coastal areas and climate • Biological system includes natural and semi-natural vegetation *Hierarchy of two levels:* • First level: water, wet system, soil, coastal areas, sloping areas, vegetation, nature conservation and geosites • Second level: hilltops in old wet systems, maximum infiltration areas, highlands, vegetation and climate
Albert and Von Haaren (2014, p. 9)	*Four levels of priority:* • First level includes areas identified as exceptionally important for habitats and ecosystems and are protected by EU, federal or state legislation (mandated by law) • Second level includes very highly important areas for the provision of at least one ecosystem service • Third level includes multifunctional areas, defined as those that are highly important for the provision of two or more ecosystem services • Fourth level includes highly important areas for the provision of only one ecosystem service

contribute to protect the state and biodiversity of ecosystems, floodplains and riparian areas contribute to improve ecosystem functioning and promoting ecosystem services and public parks and green spaces in residential communities contribute to promote societal health and well-being.

Only the most recent publications (Magalhães, 2013; Albert & Von Haaren, 2014) have referred to a hierarchical system between areas, enabling their integration into planning schemes. Some studies have identified ES elements, based mainly on biological (e.g. PAs, natural and semi-natural vegetation, and planted forests) and physical (e.g. artificial features of connectivity, maximal infiltration and geological risks) criteria.

2.1. Benefits of ES

Despite the debate, the referred authors agree with several of the benefits provided by ES. Such a structure helps to reconnect existing natural, rural or urban areas and to improve the ecological quality of surrounding areas. It also helps to maintain healthy ecosystems, which provide valuable goods and services to communities (e.g. water purification, restoring soil and forest functions, carbon storage and protection against natural hazards) (Benedict & McMahon, 2002; EC, 2010; Wright, 2011; COM, 2013). ES in marine and coastal environments can contribute to marine spatial planning and the integrated management of coastal zones, namely using blue-carbon approaches, which benefit fish stocks and other marine ecosystem services (COM, 2013). ES may also create or improve cultural, athletic and recreational areas, and enhance local identities and senses of place (Benedict & McMahon, 2002; Kambites & Owen, 2006; Wright, 2011). The objectives of most ES projects in Europe are focused on the conservation of biodiversity, but many other projects are focused on sustainable land management, water management and the mitigation of, and adaptation to, climate change, emphasizing the multifunctionality of ES in benefiting both nature and communities (Naumann *et al.*, 2011; EC, 2012). ES has also been used to decrease the cost of public infrastructure and services, for example those associated with storm water management and water treatment systems (Benedict & McMahon, 2002; Mell & Roe, 2007). Investing in ES is economically sensible (EC, 2010), and well-planned green spaces, maintaining nature's capacity, may increase property values and be more durable and cost-effective than conventional public-works projects or be complementary to standard gray infrastructure (Benedict & McMahon, 2002; Mell & Roe, 2007; COM, 2013).

The capacity of natural solutions to provide several functions and benefits in the same area is a main advantage. This multifunctionality of ES may include environmental (e.g. conservation of biodiversity), social (e.g. green spaces) and economic (e.g. providing jobs) functions (EEA, 2014). Lucius *et al.* (2011) reported that 'win-win solutions' or 'small loss, big gain' combinations deliver multiple benefits for both land users and society through ecosystem services, and integrated planning can bring together these different sectors. The European Commission (EC, 2010) stresses that ES can definitely contribute to the integration of biodiversity into other policies, namely agricultural, forestry, water, regional, and cohesive policies, the mitigation of climate change and land use management. ES is then a matter for conserving nature and is a strategic tool to integrate, benefit from, and bring benefits to other sectors (Mazza *et al.*, 2011; Albert & Von Haaren, 2014), but it can be better implemented within integrated and careful land management and strategic spatial planning (EC, 2010).

2.2. ES and ecosystem services

The concept of nature conservation has evolved in recent decades from a species-centered approach to one based on the protection of ecosystems and their functions and impacts on human well-being, through the provision of ecosystem services. Earth's ecosystems and the services they provide, such as food, water, climatic regulation, esthetic enjoyment and spiritual fulfillment, are critical foundations of all human societies (MEA, 2005).

A similar evolution may also be found in the elements constituting ES (Table 2). Earlier frameworks referred mainly to geographical variables of biophysical features, and later frameworks were more focused on ecosystem functions and services. An effective strategy for conservation depends on people's understanding of the reasons for it and the need for action (Green, 1996). Strategies incorporating ecosystem services assess the value of natural capital to society and should help to improve public awareness and the long-term protection and sustainable use of natural resources (Albert & Von Haaren, 2014). Such strategies are also an opportunity to reconcile divergent perspectives of natural resources and to avoid unsustainable management practices (Hauck *et al.*, 2013). As with the ES concept, however, integrating ecosystem services into landscape planning, management and design still faces many challenges, despite the increasing body of studies (De Groot *et al.*, 2010; Albert &

Von Haaren, 2014). The European Commission (COM, 2013) also stated that ES can contribute to an understanding of the value of the benefits provided by nature to societies and to mobilize investments to sustain and enhance them.

The implementation of the ES concept could be a powerful tool for communicating strategies for the conservation of biodiversity and for ecosystem services, both to the public and decision-makers (Albert & Von Haaren, 2014), and the concept should be implemented with proactive, strategic and coherent actions across all policies that influence the uses of land and sea (Mazza *et al.*, 2011).

Strategies of nature conservation can have increasingly fewer trade-offs between environment and development (De Groot *et al.*, 2010), so the goals of both environmental and non-environmental policies should be promoted with ES, and ES should be incorporated into other policies to identify potential synergies (EEA, 2014). Spatial planning and territorial management should consciously integrate the protection and enhancement of nature and natural processes through ES, which is associated with the concept of ecosystem services (COM, 2013) and is of increasing political importance (Albert & Von Haaren, 2014).

2.3. ES in the European framework

EU leaders recognized that the loss of biodiversity could not be reversed by the target date of 2010, despite all efforts and some successes (e.g. Natura 2000, the world's largest network of PAs) (COM, 2011a). A new long-term target and vision were consequently defined (COM, 2011b) 'to halt the loss of biodiversity and the degradation of ecosystem services by 2020' and to protect, value and appropriately restore biodiversity and the ecosystem services it provides, i.e. its 'natural capital', by 2050, advocating biodiversity's intrinsic value and its crucial contribution to human well-being and economic prosperity and to avoid catastrophic changes caused by the loss of biodiversity.

Of the six targets defined by the European Commission for 2020 (COM, 2011a), one focused on 'maintaining and enhancing ecosystem services and restoring degraded ecosystems by incorporating green infrastructure in spatial planning'. This target will contribute to the EU's objectives defined in COM (2011b) associated with sustainable growth in Europe by 2020, the mitigation of, and adaptation to, climate change, and with ensuring better functional connectivity between ecosystems within and between Natura 2000 areas and in the wider countryside (COM, 2011a). The European Commission nevertheless recognizes that reaching the 2020 target depends on the full implementation of existing EU environmental legislation and on action at the national, regional and local levels (COM, 2011a).

As a commitment from the EU Biodiversity Strategy to 2020, the European Commission published the green infrastructural strategy in 2013 to help conserve and enhance natural capital, recognizing its utility in providing ecological, economic and social benefits through natural solutions (COM, 2013). The EU strategy can be implemented within current legislation, policies and funding mechanisms by (COM, 2013): (i) promoting GI in the main policy areas (such as regional cohesion, climate-change and environmental policies, disaster risk management, health and consumer policies, and the Common Agricultural Policy, including their associated funding mechanisms), (ii) improving information, strengthening the knowledge base and promoting innovation, (iii) improving access to innovative financing mechanisms to support green infrastructural projects and (iv) assessing the opportunities for developing a trans-European GI network.

2.4. ES in the Portuguese and Azorean legal frameworks

Decree-Law No. 46/2009 established the current legal framework for territorial management at the Portuguese national level. This system of territorial management is organized into three coordinated levels: national, regional and municipal. The national level includes the National Program for Spatial Planning Policy, Sectoral Plans and Special Plans for Spatial Planning (e.g. spatial plans for PAs and coastal areas). The regional level includes Regional Plans for Spatial Planning. The municipal level includes Intermunicipal Plans and Municipal Plans for Spatial Planning (e.g. Municipal Master Plans). All these tools for territorial management have a public scope and the special Plans and Municipal Plans for Spatial Planning also addresses private users.

Regional Legislative Decree No. 35/2012/A established the current legal framework for territorial management in the Azores. The regional system is organized into only two levels: regional and municipal. Special Plans for Spatial Planning defined at the island scale is the main difference between the national and regional levels.

The obligation to identify ES in territorial management is therefore defined in the Portuguese and Azorean legal decrees at the national and regional levels, with slight differences between them. Both the national and regional legal frameworks define that the tools for territorial management must identify the territorial resources, namely ES, including fundamental areas, values and systems for environmental protection and the valorization of rural and urban spaces. These tools, with applicability at national or regional scales, define 'principles, directives and measures that constitute policy guidelines for environmental protection and valorization that ensure protection of ecosystems and intensification of biophysical processes'. The tools applicable at the municipal scale (e.g. Municipal Master Plans) also establish the parameters for occupation and land use, which ensure the compatibility of the functions of protection and regulation with production, recreation and the population's welfare.

Both Decree-Law No. 46/2009 and Regional Legislative Decree No. 35/2012/A established that ES must be delimited by each municipality, within each Municipal Master Plan. These two documents, however, differ. Regional Legislative Decree No. 35/2012/A defines municipal ES (see Table 1); it clearly specifies that Municipal Master Plans must include an ES map and states that ES exists in continuity in both rural and urban spaces, but without being an autonomous category of space. In rural spaces, ES includes the Fundamental Network for Nature Conservation, natural areas subject to risks and with vulnerabilities and other areas of municipal interest for environmental, landscape and natural heritage valorization. According to Regional Legislative Decree No. 15/2012/A, the Fundamental Network for Nature Conservation includes the Natura 2000 network, PAs of regional relevance, Ecological Reserves and Agricultural Reserves. ES in urban areas includes green spaces for collective use and other public or private spaces needed for balancing environmental, landscape or natural spaces within urban spaces (e.g. hydrological cycles and urban bioclimatic regulations).

3. A theoretical proposal for ES on small islands

This section presents a conceptual proposal to integrate ES in the spatial planning system of small islands, especially those of the Azores and the Macaronesian region.

3.1. The Azores archipelago and the Macaronesian region

The Azores archipelago is composed of 9 islands in the North Atlantic Ocean, ca. 1,500 km from Lisbon and 3,900 km from the east coast of North America. The islands have a total surface area of 2,322 km^2 distributed along 600 km between 37 and 40°N and 25 and 31°W and are divided geographically into three groups: the Western (Flores and Corvo), Central (Graciosa, São Jorge, Faial, Pico and Terceira) and Eastern (São Miguel and Santa Maria) Groups (Figure 1). The archipelago is part of the Macaronesia biogeographic region, along with Madeira (Portugal), the Canary Islands (Spain) and Cape Verde, with a total area of 14,610 km^2 between 15 and 40°N (Figure 1).

The Macaronesian islands are of volcanic origin, with steep landscapes (Petit & Prudent, 2010) contrasting with wide valleys and sheltered bays (Sundseth, 2009). The climate of the islands range from cool and humid in the Azores, to subtropical in the Canary Islands (Morton *et al.*, 1998; Petit & Prudent, 2010). The islands have never been connected to any continent and so have high levels of animal and plant endemism (Petit & Prudent, 2010). The biodiversity of the Macaronesian region is unique for Europe (Condé & Richard, 2002). The thermoregulatory capacity of the surrounding ocean has enabled the Macaronesian archipelagos to retain a large part of their ancient vegetation, and marine biodiversity is also exceptional (Petit & Prudent, 2010). The conversion of land use has increased the fragmentation of natural ecosystems, allowing the spread of exotic and invasive species (Petit & Prudent, 2010). The Azorean archipelago has a wetter climate and different species composition from the other Macaronesian regions. Species composition is more heavily influenced by northern European than by Mediterranean species. The Azores also have a less rugged

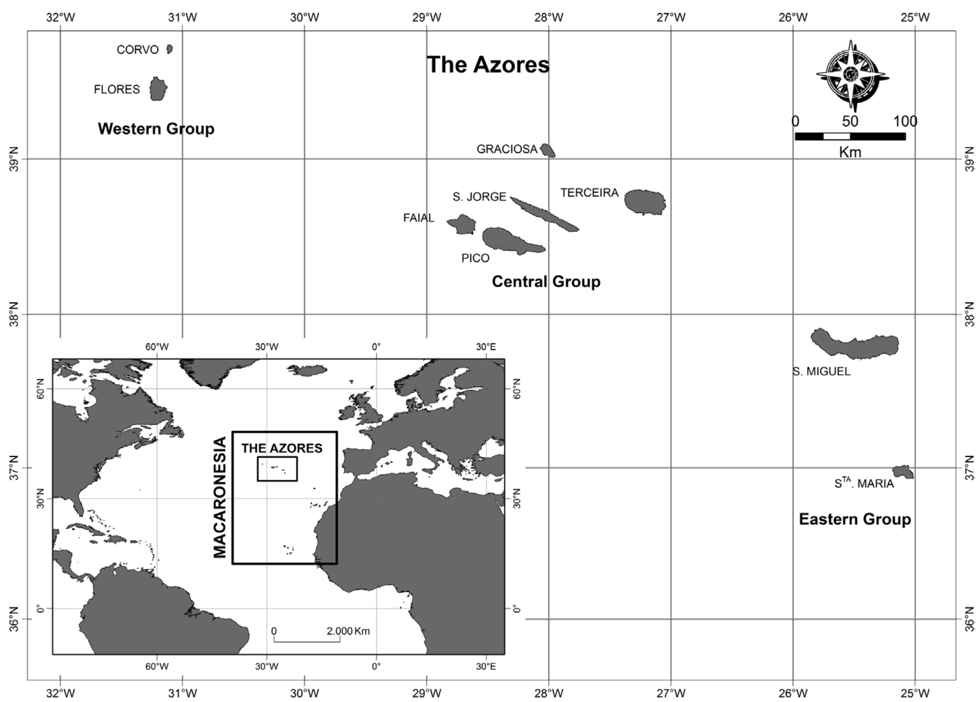

Figure 1. Location of the Azores archipelago (Portugal).

topography, with undulating hills and peaks rather than abrupt precipices (Sundseth, 2009). Madeira's topography is more precipitous and jagged, and half the slopes have a gradient ≥25%. Local climate is also influenced by this abrupt landscape, with the north much wetter than the south (Sundseth, 2009). The Canary Islands are the most easterly, with a climate highly influenced by the African continent, and so generally much warmer and drier, which creates arid, almost desert-like, conditions on the low-lying islands (Sundseth, 2009).

Human settlements, transportation routes, infrastructures and other economic activities are mainly concentrated in coastal areas throughout Macaronesia, due to the islands' geological, morphological and climatic constraints and their dependence on the sea as the most important communication route. The economy of the Macaronesian islands is currently dependent mainly on agriculture, fisheries and tourism (Petit & Prudent, 2010; Calado *et al.*, 2014). The four groups of islands rely economically on exterior help: the Azores, Madeira and the Canaries on their affiliated European countries, and Cape Verde on international agencies.

The Azores, Madeira and the Canary Islands also share similar political-administrative statutes of autonomy (Suárez de Vivero, 1995). As member states of the European Union, both Portugal and Spain must comply with the European Union's recommendations, and both countries have, for example, similar spatial-planning policies for coastal zones. Cape Verde, despite being an independent nation, has coastal-planning legislation similar to Portugal's and is based on the same structure, principles and policies (Calado *et al.*, 2007).

3.2. A conceptual proposal for ES

Solutions for spatial planning, including both environmental and socioeconomic objectives, are fundamental on small islands due to their constraints. ES in these territories must especially comply with a tripartite system (Figure 2): (i) the current legal framework, (ii) the socioeconomic sustainable development and (iii) the conservation of ecosystem functions.

The legal framework is built on each nation's particularities and usually includes legislation for several environmental issues. ES should integrate and/or complement guidelines from the current legal system to facilitate the integration of ES into the governmental and

Figure 2. Ecological structure (ES) and territorial systems.

local procedures and the daily management of resources. The legal planning system in the Azores is focused mainly on conserving or managing natural resources, including classified PAs, the National Ecological Reserve (NER), the Regional Agriculture Reserve (RAR), Public Water Domain, Costal Management Plans, Watershed Ponds Management Plans and other specific spatial-planning instruments tools developed on each island (e.g. the Spatial Plan of the Protected Landscape for Vineyards for Pico Island). According to the Azorean legal framework, ES should contribute to the ecological balance and protection of the environment, landscape and natural heritage (Regional Legislative Decree No. 35/2012/A, 2012). The socioeconomic system is integrated into the ES perspective of harmonizing the objectives of conservation and development. Adding the developmental expectations of communities to the ES equation will enable the proposal of integrated solutions.

Ecosystem functions and services are intricately related, but different authors have different perspectives on their differences (Boyd & Banzhaf, 2007; De Groot *et al.*, 2010). The term 'ecosystem function' is sometimes used to describe the internal function of ecosystems (e.g. energy and nutrient flows), but the term has also been associated with the benefits to society from properties and processes of ecosystems (e.g. food). In this proposal, the term is used as suggested by De Groot *et al.* (2010): 'ecosystem services are generated by ecosystem functions which in turn are underpinned by biophysical structures and processes'. Ecosystem functions are thus the result of the natural processes of ecological subsystems, which are in turn the result of complex interactions between biotic and abiotic components of ecosystems. These interactions are the basis for the integrity and resilience of ecosystems and constitute direct and indirect sources of goods and services for human societies (De Groot *et al.*, 2003). The ecosystem-service approach represents the dependence of human well-being on the capacity of ecosystems to provide essential services, and ES is a strategy to guarantee or enhance the provision of those services (Albert & Von Haaren, 2014).

In the operational process of developing land-planning instruments, either at the municipal or the island scale, ES should be developed to support decision-making and not the result of the decision-making process. ES can thus be strategically and flexibly designed to increase the real potential of a territory and contribute to improve land planning and the management of natural resources. Ecosystem functions, and not ecosystem services, are proposed to be part of ES as the basis of a strategic approach. Ensuring well-functioning ecosystems produces good conditions for providing ecosystem services. Using the Portuguese Municipal Master Plans, which are only reviewed every 10 years (sometimes longer), as an example, ES should be as up to date as possible during that period, avoiding the dependence of evaluations of ecosystem services on market prices or political will. Decisions for changing land use and exploiting natural resources would then be based on participatory assessments of trade-offs to optimize multifunctional uses, as suggested by De Groot *et al.* (2010). The status and potential of an ecosystem are thereby analyzed, not only its benefits to society, avoiding misleading assessments of its conservation status or valuing areas already providing ecosystem services but not the services for which they are better suited. This approach is in line with SEP (2015), who state 'that maximizing a single or few ecosystem services in the short term is not the aim of using the ecosystem services concept in policy. […] The long-term, stable provision of ecosystem services is therefore the definitive goal'.

The framework (Figure 3) presented here to define ES for small islands is based on the assumption that territorial units are minimally or not changeable in time and represent the

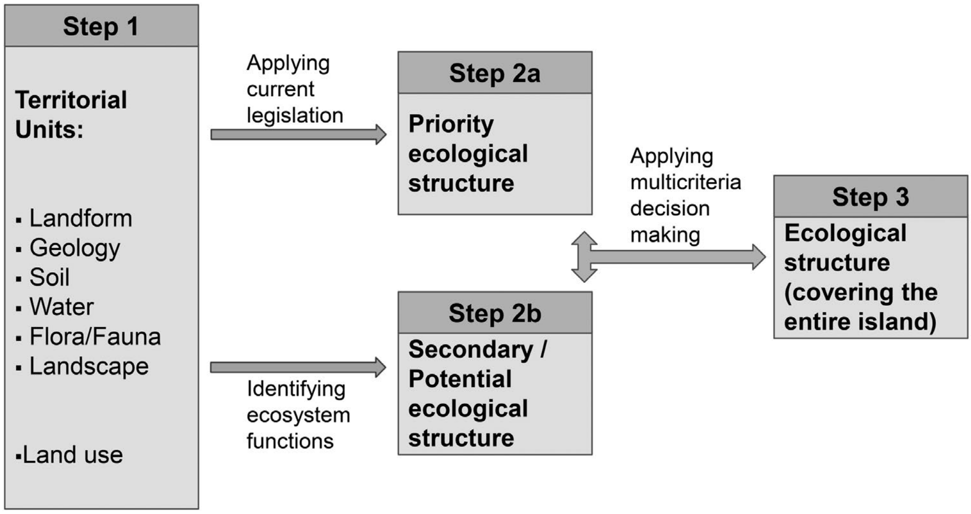

Figure 3. Theoretical framework for ecological structure for small islands.

potential of the territory, for both ecosystem health and the provision of services. The first step of the process (Step 1) consists of identifying the island's territorial units, ensuring the entire island is covered and analyzed. Each territorial unit is mapped, identifying and characterizing the island's territory and potential and/or the major fragilities. The second step consists of categorizing the territorial units. A 'priority ES' is defined to ensure that ES is integrated into the island's legal framework and complies with the current legislation (Step 2a). The applicable legislation (e.g. PAs and NER) is analyzed and mapped, and restrictions and constraints to resource use are defined by the specific legislature. This priority ES is similar to the 'core areas' of the proposal by Benedict and McMahon (2002), representing the most sensitive and ecologically important areas where socioeconomic activities might have severe impacts and where uses need to be prohibited or highly constrained. For the remaining island territory, a 'secondary or potential ES' is defined (Step 2b). Ecosystem functions are analyzed and mapped based on previous territorial units, identifying the potential of the territory to provide ecosystem services. Several types of ecosystem functions (e.g. De Groot *et al*., 2002; MEA, 2003) and the number of functions occurring simultaneously in the same space are identified. These areas are less sensitive than the 'priority ES' but require careful analysis while deciding whether to use or preserve. The final step (Step 3) will combine the information from Steps 2a and 2b for producing a map of ES for the entire island showing the different ecological and socioeconomic potentials and constraints and providing support to technicians and decision-makers for improving the management of the island territory. Decision-making attempts to find the best solution among all possible alternatives (Angelis & Lee, 1996). The challenge for ES is to determine, among all ecosystem functions identified, if the presence of more functions increases the importance of an area or if one function would be more crucial than a set of functions. For example, Egoh *et al.* (2008) assessed the relationship and spatial congruence between five ecosystem services (surface-water supply, water-flow regulation, soil accumulation, soil retention and carbon storage) and concluded that one ecosystem service cannot be used to plan for others. The use of multiple criteria for decision-making (Step 3) is proposed to overcome this handicap, which according to Zanakis *et al.* (1998) allows decisions to be made using multiple and usually conflicting criteria.

3.3. ES governance model for small islands

Governance can be theoretically defined as 'the rule of the rulers' (TWB, 2013). In the most common meaning, 'Governance determines who has power, who makes decisions, how other players make their voice heard and how account is rendered' (IG, 2015). Governance 'requires the identification of both the rulers and the rules, as well as the various processes by which they are selected, defined, and linked together and with the society' (TWB, 2013). Environmental management has a long tradition of participation and stakeholder involvement to ensure the successful implementation of environmental policy (Booth *et al.*, 2009).

Trends have shifted in recent decades from top-down approaches to governing to collaborative, involved and participative solutions. Models of environmental governance, however, raise some concerns and challenges about the balance between excessive and, in contrast, insufficient governmental decisions for addressing conflicts and the level of authority should be delegated (Sandström & Widmark, 2007). ES governance models for small islands must address these questions based on the level of influence of the role, authority and decision-making of each the three pillars of governance (Figure 4). The collaborative/negotiated balance among them must be based on the fundamentals of decisions of national interest, and these must be fully understood and approved by all players.

3.3.1. Island regional government

The regional government of the Azores, similar to those of the other Macaronesian islands, includes a network of agencies responsible for environmental issues: an environmental agency, a public administration and planning agency and the Island Park agency. These agencies are responsible for complying with international agreements (e.g. Natura 2000), national policies and the regional goals of environmental conservation and for ensuring the defense of public interests (such as national defense, security, citizen safety, and territorial equilibrium and cohesion). The constraint for governance for small islands is a certain level

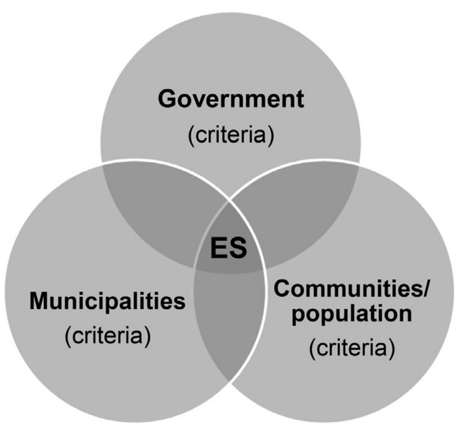

Figure 4. The governance model for ecological structure (ES).

of 'partisanship' (Briguglio & Kisanga, 2004; Calado *et al.*, 2007) that can interfere with national decision-making.

3.3.2. Island municipalities, services and industry

The main goal of municipalities is to create the conditions and infrastructures for social and economic development. The installation of industry and services is the main source of revenue and job creation. Island municipalities therefore tend to facilitate licensing and changes in land use to attract new economic activity. They are also responsible, however, for a series of services to citizens that largely depend on the health of ecosystems (e.g. water supply) and ES coherence. The main constraint in small municipalities, such as those on small islands, is the lack of staff skilled in environmental management, in addition to the cumulative constraints previously discussed for governments.

3.3.3. Island communities/population

Island communities and populations are directly and indirectly affected by regional policies. Local communities are often not compensated for ecosystem losses by activities in their surroundings and fields or do not share the profits from the exploitation and use of resources (e.g. bottled mineral water). The limited resources on small islands and the low level of economic resilience of these small communities also hinder decision-making by fostering the adoption of new economic activities with short-term benefits but with little consideration for long-term losses of ES quality, coherence and ecosystem services. In addition, low levels of education and a lack of information on environmental issues frequently discourage public participation in defining policies and delineating strategic plans that will affect them.

An equilibrium among these three large groups of players should be achieved based on sound and exhaustive scientific knowledge of island natural resources, ecosystem functioning and services, and the establishment of limits of acceptable change (Stankey *et al.*, 1985), all of which must be based on clear criteria of the viable trade-offs for each group of players. The establishment of the criteria should leave no room for free interpretation or case-by-case adaptation. A mechanism for negotiation designed to be operational, effective and equitable should instead be adopted.

The mechanism for negotiation and the entire governance model, in the case of the Azores, is based on the Island Park management body and consultation committee (Regional Legislative Decree No. 15/2012/A, 2012), which would benefit from the existing administrative and management structure that would only need to improve its capacities to involve the population in decision-making. Island Park agencies concentrate their efforts and actions on PAs but should be able to act in other areas. In fact, a strict interpretation of the law (Regional Legislative Decree No. 20/2008/A, 2008) indicates that Island Parks can contribute to any island environmental decisions.

4. Discussion and conclusions

This study presents an adapted theoretical proposal to implement the ES concept for small-island territories based on the available literature. Some methodological frameworks for ES (Table 2) still represent some limitations for small islands. For example, Benedict and McMahon (2002) presented a methodology focused more on species and habitats than on human societies, even though the latter benefit from healthy ecosystems. Methodological frameworks focused mainly on existing areas (e.g. established PAs and forests) could neglect degraded areas with a high potential for restoration and healthy ecosystems. Identifying these areas and integrating them into an ES is an opportunity to reverse their conservational status and allow them to meet their potential, promoting ecosystem functions with higher probabilities of persisting naturally over time.

Legally established areas and other natural PAs are fundamental for accomplishing the environmental objectives of ES. ES, however, cannot be limited only to established areas. Adopting the ES concept is an opportunity for identifying the potential uses of areas without establishing the status of legal protection, which is often too restrictive for socioeconomic uses. Including areas of social relevance in an ES for meeting socioeconomic objectives cannot be considered in the same way as for conservation areas. A decision-making scheme using multiple criteria to identify different areas within an ES could be useful for setting priorities (as suggested by Albert & Von Haaren, 2014), considering the environmental or social potential of each area, and for supporting decision-making when trade-offs must be selected. Mell and Roe (2007), for example, analyzed several initiatives of green infrastructure in the UK that have helped stakeholders to understand the potentials of more holistic and sustainable landscape planning, which is a major benefit of ES.

The NER in Portugal is a legal spatial planning tool for defending natural values and areas of ecological value or of high sensitivity or susceptibility to natural hazards (Decree Law No. 239/2012, 2012). The Commission Staff Working Document on Technical information on GI (SWD, 2013) identifies the NER as an example of ES in Portugal. NER objectives are in accordance with the general objectives of ES. The NER legal framework in the Azores, however, should be adapted to better comply with Azorean features (Vergílio & Calado, 2015). In addition, Vergílio and Calado (2015) reported that the application of current NER criteria results protecting mainly against natural hazards and that an effective ecosystem approach was necessary to complement the current NER structure. The NER legal framework has not yet been implemented in Madeira, but a transitional period has been established (Regional Legislative Decree No. 18/2011/M, 2011) for its application. During this period, the NER is defined based on the regional legal framework for PAs. The ES approach focused on ecosystem functions as proposed will be an improvement for the Macaronesian islands, and especially the Azorean spatial-planning system, and will contribute to the preservation of ecosystem functions and consequently the services they provide. Applying the ES approach in Cape Verde could enhance the spatial-planning schemes and strengthen the recently created national system of PAs (United Nations Department of Economic and Social Affairs, 2016; United Nations Development Programme, 2016).

Studies have suggested that spatial-planning schemes for small islands should be applied and defined at the island scale instead of the municipal scale (Calado *et al.*, 2014; Vergílio & Calado, 2015). The integrated perspective underlying ES and the particular features of small islands (e.g. size and limited resources) suggest that ES would be most efficiently defined at the island scale because it would recognize the entire island as a unique system. In addition, ES should be defined by governmental agencies with decision-making power at the island scale rather than the municipal scale to realize the potential of ES as a spatial-planning tool. This recommendation can be corroborated by comparing the NER and the RAR rationales in the Azores. The goal of NER (Decree-Law No. 239/2012, 2012) was to protect natural values and areas of ecological value, or with sensitivity or susceptibility to natural hazards; its legal framework has not been adapted by the Azorean Government to the regional legislation but is delimited by each municipality, and inspections are distributed by different entities. The goal of RAR (Regional Legislative Decree No. 32/2008/A, 2008) was to ensure the preservation and proper use of Azorean soil, safeguarding the well-being of rural populations and wealth creation. The Azorean Government, however, has established its own legal framework for RAR; management and inspections are the responsibility of a single institution acting throughout the entire island. The centrality created for RAR's rationale increases the homogeneity of decision-making throughout different islands and municipalities and decreases the effects of partisanship, which is more common in island societies (Calado *et al.*, 2007). A similar structure for ES defined by governmental agencies will be more effective, because similar criteria, with proper adaptations, will be applied to an entire island, regardless of the interests of municipalities that might administratively disrupt the natural continuity of the island territory.

The framework presented will then be a strategic and flexible tool to identify both the important elements (recognized in current legislation) in a territory and the remaining potential of the territory. Decision-making using multiple criteria will allow the identification of integrated solutions that reduce trade-offs as much as possible, increase multifunctionality and reconcile the needs of nature conservation and socioeconomic development. This theoretical proposal could be applied to other small islands and other territories with local adaptations.

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