Green and blue infrastructure as a tool to support decision-making in the spatial planning process. The case of Lake Trichonida, Greece

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Abstract. Green infrastructure (GI) has gained high interest over the last two decades, as a policy tool to promote sustainable development and enhance the resilience of both the urban and rural environments. GI has the potential to offer multiple benefits through the services and functions performed within ecosystems, and thus its implementation requires an integrated and balanced approach that emphasizes the multifunctional nature of a territory. Multifunctionality along with connectivity and networking appear to be core features accepted by all disciplines using the term. GI incorporates green spaces, or/and blue if aquatic ecosystems are concerned, and other physical features in terrestrial and marine areas. This paper presents the development and application of a methodology to facilitate spatial planning choices, incorporating a green and blue infrastructure (GBI) approach, in a Greek case, the wider area of Lake Trichonida in Western Greece. The conceptual basis of the proposed approach embeds both natural and man-made features that could function as green or blue infrastructure. The methodology and its application facilitated the identification of planning priorities and the pursue of planning objectives, thus supporting the decision-making in the spatial planning process.

1. Introduction: The concept of Green and Blue Infrastructure
Urban and rural areas are confronted with varying and intense environmental threats mainly due to climate change. This new reality created an urgent need for new concepts and tools in order to manage development in a manner that protects natural and cultural resources and promotes urban resilience. The notion of Green and Blue Infrastructure (GBI) has been frequently used to respond to these new challenges. The main idea behind the concept of GBI is that they can enhance the health and resilience of ecosystems, while at the same time can contribute to a wide variety of societal benefits [1,2]. The original GBI concept has its roots in ecosystems conservation efforts but recently has acquired new dimensions that they are more often associated with environmental or sustainable goals that cities strive to achieve through a combination of natural approaches [2].

The European Commission has defined Green Infrastructure (GI) as “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” [3]. The notion of GI incorporates green and blue spaces if aquatic ecosystems are concerned and other physical features in terrestrial, coastal and marine areas.
On land or water, GI is present in rural and urban settings. The EC definition, which is the most extensively used, is based on three key features that are important for the effective implementation of GI in sectoral policies: connectivity, multifunctionality, and links to spatial planning [4]. Connectivity refers to biodiversity enhancement and habitat provision and it relates to the ability of species to move between areas. Connectivity can be either structural (i.e., habitat continuity) or functional (i.e., the ability of landscapes to allow various species to move and expand to new areas without them necessarily being physically connected) in nature [5]. Multifunctionality is the ability of GI to provide not only ecological services but also many other ecosystem services (e.g., ecological/regulating, social/cultural, and/or economic/provisioning services) simultaneously in one locale [6].

Integration of GBI in spatial planning became a large part of its promotional agenda and in 2013 the EC put forward a GBI strategy to ensure that the protection, restoration, creation, and enhancement of GBI become standard and integral parts of spatial planning and territorial development whenever they complement or offer a better alternative to standard grey choices [3]. Nevertheless, application and integration of GBI in spatial planning has been quite limited [7], while there is still a lot of room for development of existing methodologies. Under this notion, this paper provides the first steps towards the establishment of a methodology that facilitates a spatial planning approach to GBI planning. The methodology was developed and applied within the context of the ideas competition with prizes awarding entitled "Study of strategic spatial development in the area of Lake Trichonida", sponsored by the Regional Development Fund of the Region of Western Greece in 2019. The authors participated in the competition as members of the CONSORTIS team, which received the second prize.

2. The case study area: physiognomy and vision for development

The study area includes Lake Trichonida and a wider area that encloses it, with many small population-sized settlements and variations in the landscape and relief, which form an interesting natural and man-made environment. Lake Trichonida is the largest and deepest lake in Greece and is located in the Regional Unit of Etołaokarnania in Western Greece.

The central element for the spatial and functional organization of the study area is the lake, which in combination with the varied relief of lowland to intensely mountainous areas comprise elements of unique spatial organization. The main land use is agriculture, while the local microclimate contributes to the formation of a special natural landscape. The area has a rich cultural environment that has not been properly utilized, while the tourism infrastructure is insufficient. The economic-productive activities that are located outside the settlements are characterized by low intensity and do not present any land use conflicts. As for tourism and leisure activities, they are concentrated mainly on the north and northeast side of the lake, both in the coastal and in the mountainous areas, where the natural landscape is suitable for the development of various activities (Figure 1).

The reinforcement of mild and alternative forms of tourism (agritourism, sports tourism, spa, etc.) is an important development perspective for the area. Therefore, expanding or creating new hiking and bicycle networks, that have a multi-themed character, is necessary. Furthermore, local tourism destinations need to upgrade their image in order to become more attractive, highlighting elements of identity and brand awareness.

The vision set for the study area was "establishment of a balanced natural, man-made and socio-economic landscape that is networked, complemented and operates on multiple levels". The vision is supported by the triptych "Creation-Maintenance-Enhancement" and is structured around three Strategic Objectives: 1. Creation of new opportunities for leisure and alternative tourism, in combination with the remarkable natural and man-made environment; 2. Preservation and protection of the special elements of the natural and man-made environment, preservation and promotion of ecological and cultural values and functions; 3. Enhancement of the productive landscape by promoting the local advantages to ensure the economic resilience of the area.
The reasons that led to the adoption of GBI as the most appropriate tool for analysis and synthesis for the study area are the intense fragmentation of the natural landscape, the reduced connectivity and accessibility of important natural and man-made elements as well as the ability to redefine the identity of the area by highlighting the unique features of its natural landscape and cultural reserve. Finally, the use of GBI is a prerequisite for development in terms of mitigation and adaptation to climate change.

3. Methodology
The methodology was based on the elaboration of two classification models for GI elements so as it fits the needs and scope of spatial planning. These models were the Benedict and McMahon model and the Ahern model [1,8]. Both models highlight the critical aspect of the structural form of the landscape elements as well as the importance of connectivity amongst them, so as to ensure the functional flows and movements within the landscape and the evolution of its structure and processes over time [7]. It is worth noting that the Benedict and McMahon typology was developed to classify areas and improve the application of GI as a tool, while the Ahern model is a more general model that is used to analyse GI spatially. Therefore, for the purposes of this study, a typology derived from the combination of the two approaches has been developed.

The conceptual basis of the proposed typology embeds both natural and man-made features that could function as green or blue infrastructure (GBI) and includes three structural elements: hubs, corridors / links and transition points (Figure 2). The hubs are homogeneous terrestrial or marine areas of all shapes and sizes that differ from the surrounding landscape and may serve different purposes. For instance, hubs could be natural reserves, regional parks, natural landscapes and cultural/historical/recreational areas. The corridors/links are linear areas of a particular type of land cover that differ in content and physical structure from their surrounding environment but contribute to the creation of the GI network via the properties of connectivity and accessibility. Corridors can occur in both terrestrial and marine landscapes. For instance, terrestrial or marine corridors could be landscape links, conservations corridors, green/blue zones, trails etc. Finally, transition points are areas that serve as attraction points and thus points of origin and destination for functional flows. Transition points include selected ecological, recreational, or cultural/historical areas that are equipped with appropriate services for visitors, serve as points of origin or destination, and are connected by routes. These sites may be located in rural, agricultural, or residential areas.
A three-step process was followed to develop the GBI network: identification of GBI elements, functional evaluation and composition.

**STEP 1. Identification of GBI elements.** The first step is to identify key categories of elements, natural and man-made, that could be part of the GBI network, and then classify them into the following categories: 1. Outstanding Natural Landscapes; 2. Coastal Ecosystems; 3. Water Corridors; 4. Anthropogenic Landscapes; 5. Tourism, Leisure and Sports Infrastructures; 6. Productive Landscapes; 7. Access and Networking Infrastructures. The list of these categories is dynamic and can change at any time, while in practice it is imperative to incorporate local stakeholders and community at every step of the identification process.

**STEP 2. Functional evaluation.** The next step is to determine the function that each of the elements performs or is desirable to perform. The functional evaluation of the GBIs in combination with their spatial mapping carried out in the previous step are necessary to identify the physical and functional "gaps" of the study area. In order to determine the function of the individual components of the GBI, it is necessary to take into account a) their existing mode of function, b) the role of each element in the local and regional scale and c) any functional specializations arising from upper-level strategic spatial plans.

**STEP 3. Composition of the network.** Following the functional determination of the GBI elements, the GBI network is established. An essential condition for its formation is the categorization of the GBI elements into the three structural elements of the network: hubs, corridors / links and transition points. The categorization is based on the geographical location and function that each element performs or can perform as part of a wider functional network. In addition, the categorization is related to the vision and objectives of the proposed spatial strategy and the priorities it sets.

4. **Results: Methodology application to the study area**

4.1. **STEP 1. Identification of GBI elements**

All the GBI elements of the study area were classified into the 7 categories mentioned above as follows:

1. Outstanding Natural Landscapes. The outstanding natural landscapes refers to natural areas which are important for the ecosystem function of the study area and the wider area. It includes protected areas such as areas of the Natura 2000 Network, landscapes of special natural beauty, wildlife refuges, etc. They also include forest areas that are particular to the study area such as plane trees, kermes forests as well as the Fraxos forest which is a small but of special value forest patch and the calcareous swamps with Cladium Mariscus & carex davalliana which are priority habitats.

2. Coastal Ecosystems. This category includes all areas dominated by wetland habitats that function as coastal habitats including lakeside forests, reedbeds and water lilies. The beaches also belong to this category as areas that host human activities, while at the same time they are elements of the coastal ecosystem and therefore need special management.
3. Water Corridors. All "areas" through which water passes such as rivers, streams, irrigation canals and water sources are included. The lake as a central element of the water system also belongs to this category.

4. Anthropogenic Landscapes. This category includes manmade constructions that can be archeological and historical findings that shape the historical landscape of the area. They can be located inside or outside settlements and can be either visited or not. Such elements are the monasteries, ancient settlements, watermills, etc.

5. Tourism, Leisure and Sports Infrastructures. They include all the physical (building) infrastructure related to various activities and aim to their support and enhancement. Sports and other outdoor activities such as sailing, horseback riding, rowing, basketball etc. are included, they can be public or private and are often located in the lakeside area. This category also includes the infrastructure related to the support of tourist activities located within the settlements, such as museums, environmental education centers, etc. Settlements are considered as multi-functional core areas and are included in this category.

6. Productive Landscapes. It includes natural areas related to agricultural production as key element of the local economy. Special emphasis is given to intensive crops as well as to special value (aesthetic / economic) crops, such as olive groves and orchards. Pastures belong to this category both as a landscaping factor as well as a productive activity. In addition, this category includes Renewable Energy Sources (RES) installations, which constitute another type of productive landscape.

7. Access and Networking Infrastructures. They include the transport networks and infrastructure of the area and concern the provision of access to activities but also the networking of all activities and or GBI elements within the study area. There is a relative functional differentiation that depends on their location and type, e.g. lakeside roads, port "Amparia" etc.

The list of natural and man-made elements of the study area was supplemented with regional elements, to achieve maximum networking and multifunctionality benefits.

Based on the above-mentioned classification a series of diagrammatic maps were created. The geographical representation of these elements indicated several spatial concentrations but also spatial discontinuities in the landscape (see Figure 3).

Figure 3. Illustration of the spatial distribution of elements that may be part of the GBI network.
4.2. STEP 2. Functional evaluation

Based on the international literature [9,10,11] as well as the physiognomy and the special characteristics of the study area, 19 types (categories) of functions were identified. These categories are quite general and some of them may occur when the GBI is considered on a macro-scale, e.g. food production, mitigation and adaptation to climate change, while some other functions are activated only when there is a correlation with the local community and specific place. It is also possible for multiple functions to coexist, leading to multifunctionality, and thus contribute to the achievement of economic, environmental and social objectives through the spatial integration of land uses and the development of activities. In the case of GBIs, multifunctionality is desirable, as it encourages efficient land use, offers a wider public benefit and contributes to the creation of partnerships, leading to better management and efficiency of GBIs.

Figure 4 presents the functional evaluation of the GBI elements of the study area. The existing functions are marked in light green and the functions that can be performed as part of the proposed GBI network are marked in dark green. The last column indicates the structural classification: H – Hub, C – Corridor/link, TP – Transition Point.

Figure 4. Extract of the full functional evaluation of the GBI elements of the study area.

4.3. STEP 3. Composition of the network

Following the categorization of each GBI element, Figure 5 shows the composition and spatial imprint of the network.
Figure 5. Spatial imprint of the GBI network in the study area.

Hubs: The spatial concentration of various functions and their potentially physical networking was a key criterion for determining the hubs of the network. It is important to understand that spatial concentration or proximity was the main criterion for designating a GBI element as a hub or as a transition point. For example, the port at ‘Amparia’ as an accessibility infrastructure could be described as a transition point. Nevertheless, features such as its location, proximity to other important functions in the immediate area of influence, as well as its potential function and physical networking based on the proposed spatial development strategy, lead to the classification of this ‘point’ element as a hub. Therefore, the existing and the strategically proposed spatial and functional interdependencies between the elements highlighted 6 hubs (see Figure 5).

Corridors / links: Links are defined as those linear areas that contribute to the physical and functional interconnection of hubs. These links follow existing linear elements, such as roads, coastlines and streams, or existing functions which, due to their geographical location, form linear functional links. As shown in Figure 5, 7 links are proposed, 5 land and 2 aquatic, as functional corridors between the hubs. These links incorporate existing and proposed functions such as valuable elements of the natural and cultural landscape, tourism, sports and leisure infrastructure, as well as accessibility and networking infrastructure.

Transition points: Transition points are defined as activities or locations that do not belong to a hub or corridor / link, mainly due to their non-proximity to other elements of the area. However, they are important activities that shape the physiognomy of the landscape and are elements of origin and destination of human flows. Therefore, they are elements of the proposed network, but there are no defined corridors to and from them. Such elements are the forest of Fraxos (see Figure 5), the bridges of Alabei etc. This category also includes elements outside the study area as important poles of origin or destination of human flows, such as the tobacco museum of Agrinio, the gorge of Kleisoura etc. The transition points are not connected by functional links but can be connected to specific infrastructures, such as cycling and walking trails.

5. Conclusions
GBI is considered to be essential in supporting sustainable and resilient territorial development since it presents us with the opportunity to embody the benefits of ecosystems services and enhance the multifunctional nature of a territory. The proposed methodology highlights and promotes a much
need territorial approach to GBI planning embodying as basic design properties the connectivity and multifunctionality of its elements.

Its application to the Greek case study facilitated the identification of planning priorities and the pursuit of planning objectives, thus supporting the decision-making in the spatial planning process. GBI was treated as a fundamental infrastructural resource that can provide multiple ecosystem services and help achieve balanced territorial development.

The end-product of the application of the methodology was a plan with a spatial and functional organization of land uses and activities. The proposal highlighted the potential of individual sites, routes and habitats, in accordance to the principles of environmental planning and design. It was essentially a topocentric approach with an extroverted orientation, with a high degree of networking, multifunctionality and complementarity.

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