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Integration of Ecosystem Services in Strategic Environmental Assessment of a Peri-Urban Development Plan

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Abstract: Strategic environmental assessment (SEA) can support decision-makers in constructing more sustainable plans, programs, and policies (PPPs). To be more coherent with new frontiers of sustainable cities, PPPs need to include conservation objectives and to increase ecosystem service (ES) strategies. The ES concept is not intrinsic to the SEA process; therefore, it is necessary to develop an approach and methodology to include it. In this paper, we propose a methodology to integrate the concept of ecosystem services in all phases of the SEA process for a sub-urban plan, including the design of mitigation measures. The case study is represented by a peri-urban development plan in the municipality of Gallipoli in South Italy, characterized by a strong tourism economy and valuable agro-ecosystems. The analysis shows the priority ecosystem services that are selected considering the sustainable development and environmental goals, the context of referment, and the aims of the peri-urban plan. After, we highlight the potential ecosystem services developed considering the design of mitigation actions like green infrastructure, which could be implemented in the peri-urban plan. The capacity to develop green infrastructure in SEA processes can configure the SEA as a tool for ecological urban design that is integrated with urban planning. This requires the ability to transfer ecological and planning theories into practical actions and the capacity of different disciplines to work in a transdisciplinary approach.

Keywords: environmental assessment; environmental goals; ecosystem services; mitigation actions; green infrastructure; urban plan; landscape planning

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1. Introduction

Ecosystem services (ESs) represent the human benefits derived from a combination of biophysical structure and ecological functions that characterize the landscape and can be conditioned from the method and purpose for which humans use the land [1,2].

The concept of ecosystem services should be included in decision-support procedures, such as strategic environmental assessments (SEAs) for public plans or programs and environmental impact assessments (EIAs) for individual projects because the conservation of ecosystem services is essential to safeguarding people's well-being [3,4]. SEA refers to a "range of analytical and participatory approaches that aim to integrate environmental considerations into Policies, Plans and Programmes (PPPs) and evaluate the inter-linkages with economic and social considerations" [5].

Currently, interest is growing in the potential role of the ecosystem service (ES) concept within SEA [6–8]. Integrating ecosystem services into SEA is aimed at reducing the environmental impacts of PPPs and the potential impacts on ecosystem service provision.

However, the inclusion of ecosystem services should be contextualized considering the objectives and the administrative scale of PPPs. Particularly, neither ESs can be addressed with a standard approach for all PPPs nor do all ESs linked with landscape transformations have the same importance [9]. Hence, it is important to determine priority ESs that could be positively and negatively affected by policy- and decision-maker choices [3,6]. The application of ES analysis in SEA is still in the exploration phase, although several applications have been developed [6,7,10,11]. Many of these applications concern plans at the regional or urban scales, but few studies are related to peri-urban plans at the sub-urban scale. These plans are important because they determine the features of the future urban space and, hence, of the well-being of the people living therein. Peri-urban landscapes play an important role in ES provision, but they are often characterized by ES trade-offs [12].

The difficulty of adapting regional- and urban-scale approaches at the sub-urban scale is in the nature of the planning. In the first case, the planning exercise is a public initiative for the public interest of a vast range of stakeholders and affects private interests. This is the case of top-down planning processes. On the sub-urban scale, planning can be promoted for private interest. Therefore, it is important to match private economic interest with the social-ecological effects of the transformation plan. This is, in turn, the case of bottom-up processes, which, however, are conditioned by top-down plans [13]. Currently, an emerging concept for urban planners to foster sustainable development is represented by green infrastructure (GI), which is promoted by the European Union (EU) policy for both rural and urban areas [14,15]. It is possible to consider GI as part of nature-based solutions (NbSs) integrated with grey infrastructure (e.g., roads, sewer systems, and buildings) able to provide multiple ecological functions supporting the city's activities and human well-being, involving both public and private spaces [16–19].

For these guidelines to consider ecosystem services in SEA processes, the priority ecosystem services considering other strategic actions need to be defined and the variation in ecosystem services in different scenarios must be assessed considering the evolution approach developed [3,20,21]. Currently, the decision support processes in SEA do not consider GI/NbS-based ecosystem service assessment. This is an important gap requiring action to clarify the feedback between the built environment, GI, and human well-being during planning to find the best solutions to achieve urban sustainability.

The aim of this work was to construct a methodology to integrate ES in all phases of the SEA process for a sub-urban plan, including the design of mitigation measures, such as green infrastructure. Mainly, we wanted to include GI in the analysis of alternative scenarios to reinforce the impact assessment on ecosystem services. A central element of the approach is the identification of priority ESs based on analysis of the objectives, environmental goals, and strategic actions of the plan. The case study is represented by a peri-urban development plan in the municipality of Gallipoli, in Southern Italy, which is characterized by a strong tourist economy and valuable agro-ecosystems.

2. Materials and Methods

2.1. Study Area

The study area (Figure 1) is a relatively small urban plot characterized by buildings scattered within a mosaic of arable lands, uncultivated areas, and olive groves. Olive groves represent the most critical element because they are characterized by monumental olive trees, which are protected under regional legislation by virtue of their production, ecological, and hydrogeological functions as well as their cultural and historical value. However, in recent years, almost all olive groves in Gallipoli have been severely damaged by the spread of *Xylella fastidiosa* [22–24].

Figure 1. Study area.

2.2. Methods

The methodology was inspired by the UNEP guidelines [3] and the work of Geneletti [11] and Vasquez et al. [8], which is based on establishing the ecosystem service context (stage 1), determining and assessing priority ecosystem services (stage 2), identifying alternatives and assessing impacts on ecosystem services (stage 3), and following up on ecosystem services (stage 4).

The definition of priority ecosystem services together with environmental goals can be useful for incorporating the ecosystem service concept in all phases of the SEA process, creating an interconnected workflow between the SEA process and the inclusion of ecosystem services in the peri-urban plan. The main difference compared to the reference approach is the phase in which the mitigation measures are considered. This is applied as the last action in stage 3. We instead implement this phase as a specific action to foresee mitigation figures to be developed as GI. The effect of GI in ecosystem service production is assessed during the analysis of plan alternatives (Figure 2).

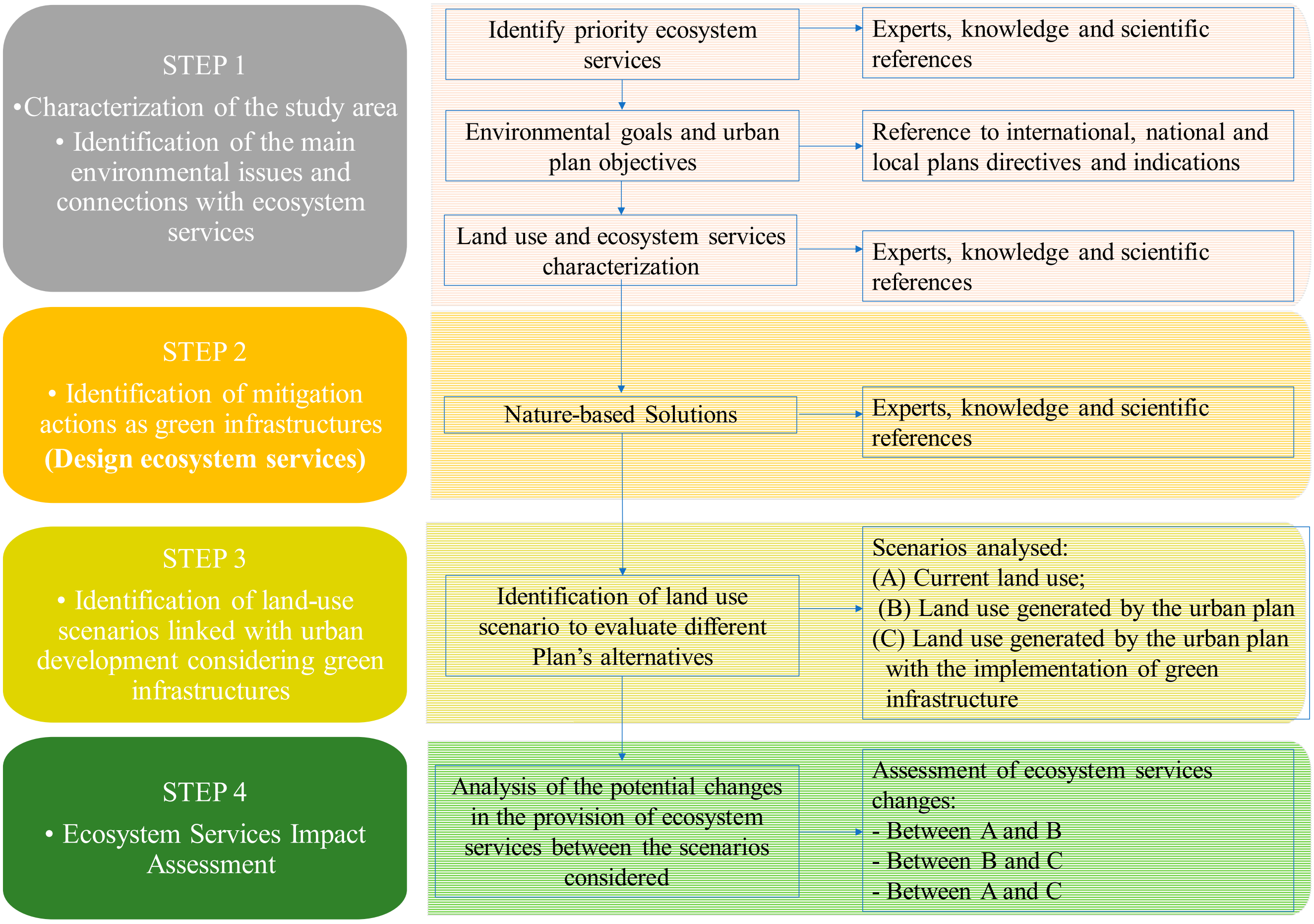

Figure 2. Scheme of the methodology modified considering Therivel, UNEP, Geneletti, and Vasquez et al. [3,8,11,25].

In this study, we did not develop actions for follow-up on ecosystem services (action 4).

2.2.1. Step 1

This step is focused on establishing the ecosystem service context and on determining and assessing priority ecosystem services. Priority ESs are those that contribute the most to social welfare on the basis of the objectives, environmental goals, and strategic actions of the urban plan. Environmental goals were selected considering international and national directives. The definitions of the environmental goals started with consideration of the UN's Sustainable Development Goals (SDGs) [26]. Afterwards, we analyzed the relationships with other relevant plans (at different spatial tiers) by comparing the objectives/actions of the plan and the guidelines/forecasts of other plans (external consistency analysis) [27]. This is important because the SEA process needs to analyze the coherence between the peri-urban plan with PPP strategies of different administrative levels and scales, as stated by international and national directives and laws. Once goals were identified, priority ESs that can support the achievement of these goals in the study area were selected. ESs were classified according to the Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations, Earthscan [28].

In this phase, it is necessary to analyze the land use that characterizes the biophysical structure and the ecological functions that support priority ecosystem services, such as the cultural value of the landscape elements that have to be preserved or regenerated. It is necessary to consider their evolution in time to evaluate the loss to social welfare with the loss or gain of ES vis-à-vis the benefit of development. This is important for defining how to develop the peri-urban plan to reduce the negative effects on ecosystem services. Moreover, it can represent the starting point in the evaluation of the interaction between the built environment and the existing vegetation, which supports ecosystem services important for human well-being.

2.2.2. Step 2

The SEA process can introduce mitigation actions to reduce negative environmental impacts and to simultaneously improve the quality of human life. In an urban context, mitigation actions should be identified to develop urban elements harmonizing economic income with social-ecological needs and without compromising the ecological functions and ecosystem services' provision [17,29]. By linking scientific knowledge and planned activities, practical solutions were identified that can meet ecological needs with economic and social needs. These solutions consist of green infrastructure (GI) proposals in coherence with priority ecosystem services, land use characterizations, and structural elements that characterize the landscape.

GI provides an alternative to grey infrastructure, having many co-benefits for planners to foster sustainable urban land-use, to compensate for the negative effects of urban density, and to enhance human wellbeing [30,31]. GI has been defined 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" [15].

Following the definition of GI, it is possible to divide it into green (e.g., parks, playing fields, and private gardens) or blue (e.g., rivers, wetlands, and canals) areas, interconnected with technological built forms and grey infrastructure (e.g., roads and sewer systems) [17,32–35]. Urban GI can partially replace specific urban ecosystem services like gas regulation; carbon sequestration; micro-climate regulation; rainwater drainage, and sewage and waste treatment; biodiversity conservation, preservation of traditional cultural needs, and historical characteristics of the landscape; recreational activities; and educational values [35–37]. Other services that are lost to development, such as food production, usually have lesser importance within urban boundaries but may become relevant when examining more extended contexts (i.e., metropolitan or regional areas), especially under the eventual pressures potentially exerted by climate change on urbanized areas [35,38].

Mainly, we adopted the solutions reported in the literature [34,37,39–42] but focused on the study area. Therefore, each specific solution needs to follow specific conditions, such as the type of vegetation, functional use, and localizations.

The design of ecosystem service actions is also considered in the next phase, where plan scenarios are identified and subsequently analyzed to value the best alternative.

2.2.3. Step 3

In this step, we analyzed the ecosystem service evolution of land use considering the current conditions of the study area, potential land use decisions of the peri-urban plan, and the scenario of a peri-urban plan that integrates the planned GI. Land use scenarios were then generated and described.

2.2.4. Step 4

A qualitative analysis was conducted by identifying losses and gains in ES provision [3,43] using a seven-point Likert scale: from low, medium, high (for losses and for gains), and null values, where there was no type of variation [24]. The ecosystem service evaluation included methods identified in the literature, which link ecosystem service production with different classes of land use and integrated field surveys to characterize vegetation types. The ES valuation, therefore, links biophysical structures indicated in the literature important in determining ecosystem services with specific ecological functions supported by the status and type of the vegetation currently present and proposed in different scenarios, also including GI (Table 1). We used the Economics of Ecosystems and Biodiversity Ecological and Economic Foundations ecosystem services classification as a reference for this study [44].

Table 1. Actions applied to assess ecosystem services in peri-urban area and in different scenarios analyzed. ES, ecosystem services; SEA, strategic environmental assessment.

Elements of ES Assessment	Actions	References
Scientific Literature	Valuations and mapping of ecosystem services considering land-cover analysis	Reference manuscripts [24,43,45–47]
	Method to assess the symptoms of *X. fastidiosa* related to leaf scorching and wilting of the canopy	Reference manuscripts [23,24,48]
Regional law of monumental olive groves	Parameters indicated by the regional legislation for the classification of monumental olive trees and monumental olive groves	Regional law 14/2007 [49]
Field activities	Floristic and vegetation relief to better calibrate the ecosystem services linked with land use, considering species that characterize them and the local context	Ecologist, botanist, agronomist, faunist
	Visual inspection to assess the symptoms of *X. fastidiosa* related to leaf scorching and wilting of the canopy	
	Classification of monumental olive trees and monumental olive groves	
Skills and experience of the expert involved	Ecosystem service design to improve benefit	Expert in endemic vegetation; ecological role of vegetation, biodiversity restoration; ecosystem service analysis, planner, and SEA processes; references of local vegetation [50–52]
Regional law of *Xylella fastidiosa*.	Actions implemented in olive groves affected by *Xylella fastidiosa*	Apulian Regulation guideline 02/2019 [53]

3. Results

Next, we applied the conceptual framework to the case study. The structure of the sections and subsections follow the methodologies reported in Figure 2.

3.1. Step 1

3.1.1. Priority Ecosystem Services

The plan was developed on a local scale; therefore, it was possible to define priority ecosystem services that can be developed considering the specific environmental issues that characterize the urban area, such as air-quality microclimate issues associated with built environmental and human activities. For these reasons, air-quality regulation, climate regulation, and moderation of extreme events were selected as priority ecosystem services that need to be enhanced in the area through mitigation actions [26,54–57]. In addition, we considered cultural and amenity services as priority ecosystem services, which are important due to the presence of many monumental olive trees, currently threatened by *Xylella fastidiosa*.

Focusing on priority ecosystem services does not exclude the possibility to enhance additional services. For example, in the case study, habitat services are considered co-benefits since the aim of the sub-urban plan is the development of residential areas and since green areas will be planned to increase human well-being. Specific design choices can improve the capacity of green areas to support biodiversity, but this is not the primary scope and we cannot predict with certainty those birds and animal species that will be able to settle in the spaces.

3.1.2. Environmental Goals

Table 2 reports the overall environmental sustainability objectives relevant to urban development plans drawn from international, national, and regional environmental legislation (internal consistency analysis). The study area is mainly characterized by a peri-urban landscape, and provisioning services are not relevant because the value of food and raw material production is low. However, regulating and cultural services have strong relevance considering the area as a socio-ecological system [24,35,36].

It is difficult to establish a connection between ecosystem services and all environmental objectives. For example, aspects connected with mobility and electromagnetism are mainly related to the project techniques, so they can indirectly concern the ecosystem services. For this reason, in this phase, we only report the environmental goals that are directly linked to ecosystem services and that satisfy the internal and external consistency analysis, which characterizes the SEA process.

3.1.3. Land Use and Ecosystem Services Characterization

The land use of the area shown in Figure 1 is mainly characterized by arable land (33.3% of the total surface) and olive groves (28.7% of the total surface) (Table 3 and Figure 3). There are also artificial surfaces (roads and buildings) covering 14% of the total study area. The presence of natural vegetation is very low (shrub, covering 0.3 ha). The herbaceous vegetation is nitrous and ruderal flora with a low ecological value and its development has been conditioned by present and past anthropic activities.

Although 62% of the area is characterized by agricultural use, its productive role is minimal. The arable land is characterized by strong owners' fragmentation and, in many cases, represents small plots used as vegetable gardens for self-production. These garden plots might not have strong economic value for landowners, as 97% of these plots have joined the development of the peri-urban plan, thus renouncing future use as vegetable gardens.

The olive groves were almost all affected by *Xylella fastidiosa*. Symptoms of *Xylella fastidiosa* related to leaf scorching and wilting of the canopy were assessed by visual inspection, estimating disease severity using the following scale: 0 = symptomless, 1 = leaf scorching on few branches or few desiccated branches affecting the portion of the canopy, 2 = leaf scorching on several branches or desiccation affecting a large part of the portion of the canopy, and 3 = canopy with desiccated branches uniformly distributed [23,24,48]. The olive trees were classifiable as 2 and 3; in this case, almost all olive trees were dry or potentially dry because they were severely infected by *Xylella fastidiosa* (Figure 4). Therefore, it was possible to consider these plants dead [48].

Xylella fastidiosa produced a strong ecological impact because the olive groves lost their ecological function in the landscape, as some of them were monumental trees with important cultural and aesthetic values in the landscape. Many olive groves are characterized by historical and monumental trees. The cultural value of monumental olive groves was then analyzed through objective measures concerning the diameter of the trunk and through a visual analysis of the shape of the trunk of the plants, as established by regional law 14/2007 [23,49].

The elimination of infected monumental olive trees will cause the loss of an identity element of the landscape of Gallipoli (Table 4). Moreover, the olive groves were important carbon sinks and therefore played an important role in mitigating the local microclimate and air quality [24].

Table 2. Indications of priority ecosystem services connected with environmental goals for each sector indicated by the international, national, and regional directives, policies, programs, and plans: ecosystem services from 1 to 6 are provisioning services; from 7 to 15 are biological services; from 16 to 17 are habitat services; and from 18 to 22 area cultural and amenity services [28,44]. P, priority ecosystem services that we want to directly enhance by integrating it into the peri-urban plan's green infrastructure related to the mainly environmental problems. C, other ecosystem services that can be linked indirectly with the green infrastructure.

Sector	Environmental Goals	National and International Directives	Ecosystem Services
1.Population and human health	1-1. Protecting the population from health risks originating from situations of environmental degradation 1-2. Preventing and reducing sources of urban pollution and the risk of major accidents 1-4. Improving the quality of life in urban context 1-5. Promotion of shared territorial choices 1-6. Human health	2001/42/CE 2014/52/EU National environmental law: D.Lgs. 152/2006 and modifications	1 Food (C) 2. Water (C) 7. Air quality regulation (P) 8. Climate regulation (P) 9. Moderation of extreme events (P) 10. Regulation of water flows(C) 11.Water treatment (C) 15. Biological control (C) 17. Maintenance of genetic diversity (C) 19. Opportunities for recreation and tourism (C) 20. Inspiration for culture, art and design (P) 21. Spiritual experience (P) 22. Information for cognitive development (P)
2. Soil	2-1. Protection, prevention, and mitigation of hydrogeological and hydraulic risks 2-2. Preventing and mitigating current and potential risks associated with forest fires 2-3. Ensuring the permeability of the soils and quality	National environmental law: D.Lgs. 152/2006 and modifications Regional Territorial Landscape Plan (Apulian Regiona); Regional Document of General Asset	9. Moderation of extreme events (P) 10. Regulation of water flows (C)
3. Water	3-1. Guaranteeing the quantitative/qualitative protection of groundwater bodies 3-2. Reducing water consumption	91/271/EC; 2006/118/EC; 2007/60/CE; 2008/105/CE; National environmental law: D.Lgs. 152/2006 and modifications Regional Water Protection Plan; Regional Hydrogeological Plan. (Apulian Regiona)	2. Water (C) 10. Regulation of water flows (C) 11. Waste treatment (C)
4.Climate, microclimate and air quality	4-1. Reduction of climate altering and polluted atmospheric pollutant gas emissions 4-2. Enhancement of carbon sink vegetation cover 4-3. Reduction of local climatic changes	2018/841/EU 2016/2284 2008/50/CE National environmental law: D.Lgs. 152/2006 and modifications	7. Air quality regulation (P) 8. Climate regulation (P)

Table 2. *Cont.*

Sector	Environmental Goals	National and International Directives	Ecosystem Services
5. Biodiversity	5-1 Enhancement of agro-ecosystems to support fauna and flora (especially endemic) 5-2. Development of widespread ecological connectivity at the provincial level 5-3. Increase in endemic and local biodiversity	79/409/CEE 92/43/CEE; Nature 2000. Biodiversity strategies 2020 Biodiversity strategies 2030	16. Maintenance of life cycles of migratory species (C) 17. Maintenance of genetic diversity (C) 14. Pollination (C) 15. Biological control (C)
6. Landscape and cultural heritage	6-1. Conservation or enhancement of the elements of the local landscape 6-2. Implementing the integration of the urban sprawl in the landscape context of reference 6-3. Policies and actions of discovery and rapprochement of residents to cultural capital 6-4. Development of strategies for sustainable use of landscape heritage	Regional Territorial Landscape Plan (Apulian Region)	18. Aesthetic information (P) 19. Opportunities for recreation and tourism (C) 20. Inspiration for culture, art and design (P); 21. Spiritual experience (P) 22. Information for cognitive development (P)
7. Energy	7-1. Promoting energy savings 7-2. Incentivize energy efficiency in buildings	2009/28/CE 2001/77/CE	7. Air quality regulation(P) 8. Climate regulation (P)
8. Waste	8-1. Efficiency of natural resources	National environmental law: D.Lgs. 152/2006 and modifications	7. Air quality regulation (P) 11. Waste treatment (C)

Table 3. Composition of the main land use of the study area.

Land Use	%
Fruit trees	0.6
Herbaceous vegetation	23.4
Shrubs	1.1
Arable land	45.1
Artificial surfaces (building)	19.0
Olive groves	38.9
Green urban areas	4.2
Vineyards	3.0

Figure 3. Spatial configuration of the main land use of the study area.

Figure 4. Example of the olive trees affected by *Xylella fastidiosa* in the study area, highlighting the state of desiccation of the monumental olive trees.

Table 4. Qualitative characterization of the ecosystem service provision linked with the main land use in the study area. -, not relevant for ecosystem services [13,34,44].

Main Services Type	Olive Groves	Olive Groves Affected by *X. fastidiosa*	Arable Land	Herbaceous Vegetation
1-Food	medium	-	medium	-
2-Water	-	-	-	-
3-Raw Materials	medium	-	low	-
4-Genetic resources	medium	medium	low	medium
5-Medicinal resources	low	-	-	-
6-Ornamental resources	-	-	-	-
7-Air quality regulation	strong	low	low	low
8-Climate regulation	strong	low	low	low
9-Moderation of extreme events	medium	low	low	low
10-Regulation of water flows	low	low	low	low
11-Waste treatment	low	low	low	low
12-Erosion prevention	medium	low	-	low
13-Maintenance of soil fertility	medium	low	low	low
14-Pollination	low	low	low	low
15-Biological control	low	low	low	low
16-Maintenance of life cycles of migratory species	medium	low	low	low
17-Maintenance of genetic diversity	low	medium	medium	medium
18-Aesthetic information	strong	low	low	low
19-Opportunities for recreation and tourism	strong	low	low	low
20-Inspiration for culture, art and design	strong	-	-	-
21-Spiritual experience	strong	-	-	-
22-Information for cognitive development	strong	-	-	-

As a paradox, the olive trees that were previously a valuable element of the landscape now represent an element of degradation of the landscape (Figure 5). The provision of ecosystem services of the olive trees affected by *Xylella fastidiosa* is now more comparable to uncultivated areas characterized by herbaceous ruderal vegetation [23,24].

Figure 5. Panoramic view of dead olive trees in the study, highlighting the state of desiccation of the olive groves.

The species detected for the herbaceous vegetation belong to the ruderal type, which characterize land exploited for human activities of low ecological value and not relevant for food or medicinal uses.

3.2. Step 2: Identification of Natural-Based Solutions

This phase was developed considering the GI that can be developed in urban areas to support priority ecosystem services and its associated co-benefits. The type of solution was planned considering the typologies of the space that can be used: roofs and walls of the building, private green areas, public green areas, and parking areas. The natural-based solutions were conceived and planned considering the typologies of vegetation species that can be used to develop priority ecosystem services. NbS considered the typologies of the area that could be developed and potentially used (Table 5). For example, we propose two types of green roofs considering the type of buildings. Mainly, we previously suggested the use of extensive green roofs for houses and intensive green roofs for schools, markets, and public buildings [30,58]. The use of scientific literature was important for setting human benefit and ecosystem services connected with the GI.

If food production could not be considered a priority ecosystem service in the urban context, urban community gardens can be important strategies to promote social activities and integrations between different cultures in the newly created neighborhood. It is important to plan urban parks integrated with a water body and wetland vegetation to give it multifunctional social uses and to contribute to important ecological functions [59]. These pieces of green infrastructure, although relatively small in size, can improve specific ecological functions, increase human health, and enhance local biodiversity. In a highly urbanized context where ecological land use is in competition with social and economic land use, these may represent interventions.

Table 5. Connections between benefit and biophysical structures of mitigation action design, like green infrastructure (GI) useful for increasing priority ecosystem services and satisfying the environmental goals identified in Table 2 [27].

Mitigation Actions and GI	Ecosystem Services	Benefit	Reference	Environmental Goals (Table 2)
Reduction in the impermeable surface with respect to the indications of the municipality urban plan development intensive and extensive green roofs for big buildings Green Wall Reforestation: mixed shrub, arboreal agricultural uses, and natural flora The use of endemic vegetation with germplasm derivate from the local context (use of seeds and cuttings collected in the reference context) Creation of microhabitats and structures able to support local insects and animal The use of melliferous, aromatic flora Creation of a wetland and flooding area Creation of forest habitat Urban community gardens Squares, streets, and parking lots with Grassy floors Using flora for environmental monitoring Rainwater collection and use systems	1-Food (C)	Fruits, small-scale subsistence; Food security; Raising awareness of the inhabitants; Food production and processing; Energy consumption and production.	[42,60–62]	1-1; 1-2; 1-3, 1-4; 1-5; 1-6
	2-Water (C)	Water availability	[42,58,59]	1-1; 1-2; 1-3, 1-4; 1-5; 1-6; 3-1; 3-2
	7-Air quality regulation (P)	Remove air toxins and nursery gasses like particulate matter, carbon dioxide, nitrogen dioxide, carbon monoxide, and sulfur dioxide; Carbon sinks; Reduction of carbon footprint.	[42,58,59,63–68]	1-1; 1-2; 1-3, 1-4; 1-5; 1-6 4-1; 4-2; 4-3 7-1; 7-2 8-1
	8-Climate regulation (P)	Reduced heat flux into the building Reduced energy demand for space climate conditioning; Reduction of urban heat island effect; Increase in thermal comfort; Reduced urban energy consumption; Reduction of carbon footprints; Decreasing cooling and heating loads.	[42,58,59,64,66–71]	1-1; 1-2; 1-3, 1-4; 1-5; 1-6 4-1; 4-2; 4-3
	9-Moderation of extreme events (P)	Reduction in stormwater volume; Decrease the burden of the water treatment facilities in an area; Stormwater retention to reduce peak flow and runoff; Improve the use of rainwater.	[42,55,58,59,66–72]	1-1; 1-2; 1-3, 1-4; 1-5; 1-6
	10-Regulation of water flows (C)			2-1; 2-2; 2-3
	11-Waste treatment (C)			3-1; 3-2 8-1

Table 5. *Cont.*

Mitigation Actions and GI	Ecosystem Services	Benefit	Reference	Environmental Goals (Table 2)
	14-Pollination (C)	Provide habitat for spiders, mites, beetles, grasshoppers, butterflies, and birds; Implementation of vegetation biodiversity and improve landscape value.	[42,58,59,62,66–68]	1-1; 1-2; 1-3, 1-4; 1-5; 1-6
	15-Biological control (C)			
	16. Maintenance of life cycles of migratory species (C)			5-1; 5-2; 5-3
	17-Maintenance of genetic diversity (C)			
	18-Aesthetic information (P)	Promote green lifestyles; Increase community engagement; Provide recreational green spaces; Reduced anxiety and tension; Positive effect on mental processes and behavior; Attentional restoration Reduced mental fatigue/fatigue; Improved cognitive function; Improved productivity/ability to perform tasks/positive workplace attitude; Aesthetic appreciation; Increased inspiration; Increased recreational satisfaction Positive effect on physical function and/or physical health; Relaxation and recreation, release stress, and relax the mind; Provide recreational space; Horticultural practices; Community support; Social activities; Social integrations between people of different cultures.	[35,42,58,60,62,66,69, 73–75]	1-1; 1-2; 1-3, 1-4; 1-5; 1-6
	19-Opportunities for recreation & tourism (C)			
	20-Inspiration for culture, art and design (P)			
	21-Spiritual experience (P)			6-1; 6-2; 6-3; 6-4
	22-Information for cognitive development (P)			

These actions can be framed as ecological urban design tools, which need to combine scientific knowledge and applied knowledge from different disciplines, such as ecology, engineering, and planning. Moreover, it needs to involve private and public bodies to guarantee the development and the capacity to maintain these solutions in the long-term.

3.3. Step 3: Analysis of Different Scenarios

In this phase, we considered four different land-use scenarios: Past, with olive groves in good status; Scenario 0, representing the current situation with olive groves affected by *Xylella fastidiosa*; Scenario 1, with the foreseen actions by the peri-urban plan; and Scenario 2, with the peri-urban plan integrated with GI.

We included the scenario with *Xylella fastidiosa* (Past scenario) because introducing the concept of ecosystem services in the urbanization process has to drive land use transformation considering pre-disturbance conditions. This increases the level of comparison between the scenarios to produce solutions that improve ecosystem service production. As such, the urbanization processes can develop the actions needed to regenerate the degraded landscape. The ante-*Xylella fastidiosa* scenario (Past scenario) was included because it shows an agro-ecosystem in which there was not this specific disturbance. Considering Scenario 0 (olive groves affected by *Xylella fastidiosa*), we applied a likely scenario (from olive groves to uncultivated soil) following implementation of the regulation of the Apulia region of 5 February 2019 [53], which requires the felling of trees infected with *Xylella fastidiosa* [23,24]. In the current state, the low value of the area for agricultural production can push landowners to abandon land [23], which negatively affects ecosystem services or landscape restoration. Moreover, in the medium term, considering the interest of landowners to develop a peri-urban plan, they would not be interested in planting new olive groves while waiting for approval of the plan.

We hypothesized an urban development plan (Scenario 1) that reduces the area destined for residential and commercial structures, increasing the areas assigned to urban standards, mainly green areas. This scenario was developed by reducing the interaction of the built environment with monumental olive groves. The few monumental olive trees that interfered with viability of the municipality plan at the urban scale have to be relocated to an area of interest in the peri-urban plan [49]. This is important to preserve the agricultural element that characterizes the area.

In these scenarios, vegetation was designed only to keep monumental olive groves but without considering the priority ecosystem services. Therefore, no indications of the type of biophysical structure and ecological functions to develop in specific locations of the sub-urban area were provided. However, the spread of *Xylella fastidiosa* in the area results in the abatement of infected olive trees regardless of the urban plan. This was foreseen by national and regional law [53]. Therefore, in the future, it will be necessary to replace olive trees that will be placed in public or private green space.

In Scenario 2, we integrated the sub-urban plan with specific natural-based solutions to increase ecological functions able to support priority ecosystem services. The urban plan envisages replacing the olive trees with other trees to retain the agricultural value of the area. Mainly, these areas can be destined for the development of community urban gardens and agriculture park. The adoption of the strategies shown in Table 4 could reduce the impact of urban land-use change. In the case of building construction, mitigation solutions include green roofs and green walls. Considering the original land use (arable land), these strategies can increase the provision of priority ecosystem services. For the parking area, we foresaw the use of lawn flooring, and for private and public space, we foresaw the design of urban community gardens to try to recover the loss of cultural value due to drying of the olive groves. Moreover, the mitigation solutions can enhance green infrastructure by creating specific habitats capable of increasing priority ecosystem services identified according to environmental objectives. In this case, the amount of green space, the typologies of the green spaces, and the vegetation used are important. This is the main difference between Scenario 1 and Scenario 2.

3.4. Step 4: Ecosystem Service Impact Assessment

The transition from the Past scenario to Scenario 0 produces a loss of ecosystem services such as air-quality regulation, climate regulation, and moderation of extreme events related to the loss of the thick crown of the dead olive trees that are still present in the area (Figure 2 and Table 6).

Table 6. Qualitative variation in ecosystem services from the scenarios analyzed. ☺ indicates positive variation, ☹ indicates negative variation, and the number of emoticons indicates the potential intensity of the variation: 1, low variation; 2, medium variation; 3, strong variation. =, no significant variation. "Not evaluated" indicates the inability to form a significant judgment.

Main Services Type	From Past Scenario to Scenario 0	From Scenario 0 to Scenario 1	From Scenario 1 to Scenario 2
7-Air quality regulation	☹☹	☺	☺☺
8-Climate regulation	☹☹	Not evaluated	☺
9-Moderation of extreme events	☹	☹	☺
10-Regulation of water flows	=	☹	☺
11-Waste treatment	=	Not evaluated	☺
14-Pollination	=	Not evaluated	☺☺
15-Biological control	☹	Not evaluated	☺☺
17-Maintenance of genetic diversity	☹	Not evaluated	☺☺
18-Aesthetic information	☹☹☹	=	☺☺
19-Opportunities for recreation and tourism	☹☹☹	=	☺☺
20-Inspiration for culture, art and design	☹☹☹	=	☺☺
21-Spiritual experience	☹☹☹	=	☺☺
22-Information for cognitive development	☹☹☹	=	☺☺☺

The most important impacts, however, affect the following ecosystem services: aesthetic information; opportunities for recreation and tourism; inspiration for culture, art, and design; spiritual experience; and information for cognitive development. These can be considered irreversible transformations.

Moving from Scenario 0 to Scenario 1, air-quality regulation increases due to the presence of green urban areas structured with shrub and arboreal vegetation. Dead olive trees will be replaced with new trees, promoting biophysical structure able to support pollution absorbance such as CO_2. The climate regulation service was not evaluated because, even if the green urban areas can improve this service, 39% of urbanization of the total area (considering building construction, roads, and parking areas) can increase local temperature. Therefore, there is no direct information about the relation between vegetation and environment building that indicates a changing value. However, without specific mitigation actions, the urbanization area reduces the moderation of extreme events and regulation of water flow services because there is an increase in the impermeable surfaces. In addition, the presence of dry olive trees and uncultivated trees can create the perception of a degraded and abandoned landscape.

During the SEA process, specific solutions are provided to increase specific priority ecosystem services (Table 5 and Figure 5). Moving from Scenario 1 to Scenario 2, NbSs were planned for the realization of new land cover characterized by urban elements in an agroecosystem matrix and natural habitat. Therefore, the vegetation is not designed like simple ornamental flora but how new ecosystems are able to create structures and functions similar to the land cover characterized by olive groves before the spread of *Xylella fastidiosa*. Mainly, the new land-cover was designed to implement priority ecosystem services.

In particular, NbSs increase the permeable surface of the area thanks to the implementation of green roofs. This can improve ecosystem services such as climate regulation, moderation of extreme events, and regulation of water flows. The presence of green areas integrated with flood areas can help implement these ecosystem services and can improve the biodiversity of the area. In particular, these two areas were designed to try to create a continuous habitat between private green urban areas and public green urban areas.

The forecasts for urban agricultural parks and urban gardens can improve the cultural aspect of the area linked to the agricultural landscape. These cannot introduce the same cultural aspects as the monumental olive groves, but they can contribute to providing new value and cultural functionality of the area. Therefore, the transition from Scenario 1 to Scenario 2 is favorable and should be supported.

However, the presence of community gardens can improve social aspects like psychological well-being, reinforcing the sense of community with respect the actual status [76]. In a social-ecological system, it is important to have not only these cultural elements but also the accessibility and possibility of stakeholders using them [27]. GI supports maintaining the cultural agricultural value. In this case, it is important to choose agricultural vegetation to implement social and educational values. Table 7 shows the historical fruit, aromatics, and medicinal flora identified for these community gardens. The peri-urban area is located in the context compromised by *Xylella fastidiosa*; therefore, the species that are hosts of *Xylella fastidiosa* (subsp. *pacua*) can be reproduced directly from seed, such as for *Lavandula officinalis* L. and *Rosmarinus officinalis* L. [77].

Table 7. Examples of the vegetation proposed for community gardens [50–52].

Historical Fruit	Aromatics and Medicinal Flora
Ceratonia siliqua L	*Hypericum perforatum* L.
Ficus carica L.	*Lavandula officinalis* L.
Malus domestica L.	*Melissa officinalis* L.
Mespilus germanica L.	*Menta spicata* L. subsp. *glabrata* (Lej & Court) Lebeau
Opuntia ficus- indica L.	*Rosmarinus officinalis* L.
Punica granatum L.	*Salvia officinalis* L.
Zyziphus sativus L.	*Satureja cuneifolia* Ten.
Cydonia oblonga L.	*Thymus capitata* (L.) Cav.
Morus alba L.	*Ruta graveolens* L.
Morus nigra L.	*Capparis spinosa* L.
	Origanum vulgare L.

These urban gardens can therefore represent a point of reference for educational and social activities, which can also strengthen the neighborhood community [76]. In addition, these gardens can constitute a constant safeguard by the population over time, allowing increasing urban resilience to abandonment and degradation phenomena when socioeconomic conditions are no longer favorable. In addition, they avoid undesirable abandoned lots [76].

Some proposed plants have a cultural and landscape value similar to the monumental olive tree but that is less known. *Ceratonia siliqua* L-Carob could be compared with monumental olive trees both for its beauty and for its high cultural value in the landscape because its fruit was used in Southern Italy when food was scarce (Figure 6). The carob tree can provide the characteristics of monumentality and beauty over time, comparable to the olive trees (Figure 6). Finally, the carob tree has edaphic and water needs similar to the olive tree. Therefore, this species fits perfectly into the Salento landscape to help restore the biophysical structure that characterizes the agricultural landscape.

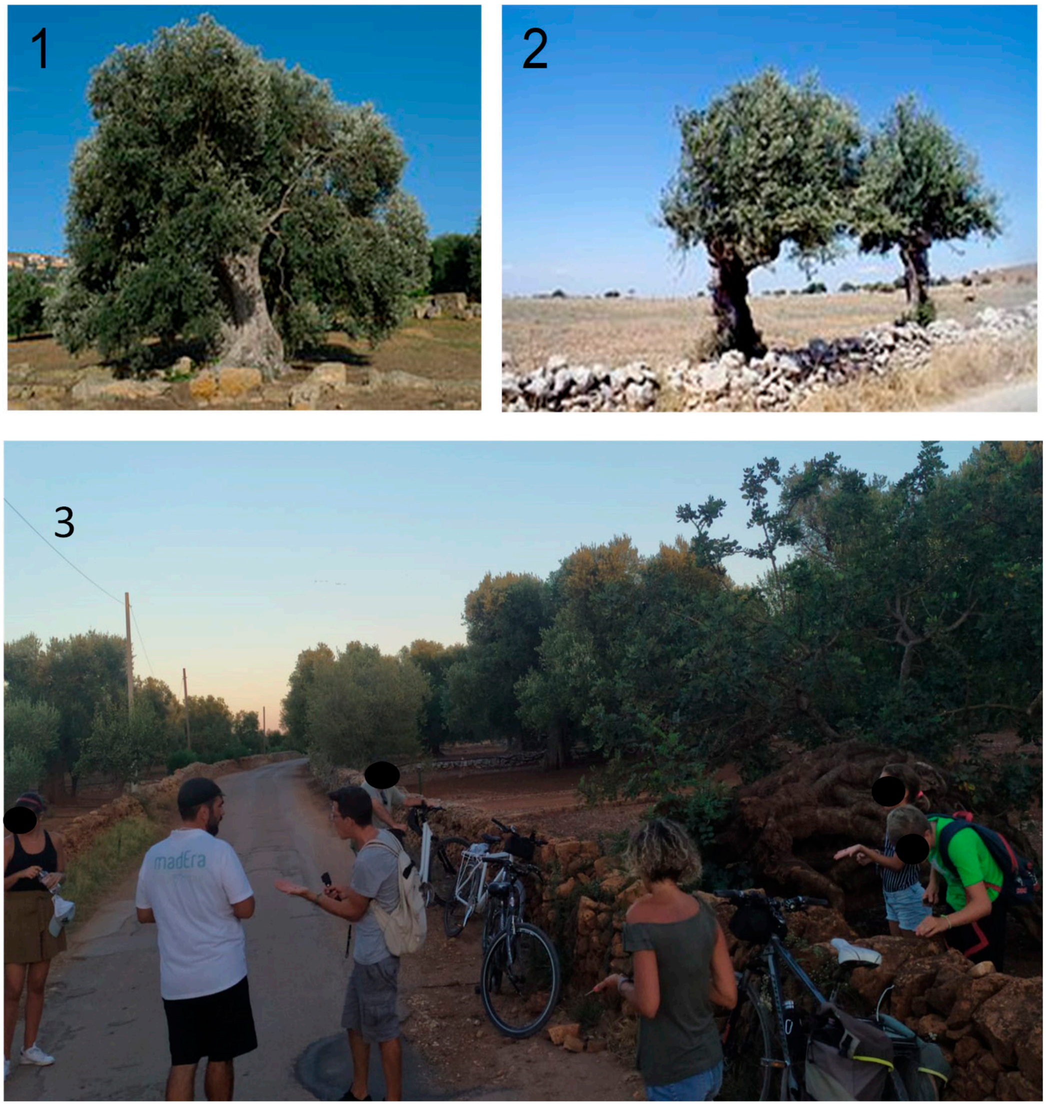

Figure 6. Comparison between monumental *Ceratonia siliqua* L and monumental olive trees in the landscape: (**2**) monumental *Ceratonia siliqua* L; (**1**) monumental olive trees, highlighting the capacity of new vegetation to regenerate the esthetical view, the opportunities for recreation and tourism, and the spiritual experience of the landscape in the medium and long terms; (**3**) a scene of a group of tourists who taste the fruit of *Ceratonia siliqua* along the itinerary of a bike tour.

In conclusion, the enhancement of identity can undergo the rediscovery of social and cultural values that have faded over time and are currently reinterpretable only through the testimonies of those who have experienced those times, free books, and information on the Internet.

4. Discussion

The peri-urban plan results in the conversion of arable land to construction and road networks, but this is an intrinsic aspect of the urbanization processes. Therefore, the concept of ESA in the SEA must contribute to reducing the negative effects of land use transformation by providing indications to develop the best solutions, reducing the loss of ecosystem services generated by the built environment and integrating natural-based solutions to increase ecosystem service provision. These actions should be selected considering both public and private spaces.

The enhancement of priority ecosystem services assessed for this plan can help to achieve the environmental objectives set in the first part of the SEA process; therefore, the sub-urban plan can be considered largely consistent with the hierarchical PPPs that have inspired the environmental objectives. This phase is important because it can influence all phases of the SEA process, mainly the design of mitigation actions like green infrastructure, the analysis of different scenarios, and the choices that will determine future transformations of the area. This increases the coherence between bottom-up planning and top-down planning, reinforcing the sustainability of human chose and actions.

However, the analysis of ecosystem services is not a substitute for evaluations of the effects caused by waste production, mobility, quality of the area, use of water resources, etc. ESAs should be considered as a tool to better understand the relationships between biodiversity, ecological functions, and land use transformation and to avoid unintended negative consequences on the provision of ecosystem services and human well-being. Therefore, the analysis of ecosystem services in the SEA process must be considered complementary to other analysis and methodologies and not preponderant or exclusive. For example, in this case, the analysis of ecosystem services should be weighed with other social and economic factors, such as the needs of houses for the population, especially those with economic difficulties. For example, if the residences that will be built are destined to be public housing, they can support homeless families.

The use of ecosystem services within the SEA can be considered an additional tool to bring designers closer to ecological and social issues not yet widespread in sub-urban planning. Above all, it helps to perceive actions aimed at sustainability as important for obtaining a quality and more attractive plan and not as an additional cost for planners.

The difference between the proposed method of using the ES concept in the SEA process on the sub-urban scale and the existing methods is the accuracy of the evaluation and the design of the ecosystem services. The many difficulties facing current methods of evaluation of ecosystem services develop on the regional or local scale in specific peri-urban areas. Many landscape-level ecosystem service assessments in SEA are performed considering the biophysical structure and ecological functions [46,47] without a focus on the specific characteristics of vegetation and human intentions. The assessment approach on a finer scale needs to incorporate more complexity in the analysis [2,78]. For example, the olive groves, on an urban or regional scale, can be considered homogeneous. However, on a sub-urban scale, they can be distinguished on the basis of age, structure, health status, understory vegetation, productive or nonproductive, and type of variety. All this information can be used to discriminate the ability to support ecosystem services. This example also extends to other land use classes.

In this study on the sub-urban scale, the ecosystem services approach is influenced by the skills needed to assign value and priority to specific ecosystem services considering specific use of the area. We had to adapt the existing ecosystem service assessment approach to vegetation knowledge (type, specify ecological processes that can be supported, ecological role, and human intentions in future use). Mainly, some ecosystem services highlighted in the literature for land cover like olive groves were corrected considering the status of *Xylella fastidiosa* and the characteristic of the olive trees. For example, concerning herbaceous vegetation and shrubs, we considered the capacity of the detected species to support regulating services and others. Therefore, an important contribution to the assessment process was to directly involve different experts such as botanists, agronomists, faunists, ecologists, planners, decision-makers, and different public institutions that participate in SEA processes.

Peri-urban plans are more influenced by human interests in land use than urban or regional plans. Therefore, the SEA process needs to assess the effect of specific land use changes, providing more information on the types of building, localization, specific interaction with the vegetation, and ecosystem services, which is not possible on the urban and regional scales. These plans provide general information about potential landscape or urban transformation driving and conditioning the type of transformation at the sub-urban scale, but plans at the sub-urban scale need to be actuated. Therefore, we have more detailed information to consider and the final decision has a direct effect on landscape transformation. Hence, in this study, the applied ecosystem service approach is not limited to simple assessment but can be extended to designing priority ecosystem services by planning specific green infrastructures to increase social benefits. This is important because ecosystem service design is directly included in peri-urban plan formation. Differently, mitigation actions are often specific sections of SEA processes which follow the scenarios' analyses, indirectly linked with peri-urban plan formation. As such, ecosystem service enhancement is an active part of the plan's development process and not just a part of SEA processes, including them in the analysis of different scenarios to help find the best solution for human well-being.

In this paper, we provided ideas about how the ecosystem service concept can be integrated into the workflow of the SEA process and the positive effect of integration of vegetation in the urban infrastructure with the possibility of developing specific green infrastructure. However, in the specific urban contexts and plan, it is necessary to consider the potential ecosystem disservices that can be produced by vegetation, like the production of allergens [79]. For example, green roofs and urban community gardens may have negative ecological effects or may create ecosystem disservices. Nitrogen, phosphorus, and potassium, for example, may accumulate in high concentrations in garden soil due to the indiscriminate application of fertilizers or compost, polluting urban stormwater runoff or groundwater [37,78].

An important element is the temporal projection of the green infrastructure that is developed. In this study, the cultural amenity services were considered priority ecosystem services given the past characteristics of the study area, where beautiful monumental olive trees were present, which have now been destroyed by *Xylella fastidiosa*. The urban plan has to regenerate the cultural value, potentially by developing specific strategies, and the SEA has to value this with a strategic vision in the future. The sustainable concept upon which ESA is based focuses on future generations; therefore, sustainable cultural strategies have to promote the transformation developed from the sub-urban plan over time. Therefore, the cultural strategies have to be developed by considering how the area can evolve in the future. In this study, for example, it is impossible to quickly restore the cultural value of monumental olive trees However, considering the mitigation actions adopted, within a 50-year timeframe, the landscape structure can partially recover the cultural value of olive trees.

In a peri-urban plan, mitigation actions must be programmed during the development phase of individual activities to identify adequate technical solutions from both a structural and vegetational point of view. Furthermore, if these actions are programmed as green infrastructure during the development phase of the plan, they allow a new vision in the planning of both public and private spaces. Private spaces can also contribute to ecological and social well-being.

This opens an interactive dialogue between designers of the plan and experts who develop the SEA process by considering the active role of GI in the peri-urban plan. This creates increased openness about the real benefits of these actions and therefore about accepting some design solutions that could otherwise be seen as simple additional costs. The winning aspect of this methodology is the incorporation of the ecosystem service concept and GI in the technical rules for implementing the plan, which thereby become elements of the plan, being binding for its execution.

5. Conclusions

This paper presented a methodology that combines the assessment of ES with the possibility of designing suitable planning interventions and mitigation measures. This is essential for developing feedback between evaluation and design by increasing the ability to find more sustainable solutions in urban development, which can range from the scale of the individual building to that of the neighborhood. This can support the construction of more accountable peri-urban plans, providing transparency and replicability to decision-makers about the proposed transformations.

The integration of ecosystem services analysis into SEA requires a strong vision of the expected added value. Therefore, before starting the analysis, a workflow must be developed that clarifies how this analysis can be integrated with the various assessment stages of the SEA and with other elements of the analysis. The consideration of green infrastructure as mitigation measures to reduce the negative effects of plans on the environment can arguably evolve the role of the ecosystem service concept from a simple assessment phase to a design phase of ecosystem services. Therefore, the capacity to develop green infrastructure in SEA processes can configure the SEA as a tool of ecological urban design that is integrated into an urban plan design. This requires the ability to transfer the ecological and planning theories into practical actions and the capacity of different disciplines to work in a transdisciplinary approach, where different contributions act complementarily to develop the best solution.

Through this research, we provided a pilot case study application that can also be adapted to other similar plans, programs, and policies or can provide stimuli and suggestions to improve the integration of ecosystem services into environmental assessments. The ES assessment methodology adopted in this work can be considered independent of the conceptual model developed. However, the methodology chosen must be able to functionally assess the variation in ecosystem services deemed to be priorities or to focus on some of them deemed most important.

The integration of ecosystem services in environmental assessments can produce many benefits contributing to better designed PPPs, but there are also critical issues, such as the complexity of appropriately identifying priority ecosystem services and the lack of well-established methods. From this perspective, an important issue is the consultation of stakeholders because they are affected by the new PPPs and can provide useful information, such as their needs, values, and dependencies on priority ecosystem services. Ensuring the participatory approach of stakeholders in the SEA process is crucial because it guarantees transparency and the effectiveness and efficiency of the strategic actions proposed [27].

The concept of ecosystem services should be used within the SEA to increase the performance of the human well-being aspect of urban plans, creating a stronger connection between ecological urban design choices and human benefits. These benefits have to be monitored after realization of the urban areas to check if the environmental objectives of the plan have been met and if the actions developed were effective in achieving them. This is an important aspect of the SEA process: the monitoring program of the plan has to be developed. Therefore, another point that can be expanded in the future is the follow up on ecosystem services [3], linked to the development of well-being performance indicators to value the achievement of environmental goals. This is particularly challenging for plans on the sub-urban scale due to the lack of site-specific well-being data and indicators.

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