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Green Infrastructure to Improve Ecosystem Services in the Landscape Urban Regeneration

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Abstract. The concept of Green Infrastructure (GI) emphasises the quality as well as quantity of urban, peri-urban greens spaces and natural areas, their multifunctional role, and the importance of interconnections between habitats. If a Green Infrastructure is proactively planned, developed, and maintained it has the potential to guide urban development by providing a framework for economic growth and nature conservation. GI includes parks and reserves, sporting fields, riparian areas like stream and river banks, greenways and trails, community gardens, street trees, and nature conservation areas, as well as less conventional spaces such as green walls, green alleyways, and cemeteries. Today we have to face new challenges about increasing energy use, decreasing water resources, limited spaces and ecological preservation. This problem must be solved in a sustainable way using innovative GI that combine technology with landscape design by enhancing ecosystem services provision.

The aim of this research is to evaluate and develop multifunctional role of GI in terms of biodiversity and ecosystem services' enhancement by taking into account two case study in southern Italy: Constructed Treatment and photovoltaic energy plants. An effective way of tackling water resource problem is to use Constructed Treatment Wetlands (CTW) as low-cost alternative to conventional secondary or tertiary wastewater treatment. For this purpose, an annual monitoring of fauna and vegetation was carried out in order to identify species of national and international interest strongly related to the new habitats availability. Results have shown the ability of CTW in providing ancillary benefits, well beyond the primary aim of water purification, such as sustaining wildlife habitats and biodiversity at local and global scales, as well as its potential role in terms of recreational and educational opportunities.

In the second case, we developed a GI project idea that proposes to evolve the photovoltaic energy plants in southern Italy, especially in Apulia region, into "new urban photo-ecological gardens". The aim of our research is to harmonise economic development and biodiversity conservation to safeguard the ecological processes that underpin human well-being, creating a strong synergism between renewable energy planning and valorisation of ecosystem services. Therefore, a new approach is proposed to manage photovoltaic solar farms, shifting from "negative vegetation management", focused mainly at the elimination of invasive plants, to "active vegetation management", i.e. the cultivation of plants with an economic and ecological value. This approach would offer many opportunities for integration between economic development, nature valorisation and public health promotion.

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1. Introduction

In the field of restorative politics related to urban environment, the cities should ask themselves about the realization process, the organization and financing of the planning of spaces left empty and able to be recovered. These spaces can be appointed with a relevant role in the overall organization of the city and its functions, provided that innovative issues like the right of land use are discussed and clarified [1].

The role taken on by green areas in the growing city requests the planning of open space not to be considered anymore as part of a sectorial planning or green areas to be originated because of the lack of construction interests. The ecological, social and economic values linked with such areas have to become a central issue in the urban planning and governance [2].

Empty urban areas can be planned as green areas where small ecosystem can take place in order to introduce or enhance ecological functions supporting the city's activities.

A number of researches indicate the contribution of the green areas in the longevity of the population, due to the high quality of life they support. Green areas contribute to the diminishing of stress and anxiety and seem to have a role in the reduction of aggressiveness and crime rate. Therefore, green areas provide benefits to mental and physical health, with social and economic positive consequences [3, 4].

Such ecological functions providing benefits to the population and enhancing human welfare are defined as **ecosystem services** [5]. Ecosystem services (ESS) include the production of goods (vegetables, fish, wood, forerunner elements for industrial and pharmaceutical industry). Also representing a relevant part of human economy; ESS are also the fundamental functions or ecological process supporting life on earth, like pollination, water purification, climate regulation, or those conditions improving the psychophysical well-being (serenity, beauty, cultural inspiration), as well as the conservation of the biodiversity [5]. Such ESS were grouped in four categories [6, 7, 8], (figure 1):

- Provisioning or production services: the products obtained from ecosystems, including food, water, fuel and other goods, as well as genetic materials and ornamental species;
- Regulation services: regulate the climate, air and water quality, soil formation, the pollination, waste digestion and provide mitigation against natural risks like erosion;
- Supporting services: include habitat creation, biodiversity conservation. Such ESS differ from the others because their impacts on human well-being are indirect or can be observed over a long period of time, like photosynthesis, soil formation, nutrient cycling.
- Cultural services: they include non-material benefit, like cultural heritage or identity, spiritual and intellectual enrichment, aesthetic and recreational values.

The study of ESS gained a great attention in the last years. Despite the principles of ESS have been developed in 1970, until the 80s this issue had only academic relevance and was never introduced in decision process or planning or administrative backgrounds. From the '90s, the research in this scope moved new steps, deeping the knowledge and the definition of the ESS [10]. Only after the year 2000 the topic gathered new interest and discussion spaces in a political context, primarily thanks to the adoption of an "ecosystemic approach" by the United Nations Environmental Program, [11].

Such approach can lead to a better understanding of the society dependency from ecological functions or process and relative supporting systems [12]. Boyd e Banzhaf [13] provided an alternative definition of ESS, underlining that they are not the benefits humans receive from the ecosystems, rather the ecological factors that humans use or consume, producing well-being. Therefore, services and benefits are not the same: as an example, pollination is a service, whose benefit could be the fruit to be eaten. In an anthropocentric view, ecosystem functions and processes became services or benefits only if there is a person gaining an advantage from them.

Figure 1. Representation of potential ESS provided in an urban environment [9].

In the Conference of the Parties held in Nagoya, 2010, were draft the Strategic Plan for Biodiversity 2011-2020 and the Rio+20 Declaration; signatory states are committed to:

- Expand sensitivity on biodiversity values in the public opinion, political representatives and administrations;
- Integrate the ESS assessment in plans and strategies concerning the environment;
- Include the ESS assessment, with either an economic approach or not, in national plans and strategies concerning the biodiversity;

On the basis of such objectives, in 2011 the European Union (EU) approved its own Biodiversity Strategy aiming to halt the biodiversity loss and the decline of the ESS in the EU by the 2020.

The Strategy accounts for six targets, complementary and synergic at the same time, focused on the main causes of the biodiversity loss and with the purpose of reducing the pressures exerted on the nature and ESS in EU [14]:

Target 1: fulfil the application of Habitat and Birds Directives;

Target 2: Maintain and restore ecosystems and associated services;

Target 3: Achieve more sustainable agriculture and forestry, raising their contribution to the conservation and enhancement of the biodiversity;

Target 4: Make fishing more sustainable and seas healthier;

Target 5: Combat invasive alien species;

Target 6: Help stop the loss of global biodiversity.

There are different policies for the management of environmental resources: among the others, the realization of Green Infrastructures can promote the enhancing of ecosystem services.

Following the EU definition, Green Infrastructures (GI) are “strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities and enhances biodiversity. The Natura 2000 network constitutes the backbone of the EU green infrastructure”.

Therefore, GIs are based on the principle of the protection of the nature to be integrated in the spatial planning with reference to the ecological connectivity, ecosystem conservation and multifunctioning. Protected areas, peri-urban agriculture areas, forests and urban gardens.

Notably, GI are mentioned as a priority funding in the proposition for the EU Cohesion Fund COM(2011)612 and the European Regional Development Fund (ERDF) COM(2011)614. Therefore, GIs become a Regional Policy contributing to sustainable growth enhancing Europe's Natural Capital COM(2011)17.

In the present paper, two examples of Green Infrastructures are presented: the first one takes into account the realization of a water purification process using a phytodepuration plant; the second one considers the enhancing of the pollination service by means of a multifunctional use of areas already occupied by photovoltaic panels.

2. Results and discussions

The study area is represented by a CTW realized in 2008 in the Municipality of Melendugno, province of Lecce, southern Italy in the context of the regional policy of environmental restoration.

This plant started its operation in August 2009 and it was designed for the refining of the effluent water from the sewage treatment plant of the three neighboring municipalities (municipality of Calimera, Martignano and Melendugno) and their coastal areas, able to treat a waste load of 41,000 equivalent inhabitants. The technical solution adopted considered the creation of a system of reconstructed wetlands. The plant covers 8.3 ha, 5.1 ha of which were occupied by 6 reservoirs working in conditions of the surface flow (FWS systems—free water surface) (Table 1). 5 species of plants were used in the CTW: *Phragmites australis; Typha latifolia; Juncus effuses; Lemna* sp. pl.*; Nymphaea alba*. The choice of plants was based on the purifying effectiveness of the different species, their ecology, the compatibility with the environment and their availability on the territory.

As highlighted in figure 2, the socio-ecological landscape where the CTW was realized, has been deeply transformed over the last sixty years because of urban sprawl in coastal areas, due mainly to tourism.

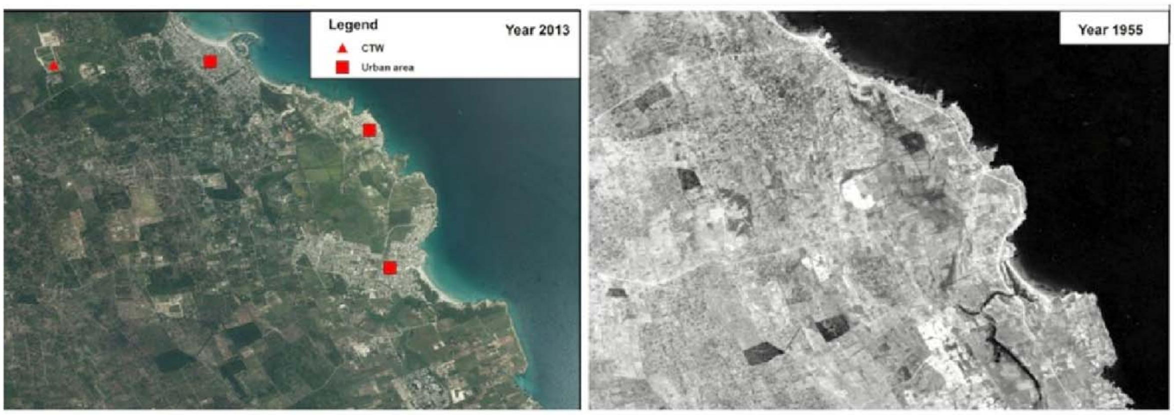

Figure 2. Aerial photos of 1954 and 2013 of the socio-ecological landscape where the CTW is located

This driving force reduced aesthetics and biodiversity and emphasized the need for a careful water resource protection and management to prevent sea pollution, allow bathing and the use of such areas for recreation. In fact, the existing sewage treatment plant is designed to release purified water in the sea; however, insufficient treatment, excessive waste load or treatment problems can lead to release still contaminated waters at a short distance from the coastline. In such a case, it would be necessary the inhibition of the bathing along an extensive area, heavily affecting the tourism. Therefore, the CTW is an engineered ecosystem designed as an additional water treatment with low technological complexity and remarkable simplicity management. The CTW combines the wetland function related to hydrology and water quality with the enhancement of the aesthetics and biodiversity, by introducing a pleasant natural element in the landscape (figure, 3).

Figure 3. Photos of the CTW

As demonstrated by Semeraro et al. [15] the realization of marsh basins and the new vegetation developed within the plant provided ancillary ecological benefits such as wildlife habitat provisioning and biodiversity enhancement. The 18% of the total number of birds' species detected in the study area are included in Annex I of Directive 2009/147/EC on the conservation of wild birds, highlighting the ecological value of the site.

Furthermore, Semeraro et al. (ibidem) showed that the CTW is strategically located within the routes of migrating birds and therefore it is a site suitable for the permanent presence of different wildlife species. For this reason, CTW carries out an important role in terms of contributing to biodiversity both at the local level, supporting local birdlife, and at the global scale, providing vital nesting and migratory flyway areas.

As such, the results of this research show that these plants, if properly localized, designed and managed over time, may favour the presence of species of high conservation value (Habitat Directive 92/43/CEE and Directive 2009/147/EC) and, thus, strengthen the European Natura 2000 ecological network with benefits at multiple scales.

In this perspective, the CTW in Melendugno is also used for environmental communication and education activities. Every year residents use the CTW for recreation, birdwatching, and scientific studies (figure 4).

Therefore, these sites should be managed not only as effective infrastructures for water purification, but also as engineered ecosystems that can mimic "natural areas". They support human well-being by providing several valuable wetland ecosystem services [16] and urban functions [17, 18, 19]: sinks of biodiversity and stepping stones in ecological networks, wildlife habitats, flood abatement, food, a clean water supply, aesthetic beauty, pollution reduction, educational and recreational benefits (figure 5).

Figure 4. Examples of environmental education activities developed in the CTW of Melendugno

The second case study of GIs reported in this paper has the aim to harmonise energy production, agriculture and the safeguard of the ecological processes that underpin human well-being. The project described in the following creates a strong synergism between economic and institutional players in the regions of southern Italy.

Italy traditionally has a large agricultural sector, and southern regions represent the engine of Italian food production. The agricultural sector is often characterised by excessive recourse to monoculture and high fragmentation of farms, which have led to severe loss of biodiversity and associated ecosystem functions, such as pollination.

Figure 5. Potential ecosystem services provided by the designed multifunctional CTW

Guaranteeing the fertilisation of about 80% of flowering plant species, pollinator populations are indispensable for the salute of the entire ecological and agricultural system. This service had been estimated [20] to be worth between 235 and 577 billion dollars a year globally. Honey production in Italy fell by 50-60% in 2016, touching 80% in some areas, mainly due to the death of bees.

Change in soil use is one potential cause of the reduction in pollinators, together with climate change, the use of pesticides and herbicides, fragmentation of habitats and invasion by alien species [21]. In the southern Italy and Apulia region in particular, a further problem that has emerged in the last few years is the full-scale competition for use of the land between agriculture and renewable energy production, the result of increasing energy demand from consumers and the need to decarbonise the economy.

Many farms have converted to photovoltaic electricity generation in return for certain earnings, helped by legislation and tax breaks as well by intrinsic regional characteristics, such as the topography the high solar irradiance: Apulia has more installed photovoltaic capacity than any other region in Italy.

We argue that technology lies in the different approaches to the issues that humanity has been faced with for years, and it is this principle that inspired the project that propose to convert Photovoltaic (PV) Parks in New Photo-Ecological Urban Gardens, aiming to ensure multifunctional use of the soils combining energy production with pollination support. This project was developed within the “Innovative Ideas in rural environments” contest promoted by the Italian Ministry of Environment and was awarded among the first 12 ideas.

The GI project was developed in a solar farm owned by Global Solar Fund (figure 6), an Italian industrial firm founded in 2008 which operates in the photovoltaic energy sector. GSF is the main producer of photovoltaic energy in Apulia, managing 180 solar farms with an installed capacity of 141 MW and an annual production of 222 GWh, avoiding the emission of 112,000 tonnes of CO_2.

Figure 6. Project area of the New Photo-Ecological Urban Gardens

The solar panels analysed were found to be surrounded by invasive herbaceous vegetation with no valuable floral elements. The flora was of the ruderal, nitrophlous type, requiring frequent removal (at a cost of about € 3,300/MWp) to reduce the risk of fires and prevent them from casting shade on the panels. The basic idea is to replace the invasive vegetation with autochthonous melliferous and medicinal flora, "photo-ecological urban gardens" will be set up where bee-keepers can bring their bees to forage. Solar tracking technologies, such as the double-axis tracker developed by GSF, are more suited to project because they avoid cones of permanent shade on the soil (figure 7).

Therefore, a new approach is developed to manage photovoltaic solar farms, shifting from "negative vegetation management", aimed mainly at the elimination of invasive plants, to "active vegetation management", i.e. the cultivation of plants with an economic and ecological value.

The expected results are:

- Technological innovation;
- Reduced management costs and increased revenues;
- Supporting declining agricultural activities;
- Improvement of ecological quality of the landscape;
- Supporting the well-being of local population;
- Reduce the ecological footprint of the PV company; and
- Better return in terms of company's image.

Both the case studies show the multi-functional role of the projects: the CTW and the "photo-ecological urban gardens" provide a range of services well beyond the primary aim of water purification and energy production. Therefore, these strategies are linked to the concept of *serendipity* and hence the possibility of such interventions to obtain benefits that were not foreseen in the initial design goal, without the need of quantifying or evaluating them.

Figure 7. Identification and distribution of vegetation species to be introduced in the PV plant for the realization of proposed GI

A proper design of a GI should require a multidisciplinary approach: the engineering skills have to be integrated with sustainable and environmental sciences related to landscape and urban planning. The land planner has to take into account how these systems will evolve over time, even when the GIs will not be used for their productive purposes anymore, ensuring the support to ecosystem services production [15].

3. Conclusions

The Strategic Environmental Assessment (SEA) is an appraisal tool used to assess plans and strategies at usually high hierarchical level, often requested in the urban planning process. Specifically, the SEA process aims to enact a high level of environmental protection and the integration of environment-enhancing principles in the drafting, adoption and approval of plans and programs, in order to promote the conditions for a sustainable development. The SEA was introduced in the EU regulation with Directive 2001/42/CE, adopted in Italy with Law no.152 of 3 of April 2006.

An important part in any SEA is represented by the mitigation measures, actions to be implemented in order to mitigate the expected adverse environmental impacts. The definition of the mitigation measures to be implemented are either proposed by the proponent or requested by the authorities. Among these measures, few or none takes in consideration the ecosystem services approach. Very few consider green infrastructures finalized to enhance ESS or ecological functions providing support to the water cycle, mitigation of building temperature, urban surroundings, biodiversity improvement, reduction of flooded areas. Notwithstanding ESS are widely accepted and considered in the scientific community and more often adopted within international strategies, are still underestimated in local spatial planning.

Therefore, the question arising is if the EU (and other international organisms) consider ESS fundamental for the environmental sustainability, are those Urban Plans and programs not including ESS sustainable?

An approach to ESS via the green infrastructures can lead to review, rethink and planning urban functions based not on strict boundaries, but considering also the surroundings of the spatial unit under study. Such approach can be applied at various spatial scales: single buildings, blocks, neighbourhoods, the entire cities or metropolitan areas. Strategies based on GI can be implemented trough great public projects or applied to small private properties. As an example, the “New photo-ecological urban garden” project considers a worldwide issue affecting the Planet, the pollination process, with a specific application at the local level.

The exciting aspect of these approaches is that at a project implemented at a local level can contribute to major issues (think global, act local). This vision is fundamental in order to apply the concept of ecological footprint to the city. The ecological footprint is an environmental sustainability index able to assess the impact a population exert on the environment based on consumption; the index quantifies the total area of terrestrial and water ecosystems needed to provide, in a sustainable manner, all the emissions produced [22, 23]. The city does not coincide with its boundary, but include also the areas needed for its own sustenance, [24].

At the same time, sustainable cities should not exceed their carrying capacity: the maximum population of a species which can be indefinitely sustained in a habitat, without compromising the productivity. In a global economic and social context, where resources supply relies on global markets and not local ones and technology improves continuously, the carrying capacity concept is often considered not applicable or outdated, [25]. The two concepts use different approaches: the carrying capacity in an urban context focuses on the maximum population load an area can bear without compromising its productivity. The ecological footprint overturns the previous because assesses the productivity area used by residents unconcerned if such area corresponds with the one occupied by the population, [23].

The unifying element of the two concepts is the territory or the ecosystems sustaining the human and its activities. It can be affirmed that in an ideal sustainable city and able to self-sustain, carrying capacity and ecological footprint should be equivalent. Green infrastructures can be considered as strategies able to increase the carrying capacity of an urban system, because can enhance the ecological functions sustaining a population in an area (ESS such as water, soil and atmosphere purification, biomass production etc.). At the same time, GIs would reduce the ecological footprint of the city, because they can carry out urban primary functions without using technology or addressing global markets but considering in-house solutions. Authors believe that a correct and profitable application of GI strategy requires an approach to ESS not with a conservation aim, but tending to enhance and using them within territory transformation processes.

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