Landscape Project for the Environmental Recovery of a Quarry

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Abstract. The growth of urban populations causes cities, and their suburbs, to spread, expand, and replace natural lands by agricultural. Urbanization brings land-use change, altering the relationship between human societies and environmental resources. Therefore, the management of natural resources connected to urban expansion has become one of the most important challenges in attaining sustainable landscape. Quarrying is a crucial component of local socio-economic development providing key materials for infrastructures and buildings. However, like many other human activities, quarrying causes a significant impact on the environment. In Mediterranean countries, quarrying activities exert increasing pressures on limited soil and water resources, thus accelerating erosion processes and subsequent destruction of existing arable lands. Quarrying operations can profoundly alter pre-existing ecosystems and perturb hydro-geological and hydrological regimes. They can profoundly modify the substratum, change landscape patterns and integrity, destroy natural habitats and interrupt their natural succession, as well as alter genetic resources. The resulting situation is seriously compromised by anthropic regeneration processes on degraded sites after the end of quarrying activities, which are not focused on potential natural vegetation which these sites could develop, considering the surrounding ecosystems. In this work, we propose a landscape regeneration project which was developed as part of the Environmental Impact Assessment procedure on quarrying activity located in the municipality of Lecce, South Italy. This project aims to integrate environmental and landscape aspects with the economic and social ones in order to guarantee the sustainability of the proposed intervention. The new project modifies the one presented at the start of the quarrying activity which planned planting of trees directly on the bottom of the quarry, (about 40 meters deep from the ground level and three meters above the groundwater level). The new project foresees the partial filling of the quarry using waste materials according to the environmental legislation. This allows to protect the groundwater better and to create a microclimate more suited to the development of natural vegetation. The quarry filling activity represents an economic activity for the company and therefore can guarantee the development of jobs for at least 5 years. In addition, the proposed project aims to reconstitute the pre-existing vegetation, consistently with the surrounding ecosystem. This will allow the development of the
priority habitat *6220: Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea (Directive 92/43/CEE), producing a landscape of recognized ecological value, not detached from the surrounding landscape. In this way, the closed quarry can act as a stepping stone and play a significant role in regulating green infrastructure in landscapes.

1. Introduction

Currently, approximately 55% of the world’s population resides in urban areas. It is estimated that by 2050, 68% of the world’s population will be urban [1]. The growth of urban populations leads to the development of cities and their suburbs, and also spreads to agricultural and natural lands. Urbanization brings land-use change, altering the relationship between human societies and environmental resources [2]. Land use could be understood as the way and the aim in which human societies use land resources, creating patterns that can alter natural processes, modifying the natural evolution of the landscape [3]. The rise and expansion of human activities, combined with the constantly alteration of natural processes, are also the main causes of fragmentation of habitats [4]. Therefore, the management of natural resources and land use transformation connected to the urban expansion has become one of the most important challenges in attaining sustainable landscape.

Quarrying is a crucial component of local socio-economic development providing key materials for infrastructures and buildings. However, like many other human activities, quarrying causes a significant impact on the environment. In Mediterranean countries, quarrying activities exert increasing pressure on limited soil and water resources, thus accelerating erosion processes and subsequent destruction of existing arable lands or natural landscapes. Quarrying operations, indeed, can profoundly alter pre-existing ecosystems and perturb hydro-geological and hydrological regimes [5, 6]. They can profoundly modify the substratum [7], change landscape patterns and integrity [8], destroy or fragment natural habitats, interrupting their natural succession [9], as well as alter genetic resources [10, 11, 12]. The resultant degradation of the landscape caused by quarrying operations may last long after the mining activity has ceased [13].

The resulting situation is seriously compromised by anthropic regeneration processes on degraded sites after the end of quarrying activities, which are not focused on the potential natural vegetation that these sites could develop considering the surrounding ecosystems.

The increasing and unsustainable anthropogenic pressures are depleting biodiversity and compromising the provision of ecosystem services. In the past decades, biodiversity loss has been so dramatic that it has been recognized as crucial in the context of global change [14, 15] and quality of human life. Recovery activities of sites degraded by quarrying activities can play a relevant role in the overall organization of the landscape if they are planned as Green Infrastructure areas (GI). Small ecosystems can take place in order to introduce or enhance ecological functions supporting biodiversity and landscape quality.

The European Commission defines GI as “a strategically planned network of natural, semi-natural and artificial networks areas with other environmental features designed and managed to deliver a wide range of ecosystem services” [16]. They include green and blue spaces, as 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 [17]. They are present in rural and urban settings.

The concept of 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 [18, 19, 20, 21]. If a GI is proactively planned, developed, and maintained, it has the potential to guide urban development by providing a framework for economic growth and nature conservation [22, 23, 24].
The ecological, social and economic values linked with such areas have to become a central issue in the landscape and urban planning and governance [25].

In this work, we propose a landscape regeneration project developed as part of an Environmental Impact Assessment procedure (EIA: Directive 37/85/CEE, 2011/92/EU, 2014/52/EU) on quarrying activity located in municipality of Lecce, South Italy. EIA is a tool aimed to evaluate environmental impacts of projects, in order to promote the sustainable development of human activities. An important part in the procedure is represented by the implementation of compensation and mitigation measures to prevent or mitigate the significant adverse environmental impacts.

This project aims to integrate environmental and landscape aspects with the economic and social ones in order to guarantee the sustainability of the proposed intervention. The project was carried out designing and planning a social and economic use of a quarry that had been worked out, allowing to improve its ecological performances, exploit local biodiversity with habitats and vegetation of high conservation value.

2. Method
We developed a landscape regeneration project of a quarry sites located in the municipality of Lecce, Apulia Region-South Italy (figure 1a, b, c).

Currently, the quarry covers an area of about 7 hectares. It is a “pit” in the land with stepped morphology, therefore it is characterized by sub-vertical walls with a height varying from 10 to 15 meters.

The regeneration project adopts a transdisciplinary approach in order to develop a landscape system for the areas that allows economic, ecological and social aspects to coexist without causing trade-off among them.

The engineering skills were integrated with sustainable and environmental sciences related to landscape and urban planning. The land planner, assisted by a group of experts (i.e. an ecologist, a botanist, a geologist, a forest agronomist and a zoologist), has taken into account how the quarry site could evolve naturally over time. They have considered the characterization of the study area; a multi-scale study of the context of reference; the identification of the main environmental and ecological issues; the identification of a spectrum of suitable species and habitats to enhance the biodiversity and consequently reduce habitat/landscape fragmentation.

Based on this characterization, the next step was to provide a concrete vision of how ecosystems or habitats identified can be delivered within the quarry considering its characteristics. It was necessary to determine how the plants can be cultivated on quarry promoting their conservation and an economically viable production. For this reason, it was important at this stage to conduct the characterization of green technological available solutions; the detection of potential targets and the identification of potential environmental and socio-economic impacts.

The spectrum of suitable species and possible habitats had been identified, also taking account of the risk of Xylella fastidiosa infection, present in Apulia throughout the Salento peninsula. It was necessary to consider that the host range of the sequence type ST53 that was found in Salento, includes several species of the Mediterranean vegetations. Therefore, any restrictions arising from norms designed to contain Xylella fastidiosa in areas where it has been detected must be taken into account.

Thanks to its multidisciplinary approach, this project goes beyond a vision of planning that sees the development of economic activities incompatible with the conservation and enhancement of biodiversity, developing an idea that goes in both directions.
3. Results and discussions
At the bottom of the quarry the flora was characterized by ruderal, nitrophilous species, with low ecological value: *Dittrichia (=Inula) viscosa* and *Holoptum (=Oryzopsis or Piptaeterum) miliaceum, Echium plantagineum, Dactylis hispanica, Lotus edulis, Conyza bonariensis, Conyza canadensis, Picris hieracioides, Euphorbia prostrata, Arundo donax, Nicotiana glauca and Acacia saligna*. The only relevant species with a few plants on the bottom of the quarry is *Hyparrhenia hirta*, a structuring plant of the “Pseudo steppes”.

Therefore, no relevant habitats were found considering the Habitat Directive 92/43/CEE that indicates those relevant for the conservation of biodiversity. Instead, the area surrounding the quarry is mainly characterized by “Pseudo-steppes” with grasses and annuals of the Thero-Brachypodietea and some “spots” of “Mediterranean scrub”. The “Pseudo steppes” are classified as a priority habitat (6220*) of the Habitats Directive 92/43/CEE and is characterized by Meso- and thermo-Mediterranean xerophile, mostly open, short-grass annual grasslands rich in therophytes; therophyte communities of oligotrophic soils on base-rich, often calcareous substrates (figures 2).

![Figure 1. a) quarry site, b) location of the quarry; c) photo displaying the sides of the quarry: W, N and E](image)

![Figure 2. location of the “Pseudo steppes” around the quarry](image)
The new project modifies the one presented at the start of the quarrying activity on 01 September 2003 that planned the planting of trees directly on the bottom of the quarry, (about 40 meters deep from the ground level and three meters above the groundwater level). The new project foresees the partial filling of the quarry using waste materials according to the environmental legislation, for example demolition material, excavation material deriving from building works and ec.. (figure 3a, b). This allows to better protect the groundwater and to create a microclimate more suited to the development of natural vegetation.

![Figure 3. a) Quarry section of the first recovery project; b) Hollow section of the recovery project presented in this study](image)

The filling activity allows reusing waste materials coming from construction activities of about 240,000 total mc, with economic revenue from the environmental and landscape recovery of the site. Therefore, the quarry filling activity represents an economic activity for the company, as it can guarantee the development of jobs for six operators for at least 5 years. This aspect provides an economic and social value of the recovery project.

Another important aspect of the new restoration project is the recovery of the vegetation that existed before the development of the quarry, consistently with the surrounding ecosystem, replacing the idea of the first project of using arboreal species such as: *Ceratonia siliqua* L., 1753; *Quercus* L., 1753; *Pinus halepensis*, Mill. 1768. This simple combination of arboreal plants does not refer to a specific habitat or ecosystem and doesn’t reflect the surrounding landscapes, its ecology and biodiversity. In addition, planting these species on the bottom of the quarry does not provide suitable conditions for an optimal landscape or ecosystem regeneration. Therefore, the quarry created a “drilling effect” in the original habitat [26]. The first recovery project didn’t attenuate the results of the transformation, while the new project aims to mitigate the “drilling effect” and increase biodiversity levels of the site, consistently with the surrounding area.

Recovering the pre-existing vegetation can facilitate an evolutionary process that otherwise would occur spontaneously in longer times. It represents a step forward to the spontaneous process, which might result uncertain in terms of quality and extension of vegetation, due to the disturbance exercised by human activities. Therefore, the project proposes the realization of three types of habitats (figure 4):

A. construction of a shrubs area, characterized by *Phlomis fruticosa*, *Pistacia lentiscus*, *Calicotome infesta*, *Crataegus monogyna*, *Cistus salvifolius*, *Cistus monspeliensis*;
B. realization of a Pseudo-steppe area, characterized by *Hyparrhenia hirta, Asphodelus ramosus, Euphorbia spinosa*;
C. construction of a Pseudo-steppe area on rocky soils, characterized by *Carybdis pancration, Satureja cuneifolia, Thymbra capitata*.

**Figure 4.** Layout of the landscape recovery project

This will allow the development of the priority habitat *6220: Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea (Directive 92/43/CEE) mixed with Mediterranean scrub, producing a landscape of recognized ecological value not detached from the surrounding landscape (figure 5).

For the restoration of the natural habitats we will collect the germplasm from local ecotypes (collected from surrounding areas of the quarry) in order to respect the genetic pool of the species that grow in a specific territory. To restore the Pseudo-steppe (priority habitat 6220*) we will use
hydroseeding techniques to disseminate collected seeds. The Mediterranean scrub will be restored by transplantation of potted plants, properly propagated by seeds or cuttings in a nursery, and organized in small and scattered groups of vegetation on the recovery site.

![Figure 5](image1.png)

**Figure 5.** Example of mixed vegetation between Mediterranean scrub and Pseudo steppe in the context of the quarry

The new project promotes the use of a lower quantity of top soil compared to the original recovery project. The first project was planned to use a top-soil one meter-thick. In the new landscape project, the plant species used will allow the use of top-soil for a thickness ranging from 0.10 to 0.30 m on the base of the vegetation typology that will be used. This will reduce the ecological and economic impact of the project because the top soil will be found outside the quarry.

The south-east side of the quarry has a good geomorphological stability. For this reason, on this side some “holes” in the rocks will be realized to stimulate the settlement of different animals, mainly birds (figure 6). In this way, the closed quarry can act as a stepping-stone and play a significant role in regulating GI in landscapes.

![Figure 6](image2.png)

**Figure 6.** South-east side of the quarry
The expected results are:

- reduced management costs and increased revenues;
- improvement of ecological quality of the landscape;
- reduce fragmentation of habitat/landscape;
- supporting the well-being of local population;
- reduced ecological footprint of the quarrying operations;
- better return in terms of company's image for future quarrying operations.

This regeneration project of the quarry in the peri-urban and agricultural landscape could represent a source of biodiversity and ecosystems, because it improves the presence of vegetation with an important ecological role in the monocultural landscape. In this way, the new project can constitute the stepping-stone for the species that move in this landscape. Figure 7 shows the localization of the quarries in Apulia region that have been localized and digitalized using the orthophoto in 2016. This Figure shows how the quarries can be considered as GIIs in a mono-cultural landscape. In such a scenario, they could support the network of nature at both local and broad scale: on the one hand, the native species of insects and animals can use the plants within the quarry as a habitat, and on the other hand, foreign species, such as migratory birds, can find refuge in these new habitats.

Figure 7. Quarries distribution in Apulian region in 2016
4. Conclusions
The new regeneration project of the quarry shows how it is possible to promote economic activities and biodiversity in the same time and place without trade-off. This approach is fundamental to overpass the concept that planning for biodiversity conservation and the development of economic activities at the same time and in the same place may be difficult. As pointed out in this strategy for biodiversity protection, the development of green infrastructures can have an important role for the restoration of degraded ecosystems and protects our natural capital.

This type of project, which represents a green infrastructure to implement the ecosystem and the biodiversity related to human activities, is an integral part of the Environmental Impact Assessment. The landscape recovery project of the quarry as a GI does not represent a simple mitigation measure, but a development strategy that administrators (local, regional and national) should request in order to create added ecological and socio-economic values in the landscape and urban areas. Therefore, the GIs can be considered as strategies able to promote sustainability of an urban system, as they can enhance the ecological functions [25, 27]. The quarry considered as a GI, requires an ecosystem-type design approach. In particular, the vegetation should not be developed as a simple set of plants but designed to reproduce an ecosystem consistent with the reference landscape context.

In highly urbanised landscapes, the quarries are an exceptional opportunity to maintain rare and threatened transient habitats that host pioneer species. However, the lack of knowledge of the ecological potential in and around quarries is hindering the protection of biodiversity and preventing the restoration of ecosystem following their end of activity. Therefore, in line with the multifunctional character of landscape, a project for the environmental recovery of a quarry should require a multidisciplinary approach: the design skills of engineering should be integrated with sustainable and environmental sciences related to landscape and urban planning. The conservation policy and management should be also interdisciplinary. The urban planning should rely on solid knowledge of ecological, social and economic processes and define opportunities and priorities to achieve both the conservation objectives of the sites and the sustainable socio-economic development [28].

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