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Assessment of landscape regeneration of a Natura 2000 site hosting greenhouse farming by using a dashboard of indicators. A case in Sicily through the territorial implementation of a "pilot project" at farm level

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ABSTRACT

Rural landscapes within Natura 2000 network are particularly sensitive to any anthropic action which could cause the compromise of protected habitats. Agriculture, if conducted with unsustainable techniques, could cause loss of biodiversity and landscape quality. The aim of this study is to propose a dashboard of indicators to assess the landscape and environmental benefits achievable by a landscape transformation based on a sustainable management of the agriculture activity in an area characterized by the presence of intensive greenhouse farming. The method was applied in the southern coast of Sicily, where there is the largest SCI (Site of Community Importance) and SPA (Special Protection Area) site of the Region. Here, the dune system was seamlessly occupied by greenhouses, so endangering habitats that guarantee the survival of endemic species, such as the *Leopoldia gussonei*. The main dimensional, visual and agro-environmental indicators for assessing the landscape and environmental pressure were identified and valued both in the actual state and after the hypothesized conversion. The results show that the proposed intervention would allow a meaningful landscape improvement combined with a considerable reduction of the pollution of the area.

1. Introduction

Rural landscapes which fall within the Natura 2000 network (European Ecological Network) are particularly sensitive, so that any anthropic action could cause the damage of protected habitats, if not accurately assessed (e.g., through the impact assessment indicated in article 6 of the European Habitats Directive (European Commission, 2018)). If no action is taken by means of plans and projects focused on the preservation and the implementation of natural components (Gabellini et al., 2007; Rechtman, 2013), these landscapes risk to lose those characteristics that justified their inclusion in the ecological network. It has been noted that agriculture, when carried out according to sustainable techniques, can coexist with the naturalness of the protected areas better than any other economic activity (industrial, tourist, administrative) and it is included among those ecosystem services whose adoption is desired by the current European policies (Agnoletti, 2014; Riguccio et al., 2015; Russo et al., 2014). On the other hand, intensive agriculture is often responsible of a loss of biodiversity and landscape quality (Rogge et al., 2008) as demonstrated by many cases worldwide (VV.AA. Biodiversity for Food and Agriculture, 2011).

Therefore, for those areas with high ecological value, which are heavily compromised by intensive agriculture, it is necessary to define evaluation tools able to asses new landscape assets based on a sustainable management of the agriculture activity.

Since the 1990s indicators have been applied to the agricultural sector by many international institutions such as the Organisation for Economic Co-operation and Development (OECD) and the Eurostat (Abitabile and Arzeni, 2013), as well as the Food and Agriculture Organization (FAO) which sponsored an International Framework for Evaluating Sustainable Land Management (FESLM) (Smith and Dumanski, 1994). Furthermore, the use of a set of indicators as an evaluation tool has been proposed in several environmental and landscape studies (De Montis et al., 2017; Torreggiani et al., 2014).

In this study a dashboard of indicators was proposed, suitable for greenhouse farming, which can be applied to different spatial scales so that it can be used as a valuable tool to support planners in sustainable land management as well as farmers in farmyard reconversion projects on a more sustainable model. The set of indicators highlights the key features of landscape and environment and allows the comparison between the current state and one or more project proposals.

The method was applied for the evaluation of a recovery project for an area in the southern coast of Sicily (Italy), belonging to the Natura

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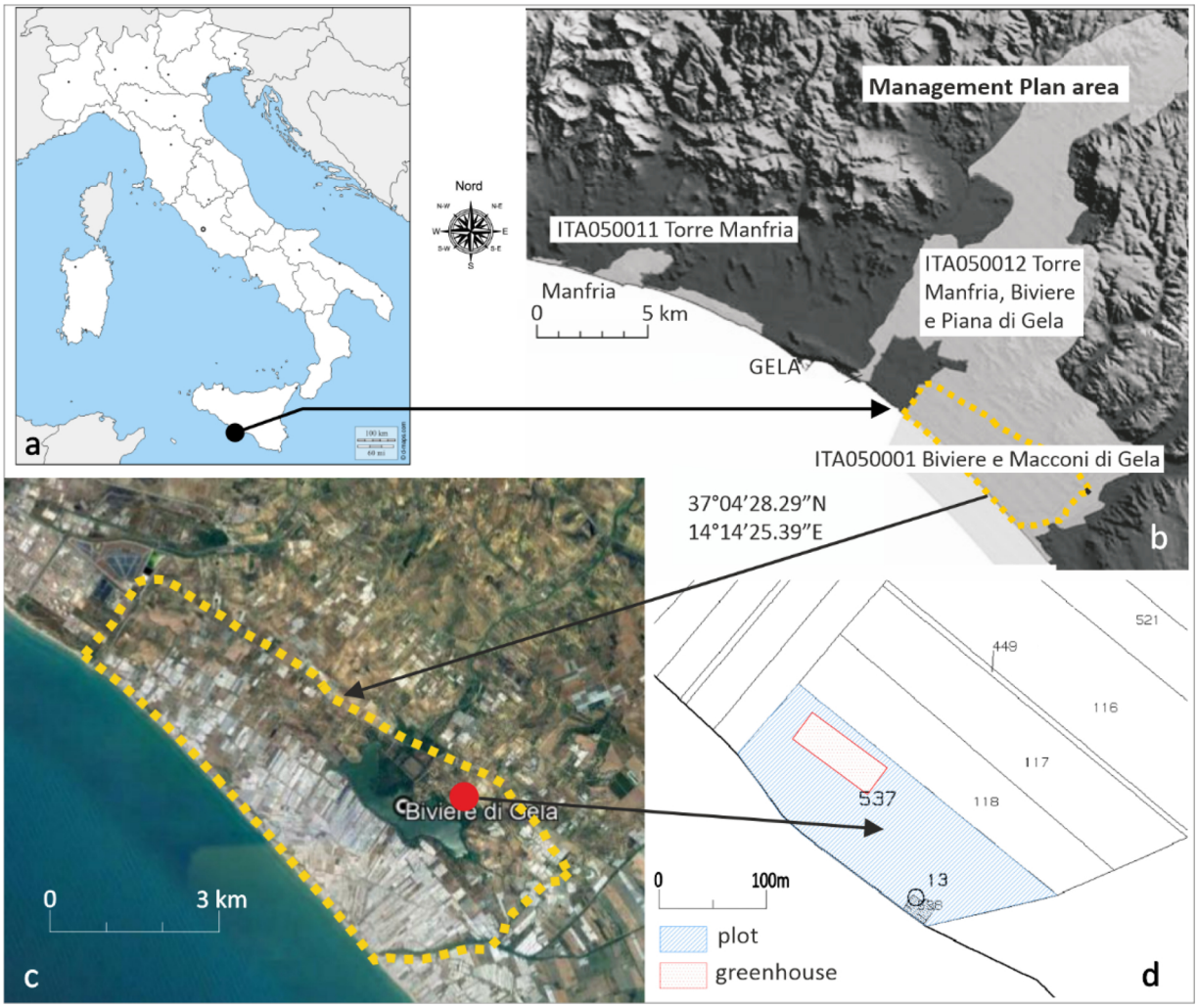


Fig. 1. Localization of the study areas: a) Italy (source: d-maps.com); b) Management Plan area (elaboration from Regional Technical Map); c) Master plan area (elaboration from a Google Earth image), d) lot area (cadastral map).

2000 network. Here, the dune system has been seamlessly occupied by greenhouse farms, which represent a threat for those habitats that make possible the survival of endemic species (IUCN, 2019; Sciandrello et al., 2015). This area was affected by the Life Leopoldia project funded by the LIFE program (the EU's financial instrument supporting environmental, nature conservation and climate action projects), which main objective was the preservation of an endemic bulbous (*Leopoldia gussonei*) and of its habitats. Spatial analysis and assessment were carried out on three different territorial scales ranging from farm level to the whole Natura 2000 site.

2. Materials and methods

2.1. The case study

The area considered in this study include Natura 2000 sites identified by the code ITA050001 ("Biviere e Macconi di Gela"), ITA050011 ("Torre Manfria") and ITA050012 ("Torre Manfria, Biviere e Piana di Gela").

The area is located in the southern part of eastern Sicily (Fig. 1). Its total surface, also including the area which extends over the waters of the Gulf, is about 179 km^2, whereas the soil surface is about 159 km^2. The site covers a large part of the mainly sandy coastline of southern Sicily facing the Gulf of Gela, almost all the plain behind it and part of the crowning hill system (Fig. 1).

Although heavily conditioned by strong anthropization, the area is a fundamental ecological unit for both the aspects concerning flora and vegetation (Minissale et al., 2010) and the ones concerning the fauna (Mascara and Sarà, 2007). Indeed, this site is also classified by BirdLife International as Important Bird and Biodiversity Area (IBA), i.e. an area identified using an internationally agreed set of criteria as being globally important for the conservation of bird populations. The site also includes wide wetland and, specifically, the "Biviere di Gela" (Fig. 1), which is an area protected by the Sicilian Region and a Ramsar site, i.e. a wetland designated to be of international importance under the Ramsar Convention. The Convention on Wetlands, also called the Ramsar Convention, is the intergovernmental treaty, established in 1971 by UNESCO, that provides the framework for the conservation and wise use of wetlands and their resources. Indeed, this area is of crucial importance for living, wintering and nesting of various resident or migratory species. The coast of Manfria (Fig. 1) is equally of relevant interest, as it is characterized by the coexistence of various lithological substrates and by peculiar climatic conditions, which favor the conservation of a remarkable floristic and phytocoenotic biodiversity. The actual vegetation (psammophilous, halophyte, marsh and rupicolous communities, scrubland formations, garrigues, prairies, hydro-hydrophytic coenosis, halophilous rephases to tamarisks, etc.) gives rise to a multitude of habitats colonized by a rich fauna.

The dune area overlooking the sandy coast was entirely covered by Mediterranean maquis (shrubland) until the 1950s. Nowadays, it is

largely tampered and overgrown with exotic species or with non-native Mediterranean species. Almost all of the native maquis species are extinct, especially near the coast. The residual dunes tend to be endangered by the vegetation behind them, as well as by the effects of anthropization. Indeed, the coast is full of anthropic activities with a very high visual and environmental impact (industrial sites, oil wells, greenhouses, illegal buildings, etc.), but it also hosts some elements of notable historical and archaeological value (medieval monuments and villages, as well as many Greek and Roman archaeological sites).

The abandonment of traditional agriculture (dry vineyards) towards more intensive forms (greenhouses) is exposing the agriculture ecosystems at risk. Greenhouse crops are causing the depletion of the aquifers, especially those ones hydrologically linked to the fragile wetland systems, and the increase of pollution due to both hazardous wastes (e.g. disused polyethylene sheets) and an excessive use of chemicals, which are a serious health and environmental problem (Macedo-Sousa et al., 2009). The lack of coherent planning instruments causes an incorrect use of the territory, especially where the expansion of civil constructions and industry occurs without any measure for the protection of biodiversity. As a result, most wetlands were drained to be urbanized for commercial, industrial and building activities (Natura 2000 network, 2018). *Leopoldia gussonei*, an endemic bulbous of the Gulf of Gela, grows in the residual area behind the dunes, set among the greenhouses. This species is in danger of extinction and is included in Appendix II of the 92/43/EEC Habitat Directive, in the Red List of the International Union for Conservation of Nature (IUCN), and in the list of protected species of the Convention on the Conservation of European Wildlife and Natural Habitats, also known as Bern Convention (European Commission, 2019a; IUCN, 2019; Council of Europe, 1979).

In order to deal with the current deterioration of the site and to establish the necessary conservation measures, the Management Plan (MP) "Biviere e Macconi di Gela" (VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) was drawn up for this area, in accordance with Article 6 of the European Habitats Directive.

The recovery process started thanks to the LIFE Leopoldia project, funded by the LIFE program (the EU's financial instrument supporting environmental, nature conservation and climate action projects). The main objectives of the LIFE Leopoldia project were to increase the *Leopoldia gussonei* population and to recover its habitats. Although the project was large and complex, its philosophy could be summarized into the three pillars specified in Table 1. The strategies proposed by the project for achieving these objectives are aimed at a reorganization of the agricultural activities, following a model of sustainable lot, that is a piece of land having a surface comparable to the mean value of the greenhouse farms in the area, managed with techniques of sustainable agriculture. The sustainable lot also includes nurseries for the increase in Leopoldia population, together with the dissemination of the results among the various agricultural and environmental actors and in the schools. The project also envisaged the creation of an environmental quality label which can be adhered to by farmers who reconvert their activities according to the guidelines of the MP and the LIFE Leopoldia project.

The results of the project were numerous and various (Riguccio et al., 2016), but for the purposes of this study only those ones will be focused concerning the drafting of a master plan for the behind-dune landscape in a part of the Gela Gulf (Fig. 1), and the drafting of the sustainable lot. These two activities were closely connected to the recommendations of the MP. The synthetic characteristics of the MP, the master plan and the project of the sustainable lot are reported in Table 2, whereas some specific aspects of each of them will be examined in the following sections.

Table 1
Pillars of the LIFE Leopoldia project.

Preserving the area where *Leopoldia gussonei* is present and identifying other areas potentially suitable for its growth
Reducing the impact of agricultural activities and establishing suitable conditions for the coexistence of agriculture and *Leopoldia gussonei*
Ensuring sustainable social and economic development in the areas where *Leopoldia gussonei* is preserved and implemented.

Table 2
Different planning levels considered in the study.

Management Plan: implemented in accordance with Article 6 of the European Habitats Directive for the Natura 2000 sites identified by the following codes: ITA050001, ITA050011 and ITA050012
Master plan: landscape project that outlines a new asset of part of the territory affected by the Management Plan, which considers the need to protect biodiversity, while not excluding the practice of eco-compatible agriculture
Project of the sustainable lot: a pilot project of a lot of land inside the area affected by the master plan managed with techniques of sustainable agriculture, proposed as a business model

2.1.1. Management plan

The MP of a Natura 2000 site is a planning tool foreseen by Article 6 of the Habitats Directive, which is used to formulate the site's conservation objectives together with the measures necessary to attain these objectives (European Commission, 2013). MPs are not mandatory, but they are implemented if deemed necessary to achieve the purposes of the Directive. According to European Commission (2013) "*Management plans are often used as a tool to guide managers and other interested parties in dealing with the conservation of* Natura 2000 *sites, and to involve the different socio-economic stakeholders and authorities in implementing the necessary conservation measures that have been identified*". The logical decision-making process for the evaluation of the opportunity to implement the MP and the structure of the MP are described in detail in (Ministry of the Environment, Land and Sea, 2002).

The MP "Biviere e Macconi di Gela" (VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) implemented for the study area, was approved by the competent department of the Sicilian Region in May 2016. It consists of a technical report with 20 annexes and 74 maps. The MP was implemented in order to define a new landscape asset, suitable to protect this area with high ecological value (Russo et al., 2011). A summary of the main management objectives of the MP together with the most important actions concerning the improvement of the agro-environmental conditions are reported in Table 3.

The main objective is to protect those habitats and species, existing in the site, identified in Directives 92/43/EEC and 79/409/EEC, also through actions aimed at increasing biodiversity. This objective can be achieved through a change in the characteristics of the local economy,

Table 3
Main objectives of the Management Plan "Biviere e Macconi di Gela" and related actions concerning the improvement of the agro-environmental conditions.

Main management objectives
Preserve, improve and recreate habitats and species of Community interest
Modify and/or limit the activities that affect the ecological integrity of the ecosystem
Promote the development of economic activities compatible with the conservation objectives
Create socio-economic mechanisms to be transferred into political-administrative actions
Increase and spread environmental sensitivity and knowledge on the site
Actions concerning the improvement of the agro-environmental conditions
Insertion of buffer zones of indigenous vegetation in residential and agricultural areas
Creation of strips of vegetation perpendicular to the coastline
Creation of buffer zones along the banks
Establishment of measures to mitigate the effects of greenhouses
Environmental recovery of contaminated soils
Recovery of the main dune areas
Recovery of the dune areas in the critical sites

by both harmonizing the development projects envisaged for the area with the conservation objectives, and implementing the laws for environment protection. Therefore, it is essential to work by strategies able to direct the political-administrative choices in order to guarantee an active and homogeneous management of Natura 2000 sites, as well as to increase the environmental sensitivity among economic operators. The latter objective requires a supporting activity aimed at exploiting the development opportunities offered by sustainable land management.

The selected actions aimed to improve the agro-environmental conditions, reported in Table 3, are firstly designed to establish connectivity between the residual natural areas, through the establishment of vegetation systems on the margins of agricultural land and along roads and banks, which allow animals and plants to pass artificial barriers. Furthermore, they are intended to the conversion of existing greenhouses or their removal in favor of the recovery of the original agricultural activities and landscape. Finally, they aim to protect the endangered habitats through soil reclamation and recovering of the dune systems.

2.1.2. Master plan

The master plan is a macro-project of landscape drafted within the LIFE Leopoldia project for a part of the territory affected by the MP. Specifically, the area concerned (Fig. 1) extends for about 13 km^2 and it is part of the Natura 2000 site ITA050012, which includes the Ramsar site “Biviere di Gela”. The drafting of the master plan was essential for indicating the landscape and functional assets that the area should get in the near future. The master plan consists of a technical report, the guidelines and 13 maps containing the cartography at a scale of 1:10,000 and some illustrative schemes of the landscape asset (functional and environmental). The master plan is carefully described in Riguccio et al. (2016). Here the main features are reported, which affect the reduction of land consumption and polluting materials, as well as those related to the improvement of the visual quality of the landscape.

In the current state, the dune area overlooking the sandy coast, now reduced to a strip of a few tens of meters, is endangered by the behind greenhouse crops, which are putting the residual habitats at risk. Approximately 55 % of the area is covered by greenhouses, which almost uniformly occupy the area behind the dunes. The extension of greenhouses with their plastic covers is only sporadically interrupted by abandoned agricultural lots and by unpaved roads, which laid down perpendicular to the coastline.

In order to deal with these problems, the master plan outlines a new landscape settlement able to break the impermeable greenhouse barrier, parallel to the coastline, by introducing a vegetation system at right angles to the coastline, in order to increase the naturalness and the connectivity, mitigate the loss of biodiversity and ensure a good visual quality (Arendt, 2004; Fry and Sarlöv-Herlin, 1997).

Three different levels of landscape management are proposed (Fig. 2): level 1 (total protection) for the areas immediately close to the coast, where the recovery of the dunes is planned; level 2 (high protection) for the areas behind the dunes which constitute a buffer zone, where the original traditional agriculture could be re-established; level 3 (medium protection) for the areas further away from the dunes, where even greenhouse agriculture could be practiced, in accordance with the guidelines of the MP and of the sustainable lot, provided that they connect with ecological corridors (about 5 km^2). Therefore, the project allows the decrease of the area covered by greenhouses, eliminating them in level 2 areas and reducing them in level 3 areas, where they can occupy a maximum of 10 % of the surface.

2.1.3. Project of the sustainable lot

The project of the sustainable lot was drafted within LIFE Leopoldia project with the aim of proposing a model of sustainable agriculture, which can be implemented in the whole study area.

The lot (Fig. 3) is about 7500 m^2 wide, with a perimeter of about 380 m, and is located within the area affected by the master plan (Fig. 1). It falls in E zone (agricultural land use) of the General Development Plan for the municipality of Gela, and also within the Oriented Natural Reserve (Pre-Reserve B) "Biviere di Gela".

The surface is organized on three terraces. Formerly, the lot was almost entirely occupied by multi-span greenhouses with wooden-concrete structure, covered by plastic film, which cause an almost complete impermeability of the lot and a high pollution of the soil. The hypothesis underlying the project is to convert the lot by adopting a high-tech greenhouse, able to grant a production that is quantitatively and qualitatively higher than the current one and, therefore, with a higher market value. In this way, it is possible considering to reduce the surface covered by the greenhouse to 10 % of the total area of the lot and to destinate the remaining 90 % to more sustainable activities. Specifically (Table 4), about 40 % of the lot surface is used for the cultivation of traditional crops, 30 % for the production and conservation of the plants necessary for the restoration of the Natura 2000 site habitats, 10 % for the creation of hedges and buffer zones, and the last 10 % for services (paths, resting areas, etc…). Fig. 3 reports the project plan of the lot. In detail, as regards the traditional crops in open field, the project provides for the creation of educational gardens for the production of vegetables, officinal plants and orchards, which are typical of the territory. Part of the surface is used to recover the cultivation of a traditional cultivar of *Vitis vinifera* that does not require irrigation.

Furthermore, nurseries of endemic species were planned in order to produce the necessary plants for the restoration of dune habitats and the setting-up of buffer zones.

Hedges and buffer zones are planned in those areas of the lot which are not suitable for cultivation, in order to help the conservation of plant biodiversity with the inclusion of endemic species. Specifically, the project provides a 2.50 m wide hedgerow made up of typical plants

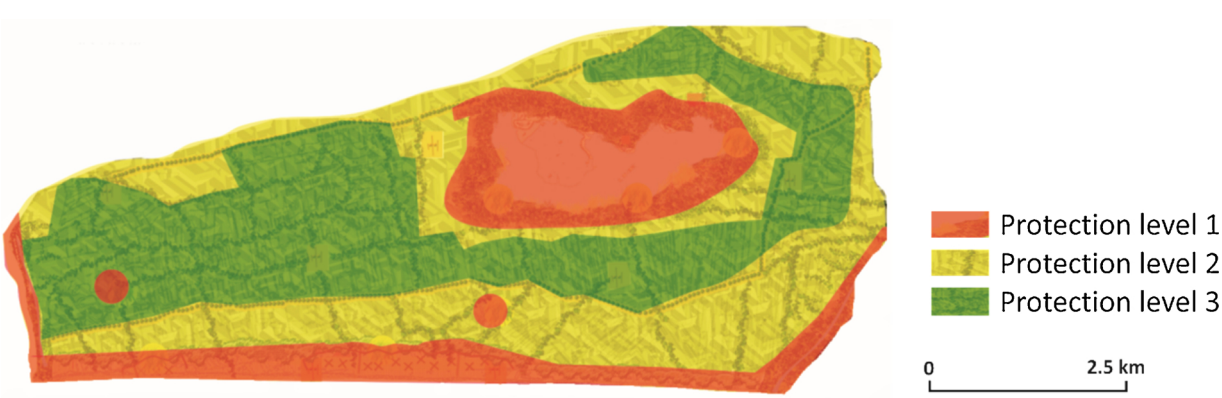


Fig. 2. Identification of the three levels of protection within the master plan.

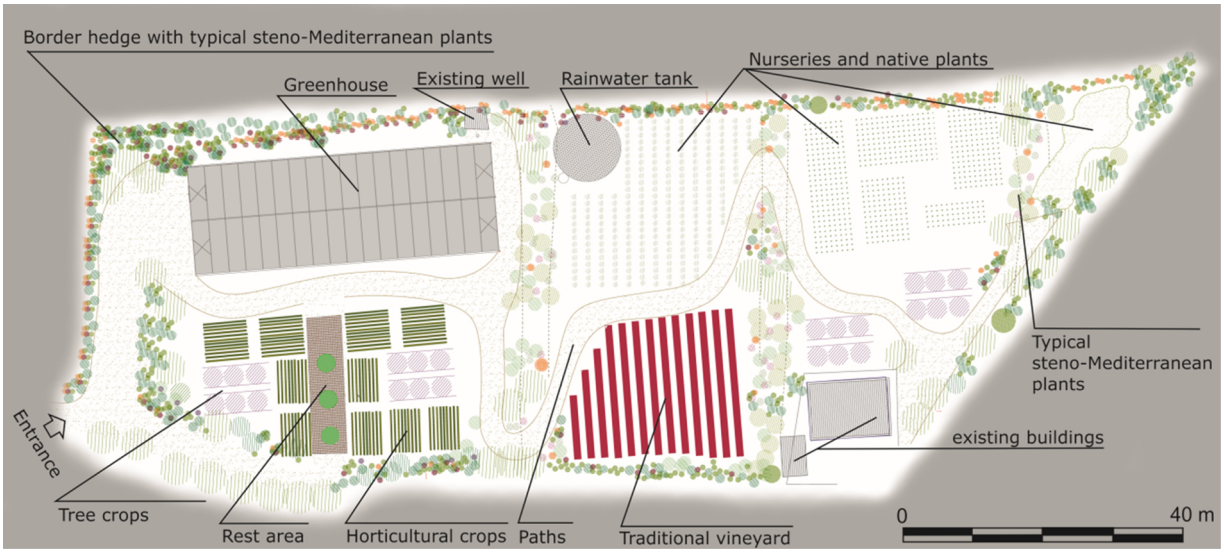


Fig. 3. Plan from the project of the sustainable lot.

Table 4
Land uses planned in the project of the sustainable lot.

Land use
Greenhouse area and technological equipment
Traditional crops in open field
Nurseries of endemic plants
Hedges and buffer zones for landscape compatibility
Areas for resting and paths

of the steno-Mediterranean area on the entire perimeter of the lot. This intervention is necessary to favor an increase in plant cover and in naturalness of the site, as well as to shield and distance human activities from sensitive areas.

The designed greenhouse is a two-span tunnel, with steel-made structure, covering a surface sized 16 × 45 m (720 m^2). The headings and a 0.75 m high strip along the perimeter of the greenhouse are made of corrugated polycarbonate. The roof and upper part of the perimeter are covered by a coextruded long-life film (at least three years) (Cascone et al., 2012). Closed soilless growing system is chosen as cultivation technique. This system eliminates both soil contamination due to the percolation of fertilizers and the need for soil disinfection before each growing season by fumigation, so allowing a consistent reduction of chemical pollutants emissions in groundwater. Moreover, soilless cultivation allows the precise regulation of fertigation and the optimization in the use of chemicals, so significantly reducing toxic residues to be disposed in the environment at the end of the cycle. The greenhouse is also equipped with a system for the mechanized distribution of natural enemies for integrated pest management (Blandini et al., 2008; Papa et al., 2018). Rainwater is recovered from the roof of the greenhouse and conveyed towards a tank of about 150 m^3 (Fig. 3). The stored water can be used for irrigation or, preferably, for the evaporative cooling system of the greenhouse, which requires low conductivity water.

Lastly, the lot includes areas for resting and paths, identified according to both the site topography and the usability of the lot.

2.2. Methodology

The adoption of sustainable agricultural practices, which take into account respect for the environment and preservation of natural resources, is becoming increasingly pressing. Therefore, many studies have been conducted on the opportunity to measure and assess the sustainability of agricultural activities. As already seen, a widely used approach is the use of dashboards of indicators able to provide information on the status of a phenomenon, a field or an area, allowing to interpret reality in a simplified and understandable way by scientists, politicians, administrators and citizens and providing the basis for decision-making processes at all levels.

Following this approach, in this study a method based on a dashboard of indicators was developed, in order to evaluate the landscape and environmental benefits achievable with a transformation of the territory obtained by improving the sustainability of agricultural activities, with specific regard to intensive greenhouse farming, in areas with high environmental value. The dashboard of indicators, used without any weight, can be applied both to support design activities on the fly by comparing different alternatives aimed to obtain environmental benefits and to evaluate the effects of actions which are already completed.

The indicators were chosen taking into account some criteria, as validity and relevance in describing what you want to know, ability to clearly highlight changes, measurability and ease of interpretation, comparability with other countries, availability and accessibility.

Moreover, the identified indicators can be applied to different spatial scales to give details of the planning or to guide the decision-makers' choices in planning. The choice of indicators followed the criteria reported in Table 5 (Dizdaroglu, 2017).

In detail (Dizdaroglu, 2017), the relevance of an indicator concerns its close relationship with the stated goals and the needs of knowledge of the user. An indicator is also required to be sensitive, meaning it should be responsiveness to changes in the phenomenon under study. Furthermore, an indicator should be intelligible, that is to be easily understood and interpreted. Feasibility is related with the option to get measures with reasonable and affordable effort. Finally, an indicator should lead to a comparable measurement of what it describes, meaning it needs to be consistent with other geographic areas or

Table 5
Criteria used for the choice of indicators.

Selection criterion
Relevance
Sensitiveness
Intelligibility
Feasibility
Comparability

Table 6
Description and characteristics of the indicators.

Indicators					
Dimensional		Visual		Agro-environmental	
D_1	Total surface of the area (m^2)	L_1	**Lot shape** (Prevailing shape of the lots) **Regular**: angles and sides of same/similar measure **Irregular**: angles and sides of any measure	V_1	**Natural vegetation on the border** (m^2) (Natural vegetation composed by native plants)
D_2	Total surface of the lots with greenhouses (m^2)	L_2	**Land texture** (Appearance of the landscape as a result of the parceling of the land) **None**: undivided land. **Fine**: small lot partition. **Coarse**: large lot partition. **Mixed**: arrangement of multiple schemes.	V_2	**Field natural vegetation** (m^2) (Surface covered by native species)
D_3	Impermeable surface covered by greenhouses (m^2)	L_3	**Crop texture** (Appearance of the landscape as a result of the presence and variety of vegetation) **None**: land fully covered by greenhouses. **Fine**: land covered by greenhouses with paths. **Coarse**: land with open field crops (herbaceous and arboreal). **Mixed**: contemporary existence of greenhouses and open field crops.	V_3	**Field crops** (m^2) (Surface intended for traditional crops)
D_4	Number of lots with greenhouses (n°) (Mean number of lots with greenhouses)	L_4	Built elements (Presence of greenhouses) **Continuous**: land completely covered by greenhouses. **Discontinuous**: land partially covered by greenhouses.	V_4	**Irrigation water** (m^3/year) (Annual water consumption for irrigation)
D_5	Perimeter (m) (Sum of the perimeters of the lots with greenhouses)			V_5	**Nitrogen** (kg/year) (Annual Nitrogen consumption)
D_6	Permeable surface (m^2) (Surface free of greenhouses)			V_6	**Phosphoric anhydrite** (kg/year) (Annual phosphorus consumption)
				V_7	**Potassium oxide** (kg/year) (Annual potassium consumption)
				V_8	**Fungicides** (kg/year) (Annual fungicides consumption)
				V_9	**Insecticides** (kg/year) (Annual consumption of insecticides)
				V_{10}	**Plastic** (kg/year) (Annual plastic consumption)

different domains.

Once the previous criteria were established, the next phase concerned the identification of the characteristics able to identify the agricultural territory, in relation to both the shape and size of the lots, and the type of cultivation (intensive under greenhouse or extensive in open field with traditional crops). The subsequent identification of the parameters focused on the evaluation of the impact of these agricultural activities on three main aspects: landscape, pollution and permeability of the soil, consumption of irrigation water.

Table 6 shows the selected indicators grouped into three different categories: 6 dimensional indicators, 4 visual indicators and 10 agro-environmental indicators, which are better described in the following sections.

Since the purpose of the dashboard is the comparison between the current status and one or more hypotheses of transformation of the territory, for the numerical indicators a threshold value or a range of variation is not suggested, but it is indicated if a growth or a decrease in the value is advisable. For non-numerical visual indicators, the desirable values are indicated.

2.2.1. Dimensional indicators

Dimensional indicators were identified in order to quantify some landscape components that are functional to both the knowledge of the reference area and to the calculation of the agro-environmental indicators. Firstly, the total surface of the reference area (D_1) was chosen because, although it is an invariant parameter with respect to the type of recovery intervention, it is necessary to understand its implementation scale.

Secondly, three indicators were adopted, able to quantify the presence of greenhouses in the reference area. Specifically, the total surface of the lots containing greenhouses (D_2), the surface made impermeable by greenhouses (D_3) that coincides with those one effectively covered by greenhouses, and the number of lots containing greenhouses (D_4). All three indicators are useful for assessing the impact of greenhouses in the reference area, and they point to an improvement when their value decreases as a result of the recovery intervention.

Furthermore, the perimeter of the lots containing greenhouses (D_5) was selected, because it can be useful for analyzing the landscape structure. Indeed, it is necessary for the calculation of the shape index or the corrected shape index (Bhardwaj and Kumar, 2019), which is commonly used in landscape ecology research.

Lastly, the permeable surface not covered by greenhouse (D_6) was adopted, in order to quantify the available surface for maintaining the hydrogeological balance of the territory and recharging the aquifers.

2.2.2. Visual indicators

Landscape perception is a result of the interaction between an individual and the landscape (Zube et al., 1982). According to several authors (Rechtman, 2013; Rogge et al., 2008), visual quality is related to life quality of the resident population. The visual indicators chosen in this study are those ones identified in Rechtman (2013) and based on the work Lothian (1999), which summarized much of the researches carried out since the 1970s on the visual perception of the landscape. Referring to the paradigm that "the viewer's response is derived from the ability to discern specific physical components of the landscape", Rechtman (2013) identified five key components to the visual preferences regarding the agricultural landscape: field size, lot shape, land texture, crop texture and built elements. These visual components were chosen as indicators for analyzing the visual qualities of the landscape, after being adapted to be representative for areas massively covered by greenhouses (Table 6). Field size was discarded as it overlaps with the dimensional indicator "surface of the area".

Tables 7 and 8 report schematic diagrams for each visual indicator, which can help to better understand both their definition and the differences among the values that they can assume. Specifically (Table 7),

Table 7
Schematic diagrams of the visual indicators L_1 and L_2.

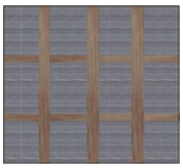
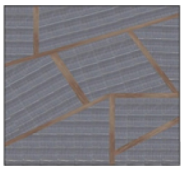
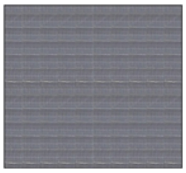
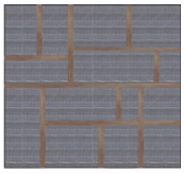
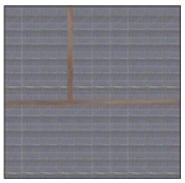
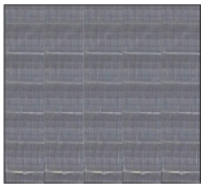
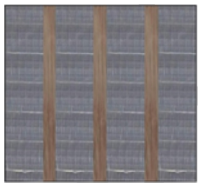
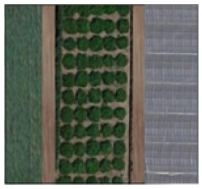
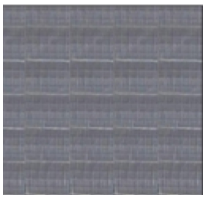
Visual Indicators			
L_1	**Lot shape** (Prevailing shape of the lots)	 **Regular**: angles and sides of same/similar measure.	 **Irregular**: angles and sides of any measure.
L_2	**Land texture** (Appearance of the landscape as a result of the parceling of the land)	 **None**: undivided land.	 **Fine**: small lot partition.
		 **Coarse**: large lot partition.	 **Mixed**: arrangement of multiple schemes.
 Greenhouse  Paths			

Table 8
Schematic diagrams of the visual indicators L_3 and L_4.

Visual Indicators			
L_3	**Crop texture** (Appearance of the landscape as a result of the presence and variety of vegetation)	 **None**: land fully covered by greenhouse.	 **Fine**: land covered by greenhouse with paths
		 **Coarse**: land with open field crops (herbaceous and arboreal).	 **Mixed**: contemporary existence of greenhouses and open field crops.
L_4	**Built elements** (Presence of greenhouses)	 **Continuous**: land completely covered by greenhouses.	 **Discontinuous**: land partially covered by greenhouses.
 Greenhouse  Arboreal crops  Herbaceous crops  Paths			

lot shape (L_1) refers to the prevailing shape of the lots and can be "regular", i.e. the lot has both angle and sides of same or similar measure, or "irregular", i.e. the lot has angles and size of any measure. The indicator land texture (L_2) expresses the appearance of the landscape as a result of the parceling of the land and it can assume four values (Table 7): "none" for undivided fields, "fine" for land with small partition, "coarse" for land with large crop partition and "mixed" for land characterized by the contemporary existence of small and large partitions.

Similarly, crop texture (L_3) expresses the appearance of the landscape as a result of the presence and variety of vegetation and it can assume four values (Table 8): "none" for land fully covered by greenhouse, "fine" for land covered by greenhouses with paths, "coarse" for land with open field crops (herbaceous and/or arboreal), and "mixed" for land characterized by the contemporary existence of greenhouses and open field crops. Lastly, built elements (L_4) refers to the presence of greenhouses and it can assume two values (Table 8); "continuous" for land completely covered by greenhouses, and "discontinuous" for land partially covered by greenhouses.

Following Rechtman (2013), land texture (L_2) and crop texture (L_3) are the most important contributors to the visual quality of the agricultural cultivated landscape. Furthermore, a land texture (L_2) characterized by partitions is preferred over an undivided one. The division into regular lots (L_1) is generally preferred to agricultural scenes dominated by irregular-shaped patterns, however different patterns of land division enriches the agricultural landscape. As regards crop texture (L_3), the presence of agricultural crops enhances landscape quality and it becomes more pleasant when there is a mixture of crops, creating diversity within the cultivated landscape. Similarly, although it is evident that greenhouses (L_4) negatively affect the visual quality of the agricultural landscape, reducing the covered area and using the freed area for cultivation in open field has a positive effect on the enrichment of the landscape.

2.2.3. *Agro-environmental indicators*

Among the different factors that cause an environmental impact due to agricultural activity, the most relevant are the conversion of natural ecosystems to agriculture and the release of nutrients and pesticides into the environment that pollute terrestrial and aquatic habitats, as well as groundwater (Tilman et al., 2002).

In order to mitigate the first issue, the integration of semi-natural landscape elements could help the preservation of natural habitats (VV.AA. Biodiversity for Food and Agriculture, 2011) and improve the sustainability of agriculture (Wezel et al., 2014). Specifically, the integration or re-integration of hedges and vegetation strips, either in or around a field, is an agroecological practice useful to protect against wind and soil erosion, as well as surface water contamination, and to assure biodiversity conservation in agricultural areas (Wezel et al., 2014). On these bases, the first two agro-environmental indicators were defined (Table 6) quantifying the surface covered by natural vegetation on the border (V_1) or inside a lot (V_2). Furthermore, the composition of natural vegetation with native species was considered important, as it allows to better pursue the objectives of a Natura 2000 site. An additional indicator was added for quantifying the surface used for traditional crops in open field (V_3), as they contribute to maintain a sustainable structure and composition of rural landscape (Biasi et al., 2017).

As regards the pollutants that come from nutrients and pesticides, the indicators from V_5 to V_9 were identified, which quantify the consumption of the most commonly used substances. Furthermore, an additional indicator (V_{10}) was added for quantifying the consumption of plastic films due to greenhouses. Indeed, plastic films is an important environmental problem, especially if they are not properly disposed of (Horodytska et al., 2018).

Table 9
Extension of the reference areas for the assessment of the landscape and environmental benefits.

Reference area	Area size	Source
Land surface within Natura 2000 sites affected by the Management Plan	159 km^2	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 588)
Surface affected by the master plan drafted as part of the activities of the LIFE Leopoldia project	13 km^2	(Riguccio et al., 2016)
Surface covered by greenhouses within the area affected by the master plan	7.15 km^2 (current) 5 km^2 (designed)	(Riguccio et al., 2016)
Surface of the sustainable lot designed as part of the activities of the LIFE Leopoldia project	7500 m^2	Land lot purchased with "LIFE Leopoldia" funds
Surface of the greenhouse designed inside the sustainable lot	750 m^2	Project of the sustainable greenhouse designed as part of the activities of the LIFE Leopoldia project
Mean surface of the greenhouse farms existing in the Natura 2000 sites affected by the Management Plan	7000 m^2	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 547)
Mean surface covered by greenhouses within the greenhouse farms existing in the Natura 2000 sites affected by the Management Plan	4000 m^2	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 547)
Surface covered by greenhouses within Natura 2000 sites affected by the Management Plan	11.0834 km^2	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 558)

Finally, given the manifold environment impacts due to a high-water consumption in agriculture (Pfister et al., 2011) and the need to increase water-use efficiency (Tilman et al., 2002), an additional parameter was introduced (V_4) to quantify water used for irrigation.

3. Results

Data needed for the calculations were acquired from official and bibliographic sources (VV.AA. Piano di Gestione öBiviere Macconi di Gela", 2009; Riguccio et al., 2016; Salvato, 2011; Signore et al., 2016; Trejo-Téllez and Gómez-Merino, 2012). Specifically, the dimensional data (Table 9), the consumption of materials in traditional (Table 10) and in soilless greenhouses, such as the one designed for the sustainable lot (Table 11) are considered. The detailed calculations are reported in Appendix A, whereas the synthetic results of the application of the indicators to the study areas are reported in Table 12. Specifically, the table shows the comparison of the indicator values between current and projected state for the three different planning levels considered in the study.

Since the project was implemented using the dashboard as guideline, no indicator shows a loss of environmental qualities. However, the value of some indicators remains unchanged between current and projected status. Therefore, in the "variation" column, also negative values represent and improvement in environmental conditions. For example, the variation of -3550 of the $D_{3,a}$ indicator denotes a reduction of the waterproof surface covered by the greenhouses within the sustainable lot, which is undoubtedly a positive fact for the environment.

The main aspect, common to the three different planning levels considered in the study, concerns the substantial reduction of the area covered by greenhouses. This implies not only the reduction of impermeable soil, but also and above all the reduction of water consumption and of pollutant. The large surface freed from the existing greenhouses allows to practice open-field agriculture with a low environmental impact and to introduce strips of natural vegetation along the boundary of the lots. The considerable presence of vegetation, both natural and due to agricultural crops, allows to obtain a diversified landscape, which is harmoniously integrated with the surrounding environment.

In the following sections the main results obtained by the indicator comparison are summarized for each planning level considered in the study.

3.1. Requalification of the lot

The *dimensional indicators* of the lot are mainly functional as a reference for the calculus of most of the other indicators. However, some improvements between current and project status can be specifically ascribed to the reduction of the surface covered by greenhouses. Indeed, Table 12 shows that the covered surface provided in the project ($D_{3,ap}$ = 750 m^2) compared to the original one ($D_{3,at}$ = 4300 m^2), would allow to make permeable up to 6750 m^2 ($D_{6,ap}$) with a free surface gain of about +3500 m^2.

The *visual indicators* change in relation to both the reduction of the greenhouse size and the introduction of new crops and endemic vegetation in those areas made available by the decrease of covered surface. Therefore, crop texture changes from "none" ($L_{3,at}$) to "mixed" ($L_{3,ap}$), as well as the texture of buildings elements changes from "continuous" ($L_{4,at}$) to "discontinuous" ($L_{4,ap}$).

The change in *agro-environmental indicators* is also relevant. Natural vegetation (V_1), field natural vegetation (V_2) and field crops (V_3), were originally completely absent and, therefore, the application of the sustainable lot model would assure absolute gains of +950 m^2, +1000 m^2 and +3000 m^2, respectively.

The reduction in use of irrigation water and pollutant is equally noteworthy and it is only related to greenhouse crops, since field crops will mostly be grown under dry and organic management. Specifically,

Table 10
Materials used in the traditional greenhouses and bibliographic sources.

Material	Quantity	Source
Irrigation water	0.8 $m^3/(m^2$ year)	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 570)
Nitrogen	0.04 kg/(m^2 year)	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 570)
Phosphorus pentoxide	0.025 kg/(m^2 year)	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 571)
Potassium oxide	0.07 kg/(m^2 year)	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 571)
Fungicides	0.0071 kg/(m^2 year)	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 573)
Insecticides	0.0058 kg/(m^2 year)	(VV.AA. Piano di Gestione "Biviere Macconi di Gela", 2009) (p. 573)
Plastic consumption differentiated by:	0.5 kg/(m^2 year)	(Salvato, 2011) (p. 15)
Greenhouse cover, soil mulch, irrigation system	0.45 kg/(m^2 year)	
Containers	0.05 kg/(m^2 year)	

Table 11
Materials used in the soilless greenhouses and bibliographic sources.

Materials	Quantity	Source
Irrigation water	0.716 $m^3/(m^2$ year)	Calculated[a] on the basis of a water consumption of 0.139 m^3/plant (Signore et al., 2016) and of the project of the sustainable lot
Nitrogen	0.14 kg/(m^2 year)	Calculated[a] on the basis of the mean value of 196.4 g/m^3 (Trejo-Téllez and Gómez-Merino, 2012) and of the project of the sustainable lot
Phosphoric anhydride	0.29 kg/(m^2 year)	Calculated[a] on the basis of the mean value of 40.75 g/m^3 (Trejo-Téllez and Gómez-Merino, 2012) and of the project of the sustainable lot
Potassium oxide	0.22 kg/(m^2 year)	Calculated[a] on the basis of the mean value of 307.3 g/m^3 (Trejo-Téllez and Gómez-Merino, 2012) and of the project of the sustainable lot
Fungicides	0	The designed greenhouse uses a closed-cycle system with UV-C disinfection
Insecticides	0.0058 kg/(m^2 year)	No significant differences are expected compared to traditional greenhouses
Plastic consumption differentiated by:	0.312 kg/(m^2 year)	Calculated[a] on the basis of the project of the sustainable lot
Greenhouse cover	0.1 kg/(m^2 year)	
Soil mulch	0.043 kg/(m^2 year)	
Irrigation system	0.154 kg/(m^2 year)	
Containers	0.015 kg/(m^2 year)	

[a] See Appendix A.

the largest savings concern water consumption (V_4) equal to -2906 m^3/year (about 84 % reduction). Here too, the reductions of phosphorous (V_6) and insecticides (V_9) are around 80 % of the original consumption, with values of -85.7 kg/year and -20.6 kg/year, respectively. The savings in consumption of nitrogen (V_5), and potassium (V_7) are respectively equal to 39 % and 45 % equivalent to -67.1 kg/year and -136.9 kg/year. As expected, the saving of plastics (V_{10}) is remarkable thanks to the reduction of the surface covered by greenhouses and the long lifetime of the film adopted as covering. Specifically, the reduction reaches 90 %, equivalent to -1918 kg/year. Finally, the fungicide saving (V_8) is 100 % thanks to the UV system adopted for the disinfestation of the nutrient solution. This value is true even for both the master plan and the MP areas.

Table 12
Comparison of the values of the indicators between the current and the projected state.

	Sustainable lot			Master plan			Natura 2000 sites		
	Current	Projected	Variation	Current	Projected	Variation	Current	Projected	Variation
Dimensional indicators									
D_1	$D_{1,a}$ 7500	$D_{1,a}$ 7500	0	$D_{1,b}$ 13×10^6	$D_{1,b}$ 13×10^6	0	$D_{1,ct}$ 159×10^6	$D_{1,cp}$ 159×10^6	0
D_2	$D_{2,a}$ 7500	$D_{2,a}$ 7500	0	$D_{2,bt}$ 7.5×10^6	$D_{2,bp}$ 5×10^6	-2.5×10^6	$D_{2,ct}$ 11.08×10^6	$D_{2,cp}$ 11.08×10^6	0
D_3	$D_{3,at}$ 4300	$D_{3,ap}$ 750	−3550	$D_{3,bt}$ 4.275×10^6	$D_{3,bp}$ 0.5×10^6	-3.775×10^6	$D_{3,ct}$ 6.315×10^6	$D_{3,cp}$ 1.11×10^6	-5.205×10^6
D_4	$D_{4,a}$ 1	$D_{4,a}$ 1	0	$D_{4,bt}$ 1071	$D_{4,bp}$ 715	−356	$D_{4,ct}$ 1583	$D_{4,cp}$ 1583	0
D_5	$D_{5,a}$ 380	$D_{5,a}$ 380	0	$D_{5,bt}$ 378063	$D_{5,bp}$ 252395	−125668	$D_{5,ct}$ 558799	$D_{5,cp}$ 558799	0
D_6	$D_{6,at}$ 3225	$D_{6,ap}$ 6750	+3525	$D_{6,bt}$ 3.225×10^6	$D_{6,bp}$ 4.5×10^6	$+1.275 \times 10^6$	$D_{6,ct}$ 4.764×10^6	$D_{6,cp}$ 9.972×10^6	$+5.207 \times 10^6$
Visual indicators									
L_1	$L_{1,a}$ Irregular rectangular	$L_{1,a}$ Irregular rectangular	None	$L_{1,bt}$ Rectangular	$L_{1,bp}$ Rectangular	None	$L_{1,ct}$ Rectangular	$L_{1,cp}$ Rectangular	None
L_2	$L_{2,a}$ None	$L_{2,a}$ None	None	$L_{2,bt}$ Fine	$L_{2,bp}$ Mixed	Mixed	$L_{2,ct}$ Fine	$L_{2,cp}$ Mixed	Mixed
L_3	$L_{3,at}$ None	$L_{3,ap}$ Mixed	Mixed	$L_{3,bt}$ None	$L_{3,bp}$ Mixed	Mixed	$L_{3,ct}$ None	$L_{3,cp}$ Mixed	Mixed
L_4	$L_{4,at}$ Continuous	$L_{4,ap}$ Discontinuous	Discontinuous	$L_{4,bt}$ Continuous	$L_{4,bp}$ Discontinuous	Discontinuous	$L_{4,ct}$ Continuous	$L_{4,cp}$ Discontinuous	Discontinuous
Agro-environmental indicators									
V_1	$V_{1,at}$ 0	$V_{1,ap}$ 950	+950	$V_{1,bt}$0	$V_{1,bp}$ 0.68×10^6	$+ 0.68 \times 10^6$	$V_{1,ct}$ 0	$V_{1,cp}$ 1.5×10^6	$+ 1.5 \times 10^6$
V_2	$V_{2,at}$ 0	$V_{2,ap}$ 1000	+1000	$V_{2,bt}$ 0	$V_{2,bp}$ 0.715×10^6	$+0.715 \times 10^6$	$V_{2,ct}$ 0	$V_{2,cp}$ 1.58×10^6	$+1.58 \times 10^6$
V_3	$V_{3,at}$ 0	$V_{3,ap}$ 3000	+3000	$V_{3,bt}$ 0	$V_{3,bp}$ 2.145×10^6	$+ 2.145 \times 10^6$	$V_{3,ct}$ 0	$V_{3,cp}$ 4.75×10^6	$+4.75 \times 10^6$
V_4	$V_{4,at}$ 3440	$V_{4,ap}$ 534	−2906	$V_{4,bt}$ 3.42×10^6	$V_{4,bp}$ 0.36×10^6	-3.06×10^6	$V_{4,ct}$ 5.05×10^6	$V_{4,cp}$ 0.79×10^6	-4.26×10^6
V_5	$V_{5,at}$ 172	$V_{5,ap}$ 104.9	−67.1	$V_{5,bt}$ 0.17×10^6	$V_{5,bp}$ 0.07×10^6	-0.10×10^6	$V_{5,ct}$ 0.25×10^6	$V_{5,cp}$ 0.15×10^6	-0.1×10^6
V_6	$V_{6,at}$ 107.5	$V_{6,ap}$ 21.8	−85.7	$V_{6,bt}$ 0.11×10^6	$V_{6,bp}$ 0.02×10^6	-0.09×10^6	$V_{6,ct}$ 0.16×10^6	$V_{6,cp}$ 0.03×10^6	-0.13×10^6
V_7	$V_{7,at}$ 301	$V_{7,ap}$ 164.1	−136.9	$V_{7,bt}$ 0.3×10^6	$V_{7,bp}$ 0.11×10^6	-0.19×10^6	$V_{7,ct}$ 0.44×10^6	$V_{7,cp}$ 0.24×10^6	-0.2×10^6
V_8	$V_{8,at}$ 30.5	$V_{8,ap}$ 0	−30.5	$V_{8,bt}$ 0.03×10^6	$V_{8,bp}$ 0	-0.03×10^6	$V_{8,ct}$ 0.04×10^6	$V_{8,cp}$ 0	-0.04×10^6
V_9	$V_{9,at}$ 25	$V_{9,ap}$ 4.4	−20.6	$V_{9,bt}$ 0.025×10^6	$V_{9,bp}$ 0.003×10^6	-0.022×10^6	$V_{9,ct}$ 0.037×10^6	$V_{9,cp}$ 0.006×10^6	-0.031×10^6
V_{10}	$V_{10,at}$ 2150	$V_{10,ap}$ 232	−1918	$V_{10,bt}$ 2.14×10^6	$V_{10,bp}$ 0.15×10^6	-1.99×10^6	$V_{10,ct}$ 3.16×10^6	$V_{10,cp}$ 0.34×10^6	-2.82×10^6

Subscript *at* refers to the current status. Subscript *ap* refers to the projected status. D_1 - Surface of the area (m^2); D_2 - Surface of the lots with greenhouses (m^2); D_3 - Impermeable surface covered by greenhouses (m^2); D_4 - Number of lots with greenhouses (n°); D_5 - Perimeter (m); D_6 - Permeable surface (m^2); L_1 – Lot shape (**Regular**: angles and sides of same/similar measure. **Irregular**: angles and sides of any measure); L_2 - Land texture (**None**: undivided land. **Fine**: small lot partition. **Coarse**: large lot partition. **Mixed**: arrangement of multiple schemes; L_3 – Crop texture (**None**: land fully covered by greenhouses. **Fine**: land covered by greenhouses with paths. **Coarse**: land with open field crops (herbaceous and arboreal). **Mixed**: contemporary existence of greenhouses and open field crops); L_4 –Built elements (**Continuous**: land completely covered by greenhouses. **Discontinuous**: land partially covered by greenhouses); V_1- Natural vegetation on the border (m^2); V_2 - Field natural vegetation (m^2); V_3 - Field crops (m^2); V_4 – Irrigation water (m^3/year); V_5 – Nitrogen (kg/year); V_6 - Phosphoric anhydrite (kg/year); V_7 - Potassium oxide (kg/year); V_8 –Fungicides (kg/year); V_9-Insecticides (kg/year); V_{10} – Plastic (kg/year).

3.2. Requalification of master plan area

The environmental and landscape improvement of the area affected by the master plan is highlighted, in the hypothesis of modifying the actual status according to the design guidelines of the sustainable lot and considering the functional layout suggested by the landscape plan.

Among the *dimensional indicators*, the one stands out related to the surface covered by greenhouses (D_2). Currently, in the master plan area alone, that is about 8 % of the area affected by the MP, it is concentrated about 68 % ($D_{2,bt}/D_{2,ct}$) of the surface covered by greenhouses in the whole area. Furthermore, approximately 58 % ($D_{2,bt}/D_{1,b}$) of the area affected by the master plan hosts greenhouse farms. Following the hypothesis of the landscape plan, the presence of greenhouses would reduce to about 38 % ($D_{2,bp}/D_{1,b}$) of the master plan area, so recovering about 20 % of the soil. It should be noticed that, in the hypothesis of adopting the same size of the sustainable lot, the number of lots would be reduced from 1071 ($D_{4,bt}$) to 715 ($D_{4,bp}$). The application of the sustainable lot would decrease the area covered by greenhouses from 4.275 km^2 ($D_{3,bt}$) to 0.5 km^2 ($D_{3,bp}$) with a reduction of -3.775 km^2 of waterproof surface. Therefore, the permeable surface would increase from 3.225 km^2 ($D_{6,bt}$) to 4.5 km^2 ($D_{6,bp}$) with a gain of +1.275 km^2.

The variation of the *visual indicators* is more marked compared to the one obtained for the sustainable lot. As a result of the application of the project, the irregular rectangular shape (L_1) of the individual lots is kept, but their texture (L_2) changes. Indeed, thanks to the reduction of the area covered by greenhouses and the introduction of field crops and natural vegetation, land texture change from "fine" ($L_{2,bt}$) to "mixed" ($L_{2,bp}$), crop texture turns from "none" ($L_{3,bt}$) to "mixed" ($L_{3,bp}$), and the presence of building elements becomes "discontinuous" ($L_{4,bp}$) from "continuous" ($L_{4,bt}$).

The changes in the *agro-environmental indicators* are particularly relevant. The application of the project prefigures a net gain for the area intended for natural vegetation (V_1), field natural vegetation (V_2) and field crops (V_3). As they are completely absent in the study area, the gain is + 0.68 km^2 for V_1, +0.715 km^2 for V_2 and + 2.145 km^2 for V_3.

The annual savings of water (V_4), phosphorous (V_6), insecticides (V_9) and plastics (V_{10}) reach or exceed 90 % in comparison with the consumption in the traditional greenhouses existing in the master plan area. The consumption would be reduced by -3.06 × 10^6 mc/year of water, -0.09 × 10^6 kg/year of phosphorous, −0.022 × 10^6 kg/year of insecticides and -1.99 × 10^6 kg/year of plastic. The annual savings of nitrogen (V_5) and potassium (V_7) would be respectively equal to 59 % and 63 %, which are equivalent to -0.10 × 10^6 kg/year and -0.19 × 10^6 kg/year.

3.3. Requalification of the MP area

The *dimensional indicators* refer to the surface covered by greenhouses within the Natura 2000 sites under study, assuming the transformation of existing farms according to the model of the sustainable lot. Therefore, the included surface is that one affected by the master plan as it stands, not considering the reduction of the surface of the lots with greenhouses, conceived by the master plan. In this way, a less favorable condition is considered which, however, is able to grant significant gains in environmental terms. Thus, the greenhouse surface $D_{2,ct}$ corresponds to $D_{2,cp}$ and is equal to 11.08 km^2, i.e. about 7 % ($D_{2,cp}$/ $D_{1,cp}$) of the surface affected by MP.

Assuming a reduction of the greenhouse surface equal to 10 % of D_2, the impermeable surface $D_{3,cp}$ becomes 1.11 km^2. Therefore, 9.972 km^2 ($D_{6,cp}$) will be permeable, with a recovery of about 5.209 km^2 which can be allocated to natural areas and crops compatible with the requirements of site protection.

The landscape would change: the presence of greenhouses would be mitigated by the introduction of field crops and native vegetation. Among the four *visual indicators*, three of them highlight the difference: the land texture (L_2) from "fine" ($L_{2,ct}$) becomes "mixed" ($L_{2,cp}$), the texture of crops (L_3), actually absent ($L_{3,ct}$), becomes "mixed" "($L_{3,cp}$), and the constructed elements (L_4), identified in the "continuous" extension of greenhouses ($L_{4,ct}$), become "discontinuous"($L_{4,cp}$).

The first three *agro-environmental indicators* show absolute gains compared to the current status characterized by complete absence of field crops and natural vegetation. The implementation of the project would lead to the introduction of +1.5 km^2 of natural vegetation (V_1) along the perimeters of the lots, +1.58 km^2 of natural vegetation inside the fields (V_2), and +4.75 km^2 of crops compatible with the environmental context (V_3).

Here too, the savings of water (V_4), phosphorous (V_6), insecticides (V_9) and plastics (V_{10}) would exceed 80 % of the respective actual quantities. Specifically, it would be saved -4.26 × 10^6 m^3/year of water, -0.13 × 10^6 kg/year of phosphorous, -0.031 × 10^6 kg/year of insecticides, and -2.82 × 10^6 kg/year of plastics. The savings of nitrogen (V_5) and potassium (V_7) are of about 39 % and 45 % equivalent to -0.1 × 10^6 kg/year and -0.2 × 10^6 kg/year, respectively.

3.4. Comparison among the three spatial scales

Due to the characteristics of the area, the greatest impacts are determined by the massive presence of greenhouses, especially in the area affected by the master plan. In fact, at present, about 68 % ($D_{2,bt}/D_{2,ct}$) of the greenhouses within the MP area is concentrated just in the master plan area. Furthermore, 33 % ($D_{3,bt}/D_{1,b}$) of the master plan area is occupied by greenhouses. This percentage is remarkable if one considers the sensitivity of the area due to the presence of residual dune and behind-dune systems, characterized by habitats which are of primary interest for the protection of biodiversity and of *Leopoldia gussonei*.

The spreading of the design model of the sustainable lot, in both master plan and MP areas, would improve the texture of the landscape. Indeed, the waterproof surface covered by greenhouses would be reduced to about 4 % ($D_{3,bp}/D_{1,b}$) of the master plan surface and to about 0.7 % ($D_{3,ct}/D_{1,c}$) of the MP surface, with a reduction compared to the current state, equal to -29 % and -3.3 %, respectively. The thinning of greenhouses, interspersed with natural vegetation and cultivated areas, restores a less man-made landscape, in which the existence of elements that create complexity, allows readability of the landscape and indicate its quality (Rechtman, 2013). According to Rechtman (2013), changes of colors, crops and vegetation, also in relation to the passing of the seasons, increase landscape appreciation by the users. The environmental gains are undoubted, because a dense ecological connection would be created among agricultural lots and between these ones and natural areas, in addition to the insertion of new uncovered surfaces and the extension of habitats. Natural areas within the master plan, currently 13 % (Riguccio et al., 2016), would grow by about +10.7 % ($D_{4,bp}$ ($V_{1,ap}$+ $V_{2,ap}$)/$D_{1,b}$), along with a further 16 % ($D_{4,bp}$ x $V_{3,ap}$/ $D_{1,b}$) of agricultural surfaces for open-field crops.

The percentage of land intended for the new agricultural framework (sustainable greenhouses and crops) within the master plan area would be about 20.3 % (($D_{3,bp}$ + $D_{4,bp}$ x $V_{3,ap}$)/$D_{1,b}$) which, together with 26 % of the existing crops (Riguccio et al., 2016), would lead to a total of man-made area equal to 46.3 %. This percentage is well below 80 % indicated for agricultural, industrial, residential and service areas, as a threshold value not to be exceeded for the protection of biodiversity and biogeochemical functions of soil (Graymore et al., 2010).

Currently, in the area affected by the MP, natural areas cover only 31.98 km^2, equal to 17.8 % of the whole surface of the Natura 2000 sites. The application of the model of the sustainable lot would allow the addition of 3.08 km^2 (($V_{1,cp}$ + $V_{2,cp}$)/$D_{1,cp}$), recovered from the current greenhouse areas, equal to 1.72 % of the surface. The total percentage (18.90 %) would be very close to that 20 % necessary to protect biodiversity and biogeochemical functions of soil (Graymore et al., 2010).

The reduction of the surface covered by greenhouses and the introduction of soilless system could allow considerable savings of irrigation water and polluting materials. The current consumption of water in one year could be enough for almost 7 years in the MP area and for almost 10 years in the master plan area. Similarly, nitrogen, phosphoric anhydride, potassium oxide and insecticides actually consumed in one year could be enough for about 1.5, 5, 2, and 6 years, respectively, in the MP area and for about 2.5, 7, 3 and 9 years in the master plan area.

Finally, following the model of the sustainable lot, the amount of plastics consumed in one year could be used in almost 10 years in the MP area and in about 14.5 years in the master plan area.

4. Discussion and conclusions

The approach of the present work is close to the "bio-ecological" vision, which considers the sustainable regeneration processes of the soil dependent on the optimization of the use of energy and nutrients, and which promotes biodiversity also in the agricultural field (Bugge et al., 2016). In this sense, the results obtained could be considered for the development of future "bio-economic" researches. According to Bugge et al. (2016) this definition includes studies that place the main emphasis on natural and engineering sciences, as well as socio-environmental studies. The present study fits well among those that “may also cause an improved understanding of the ecosystems in which we live and possibilities in terms of new and sustainable solutions and the knowledge and technologies underpinning these” (Bugge et al., 2016).

Although the method was applied on a specific area, it has been conceived as a tool applicable in various contexts characterized by the presence of agricultural activities within areas with high landscape and naturalistic value. Similar conditions can be found in various parts of Italy and Europe. The indicators can be adapted to the specific context in an objective manner, while keeping unchanged the structure of the method. Indeed, the choice of indicators was derived from both the need to monitor the pressure exerted by the agri-food production activities on the various environmental components, and their actual measurability.

Moreover, the method is adjustable to different spatial scales so that it can be applied at small scale to support farmers in functional renewal of their farmyards addressed to safeguard sites with naturalistic value, as well as at planning scale as basis for the guidelines and policies at regional level aimed at conservation, redevelopment and revitalization of rural areas.

Although the work is based on consistent bibliographic sources for the identification of the indicators and of their values, it is based on projections and hypotheses whose results cannot be verified experimentally. This aspect is identified as the main limit of the study. However, the results obtained, even if partial and theoretical, can certainly support and motivate, in the planning activities, the choices aimed at improving the landscape and environmental quality.

The application of the method to the study area provides interesting results on the achievable regeneration of lands with high environmental and landscape value, within the Natura 2000 network, which are endangered by agricultural activities that are incompatible with protection and implementation of habitats. Evidently, it remains to be seen whether the reconversion of greenhouse farms according to the model of the sustainable lot is advantageous also from the point of view of production. This aspect would require in-depth analyses of economic nature which are not covered in this work. However, even in the hypothesis of a decrease in revenues caused by the reconversion of the production methods in greenhouse, socio-environmental benefits of sure interest would still be obtained. Indeed, the environmental costs and benefits must be considered as much as the economic ones (De Salvo and Signorello, 2015).

Author contributions

The authors contributed with equal effort to the realization of the study.

CRediT authorship contribution statement

Giovanna Tomaselli: Conceptualization, Project administration, Funding acquisition. **Patrizia Russo:** Conceptualization, Methodology, Writing - review & editing, Visualization. **Lara Riguccio:** Resources, Writing - original draft. **Marzia Quattrone:** Resources, Writing - original draft, Visualization. **Alessandro D’Emilio:** Conceptualization, Methodology, Formal analysis, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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Appendix A

Calculations of numerical indicators

$D_{1,a} = 7500\ m^2$ (Table 9)

$D_{1,b} = 13 \times 10^6\ m^2$ (Table 9)

$D_{1,c} = 159 \times 10^6\ m^2$ (Table 9)

$D_{2,a} = D_{1,a}$

$D_{2,bt} = 7.5 \times 10^6\ m^2$ (Table 9)

$D_{2,bp} = 5 \times 10^6\ m^2$ (Table 9)

$D_{2,ct} = D_{2,cp} = 11.08 \times 10^6\ m^2$ (Table 9)

$D_{3,at}$ is calculated on the basis of the ratio of the mean surface covered by greenhouses to mean surface of greenhouse farm in the Natura 2000 sites within the MP. From Table 8, $D_{3,at} = 4000/7000 \text{ x } D_{2,a} = 0.57 \times 7500 = 4300\ m^2$

$D_{3,ap}$ is calculated according to the master plan prescriptions, which require a surface covered by greenhouses not greater than 10 % of the total farm surface. Therefore, $D_{3,ap} = 0.1 \text{ x } D_{2,a} = 750\ m^2$

$D_{3,bt} = 0.57 \text{ x } D_{2,bt} = 0.57 \times 7.5 \times 10^6 = 4.275 \times 10^6\ m^2$

$D_{3,bp} = 0.1 \text{ x } D_{2,bp} = 0.1 \times 5 \times 10^6 = 0.5 \times 10^6\ m^2$

$D_{3,ct} = 0.57 \text{ x } D_{2,ct} = 0.57 \times 11.08 \times 10^6 = 6.315 \times 10^6\ m^2$

$D_{3,cp} = 0.1 \text{ x } D_{2,cp} = 0.1 \times 11.08 \times 10^6 = 1.11 \times 10^6\ m^2$

$D_{4,a} = 1$

$D_{4,bt}$ is calculated as the ratio between the surface of the lot with greenhouses and the mean surface of greenhouse farm. $D_{4,bt} = D_{2,bt} / 7000 = 7.5 \times 10^6 / 7000 = 1071$

$D_{4,bp} = D_{2,bp}/7000 = 5 \times 10^6 / 0.007 = 715$

$D_{4,ct} = D_{2,ct} / 7000 = 11.08 \times 10^6 / 7000 = 1583$

$D_{4,cp} = D_{2,cp} / 7000 = 11.08 \times 10^6 / 7000 = 1583$

$D_{5,a} = 380$ m (measured on the map).

$D_{5,bt}$ The value is calculated as the sum of the perimeters of the lots with greenhouses within the master plan area in the current status: $D_{5,bt} = D_{4,bt} \text{ x } P_b$ where $P_b = 353$ m, is the perimeter of the mean lot with a side length of 60 m. $D_{5,bt} = 1071 \times 353 = 378063$ m.

$D_{5,bp}$ The value is calculated as the sum of the perimeters of the lots with greenhouses within the master plan area in the project status:

$D_{5,bp} = D_{4,bp} \times P_b = 715 \times 353 = 252395$ m.

$D_{5,ct}$ The value is calculated as the sum of the perimeters of the lots with greenhouses within the MP area in the current status: $D_{5,ct} = D_{4,ct} \times P_b = 1583 \times 353 = 558799$ m.

$D_{5,cp} = D_{5,ct} = 558799$ m.

$D_{6,at}$ From Table 9, $D_{6,at} = 1\text{-}(4000/7000) \times D_{2,a} = 0.43 \times 7500 = 3225$ m^2

$D_{6,ap}$ is calculated according to the master plan prescriptions, which require a surface covered by greenhouses not greater than 10 % of the total farm surface. Therefore $D_{6,ap} = 0.9 \times 6750$ m^2

$D_{6,bt} = 0.43 \times D_{2,bt} = 0.43 \times 7.5 \times 10^6 = 3.225 \times 10^6$ m^2

$D_{6,bp} = 0.9 \times D_{2,bp} = 0.9 \times 5 \times 10^6 = 4.5 \times 10^6$ m^2

$D_{6,ct} = 0.43 \times D_{2,ct} = 0.43 \times 11.08 \times 10^6 = 4.764 \times 10^6$ m^2

$D_{6,cp} = 0.9 \times D_{2,cp} = 0.9 \times 11.08 \times 10^6 = 9.972 \times 10^6$ m^2

$V_{1,ap}$ is calculated as the product between the perimeter of the sustainable lot and the width of the hedgerow made up by typical steno-Mediterranean plants, provided by the project along the entire perimeter of the lot. Therefore, $V_{1,ap} = D_{5,a} \times 2.50$ m $= 380 \times 2.50 = 950$ m^2

$V_{1,bp} = D_{4,bp} \times V_{1,ap} = 715 \times 950 = 0.68 \times 10^6$ m^2

$V_{1,cp} = D_{4,cp} \times V_{1,ap} = 1583 \times 950 = 1.5 \times 10^6$ m^2

$V_{2,ap} = 1000$ m^2 (from the project of the sustainable lot)

$V_{2,bp} = D_{4,bp} \times V_{2,ap} = 715 \times 1000 = 0.715 \times 10^6$ m^2

$V_{2,cp} = D_{4,cp} \times V_{2,ap} = 1583 \times 1000 = 1.58 \times 10^6$ m^2

$V_{3,ap} = 3000$ m^2 (from the project of the sustainable lot)

$V_{3,bp} = D_{4,bp} \times V_{3,ap} = 715 \times 3000 = 2.145 \times 10^6$ m^2

$V_{3,cp} = D_{4,cp} \times V_{3,ap} = 1583 \times 3000 = 4.75 \times 10^6$ m^2

$V_{4,at}$ From Table 9, the water consumption for irrigation is 0.8 m^3/(m^2 year). Therefore $V_{4,at} = 0.8 \times D_{3,at} = 0.8 \times 4300 = 3440$ m^3/year

$V_{4,ap}$ The value is calculated on the basis of the sustainable greenhouse project with a covered area of 750 m^2, considering 8 rows with 6 plants/m, a total length of 40 m and a water consumption per plant of 0.139 m^3. Therefore, the number of plants is $8 \times 6 \times 40 = 1920$ and, as a result, the water consumption per cycle is $1920 \times 0.139 = 267$ m^3. Assuming 2 cycles per year, $V_{4,ap} = 2 \times 267 = 534$ m^3/year

$V_{4,bt} = 0.8 \times D_{3,bt} = 0.8 \times 4.275 \times 10^6 = 3.42 \times 10^6$ m^3/year

$V_{4,bp} = V_{4,ap} / D_{3,ap} \times D_{3,bp} = 534 / 750 \times 0.5 \times 10^6 = 0.36 \times 10^6$ m^3/year

$V_{4,ct} = 0.8 \times D_{3,ct} = 0.8 \times 6.315 \times 10^6 = 5.05 \times 10^6$ m^3/year

$V_{4,cp} = V_{4,ap} / D_{3,ap} \times D_{3,cp} = 534 / 750 \times 1.11 \times 10^6 = 0.79 \times 10^6$ m^3/year

$V_{5,at}$ The value is calculated assuming a nitrogen consumption of 0.04 kg/(m^2 year) (Table 10). Therefore, $V_{5,at} = 0.04 \times D_{3,at} = 0.04 \times 4300 = 172$ kg/year

$V_{5,ap}$ The value is calculated assuming a nitrogen consumption of 196.4 g for each m^3 of irrigation (Table 11). The Nitrogen consumption per year is $V_{5,ap} = 196.4 \times V_{4,ap} = 196.4 \times 534 = 104.9$ kg/year

$V_{5,bt} = 0.04 \times D_{3,bt} = 0.04 \times 4.275 \times 10^6 = 0.17 \times 10^6$ kg/year

$V_{5,bp} = V_{5,ap} / D_{3,ap} \times D_{3,bp} = 104.9 / 750 \times 0.5 \times 10^6 = 0.07 \times 10^6$ kg/year

$V_{5,ct} = 0.04 \times D_{3,ct} = 0.04 \times 6.315 \times 10^6 = 0.25 \times 10^6$ kg/year

$V_{5,cp} = V_{5,ap} / D_{3,ap} \times D_{3,cp} = 104.9 / 750 \times 1.11 \times 10^6 = 0.15 \times 10^6$ kg/year

$V_{6,at}$ = The value is calculated assuming a phosphorus consumption of 0.025 kg/(m^2 year) (Table 10). Therefore, $V_{6,at} = 0.025 \times D_{3,at} = 0.025 \times 4300 = 107.5$ kg/year

$V_{6,ap}$ The value is calculated assuming a consumption of 40.75 g for each m^3 of irrigation (Table 11). The phosphorus consumption per year is $V_{6,ap} = 40.75 \times V_{4,ap} = 40.75 \times 534 = 21.8$ kg/year

$V_{6,bt} = 0.025 \times D_{3,bt} = 0.025 \times 4.275 \times 10^6 = 0.11 \times 10^6$ kg/year

$V_{6,bp} = V_{6,ap} / D_{3,ap} \times D_{3,bp} = 21.8 / 750 \times 0.5 \times 10^6 = 0.02 \times 10^6$ kg/year

$V_{6,ct} = 0.025 \times D_{3,ct} = 0.025 \times 6.315 \times 10^6 = 0.16 \times 10^6$ kg/year

$V_{6,cp} = V_{6,ap} / D_{3,ap} \times D_{3,cp} = 21.8 / 750 \times 1.11 \times 10^6 = 0.03 \times 10^6$ kg/year

$V_{7,at}$ = The value is calculated assuming a potassium consumption of 0.07 kg/(m^2 year) (Table 10). Therefore, $V_{7,at} = 0.07 \times D_{3,at} = 0.07 \times 4300 = 301$ kg/year

$V_{7,ap}$ The value is calculated assuming a potassium consumption of 307.3 g for each m^3 of irrigation (Table 11). The phosphorus consumption per year is $V_{7,ap} = 307.3 \times V_{4,ap} = 307.3 \times 534 = 164.1$ kg/year

$V_{7,bt} = 0.07 \times D_{3,bt} = 0.07 \times 4.275 \times 10^6 = 0.3 \times 10^6$ kg/year

$V_{7,bp} = V_{7,ap} / D_{3,ap} \times D_{3,bp} = 164.1 / 750 \times 0.5 \times 10^6 = 0.11 \times 10^6$ kg/year

$V_{7,ct} = 0.07 \times D_{3,ct} = 0.07 \times 6.315 \times 10^6 = 0.44 \times 10^6$ kg/year

$V_{7,cp} = V_{7,ap} / D_{3,ap} \times D_{3,cp} = 164.1 / 750 \times 1.11 \times 10^6 = 0.24 \times 10^6$ kg/year

$V_{8,at}$ = The value is calculated assuming a consumption of chemicals of 0.0071 kg/(m^2 year) (Table 10). Therefore, $V_{8,at} = 0.0071 \times D_{3,at} = 0.0071 \times 4300 = 30.5$ kg/year

$V_{8,ap} = 0$. No treatment is required on the substrates because the cultivation technique provides for the disinfestation of the nutrient solution by means of UV-rays.

$V_{8,bt} = 0.0071 \times D_{3,bt} = 0.0071 \times 4.275 \times 10^6 = 0.03 \times 10^6$ kg/year

$V_{8,bp} = 0$

$V_{8,ct} = 0.0071 \times D_{3,ct} = 0.0071 \times 6.315 \times 10^6 = 0.04 \times 10^6$ kg/year

$V_{8,cp} = 0$

$V_{9,at}$: the value is calculated assuming a consumption of insecticides of 0.0058 kg/(m^2 year) (Table 10). Therefore, $V_{9,at} = 0.0058 \times D_{3,at} = 0.0058 \times 4300 = 25$ kg/year

$V_{9,ap}$: as a precautionary measure, the consumption of insecticides is assumed to remain unchanged, so that the reduction of chemicals in the atmosphere is only related to the smaller surface occupied by the greenhouse. Therefore, $V_{9,ap} = 0.0058 \times D_{3,ap} = 0.0058 \times 750 = 4.4$ kg/year

$V_{9,bt} = 0.0058 \times D_{3,bt} = 0.0058 \times 4.275 \times 10^6 = 0.025 \times 10^6$ kg/year

$V_{9,ap} = 0.0058 \times D_{3,bp} = 0.0058 \times 0.5 \times 10^6 = 0.003 \times 10^6$ kg/year

$V_{9,ct} = 0.0058 \times D_{3,ct} = 0.0058 \times 6.315 \times 10^6 = 0.037 \times 10^6$ kg/year

$V_{9,cp} = 0.0058 \times D_{3,cp} = 0.0058 \times 1.11 \times 10^6 = 0.006 \times 10^6$ kg/year

$V_{10,at}$: the value is calculated assuming a consumption of plastics of 0.5 kg/(m^2 year) (Table 10). Therefore, $V_{10,at} = 0.5 \times D_{3,at} = 0.5 \times 4300 = 2150$ kg/year

$V_{10,ap}$: the value is calculated on the basis of the greenhouse design in the project of the sustainable lot. Specifically, $V_{10,ap} = V_{10,ap1} + V_{10,ap2} + V_{10,ap3} + V_{10,ap4}$ where $V_{10,ap1}$, $V_{10,ap2}$, $V_{10,ap3}$, $V_{10,ap4}$ are the amount of plastic for greenhouse covering, soil mulching, substrate troughs and irrigation system, respectively. In order to get $V_{10,ap1}$ the calculation of the greenhouse surface is necessary. Roof surface: $9.1 \times 45 \times 2 = 820$ m^2; side surface: $(3{,}5\text{-}0.75) \times 45 \times 2 = 250$ m^2; Total surface: $820 + 250 = 1070$ m^2. This value is increased to 1200 m^2 in order to consider the installation waste. Since a three-year plastic is adopted, the yearly consumption will be 400 m^2/year. A specific weight of 0.184 kg/m^2 can be estimated for a 200 μm thickness film. Therefore, the total weight of the plastic for greenhouse covering is: $V_{10,ap1} = 400 \times 0.184 = 73.6$ kg/year, which can be rounded upward to 75 kg/year. In order to get $V_{10,ap2}$ the calculation of the crop area inside the greenhouse is necessary. Surface of the crop area: $16 \times 42{,}5 = 680$ m^2. A specific weight of 0.046 kg/m^2 can be estimated for a 50 μm thickness film. Therefore the total weight of the plastic is: $V_{10,ap2} = 680 \times 0.046 = 32$ kg/year. In order to get $V_{10,ap3}$ the calculation of the surface of the substrate troughs is necessary. The surface of a trough $100 \times 15 \times 20$ cm is 7600 cm^2 = 0.76 m^2; the number of troughs is: $8 \times 40 = 320$ so that the total surface of troughs is: $320 \times 0.76 = 243.2$ m^2. Assuming a specific weight of 0.046 kg/m^2, the total weight of the plastic is: $V_{10,ap3} = 243.2 \times 0.046 = 11.2$ kg/year. In order to get $V_{10,ap4}$ the calculation of the length of the tubes for the irrigation system is necessary. The system is made up by 120 drippers with 2 tubes of 60 cm length for each row. Therefore the total length of the tubes is: $120 \times 8 \times 2 \times 0.6 = 1{,}152$ m. Assuming a specific weight of 0.1 kg/m the total weight of the plastic is: $V_{10,ap4} = 1{,}152 \times 0.1 = 115.2$ kg/year. Finally, $V_{10,ap} = 73.6 + 32 + 11.2 + 115.2 = 232$ kg/year

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