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Regenerative Design - Climate Adaptation & Mitigation
Circular Economy - Citizen Agency - Urban Livability

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Contents

5 EDITORIAL PREFACE
Rocco Papa

FOCUS

9 **The impact of Land Use and Land Cover (LULC) changes on coastal dynamics through landscape structure**
Makbulenur Onur

27 **Spatial and temporal evolution of urban reserve available land resources in the Karst region of North China from 1990 to 2020: a case study of Jinan city**
Shujin Wang, Shanzhong Qi

LUME (Land Use, Mobility and Environment)

41 **Assessing urban growth and pollution through nightlight data: a case study in Thailand**
Chaichana Kulworatit, Phuvis Kerdpramote, Saranya Saetang

63 **Exploring governance challenges in coastal and marine tourism. A comparative analysis of European case studies**
Barbara Gasparini di Gaetano, Emanuel Giannotti, Vittore Negretto, Denis Maragno

79 **Dynamic map decision support systems for spatial and mobility planning**
Mara Ladu, Ginevra Balletto, Tanja Congiu, Gianfranco Fancello, Ernesto Fontes Pupo

97 **Biodiversity and ecological network: connecting ecosystem services for a sustainable future. GeoAI for modica green city.**
Celestina Fazia, Chiara Spadaro

117 **Examining the temporal and spatial change of current land cover types in Demre District using machine learning**
Sibel Akten, Hüseyin Batuhan Dündar, Atila Gül

137 **Evaluating urban fabric transformations using GeoAI**
Alessandro Vitale

151 **CITISENSE. Enhancing urban well-being through smart design, data and AI in Italy's historic centres**
Pierfrancesco Celani, Daniel Enrique Sardo, Massimo Zupi, Margherita Tufarelli, Adriano Bisello

171 **Planning for sustainable tourism in protected areas. A policy-oriented spatial evaluation framework**
Rachele Vanessa Gatto, Francesca Perrone, Francesco Scorza

189 **Monitoring urban dynamics using Google Earth and GeoAI**
Francesco Lamonaca

REVIEW NOTES

201 **“Brain gain” in planning academia: learning from Albania’s practical approaches**
Irina Branko, Erida Curraj, Dorina Pojani

209 **Digital governance of the energy transition: regulatory frameworks, data infrastructures, and spatial planning**
Valerio Martinelli

217 **Governing the transformations of public space: active travel policies for people's health and well-being**
Annunziata D’Amico

225 **Soft adaptation measures for disaster risk reduction and urban resilience. Early warning systems**
Stella Pennino

239 **Modelling microclimatic characteristics for climate change adaptation solutions: the ENVI-met simulation tool**
Tonia Stiuso

245 **Adaptation insight: the state of climate knowledge**
Laura Ascione

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Biodiversity and ecological network: connecting ecosystem services for a sustainable future. GeoAI for Modica green city

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Abstract
Against a backdrop of growing environmental awareness and the need to mitigate climate change impacts, urban spatial planning and management policies inspired by European sustainable development recommendations are gaining strength. These policies address environmental issues through concrete actions aligned with the 17 goals of Agenda 2030. For these strategies to be effective, it is essential to identify tools—particularly urban planning instruments—capable of ensuring the desired outcomes, making cities resilient and ready to face the energy and ecological transition according to an ecosystemic and participatory approach, in line with Policy OP5. Several urban planning instruments promote the 'resilient' upgrading of cities by assigning ecosystem services and biodiversity an active role in counteracting climate change and territorial vulnerability. In Sicily, following Regional Law no. 19/2020, the PUG introduces environmental-ecological endowments such as the Ecological Network. Effective planning and management of environmental heritage require adopting appropriate measures to protect species and preserved areas, ensuring their conservation for future generations. This enables the implementation of an 'innovative' environmental infrastructure through the reorganization of development drivers and the digital representation of its evolving forms. An example of such an 'innovative' ecosystem approach is the "Modica Green City Masterplan," developed with GeoAI support, complementary to the PUG by providing a knowledge base for planning scenarios and environmental assessment of transformation choices.

Keywords
Ecological network; Ecosystem services; Biodiversity; Sustainable infrastructure; Resilience

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1. Introduction

The term biodiversity, coined in 1988 by the American entomologist Edward O. Wilson[1], refers to the multiplicity of living beings that inhabit our planet, thus the result of the many evolutionary processes that have taken place (Wang et al., 2020). A first official definition was provided in 1991 by the World Conservation Union (IUCN) and WWF, according to which it is 'the variety of life in all its forms, levels and combinations. It includes the diversity of ecosystems, species and genetic diversity.' It is in reading this initial definition that one realises how complex the concept of biodiversity really is, welcoming within it all the varied forms of life present in a natural area, giving rise to a dense network of internal relationships and allowing them to coexist and ensure a dynamic balance over time (Ceralli, 2023). This complex process is thus schematised into three macro levels that define biodiversity: genetic diversity, taxonomic diversity and ecological diversity. Over time, intensive anthropogenic activity and economic-industrial development broke the ecosystem balance (Ahern, 2013) and put its resilience to the test; today, the effects of climate change are particularly threatening biodiversity -the most important resource for our planet- by compromising the optimal conditions of local habitats and ecosystems (Eger, 2009). It must be emphasised that biodiversity affects landscape, social, and cultural diversification processes, bringing only and only benefits to human beings. It is also true that the effects of poor environmental management, careless human activities and indiscriminate use of resources directly and indirectly affect biodiversity, and the risk of loss of 'diversity' is considerable. Diversity that is the fundamental prerequisite for ecosystem balance (Ceralli, 2023).

Species diversity includes species richness, which can be measured in terms of the quantity of the same species present in a given area, or species frequency, understood as rarity or abundance in a habitat. The third (ecological diversity) defines the variety of genetic heritage to which all organisms contribute (Reid, 2019).

The need to geo-reference and map 'diversity' at the various levels became apparent with the establishment of the Natura 2000[2] Network. The mapping of the Network is not static. On the NNB (National Biodiversity Network, of ISPRA)[3] site, it is possible to view information on the Natura 2000 network. The NNB[4] map contains data on the presence of census species and the SIC/ZPS/ZSC of the Natura 2000 network updated to December 2023.[5] NNB spreads the care of nature in the city by renewing the way of planning urban spaces and promoting virtuous actions by administrators, communities, citizens, in order to increase biodiversity in urban systems also through urban reforestation actions and the enhancement of green and blue infrastructures (Ahern, 2013). Therefore, the mapping of Natura 2000 Network of the Iblea province and especially Modica, the pilot case of this essay, is shown in (Fig.1).

Today, we have the possibility to monitor the quantity of species, threatened species, and the surface areas of habitats, but this has all happened in less than fifty years (Trusel et alii, 2018). Introducing a brief regulatory preamble, it was from the 1960s onwards that environmental issues began to gain prominence thanks to the emergence of environmental associations such as World Wildlife Found in 1961 and Greenpeace in 1971, which adopted the first regulatory measures regarding environmental protection (Wooster, 2022). Specifically, environmental and economic issues became central within the Stockholm International Agenda in 1972. It was within this document that the definition of Sustainable Development was first introduced, understood as

[1] https://www.isprambiente.gov.it/it/attivita/biodiversita/le-domande-piu-frequenti-sulla-biodiversita/cose-la-biodiversita

[2] With the two directives, Habitats and Birds, the network is established to all intents and purposes. The Natura 2000 network consists of Sites of Community Interest (SIC), identified by Member States in accordance with the Habitats Directive, which are subsequently designated as Special Areas of Conservation (ZSC), and also includes Special Protection Areas (ZPS) established under the Birds Directive 2009/147/EC on the conservation of wild birds.

[3] https://www.nnb.isprambiente.it/it

[4] NNB is a partner of the Urban Nature initiative promoted by the WWF to spread the value and care of nature in the city, renewing the way of thinking and planning urban spaces, and promoting virtuous actions by administrators, communities, citizens, to protect and increase biodiversity in urban systems.

[5] EIONET, Central Data Repository, https://cdr.eionet.europa.eu/it/eu/n2000

'development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs'. One of the most important events was the United Nations Conference in Rio de Janeiro in 1992[6], the results of which included Agenda 21 and the Framework Convention on Biodiversity, mentioned earlier; from these important documents came the guidelines for the Natura 2000 Ecological Networks. A next step is taken with the VI Environmental Action Plan, a programme developed from 2000 to 2010, conceived as a preparatory phase for the instruments later adopted by the European Union, to make this procedure concrete.

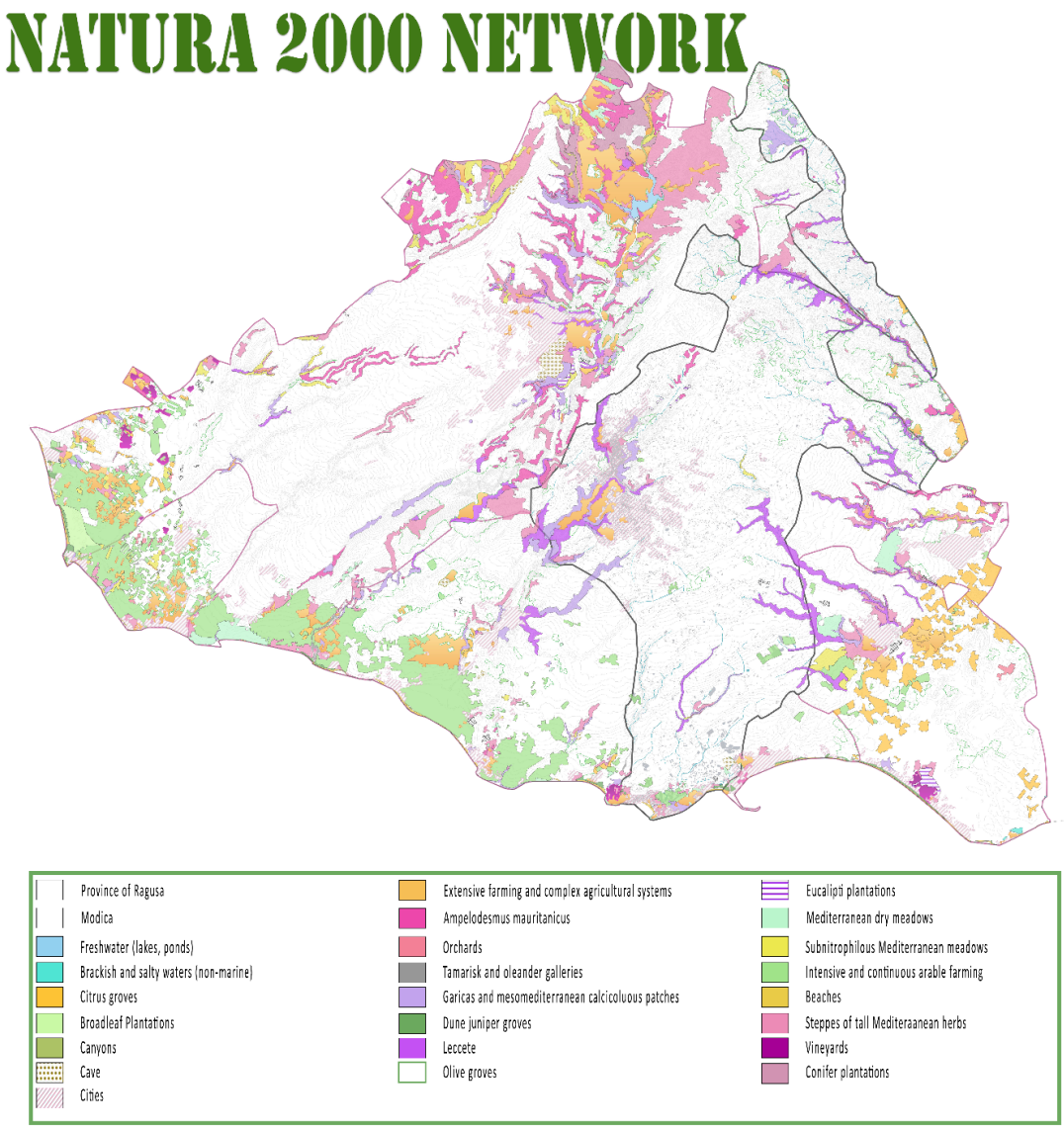


Fig.1 Mapping of the Natura 2000 Network of Modica and its province (Ragusa)

With the spread of reserves[7] -which initially had a purely aesthetic function, protecting scenic and landscape values for purely touristic purposes- and the increase in studies in the field of nature, the awareness of the importance of protected areas as 'places of conservation and protection of ecosystems and biodiversity'[8] is

[6] At this conference, global action was taken by signing two conventions and three declarations on possible strategies for sustainability and halting the negative impact of human activities on the environment.

[7] Protected areas within the dynamics of sustainability in the second half of the 19th century when parks were created only had a purely aesthetic function, as they were intended to protect scenic and landscape values for purely touristic purposes, instead they perfectly reflect the extraordinary natural diversity that surrounds us.

[8] WWF Ricerche e Progetti, Linee guida per l'interpretazione ambientale delle Aree Protette, Novembre 2008

confirmed. This new approach is the evolution of the human-environment, nature-culture binomials, and this dichotomy is being overcome precisely as a result of the socio-cultural changes that have, among other things, led to a greater awareness of environmental dynamics among communities and allowed the concept of sustainable development to take hold (Wooster, 2022). Thus, in the very early 1990s, a proposal for a European Ecological Network was put forward in accordance with the Natura 2000 programme defined by CEE Directive 92/43, mentioned above, which represented the first and official Community response to the Convention on Biodiversity introduced at the Rio Conference (Sánchez-Bayón et alii, 2020). The proposal envisages a network that can include all the protected natural habitats in the international sphere, appropriately connected to each other by means of ecological connection corridors; but the real revolution lies in the symbolic and representative value that the protected areas assume, avoiding the phenomenon of isolation, and also performing a "rhetoric of representation and socio-cultural communication, capable of activating within them models of development capable of exploring and anticipating solutions that can then be extended to the outside world, making the protected areas become a sort of points of excellence."[9] The ecological network, in these terms, translates more into a system of protected areas that relates not only habitats to each other, but also all the elements that contribute to the ecosystem balance.

In the most up-to-date approach, it is to be understood as an element of connection, use, interface and filter, aiming to overcome the fragmentation of the core natural areas by providing an international network of habitats and a programme of land management and protection, aimed at making the territory resilient. It envisages, therefore, an international network of protected natural habitats, interconnected by ecological connection corridors (typologically divided into natural areas, diffuse linear corridors, stepping stones, buffer zones, core areas), In fact, (Fig.2) shows a summary and explanatory diagram of all the components that make up this network.

The main objective is the protection but above all the improvement of biodiversity in qualitative-quantitative terms; the maintenance of this for future generations -by individually protecting the abiotic or biotic elements that make up the various ecosystems- becomes a priority (Sánchez-Bayón et alii, 2020). Recently, the protection of ecosystems and biodiversity is associated with broader strategies that include adaptation measures to manage climate change (Papa, 2024). Cities are at the forefront of the climate crisis we are experiencing[10] - extreme weather events are becoming increasingly frequent. Some cities, such as Dhaka North City Corporation and the Guadalajara Metropolitan Area, already in close contact with biodiversity, have taken tangible and positive steps to make nature, infrastructure and local communities more resilient and ready to mitigate the impacts of climate collapse, thanks to green adaptation measures and a strengthened relationship with the environment. Green adaptation measures are embodied in the system of interventions that enhance the relationship with nature, biodiversity and ecosystem benefits (Sánchez-Bayón et alii, 2020). Examples of these types of interventions are (ISPRA, 2021):[11]

- actions aimed at the hydro-morphological rehabilitation of riverbeds;
- the use and reinforcement of vegetation that can withstand high wind speeds or that can protect urban areas from direct sunlight, thus limiting overheating;
- projects for the renaturalisation of infrastructure margins and the reconstitution and enhancement of riparian greenery intercepted by watercourses in urban areas.

In relation to infrastructures, the 'climate proofing' process (articulated in two pillars, Adaptation and Mitigation, respectively) envisaged in the European Commission's guidelines (C(2021) 5430 final of 29.7.2021)

9 Gambino. R., Progetti per l'ambiente, Franco Angeli, Milano, 1996

10 C40Cities, Costruire la resilienza climatica, https://www.c40.org/it/awards/building-climate-resilience/

11 ISPRA (2021) Rapporto sulle condizioni di pericolosità da alluvione in Italia e indicatori di rischio associati, in https://www.isprambiente.gov.it/it/pubblicazioni/rapporti/rapporto-sulle-condizioni-di-pericolosita-da-alluvione-in-italia-e-indicatori-di-rischio-associati

indicates appropriate adaptation measures to climate change, with the evidence that the 'climate risk and vulnerability assessment' remains the pivot around which the identification and evaluation of the most appropriate measures to make territories resilient revolves (Sánchez-Bayón et alii, 2020).

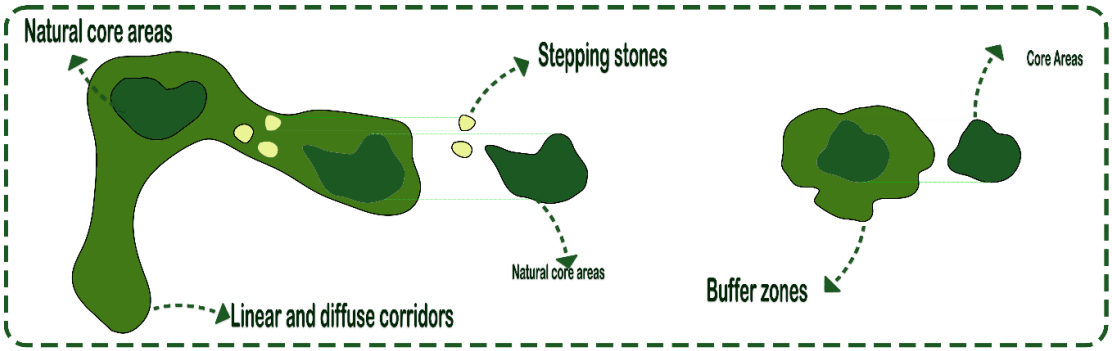


Fig.2 Explainning diagram of the ecological network

This entails both the need to manage, through sophisticated and intelligent systems, information on ecosystems and biodiversity, the dynamics of their evolution, and the use of artificial intelligence providing planners with information on the status of implementation of interventions, the identification of areas threatened or depleted as a result of incompatible anthropogenic activities.

By means of a Masterplan model linked to a QGis database, proposed within the framework of this research, it will be possible to map the different components of the ecological network, visualise and understand the planning strategies, helping decision-makers in the assessment of the sustainability of redevelopment projects, the promotion and monitoring of the actions envisaged in the Masterplan. This is aided by intelligent systems that will enable the transition from its development to future management and implementation. The implementation of the Digital Twin, i.e the development of a digital twin of the master plan, will also be useful for improving urban management and land-use planning and can enable the use of big data to optimise the delivery of new facilities and services while predicting future problems and assessing the impact of projects and their alternatives. This digital contribution -by equipping the city with sensors- allows real simulations with possible environmental, social and economic scenarios and conditions. In the European scientific sphere, some realities are moving within the Net Zero Cities programme with the help of Digital Twin technology: Amsterdam is an excellent example of a DI prototype for traffic monitoring and planning of green areas, using IoT and Big Data. Athens, still in the development phase, has implemented a model aimed at monitoring human actions in relation to the life cycle of the environment. In Florence, a model operating with the aid of software such as GIS is already operational, allowing the three-dimensional visualisation of a city environment; an interactive space where maps of heat, infrastructure, traffic flow analysis and urban development can be found.

For the case study analysed, Modica green city, propaedeutic to the construction of the master plan model was the definition of the ecosystem approach as a transversal and integrated management modality.

1.2 Materials and methods, ecosystem approach

Ecosystem management[12] is 'a strategy that promotes the conservation and sustainable and equitable use of land, water and living resources through integrated ecosystem management' in order to ensure that the ecosystem is maintained in a healthy and resilient condition and that it is productive by continuously providing humans with the goods and services they need. Compared to recurring approaches aimed at protecting a single species (humans) or specific activities and sectors, the ecosystem approach (Baldini, 2023) considers the interactions and cumulative effects of different sectors in an integrated manner.

[12] Ministero dell'ambiente e della sicurezza energetica, https://www.mase.gov.it/pagina/approccio-ecosistemico

The concept of the ecosystem approach was adopted by the Convention on Biological Diversity (CBD) in 1995 and developed by the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention-SBSTTA-which identified 12 specific principles to contribute to its achievement, Malawi Principles. Through the Framework Directive 2008/56/CE, this objective became binding on Member States and was made operational through the Good Environmental Status (GES) definitions. This approach found specific application for the management of human activities affecting the marine and coastal environment, identifying a specific process for its application, the Ecosystem Approach Process (EcAp), aimed at achieving Good Environmental Status at sea.[13] Resolutive for integrated management and to guarantee an ecosystem approach to territories, are the Community cohesion policies that dictate some fundamental principles to combine biodiversity and environmental protection with strategies for ecological transition and the fight against climate change (Ceralli, 2023).

The cohesion policy for the programming period 2021-2027 envisages the pursuit of five policy objectives (OPs):

- OP1, for a smarter Europe through innovation, digitisation and economic transformation;
- OP2, for a green and carbon-free Europe;
- OP3 for a more connected Europe with strategic transport networks;
- OP4, aiming for a more social Europe, delivering on the European pillar of social rights and supporting quality employment, education, skills, social inclusion and equal access to healthcare;
- OP5, for a Europe closer to citizens through support for locally managed development strategies and sustainable urban development across the EU.

According to OP5, territorial strategies must be implemented in synergy with other policy objectives, with the primary aim of promoting the economic and social development of the areas most affected by poverty.[14]

Strategic Policy Objective 5 'A Europe closer to the citizen' (OP5) is where the programmes' support for urban and non-urban[15] Spatial Strategies (ST) is organised. Each ST articulates a project for change shared by the local community, following a deliberative process.

The ST are supported by a broad set of resources capable of activating interventions on multiple dimensions and implemented with the active involvement of local actors. Programme resources are made available for local coalitions to choose from.

Through a careful use of the formal spaces of participatory construction, the FESR and FSE Plus Programmes organise the support to the ST through the resources of OP5 and the other OP. The Programmes narrate the overall design of the ST.[16] A Territorial Strategy is the most effective tool to actively involve communities, in fact, the local stakeholders of the ecosystem thus defined, will express themselves to concentrate resources and energies on the three dimensions of sustainability, promoting the valorisation of natural, cultural and landscape resources, the revitalisation of the economic fabric, the regeneration of places and social inclusion. The address related to the participatory construction of hypothetical future scenarios was associated with the master plan, which has the task of translating the identified instances into operational and programmatic terms.

[13] The Maritime Spatial Planning Directive (2014/89/EU) also bases the pursuit of its objectives on the application of this principle. In 2007, the signatories to the Barcelona Convention adopted the ecosystem approach for the management of human activities affecting the marine and coastal environment, identifying a specific process for its application, aimed at achieving Good Marine Ecological Status.

[14] Investments, at territorial level, can be activated with reference to the following functional areas: - inland areas facing demographic challenges and poverty called upon to improve the quality of services of general interest; - metropolitan functional areas for poverty-related challenges also caused by the 'agglomeration' effect; - medium-sized urban areas to develop innovative ways of cooperation to improve their economic, social and environmental potential, taking into account the most vulnerable groups.

[15] art. 29 del Regolamento (UE) n. 1060/2021

[16] Also taking into account other resources: national resources, FEASR (rural development) and FEAMPA (fisheries)

The Laboratory dedicated to the Policy Objective -the LabOP5- involved numerous central administrations and various Italian regional realities in addressing issues related to:

- the representation of the Territorial Strategies in the formal spaces of the Programme Template in order to accompany Administrations in formulating and explicating the programme promise of multidimensional support to the Territorial Strategies;
- the definition of the system of indicators at Programme level: analysis of the fiches of the common output indicators and preliminary activities to identify possible 'meta' result indicators, measurable, significant and implementable.

Resolutive for the integrated management and to guarantee an ecosystem approach to the territories, are the community cohesion policies that dictate some fundamental principles in order to combine the protection of biodiversity and the environment with the strategies for the ecological transition and the fight against climate change, which can take place by reorganising the rules of operation of the existing city and by providing new architectural design criteria.

The research focuses on the role of the ecological network in combating climate change; the chosen case study deals specifically with the RER, Regional Ecological Network, of the municipality of Modica and the strategies to activate sustainable development drivers. The hypothesis is to implement a 'Modica Green' Masterplan model and a memorandum of understanding to incentivise the administration to adopt the measures it envisages.

2. Literature review

In the literature review, particular attention was given to ecological network projects already in place. Of these, a series of policies, methods and significant elements were analysed in order to understand the innovations in approaches and instruments. The selection criteria chosen -such as the territorial dimension, participation and social inclusion activities- returned an interesting picture of best practices (Fig.3).

The Milan Ecological Network project was particularly interesting because the Milanese territory has undergone numerous anthropisation activities and therefore in this context, the creation of a territorial planning programme that can in some way rebalance the environmental context is of particular importance for the territory. The planning strategies therefore concern the planning and implementation of an interconnected system of natural areas that can guarantee adequate levels of protection and increase in biodiversity (Baldini, 2023). In the specific case study, the components used for the realisation of the Milan ecological network are mainly natural elements called Ganglia and territorial strips characterised by good vegetation equipment. Thanks to the project's ecological corridors, genetic exchange can be guaranteed and enhanced.

An Ecological Network Project has therefore been constructed, extended to the entire provincial territory, which has become part of the PTCP (Provincial Territorial Coordination Plan) and its Implementation Regulations.

The aims of this project are in line with those of Directive 92/43/CEE 'Habitat[17] which aims to 'safeguard biodiversity through the conservation of natural habitats and of wild flora and fauna in the European territory' and to build 'a coherent European ecological network of special areas of conservation, called Natura 2000.[18]

An interesting management method for protected areas, functional to ecological connectivity, is certainly the one adopted by Trentino with the Networks of Reserves. This project is based on the participation and integration of nature conservation policies and the social and cultural development of communities.

[17] Received in Italy by DPR 357/97

[18] Città Metropolitana di Milano, in https://www.cittametropolitana.mi.it/pianificazione_territoriale/ambiente/ambiente/rete_ecologica/

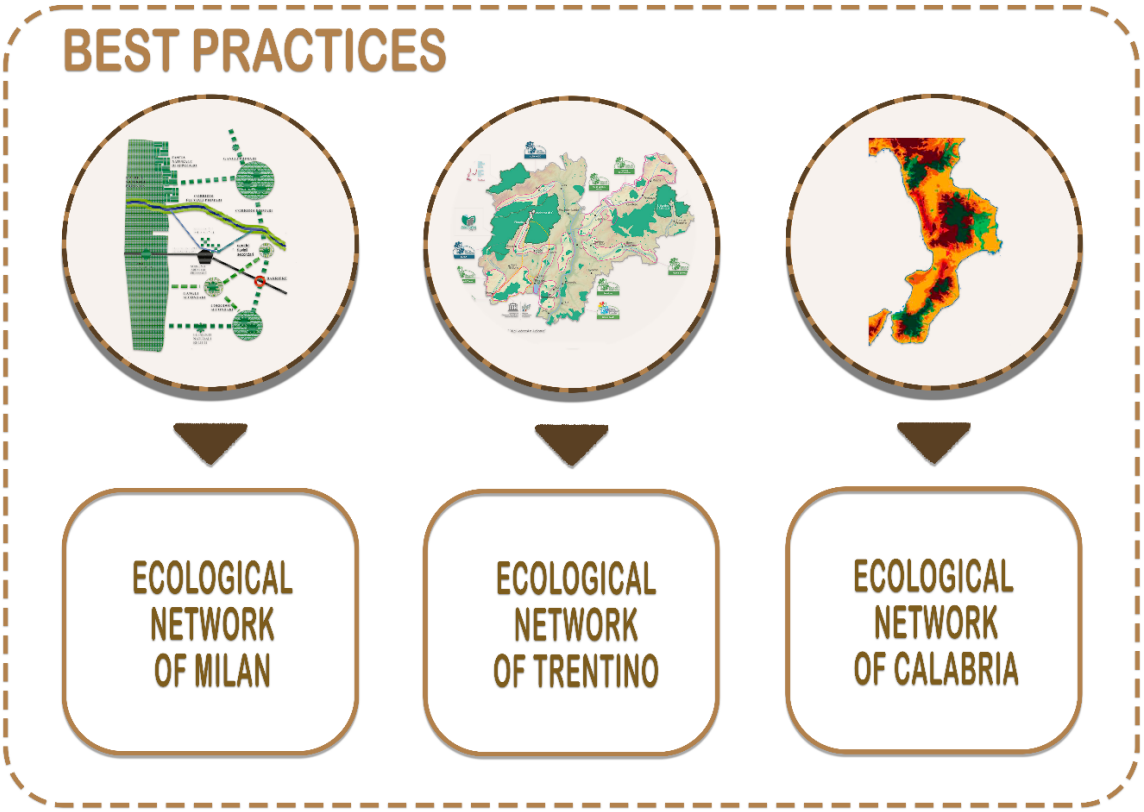


Fig.3 Best practice of Ecological Network in Italy

With the integrated 'LifeTEN' project, the drafting of the provincial ecological network was based on the Reserve Networks. The territory was subdivided into 14 homogeneous territorial areas for each of which a programme was drawn up containing protection actions and strategies for ecological connectivity; of these areas, 10 represent reserve networks that function perfectly as instruments for the innovative management of protected areas. The networks are based on the management delegation given to local authorities by the provincial administration; the direct participation of administrators, technicians, entrepreneurs is also very important in this respect. This will ensure perfect harmony between nature policies and socio-economic development instruments. The governance model used for the management of the existing protected areas has led to a series of initiatives aimed at the conservation and enjoyment of the protected areas; among the very first initiatives are the restoration of wetlands, the mowing of meagre meadows for habitats of community interest and the formation of water holes to ensure the reproduction of the yellow-bellied toad. There has also been a great deal of planning interest and territorial enhancement with the creation of equipped footpaths, the setting up of visitor centers and the establishment of information panels.

The regional ecological network of Calabria is proposed as a natural and environmental infrastructure useful to connect the different territorial areas characterised by different levels of environmental sensibility. The Region of Calabria has drawn up a project for a regional ecological network, bringing together parks, regional reserves and SIC. The RER is made up of central areas, buffer zones, continuous and discontinuous ecological corridors, areas of environmental restoration and natural development, and nodes; in all of these components, a design strategy is implemented for both development and conservation, improving the quality of the natural and cultural heritage with targeted promotional measures. Specifically, the programming completion of the Calabria POR indicates the two ways in which the RER is to be implemented:

- Protection and enhancement of natural and environmental resources, targeting local administrations and their consortia;
- Enhancement and development of non-agricultural economic activities, targeting private enterprises, associations and tourism operators.

For the efficient implementation of the Ecological Network, the Department of the Environment has promoted an operational tool: the Strategic Integrated Project approved by resolution No. 759/2003. This aims to enhance the regional territorial areas with a strong landscape value, while also guaranteeing social and economic development. Some projects were implemented immediately thanks to the stipulation of conventions with the region itself and above all thanks to the strategic action.

3. Results

At least two conditions are necessary for the existing city to dialogue with the environmental context from which it draws resources and to which it pours the pollution and waste generated by its functioning: that the overall consumption of resources is based on renewable resources; that the management of urban metabolism transforms waste into energy useful for the functioning of the built environment; and that the recycling of waste takes place in a circular process to guarantee the performance of ecosystem services (Aziz, 2021).
A pilot case capable of bringing together, according to an innovative approach, the issues of ecological network, ecosystem services, circular metabolism and cultural heritage is that of Modica Green city.[19]
Modica, located within the Ibleo territory, occupies the south-eastern part of Sicily, almost creating an island within an island. The city, belonging to the province of Ragusa, boasts a millennial history that is intertwined with the evolution of its territory. The shape that Modica takes on, typical of urbis, undoubtedly derives from the numerous influences that it has known and suffered, but above all from its geo-morphological characteristics and its characteristic orographic trend characterised by considerable elevation changes. The various influences that Modica has undergone have contributed to determining the current configuration not only of the urban fabric, but also of the rural areas linked to the typical production system and the surrounding nature. Today, Modica presents a cultural and environmental heritage of extraordinary value. (Fig.4), it explains the Modican territory, describing its environmental peculiarities on the basis of the Habitat Directive 43/92 and the Sicilian Ecological Network.mThe morphological aspect of the city of Modica is truly unique in that it develops along the eastern edge of the Ibleo territory and allows the municipal territory to be classified into macro-areas; Modica Alta, Modica Bassa and Modica Centro. Their peculiarity is their conspicuous discontinuity due to the numerous faults that make up the so-called 'Canyons', which, originating from river courses and heading towards the sea, naturally act as ecological corridors, guaranteeing the flow.
So, it is precisely the system of quarries, river valleys with V-shaped profiles and a not particularly excessive slope, that are the environmental aspect to be emphasised in enhancement strategies. Of the 'system' of valleys, the most important are Cava del Tellesimo and Cava D'Ispica; some of these host water on a perennial basis and others temporarily. Specifically, the singular Cava Ispica, six kilometres from Modica, has topographical characteristics determined by its strategic position, allowing it to act as a veritable fortress (Trombino, 2016). The Modican coast is characterised by an alternation of rocks and beaches interrupted by Falesie di Cammarana and Cava D'Aliga. These areas are also characterised by marshy areas that host a particular flora and are home to migratory avifauna that find suitable conditions for their break during their migratory routes. The Modica landscape thus gives rise to a system of ecosystems resulting from dissimilar biotic and abiotic components. The Modica territory is also characterised by numerous sites of landscape, archaeological and historical-architectural interest, which give it an extraordinary cultural value. Among the architectural assets of high cultural-historical value are the Cathedral of San Giorgio, included in the UNESCO World Heritage List, the Castle of the Counts, a visible trace of the history of the Modica County (Trombino, 2016), the Church of San Pietro together with the other 100 churches that surround Modica and enrich it with

[19] Study developed as part of Chiara Spadaro's degree thesis entitled 'Modica Greencity. Ecological Network, Ecosystem Services and Cultural Heritage' at the University of Enna Kore, supervisor prof. Celestina Fazia, discussed on 18.07.2024. Activities under the MOD_Ret Ec agreement, between the municipality of Modica and the department of engineering and architecture of Enna, kore university. Municipal Council Resolution No. 284/24

its unique Baroque character. The 7 Natura 2000 sites in the Modican territory (Cava Palombieri, Fiume Tellesimo, Torrente Prainito, Conca del Salto, Cava Ispica, Contrada Religione and Spiaggia Maganuco) create a crown within the municipal territory that can be easily connected to Modica's other historical and architectural specificities.

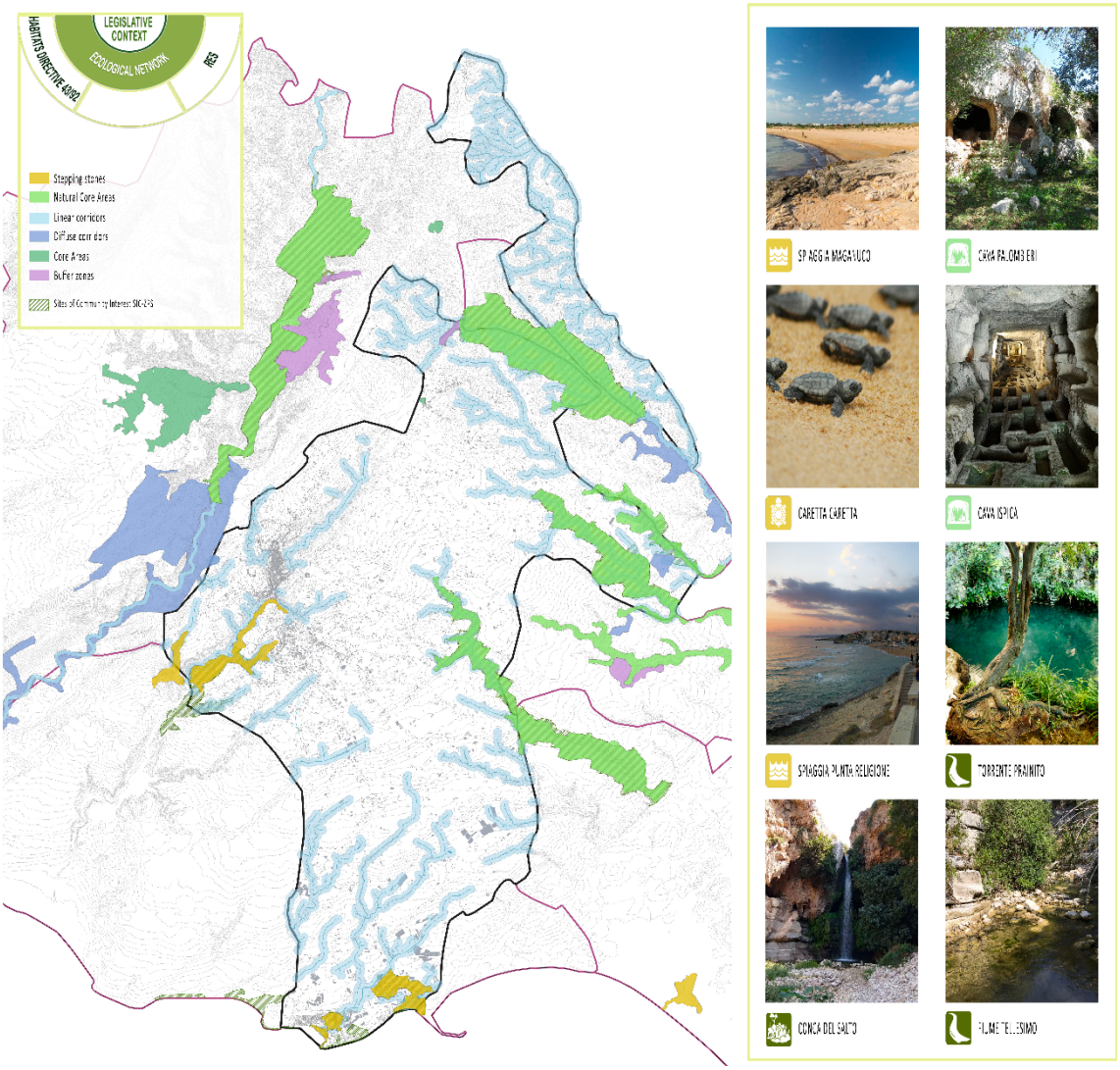


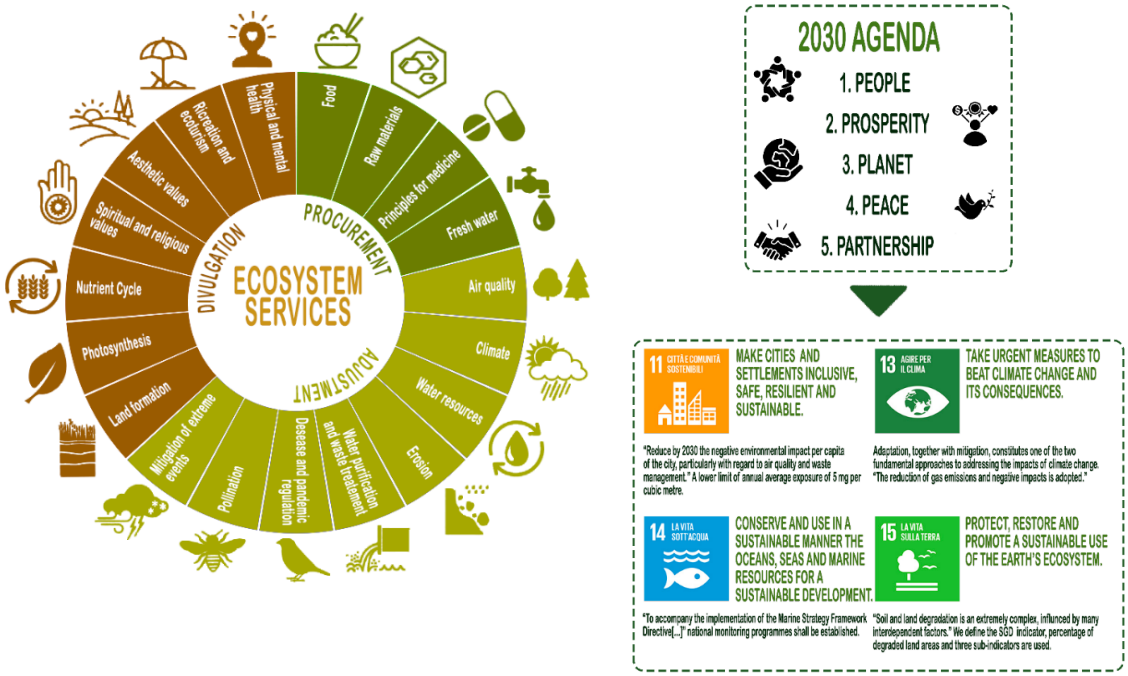
Fig.4 Cartography of Modica's spatial framework

3.1 "Modica Greencity" masterplan

The 'Modica Greencity'[20] project is aimed at the development of an ecological network intended as a sustainable environmental infrastructure capable of ensuring the resilience of the municipal territory: an interface and fruition element for the correct conservation and valorisation in qualitative-quantitative terms of biodiversity, by systemising ecosystem services and cultural heritage. The three areas of interrelation, although different, all contribute, in a coherent manner, to making the tourist-cultural experience more efficient by implementing ecosystem services in all its forms. The Network intercepts protected natural areas, SIC and ZPS zones, and ecosystem services, thus guaranteeing an interconnected system of green areas within the territory. Fig.5a,

[20] Study developed as part of Chiara Spadaro's degree thesis entitled 'Modica Greencity. Ecological Network, Ecosystem Services and Cultural Heritage' at the University of Enna Kore, supervisor prof. Celestina Fazia, discussed on 18.07.2024 Activities under the MOD_Ret Ec agreement, between the municipality of Modica and the department of engineering and architecture of Enna, kore university. Municipal Council Resolution No. 284/24

summarises the characteristics of ecosystem services. The proposal also proposes an innovative strategy to be implemented in order for the project to be concretely feasible and effectively implemented, consistent with Article 47 of Sicily's Lur 19/20. With the theoretical in-depth study of the ecological network and environmental components, we were able to functionally schematise the ecosystem services (Pennino, 2024) that can be included and enhanced within the project.[21]



(a) (b)

Fig.5 (a) Ecosystem Services and (b) Agenda 2030 diagram and goal selection relevant to the Modica Greencity project

It is only thanks to the careful study of the Ecological Network and its components, the ecosystem services and the regulatory-urban framework, taking into account the European and national directives, the Sicilian Regional Law 19/2020 and the recommendations of Agenda 2030, that it has been possible to think of a project that can be decidedly coherent with the notional and regulatory framework. The reference is to the punctual analysis of all the urban planning instruments, both municipal and super-ordinate, that have dictated the general guidelines and normative recommendations at different scales, including the relevant goals suggested by Agenda 2030. Therefore, consistent with the recommendations of Agenda 2030, the 4 goals relevant to the project under analysis are indicated. (Fig.5b) In order to return a precise survey of Modica's territory, an accurate photograph was taken by means of visual census, numerous surveys with remote piloting systems and monitoring of the state of health of the environmental components, as well as the identification of historical-cultural elements that are of interest for their greater valorisation and the identification of areas to complete the ecological network (ecological corridors). The analysis of all the data collected was carried out with the aid of a geographic information system such as QGIS, which made it possible to geo-reference all the completion areas of the RES, Sicilian Ecological Network (Minardo, 1998). This, identified as a starting point, was then implemented with the identification of existing ecological corridors -which due to their compromised state do not know their real function today- and new project corridors. These, identified punctually and with respect to their actual dimensions, make it possible, due to their strategic position, to intensify the connection between two nodes, areas of high naturalness, and to favour genetic exchange in better qualitative-quantitative terms. With the aid of Gis, it was also possible to draw up a very detailed synoptic picture, i.e. a

[21] These can be divided into three macro categories such as provisioning, regulation and dissemination, and are 'the multiple benefits provided by ecosystems to humankind'. Definition given by the 'Millennium Ecosystem Assessment.'

Data Bank, BD, for every single natural area that is defined as a Site of Community Interest in accordance with the regulations; the BD contains precise information on sizing, the presence of characteristic habitats, and correlated urban planning instruments in force (Fig.6).

SIC ITA080009 Conca del Salto

Area concerned	290.54 ha
Habitat	5330, 5420, 7220, 8210, 8310, 92C0, 9320, 9340
Related instruments in force	Piano paesaggistico di Ragusa PRG PAI Legge Regionale 19/96
Normative sources	Piano di Gestione dei Monti Iblei (SIC istituito dopo il piano di gestione
Objectives	Enhancing the tourist-cultural experience by implementing ecosystem services
Purpose	Creating a mature and resilient system
Actions	Gradual replacement of non-native by native species
Accompanying measures	PNRR PO.FERS FONDI STRUTTURALI

Tab.1 Synoptic Frameworks

Fig.6 Conca del Salto

Only a few examples of synoptic frameworks and their cartographic representation are given here, with a suggestion and reference to the master plan and the respective planned project action. However, all the synoptic pictures relating to the sites of community importance in the Modica's territory have been drawn up, thus serving to expand the GIS database, the software used for all the cartographic elaborations both for the state of affairs and for the project, where each ecological corridor is appropriately georeferenced.

4. Discussion

The project idea proposes to create the Network as a driver of sustainable, economic and cultural development and an opportunity to enhance the territory. In the project Masterplan[22] (Fig.8) drafted in line with the OP of Policy5, the ecological network, reorganised and connected to the historic city using three systems of spatial and functional organisation: Ecological Network, Ecosystem Services and Cultural Heritage (Livia, 2017), assumes centrality. It is a document that, on the basis of strategies fuelled by participation, envisages programmes and projects related to measurable objectives to be achieved, anticipates and outlines project ideas to be shared, implemented and then carried out. The Modica Green City Masterplan identifies the elements of considerable value, indicating for each one the actions and accompanying measures foreseen for the economic feasibility of the projects, envisaging, among the main measures, the completion of the existing green infrastructure and the replacement of allochthonous species with native ones. The project's green infrastructure is to be understood as a typical transect,[23] (Fig.7) a corridor connecting two areas of high naturalness and along which ecological studies are carried out to understand the distribution of plant and animal species along an environmental gradient (Gambino, 1996). On the other hand, with regard to the linear project corridors identified, the project action consists in the ex-novo creation of a typical green infrastructure, which allows the connection of high nature areas, characterised by native species.

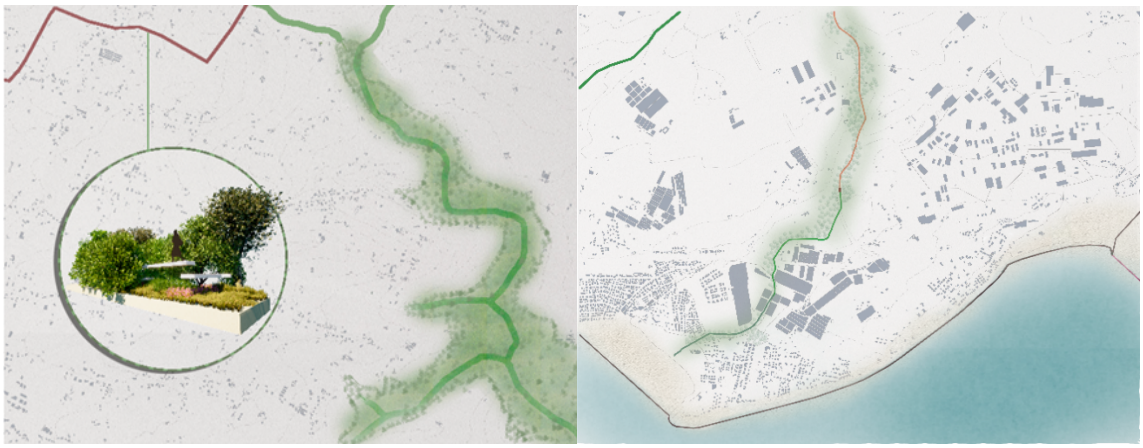


Fig.7 Project drawings for Modica, implementation of the existing ecological corridor and design of a model transect

The second aspect concerns the coastal habitat, where the project action is closely linked to increasing resilience given the numerous existing and detected fragmentations. The project action envisages naturalistic engineering activities, with the construction of embankment footbridges to preserve the naturalness of the coastal environment, windbreaks or geotextile barriers for dune stabilisation and palisades for the creation of artificial terraces that can allow the usability of coastal areas and at the same time the conservation of biodiversity and gene flow. The action planned for the Cava Ispica SIC is different; the objective is the conservation and protection of the climax, guaranteeing controlled use of the site by dictating a series of regulations and prohibitions of activities that could therefore compromise the very peculiarity of the climax. The third and final category of the Masterplan concerns cultural heritage and specifically the peri-urban park. (Fig.9) This surrounds much of Modica's layout (Raniolo, 1993), especially the historic centre of Modica Bassa and Modica Alta. This appears as a basin surrounded and framed by peri-urban forest, with considerable elevation changes and several canyons winding through the Modica territory.

[22] Study developed as part of Chiara Spadaro's degree thesis entitled 'Modica Greencity. Ecological Network, Ecosystem Services and Cultural Heritage' at the University of Enna Kore, supervisor prof. Celestina Fazia, discussed on 18.07.2024 Activities under the MOD_Ret Ec agreement, between the municipality of Modica and the department of engineering and architecture of Enna, kore university. Municipal Council Resolution No. 284/24

[23] This transect is obviously surrounded by plant species that must have certain environmental-naturalistic characteristics: Quercus Ilex; Pistacia Lentiscus; Olea Europaea var, sylvestris; Phillyrea Latifolia; Cistus Incanus; Rosmarinus Officinalis; Lavandula Stoechas

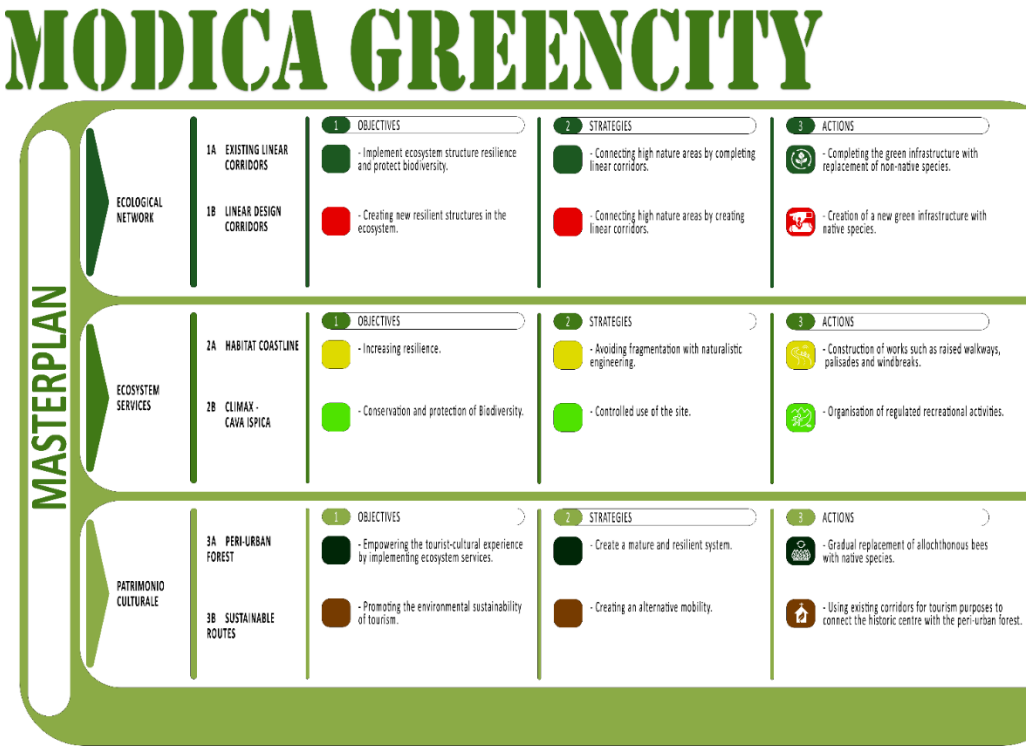


Fig.8 Modica Greencity Masterplan

4.1 IoT e Digital Twin

Urban planning is undergoing a radical transformation, making it possible, thanks to the aid of artificial intelligence, to monitor choices, spatial and environmental effects by mapping individual interventions, quantifying the areas affected, the volumes introduced and the consequent loss of natural soil and, conversely, the increase in green areas where planned. This will make it possible to calculate any loss of biodiversity and to estimate changes in ecosystem services. A further future development will be to simultaneously report, for example, the carbon stock, the contributions of (implemented) green infrastructure in terms of hydrogeological risk defence by quantifying the areas secured. In cases of particular vulnerability of territories, artificial intelligence and the digital twin are particularly useful. It is easily applied in the case of strategic/master plans. Indeed, 3D modelling can accompany the planning of planned actions and their implementation by verifying joint impacts and effects. Urban planning, by being in the vanguard of an increasingly diverse, innovative and technologically advanced range of issues, could obviate the excessively long timeframes usually envisaged for these tools of territorial government. There are numerous Net Zero Cities programmes in Europe that include Digital Twin technology. Among the most noteworthy, Florence is already operational, which with the help of software such as GIS and City4app, enables the three-dimensional visualisation of a city environment; an interactive space where heat maps, soft mobility infrastructures, traffic flow analysis and urban development can be found.

Therefore, the way of thinking and designing cities is also changing, and they are now being managed with a greater sensitivity to the unique features that are suitable for solving modern urban challenges. By now, the integration of Artificial Intelligence is becoming more and more of a necessity for urban planning, and tools such as CityEngine and UrbanistAI are becoming more and more widespread, capable of minimising environmental impact, considering socio-economic aspects, optimal use of resources, and conservation of biodiversity. Only with these technologies can we succeed in the great mission of designing cities that are truly functional and at the service of the citizen.

The implementation of the project involves, for obvious reasons, portions of municipal, state and private property. On the basis of this emerges the need to regulate the management responsibilities of privately owned areas, provide incentives and tax breaks for the non-use of the areas, useful for the creation of ecological corridors. This instrument would compensate the land owners involved in the creation of the network, ensuring a fair distribution of benefits and providing incentives for participation in its implementation.
The master plan linked to the implementable data base and the geo-referenced graphic representation, carefully drawn up on QGIS, taking on a virtual form through the use of the digital twin will be able to simulate scenarios, making it possible to explore hypotheses that would otherwise be impossible to verify for reasons of practicality and cost. However, the digital twin proposed for Modica Green City will be more than a virtual representation, providing an up-to-date and accurate representation of its state; it will be able to connect with the real system, receive data from it, conduct scenario analyses, and simulate operating processes. This is to improve urban planning, the optimal management of resources, natural capital, biodiversity and ecosystem services, and the resilience of urban systems. The model is based on the integration of data from different sources, including statistical data, sensor networks, monitoring stations and geospatial satellite data.
These data range from surface temperature to air quality and traffic flows and socio-economic information from local communities, a populable and aggregatable data framework that can aid the monitoring of SEAs, Strategic Environmental Assessments.
In recent years, thanks to advances in the field of data analysis, known as 'data analytics', and technologies related to monitoring the urban environment, satellite technologies for geospatial monitoring have been developed and low-cost sensors are frequently used to enable the development of 'Internet of Think' IoT sensor networks. These developments allow detailed information to be obtained at relatively low cost. In addition, advances in IoT allow useful information to be extracted from large amounts of data.
Among the technological tools, some already operational and others being tested, some are particularly interesting and inherent to the Digital Twin proposed for Modica. CityEngine (ArcGIS) makes it possible to visualise 2D and 3D territory; these 3D models can be useful analysis tools as well as simulation tools. The tool allows real simulations to be carried out that can simultaneously return the results of a given hypothesised strategy. Singapore has experimented with this tool and succeeded in greatly simplifying master planning processes.
UrbanistAI touches more issues close to community participation and involvement. Thus, residents are able, by consulting the platform, to visualise the urban policies implemented, evaluate the results obtained and even propose planning hypotheses. In Finland, residents themselves, with the help of the tool, have expressed their needs and shortcomings and have been able to design new parks and green spaces adapted to user demand.
Still other tools such as Cityplain and Architechtures address issues such as cloud-based analysis and socio-economic indicators of housing layouts, transforming design processes into social participation and sharing initiatives, thus reducing the timeframes for these administrative-bureaucratic activities.
Thus, alongside the 'Modica Green city' Masterplan generated on a GIS database, the Digital Twin is planned. With the use of software such as City4app or Opencities, it is possible to have a 360-degree restitution of the territory useful for mapping elements of naturalistic value such as protected natural areas, existing ecological paths and pedestrian routes; it is possible to monitor the building system, traffic flows and full-empty relationships, thanks to the integration of BIM and GIS data.
In terms of the tools needed to optimise the results and guarantee the involvement of authorities and administrations (the master plan being a voluntary document), the signing of a protocol is envisaged that would entail, in the event of adhesion by the subscribers, a series of savings (databases that can be used for the WYP) incentive benefits linked to the implementation of measures for the conservation of the ecological network (streamlining of the Vas procedure, for example) and the use of branding linked to Modica Green City.

Fig.9 Project drawings for Modica, implementation of the existing ecological corridor for periurban forest

5. Conclusions

What is proposed therefore, together with the Project Master Plan, is an innovative and immediately technically and economically feasible way of the project. It envisages the elaboration of a model protocol between municipal and private entities, in order to suggest guidelines for the regulation and use of the areas included in the Ecological Network project. The concept of the Digital Twin, or digital twin, certainly represents a digital replica of a physical entity, which can be used to simulate, analyse and optimise urban processes in real time. By integrating the Digital Twin with big data, the city can improve resource management, foresee problems and optimise services for citizens, but it also represents a resource for the territory and its residents, a dynamic snapshot of ongoing transformations and uses. The protocol would not represent a commitment that penalises municipalities or stakeholders. On the contrary, there are incentive benefits linked to the implementation of measures for the conservation of the ecological network and for the sustainable and integrated management of the intercepted areas (Trusel et alii, 2018). Getting to the heart of each measure, the protocol becomes a sort of ex-ante commitment for the assessment of plans in the territories affected by the ecological network, thus providing that when submitting environmental assessments, such as VAS and VINCA, the Proponents can sign the protocol attesting that they have complied with the principles underlying the plan, reinforcing, implementing and monitoring actions for the conservation of species and environmental protection of habitats, partly anticipating the aforementioned environmental audits. On the other hand, as far as the environmental indicator is concerned, these can be extrapolated from the Master Plan actions implemented for the conservation of the species, in this way data already collected but implementable for the purposes of species monitoring (database and GIS) would be used. Lastly, promotion and branding (Trusel et alii, 2018). After the adoption of the Memorandum of Understanding model, the municipalities involved will be able to convey the Modica Ecological Network brand as a territorial marketing tool and use it for economic-tourist purposes.
Recalling the main objective of OP 5, territorial strategies must be implemented in synergy with other strategic and environmental objectives, with the aim of promoting the economic and social development of slow

development areas. Policy5 of the European Cohesion Policy stipulates that in order to promote new urban ecosystems, approaches must be operationally translated within strategic documents, in the form of Master Plans and/or guidelines on land use, fundamental resources for ecosystem balance and biodiversity recovery, to counteract phenomena of hydrogeological instability and widespread degradation, to make services, infrastructures, transport systems and urban endowments perform. In this framework, the role of urban redesign and new forms/materials, technologies for sustainable architecture becomes essential. It becomes fundamental to reconnect, following the principle of ecological connectivity, everything to the General Urban Plan, to the thresholds of transformability of the territory and the environment as better specified and foreseen by Sicily's LUR no. 19/2020. All this also in order to strengthen the territory's capacity to provide 'preventive' environmental security the Convention on Biological Diversity, mentioned earlier, defines biodiversity as including diversity at the genetic, species and ecosystem levels. The former indicates the number and abundance of habitats, living communities and ecosystems.

It will be possible to use IoT sensors to monitor and manage natural environmental resources in real time, and then to have the possibility, with the use of GIS software and 3D modelling of the city's territory, to create simulations of urban scenarios given by the city's development, planning and enhancement activities. Therefore, once this testing model has been implemented and a series of test scenarios have been carried out, it is also possible to collect interesting public comments on the actual functionality of the Masterplan once the relevant digital twin has been fielded. This digital model also acts as an immediate interface with reality, guaranteeing the monitoring and implementation of new data, always ensuring its functionality and value as an important information tool that can be consulted by all users, whether residents or tourists.

Attributions

§Abstract, by Celestina Fazia and Chiara Spadaro; §1. Introduction, by Celestina Fazia; §1.1 Materials e methods, ecosystem approach, by Celestina Fazia; §2 Literature review, by Celestina Fazia §3. Results, by Chiara Spadaro; §3.1 "Modica Greencity" Masterplan, by Chiara Spadaro; §4. Discussion, by Chiara Spadaro; §4.1 IoT e Digital twin by Celestina Fazia; §5. Conclusions, by Celestina Fazia and Chiara Spadaro

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Image Sources

Fig.1 Mapping of the Natura 2000 Network of Modica and its province (Ragusa). Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity" degree dissertation;

Fig.2 Explainning diagram of the ecological network. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity" degree dissertation;

Fig.3 Best practice of Ecological Network in Italy. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity" degree dissertation.;

Fig.4 Cartography of Modica's spatial framework. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity" degree dissertation;

Fig.5 (a) Ecosystem Services. (b) Agenda 2030 diagram and goal selection relevant to the Modica Greencity project. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity dissertation";

Fig.6 Conca del Salto. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity dissertation";

Fig.7 Project drawings for Modica, implementation of the existing ecological corridor and design of a model transect. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity" degree dissertation;

Fig.8 Modica Greencity Masterplan. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity" degree dissertation;

Fig.9 Project drawings for Modica, implementation of the existing ecological corridor for periurban forest. Source: Graphic design by Chiara Spadaro; part of the "Modica Greencity" degree dissertation.

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