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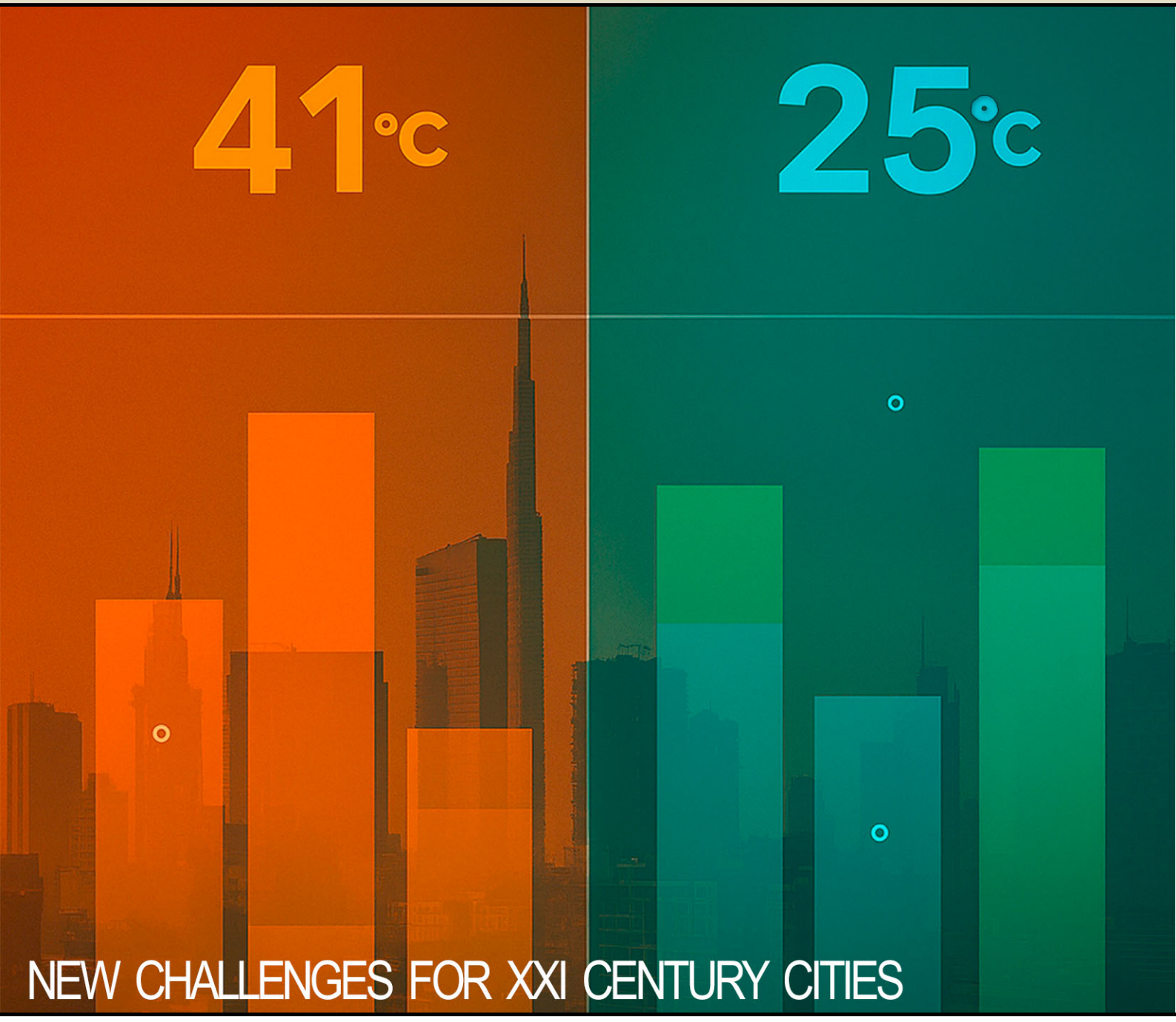
Journal of
Land Use, Mobility and Environment

print ISSN 1970-9889 e-ISSN 1970-9870
FedOA press - University of Naples Federico II

DOAJ anvur Rivista scientifica di classe A - 08/F1 Scopus WEB OF SCIENCE



NEW CHALLENGES FOR XXI CENTURY CITIES

Multilevel scientific approach to impacts of global warming on urban areas, energy transition, optimisation of land use and emergency scenario

Vol.18 n.3
Dicember 2025

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3 (2025)

Published by
Laboratory of Land Use, Mobility and Environment
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples Federico II, Italy

TeMA is realized by CAB - Center for Libraries at University of Naples Federico II using Open Journal System

Editor-in-Chief: Rocco Papa
print ISSN 1970-9889 | online ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n°6 of 29/01/2008

Editorial correspondence
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TeMA Journal of Land Use, Mobility and Environment

TeMA 3 (2025) 505-532
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/12736
Received 8th October 2025, Accepted 17th December 2025, Available online 31st December 2025

https://serena.sharepress.it/index.php/tema/

Landscape enhancement and river preservation. The case of the Aniene River in Rome, Italy

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Abstract
The objective of this study is to integrate the concepts of landscape restoration with the improvement of river areas. Often, there is a coexistence of elements of significant natural value and highly impacting artificial elements, such as large road and railway infrastructures, along watercourses. These elements have altered the landscape value and the usability of the places over time. The 'Landscape Project', as defined by current Italian landscape legislation, facilitates the implementation of measures aimed at enhancing environmental quality. Concurrently, River Contracts, a novel participatory tool, enable the execution of shared governance strategies designed to upgrade river basins and their associated territories. The case study focuses on the Aniene River, situated in a region of Rome adjacent to the Rome Ring Road. A project evaluation methodology is proposed for this study, which could be considered innovative. The methodology is evaluated through the presentation of results quantifying the benefits of the proposed project actions in terms of pollutant recovery and social welfare.

Keywords
Landscape Planning; River; Infrastructures

How to cite item in APA format
Cialdea, D. & Massera, F. (2025). Landscape enhancement and river preservation. The case of the Aniene River in Rome, Italy. *TeMA - Journal of Land Use, Mobility and Environment*, *18* (3), 505-532. http://dx.doi.org/10.6092/1970-9870/12736

1. Introduction

This paper combines two themes: that of the landscape and that of the areas affected by the course of a river. The following methodology is proposed for the purpose of verifying the enhancement of the qualities of the landscape under consideration. This methodology is supported by a case study which features the Aniene river within a mixed-use area, incorporating residential, industrial and agricultural components, situated within the municipality of Rome, Italy.

The overarching theme of rivers and the well-being of the inhabitants living in proximity to them has been addressed in recent literature from various perspectives. The international scientific community recognizes well-being as an indispensable element to guarantee the survival of the contemporary city, increasingly as a territorialized metropolis, which requires a new paradigm for the quality of life.

The landscape is the "space" from which people most benefit and in which health is determined or not. But the contemporary city is a complex organism, which faces increasingly pressing problems. Well-being is itself a multidimensional and complex challenge (Antrop, 2004; Stiglitz et al., 2009).

Starting from this premise and from the complexity of the contemporary city, well-being issues also assume uncertain boundaries and tend to broaden their reference basin, especially in relation to issues of sustainability. It is from these considerations that well-being entered into urban and territorial planning (Hough, 1984; Bentley, 1990; Breheny, 1992; Haughton & Hunter, 1994; Barton & Bruder, 1995; Rogers, 1997; Frey, 1999; Jabareen, 2008; Falk, 2019). Society, in fact, lives in a territory and therefore the challenges it poses are not vague: the population poses questions to planning to obtain responses throughout the space (Indovina, 2003; Marcelloni, 2005; Vicari Haddok, 2013; Lucia et al., 2018). However, not all of the space has homogeneous characteristics, especially the landscape, and there are numerous elements that characterise it.

The elements at stake that have the greatest influence on the health of the urban environment and of the population living there, were then illustrated: the green and blue infrastructures.

Among the elements that most contribute to well-being and therefore to health are green and blue infrastructures, because they provide "ecological, economic and social benefits through solutions in harmony with nature [...] it is a network of natural and semi-natural areas and green spaces that provides ecosystem services, which are the basis of human well-being and quality of life" (European Parliament, 2013). The term "Green Infrastructure" has its origins in the United States (Firehock, 2010), although the basic concept that ecosystems should also be considered as infrastructure has been known since the 1980s (Cardoso da Silva & Wheeler, 2017). This concept arises from the recognition that natural systems are just as important, if not more so, for social and economic well-being than so-called grey infrastructures. The first cases where this term was specifically mentioned in reference to land use planning was in the 1990s in the United States and while many other terms have been used over the years, such as ecological, natural, environmental, green and blue infrastructures, "Green Infrastructure" is the dominant term in the academic literature (John et al., 2019).

The European Union Strategy for Green Infrastructures (European Commission, 2013a) is a key element for achieving the objectives of the EU Biodiversity Strategy for 2020 (European Commission, 2011a; 2011b). The EU's Environment Directorate-General believes that Green Infrastructures have four main "roles": protecting the state of the ecosystem and biodiversity, improving the functionality of ecosystems and promoting ecosystem services, promoting the well-being and health of society and support development of a green economy and sustainable land and water management (European Commission Directorate-General for Environment, 2012). In the Technical Information on Green Infrastructures the European Commission has defined 13 groups of benefits provided by the Green Infrastructure Health and well-being: Improvement of the efficiency of natural resources, Water management, Instruction, Tourism and recreation, Green infrastructure and conservation, Mitigation and adaptation to Climate change, Low carbon transport and energy, Disaster prevention, Land and soil management, Resilience, Investments and employment, Agriculture and forestry (European Commission, 2013b; 2017; 2018). Thus they help to define environmental, social, and

economic actions such as: the conservation of biodiversity or adaptation to climate change, providing water drainage or green spaces, providing jobs and increasing of real estate values (EEA, 2011; Hansen et al., 2015; Olafsson & Pauleit, 2018; Pantaloni et al., 2024). These actions are integrated with climate and ecological benefits including increased carbon capture, improved air quality, mitigation of the effect of urban heat islands, additional wildlife habitat and recreational spaces (MATTM, 2014; Angrilli, 2015; Cialdea, 2015, 2017, 2022). Green and blue infrastructures can be thought of at different scales - local and regional - and include multiple elements -from building (public spaces green roofs, temporary flooding and bio-retention basins) to urban spaces (rain squares, infiltrating systems, gardens, parks, wooded areas, etc.) - that work in connection with each other and with other green and blue infrastructures to create a regenerated city that transforms itself.

The subject of the 'River Landscape' is also increasingly being explored by researchers. Despite the presence of divergent conditions, stemming from disparate contexts, the theoretical theme of the issues of preservation, on the one hand, and development, on the other, is being addressed in practice with highly differentiated solutions. The parameters of concern are the encouragement of landscape value and support for the enjoyment of places with physical difficulties; the combating of climate change; and the role of networking and increasing citizen participation (considering water as a common good). A comprehensive analysis of the available literature reveals a clear picture regarding the study of the planning tools utilised, which are a function of the various legislative bodies in different countries.

As early as the beginning of the 2000s, the research landscape on the topic made it clear that the study of the landscape must be approached by different professions (Butula, 2008; Eiter, 2010; Gobster & Xiang, 2012). It is evident that the overarching objective of sustainability can only be accomplished by integrating the imperatives of protection and development. The planning tool is identified as the primary means to facilitate this integration (Roe, 2013; Tomić Reljić et al., 2023).

There is an emerging consensus that effective sustainable spatial planning necessitates the establishment of models grounded in social and physical systems. However, it should be noted that theories are becoming increasingly diverse. On the one hand, there is a tendency to focus primarily on preserving natural resources as the basis for sustainable development. In this case, the focus is on plans that primarily consider natural values and consequently create development actions. Conversely, spatial policies are implemented with the objective of counteracting built development (Sarlöv Herlin, 2004; Biot & Colard, 2000; Kruse & Pütz, 2014).

In recent years, there has been an increased focus on public participation in the decision-making process. It is imperative to acknowledge the pivotal role of stakeholders in the planning process. Primarily, this encompasses the resident population; however, it is also imperative to recognise the contributions of experienced professionals specialising in developmental issues, including representatives from academic institutions such as universities. Spatial scenarios become the elective site of the results of their desiderata. The philosophy of choice will henceforth be based on an approach endowed with flexibility and adaptability and will replace the traditional, institutional and sectoral approach (Camagni, 2017; van der Voorn et al., 2023; Olesen, 2023; Juschten et al., 2025).

In the specific case of territories that include a watercourse, issues of 'river conservation' and 'river design' are also intertwined.

The principles of conservation are predicated on the concept that rivers represent a "common good" inextricably linked to the essential resource of water. Rivers have long played a pivotal role in sustaining life, providing vital water resources for various applications, including human consumption, agricultural irrigation, and energy production. However, for an extended period, they have been subjected to considerable threat. Two aspects must be considered: firstly, the state of health and the necessity of defence against pollution; secondly, the physical condition and the need for defence against hydrogeological disruption (Sweeney & Blaine, 2016).

It is imperative to acknowledge that the river constitutes more than merely the river shaft; rather, it is an integral component of the broader "river system," a concept that encompasses the "upstream-valley" complex

and exerts a significant influence on the urban environment. This influence can be traced back to the historical expansion of the original urban centre, a process that has been further facilitated by the river's presence, thereby enlarging the area under consideration.

In this regard, the significance of effective local planning is paramount. It is imperative that landscape design for river environments is informed by a comprehensive understanding of existing plans at both the general level and, most crucially, the municipal level (RESTORE, 2013; Ingaramo & Voghera, 2016; Ingaramo & Negrello, 2024).

Consequently, the river can be regarded not only as a natural system, but also as a linear system, and moreover as a complex landscape system involving both natural and anthropic environments. The methodology that will be described later aims at the theme of 'stitching together' all the elements present along the river through the construction of a landscape project that meets the physical needs of the places and the needs of the population living along it.

This paper is divided into five sections: the introduction (Section 1) describes the main issues of the paper, including the literature review. Section 2 deepens the relationship between river and landscape in the Italian corpus of planning legislation. Section 3 defines the methodology, firstly in general terms and later it contains the application to the chosen case-study. Section 4 explains the results and the related discussion and Section 5 regards conclusions and remarks.

2. Raising planning awareness: river and Landscape in Italy

In Italy, the field of spatial and environmental planning has historically been a primary concern for legislators. Indeed, as early as the 1940s, the legislator formally endorsed certain principles that are still in force today. The national town planning law, L. 1150 (Repubblica Italiana, 1942) has remained the cornerstone of reference, albeit with its additions, while the outline has changed and with it the planning criteria.

Since the conclusion of the 1970s, the Regions have been granted powers with regard to the organisation and management of the territory. It is imperative to accentuate the fact that during the 1970s and 1980s, the overarching objective of agriculture - a sector that places significant emphasis, through its diverse organisational structures, on the national territory - was the maximisation of yield quantities. The prevailing perspective was to maximise the exploitation of agricultural land through the utilisation of planning instruments, to the extent of imposing the natural vocations of specific regions.

However, over the past fifteen years, the environment has become increasingly significant, and the necessity to protect it from various threats has become a primary concern. Concurrently, the agricultural sector is undergoing a transformation in its objectives, shifting towards enhancing quality with the aim of promoting environmental rehabilitation and enhancing mountainous regions, which have historically been marginalised by the pursuit of extensive production. In recent years, there has been a notable advancement in the methodology of incorporating environmental assessments into planning documents and tools. This development is characterised by an increased emphasis on environmental considerations, which is a fundamental aspect of the concept of assessments.

However, it was also in the 1940s that the principles of landscape protection as a common good to be safeguarded were established. In the history of landscape protection, there has been a shift from an initial focus on the landscape as an asset to be enjoyed to the environment as the need to curb large-scale development and disregard for the well-being of all. The landscape is now viewed as a structural system with multiple components. In Italy, the planning instrument for landscape protection is the landscape plan, which was first mentioned in 1939. In that year, two laws were issued, L. 1089 and L. 1497, which firstly introduced the concept of constraints to be placed on assets to be protected (Repubblica Italiana, 1939a, b): the first for things of artistic or historical interest and the second on the protection of natural and scenic beauty, providing for the institution of landscape constraints.

It was not until the mid-1980s that Law 431/85 (Repubblica Italiana, 1985) introduced new concepts for the protection of areas of special environmental interest. Indeed, for the first time, the regions are obligated to carry out an organic and systematic protection of their territory. They are required to identify the areas to be protected and are obliged to draw up Territorial Environmental Landscape Plans for Large Areas. However, a significant distinction exists between the notion of constraint as outlined in Law 1497/39 and that delineated in Law 431/85. In the former context, the landscape constraint is defined as the legislative instrument that ensures the preservation of the aesthetic and visual characteristics of the landscape. Conversely, the concept is expanded to encompass the environment in its entirety, incorporating all facets of environmental protection. In the early months of 2004, the recently formulated Cultural Heritage and Landscape Code (Repubblica Italiana, 2004) was promulgated. This legislative instrument adopted the concept of landscape asset in lieu of environmental asset, with the objective of accentuating the manifold components of the landscape, encompassing the morphology of places, architecture, history, and the environmental component. Indeed, the definition provided asserts that 'landscape signifies a homogeneous portion of territory whose characteristics are derived from either nature, human history, or reciprocal interrelations. The preservation and enhancement of the landscape are vital for safeguarding the values it embodies as tangible expressions of identity'. In summary, the landscape is now subject to not only protection constraints but also enhancement obligations, in accordance with the principles of Title V of the Italian Constitution, which with the reform of 2001 now distinguishes between protection and enhancement activities. The cultural asset is to be protected and preserved for the purpose of being made available for collective knowledge and enjoyment.

Another significant legislative intervention in the country occurred at the end of the 1980s. This was Law 183/89 (Repubblica Italiana, 1989), which was designated the Soil Defence Law. This was deemed necessary in the aftermath of the calamitous events that transpired during the 1960s and 1970s, exemplified by the renowned Vajont disaster of 1963 and the Florence flood of 1966. The legal provision stipulated in Law 183/89 thus introduces the concept of a geographical unit, namely the hydrographic basin. This term is defined as a specific territorial area (Cialdea, 2007, 2019, 2022). Indeed, as stated in Article 1, paragraph 3, a river basin is defined as the territory from which rainwater or meltwater from snow and glaciers, flowing on the surface, is collected in a given watercourse, either directly or by means of tributaries. Furthermore, it encompasses the territory that may be flooded by the waters of the same watercourse, including its terminal branches with their mouths in the sea and the facing maritime coastline. Significant changes are also likely to ensue under the recently passed Nature Restoration Law (European Parliament and the Council of the European Union, 2024). The restoration of degraded areas is of particular importance, particularly within the context of the urban environment, where the specific soil type and degradation conditions are a key consideration. This theme, endorsed at the European level, is expected to have significant ramifications, particularly in Italy, where over 90% of municipalities are exposed to varying degrees of hydrogeological risk. It is imperative that significant reflections are undertaken in the domain of urban planning, with the objective of mitigating the loss of green areas within the urban context. This is essential to ensure the preservation of the entire green and blue infrastructure system. In this context, River Contracts - as a voluntary instrument of bottom-up participation, fostered by the involvement of a wide range of subjects (such as public bodies, private subjects and associations, universities) - can be the flywheel for improving the state of rivers and increasing landscape quality (Bastiani, 2022, 2025; Cialdea & Pompei, 2021a; Voghera et al., 2025).

3. Methodology

3.1 Preliminary considerations

The methodology - useful for integrating the concepts of landscape restoration with the improvement of river areas - has been defined in order to create a strong relationship between natural and landscape valuable

elements with the reduction of the impact of the artificial elements, as infrastructures are, quantifying the benefits of the proposed project actions in terms of pollutant recovery and social welfare. A number of preliminary considerations must be given due consideration.

Different methodological approaches from quantity to quality landscape improvement

Within the extensive domain of scientific literature, numerous articles have been analysed that examine aspects of quantitative assessments of the effects of projects. In addition, articles have been examined that highlight the enhancement of the landscape quality of watercourses, including through novel applications. This is achieved within a richly contextualised framework, drawing upon the historical elements of the Italian national territory.

In relation to the initial group, the i-Tree tool is frequently utilised. This tool, by analysing land cover data, identifies the presence of urban forests and determines the priorities for actions to enhance local well-being. This American software is designed to evaluate the economic, environmental and hydrological benefits of a green area on both a small and large scale. The tools most frequently employed for objectives analogous to those pertinent to the case study are Canopy, Eco and Landscape. Nevertheless, these tools are required to surmount the constraints of the American context in which they were developed (i-Tree, n.d.; Vigliocco, 2019). In this study, starting from data structured according to the basic i-Tree method, we proceeded to integrate it with i-Tree Canopy (Ghorbankhani et al., 2023) and the Natural Capital Planning Tool (Hölzinger et al., 2019; O'Keeffe et al., 2022). A combined approach to ex-ante and ex-post assessment of ecosystem services was developed. This approach was based on a combination of statistical remote sensing tools (i-Tree Canopy) and Natural Capital Planning Models (NCPT). The aim of this approach was to measure changes in natural capital and environmental impacts resulting from landscape transformation interventions. The i-Tree Canopy was used to quantify land cover and estimate the ecosystem benefits associated with trees (carbon, air quality, hydrology). The NCPT was used for a broader analysis of ecosystem services (10 categories, including cultural and regulatory services) and for the ex-ante/ex-post assessment of landscape transformation impacts.

A further application needs to be explored for river systems: using the i-Tree method as an adaptive management tool, with constant monitoring of the river ecosystem and adaptation of management strategies based on the model's results. The integration of these approaches has led to significant enhancements in the i-Tree method for riverine environments, resulting in more precise assessments of ecosystem services and the facilitation of more effective river management and restoration interventions (Hirabayashi et al., 2011; Guarini et al., 2018). The methods developed with the aim of improving the qualitative aspects of the landscape experiment with new design approaches in order to define scenarios for the transformation of the territory and landscape. The scales of analysis employed in this study range from large-scale areas - encompassing historical and cultural heritage, rural regions, symbols and traditions of identity, marginalised areas and inhabited centres (Guarini et al., 2017; Vigliocco, 2023) - to local urban scales - with a focus on urban fringes that encroach upon rural and recreational natural areas (Abastante et al*.,* 2022; Cialdea, 2022; Cialdea & Pompei, 2021a,b). Moreover, at the project scale, various complementary systems of action are identified with the objective of establishing a satisfactory river-context system (Morano et al., 2021a, 2021b; Ingaramo & Voghera, 2016). In this framework, the river functions as both a geographical identifier of locations and a connector with the surrounding territory. The objective of the present study was to investigate the applicability of i-Tree in Italy through the integration of qualitative parameters derived from the objectives of current planning tools. This dual comparison formed the basis of the project proposal for the case study.

The main features and elements involved in the case-study area

The study area is characterised by a high degree of complexity, stemming from the presence of multiple conflicting elements. The approach adopted in the present study was to identify the elements of value and

the detractor elements that undermine them. The objective of the present study was to evaluate the potential positive impacts of the proposed project. In order to achieve this objective, a reading methodology that has been proven to be effective was adopted (Cialdea, 2020a,b; Cialdea & Privitera, 2021). This methodology involved the identification of landscape values, as well as the necessity of emphasising the manner in which these values are utilised by the territory and, consequently, the population residing within that territory. Consequently, the "values" were invariably examined in relation to the presence of "detractors" within the territory that actually modify the value itself. These elements, which may be infrastructural, industrial or energy in nature, have been introduced into the territory over time in connection with the uncontrolled development of the territory itself. Methods of interpretation and combination with the values, which are by their nature linked to environmental characteristics, have been identified. With regard to Values, these are: Nature Value (VN), Landscape Value (VL) and Agriculture Value (VA). With regard to Detractors related to anthropisation, these have been identified as follows: DA1 (related to the Urban Residential Fabric), DA2 (related to the Industrial Fabric) and DA3 (related to Road and Rail Infrastructures).

- The Aniene River (VN), which originates in the Simbruini Mountains, is a left tributary of the Tiber and is the second longest river in Lazio, after the Tiber itself. Since Roman times, this waterway has been fundamental to Rome's water supply, feeding the Anio Vetus aqueduct and, later, other aqueducts, including the Acqua Marcia, which is the third aqueduct (after the Appio and Anio) of ancient Rome. The water from the upper Aniene basin was collected directly from one of its sources, rather than from the river itself. This ensured a water supply of the highest quality, which was considered to be the best that reached Rome. Pliny the Elder referred to it as "clarissima acquarum omnium" (the clearest of all waters). Along its urban course in Rome lies the Valle dell'Aniene Nature Reserve, a protected area covering 650 hectares, which does not currently extend to the area of our case study. The Aniene River was utilised for the transportation of blocks of tuff (the lionata stone, which was employed during Roman times, most likely originated from the regions of Settecamini and Salone, where it was referred to as "Aniene tuff"). These materials were conveyed to the city by means of this waterway. The Salone lakes, which were formed in these ancient tuff quarries, merit inclusion in the nearby Aniene Valley Nature Reserve due to their historical, archaeological, landscape and naturalistic significance (Comune di Roma, 1985; La Vigna et al., 2016; Rizzo, 2017; Sembroni et al., 2025).
  This element will be at the centre of the analysis and landscape design proposed here, due to its value (naturalistic, but also linked to history) and its fragility (related to the quality of its waters, but also to its susceptibility to flooding).
- The Latomie di Salone (VL) represent a significant outcrop of quarries of the aforementioned "tufo lionato". It is the only visible example of a tufo lionato quarry environment in the Roman area, especially in terms of its size and morphological structure (Funiciello & Giordano, 2008; Comune di Roma, 2016a; Fabbri & Lanzini, 2020). "The outcrop covers an area of approximately 380,000 m2 between Via delle Case Rosse, Via di Salone and the junction with the A24 Motorway. The area is characterised by morphologies linked to underground and open-air quarrying of tuff stone, which developed from Roman times (when the nearby Aniene River was used to transport the blocks of rock) until the 20th century. There are subvertical quarry faces and depressed areas linked to more recent extraction; the open-air cultivation areas are flooded by the water table, creating characteristic small lakes. In the 19th century, during the Romantic period, the area, known as the Tor Cervara Quarries, was famous among artists (especially German and French) who organised trips and parties there (Fabbri et al., 2014). The area is currently abandoned, although it is privately owned and fenced off. Given the high mechanical resistance of Lionato tuff, the only signs of deterioration are sporadic falls of blocks and wedges of rock. It is the very heart of the study area and the initial motivation behind the project concept.
- In this part of the territory, agricultural activity (VA) remains prevalent, despite the encroachment of residential and industrial development, which will be examined subsequently. This is recognised by the

current urban planning tool, which describes this part of the left bank of the Aniene as generally agricultural, with the exception of the area surrounding the quarries, which is identified as "public green areas", alongside which there is a small portion of "private green areas" corresponding to the existing sports lakes. The Landscape Plan identifies it as a generic "continuous agricultural landscape". It is noteworthy, however, that the Tenuta del Cavaliere, one of the two farms managed by Roma Capitale, is located in the vicinity of the study area. With its 388 hectares, the Tenuta del Cavaliere borders the bends of the Aniene River. This estate derives from the union of three separate estates that merged between the 15th and 16th centuries into the property of Anastasia Cavalieri. In 1640, following a donation, the property passed to the Hospitaller Order of St John of God of the Fatebenefratelli and then subsequently to Rome Capital. Currently, there is a modern cattle farm and fodder cultivation. The area is characterised by the presence of many species of wild animals and diurnal and nocturnal birds of prey (Pavolini et al., 2003; Cardillo & Cimino, 2024; Marino et al., 2024).

- Moreover, to the north of the case study area, there is a substantial residential area known as "Case Rosse" (DA1). Case Rosse was originally a spontaneous settlement that sprang up as a result of the migration of numerous families from Abruzzo to the capital. It is located on the eastern edge of the Municipality of Rome (IV Municipio), along Via Tiburtina, outside the Great Ring Road. The settlement underwent an expansion from the 1970s onwards, reaching its current form, which exhibits the characteristic features of former illegal subdivisions in isolated locations within the Roman countryside. Recent urban expansion has resulted in the town of Case Rosse becoming an integral component of a continuous urban area, extending from the Great Ring Road to the municipal boundaries along the infrastructure axis of the Tiburtina, the A24 Motorway and the railway to Abruzzo. The Case Rosse area, which covers an area of almost 50 hectares, is separate from the rest of the town. This has allowed a strip of land on the edge of the town to be kept free from development and still used for farming. Within the village, there is also a significant presence of plots cultivated with olive groves, which constitute an element of landscape and environmental quality to be enhanced in the implementation of building projects. Furthermore, the open areas under the power lines (now largely abandoned) offer an opportunity to identify a system of environmental connections to the heart of the settlement. The Capitoline Assembly has adopted the urban planning amendment to the current PRG (General Urban Plan) for this area, pursuant to Article 10 of Urban Planning Law No. 1150/1942. This urban planning amendment relates to the areas of Detailed Plans for Zone "O" No. 57 'Case Rosse' and "Case Rosse B", from Areas with Defined Detailed Planning of the City of Transformation (Article 62) to the components Fabrics (Article 52, paragraph 5) and Areas for Integrated Programmes (Article 53, paragraph 11) belonging to the City to be Restructured, as published on 31 March 2021 (Comune di Roma, 2021a, b).
- Since the 1940s, the Tiburtina area (DA2) has been characterised by the presence of industrial plants, which increased further between the 1960s and 1970s. In the 1980s, the area, known as Tiburtina Valley, converted to high-tech products, particularly for the aerospace and electronics sectors.
- In 2003, the Region established the Tecnopolo Tiburtino in the area, a coordination hub for existing companies and an incubator for future ones. According to the Rome Chamber of Commerce, 12% of Italian ICT companies were based here, and Lazio was home to one-fifth of Italy's 150,000 researchers. It covers an area of 265,000 square metres on a total surface area of 70 hectares. The Tecnopolo, which borders the project study area, was created with the primary objective of attracting high-tech business initiatives, enhancing the industrial development of the Rome area and offering new employment opportunities. It has strengthened the link between the worlds of research, academia and business, becoming part of the broader "Roman Technopole System" project, implemented with European Union structural funds under Objective 2 (Camera di Commercio, 2003). Two decades after its establishment, there are complaints about the severe lack of transport infrastructure, which hinders accessibility and

sees the nearby Great Ring Road with its congested traffic as one of the main problems to be solved (RomaToday, 2023).

- The case study area is bordered, and in some cases crossed, by major road and rail infrastructure (DA3). It is located close to Rome's Great Ring Road (GRA). As is well known, the GRA was built in the immediate post-war period. By decree of Minister Giuseppe Romita, on 27 June 1946, the ANAS (Azienda Nazionale Autonoma delle Strade Statali, now ANAS S.p.A.) was established with the task of implementing a transport development plan to boost economic recovery. One of the most important projects was the construction of the GRA, a new ring road around the city of Rome that would connect all the consular roads of the capital with a fast-flowing route, as equidistant as possible from the city centre (based on the ring road methodology introduced in Rome by Edmondo Sanjust di Teulada's 1909 Master Plan). This almost perfectly circular route was thus created. It became a fundamental structure not only for road transport but also for future plans to expand the city, playing a leading role in subsequent urban development plans from that moment onwards. At the same time, however, it left many problems unresolved in the areas close to it, such as the case study.

Furthermore, the area under study is completely crossed by the motorway, which has a significant physical and visual impact. The A24 Motorway starts from Rome's Tangenziale Est ring road, near Tiburtina station, crosses the north-eastern quadrant of the capital and ends at the intersection with the GRA. its construction began in 1960. It was not until 1990 that the section connecting the Tangenziale Est and the Barriera di Lunghezza, which involves the study area, was built.

Finally, the Rome-Tivoli railway line runs south of the area in question, as part of the Rome-Sulmona-Pescara railway, construction of which began at the end of the 19th century. The Rome-Tivoli section was inaugurated in 1887. It is a little-used artery that could be useful for reaching the area in question (Corriere, 2013; MIMS, 2022; Comune di Roma, 2022; Città Metropolitana di Roma Capitale, 2022).

The study area is shown in Fig.1 below.

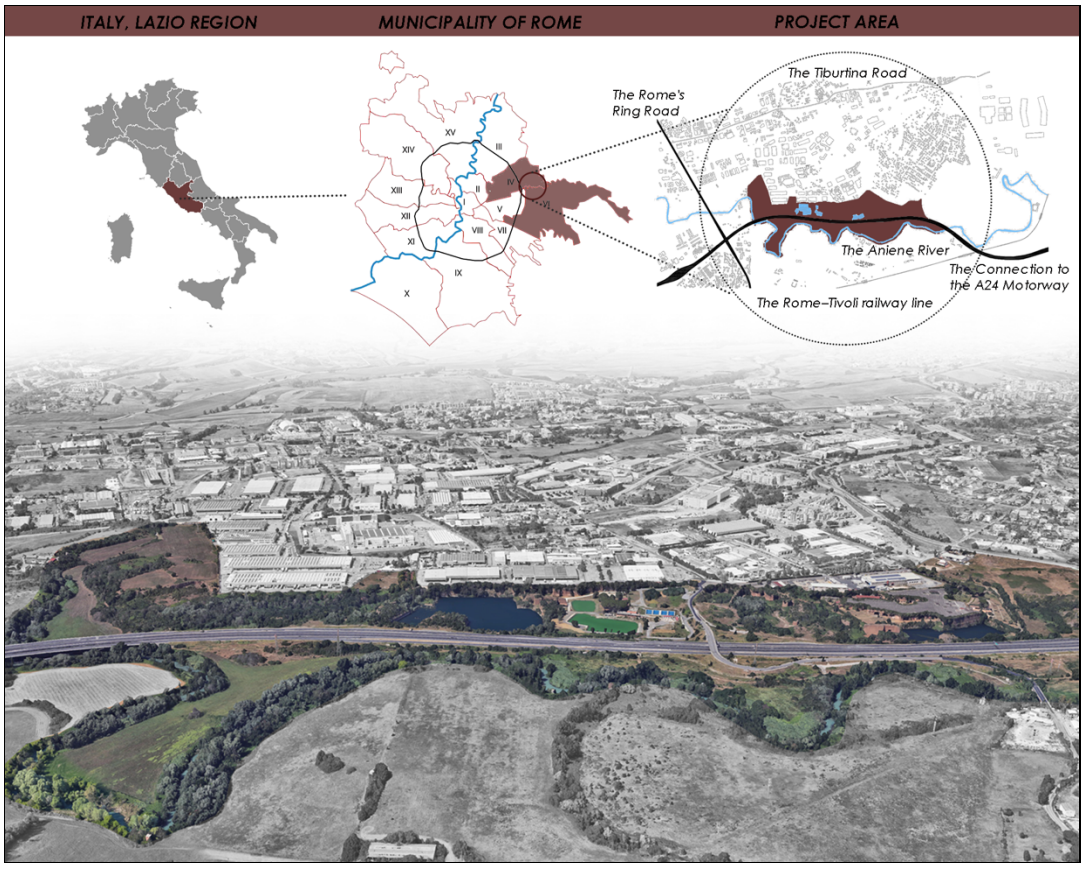


Fig.1 The case-study localization

3.2 The proposed methodological framework

Based on the investigations carried out using the planning documents, the work continued with the verification of conditions in the field. Therefore, a survey of the area was carried out. It consisted of two phases:

- the first involved a drone flight plan, in order to capture the distinctive features of the area and to verify the values and detractors described above. Fig.2 shows the reconstruction of the images taken with the drone;
- the second involved the reconstruction of the Latomie area, carrying out a topographical and architectural survey and, through data processing, creating a 3D model; the information was then implemented and potential interference verified, as shown in Fig.3 below.

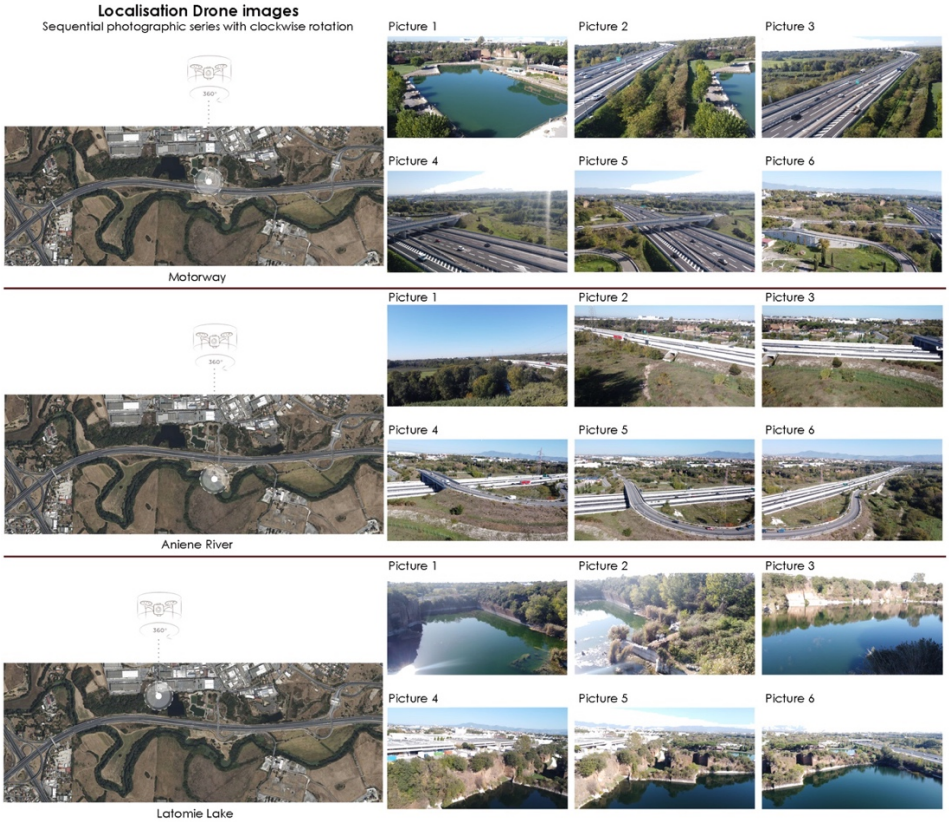


Fig.2 The Landscape Survey by drone

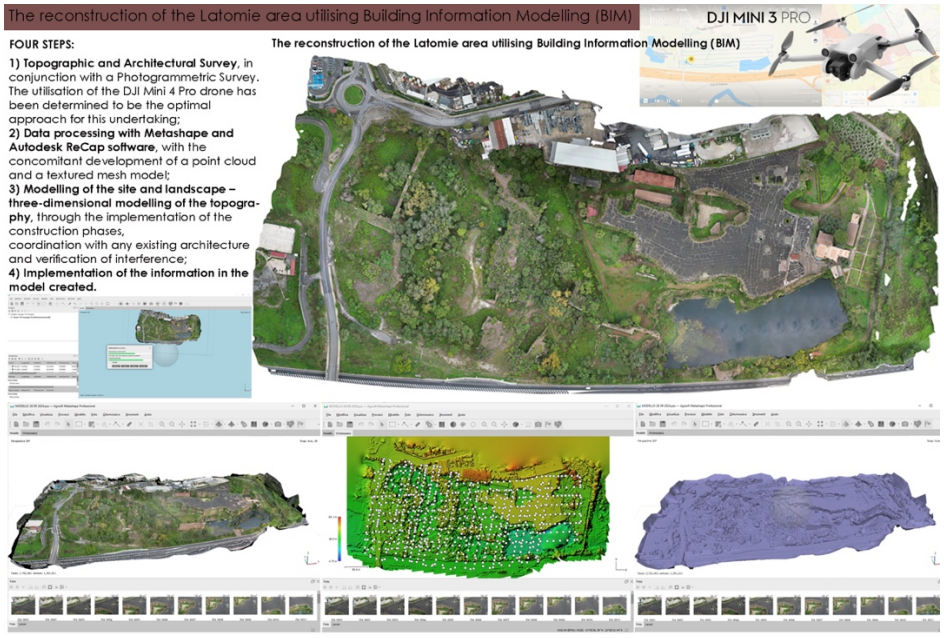


Fig.3 The reconstruction of the Latomie area utilising Building Information Modelling (BIM)

The methodology described below was therefore developed (see Fig.4). As represented in the flow chart, is structured as follows.

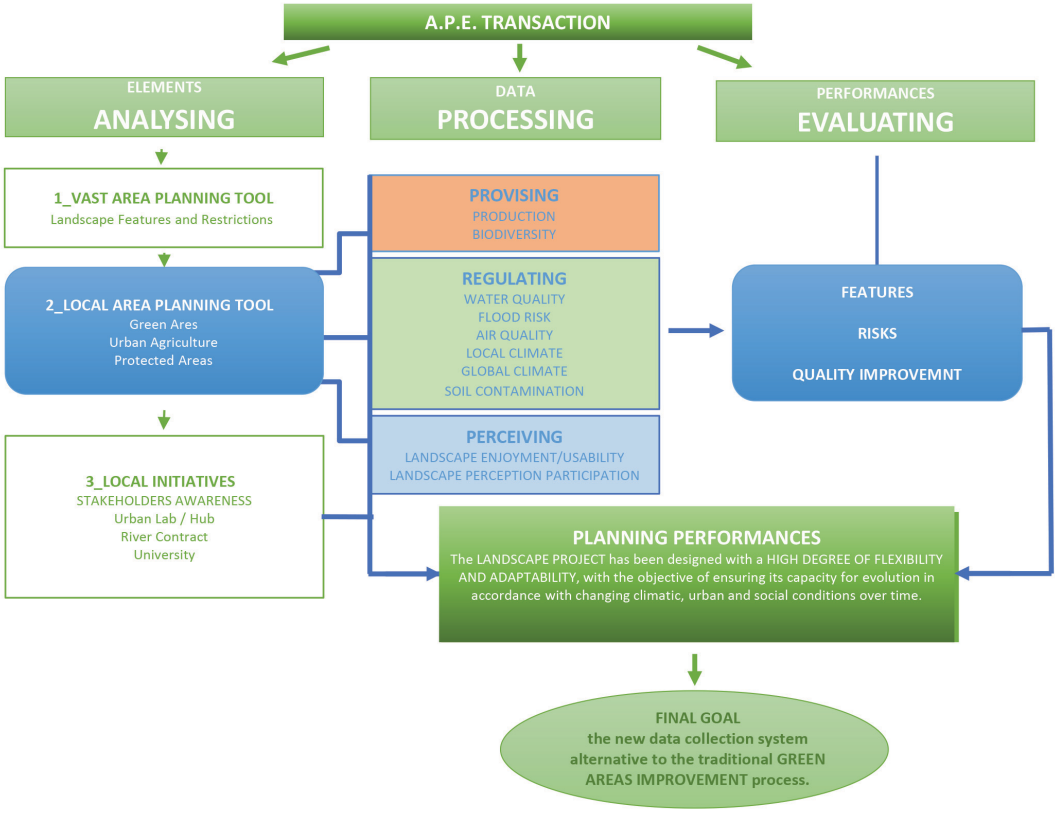


Fig.4 The Methodology's Flow-chart

We started by looking at the current planning rules. This is the first phase of the methodology, which we have named APE Transaction (i.e. ANALYSING - PROCESSING - EVALUATING), or ANALYSING. This forms the basis of the project's intentions: the intentions and forecasts for the area under consideration were extrapolated from the current planning tools.

The second phase, DATA PROCESSING, involved the analysis of survey data using the i-Tree method, which was then divided into three categories: PROVISIONING (relating to impacts on naturalness and therefore to ensuring the conservation of biodiversity and agricultural production), PERCEIVING (relating to the maintenance of aesthetic value and enjoyment) and REGULATING (with regard to water elements, and therefore the river, soil and air).

The synergy between these two phases is instrumental in identifying the site's fundamental requirements, which subsequently serve as the foundation for the landscape design.

The third phase, EVALUATING, will be initiated upon the conclusion of the design phase, with the objective of preserving characteristics and mitigating risks. This phase will also entail the delineation of avenues for enhancing the quality of the sites.

Data analysing and processing

In summary, with regard to the initial phase of ANALYSING, the starting point was an evaluation of the prevailing planning regulations for the area under study.

- Firstly, an analysis was conducted of the Regional Landscape Plan, which is the planning tool for the wider area. As previously outlined in paragraph 2, the landscape plan pertains to those geographical areas within the territory that possess distinctive characteristics derived from natural environment, human history, or the complex interrelationships between these elements. The primary objective of

landscape protection and enhancement is to preserve the values it embodies as tangible expressions of identity, as articulated in Article 131 of the aforementioned Code of Cultural Heritage and Landscape. In particular, the Lazio Region Plan, which was finally approved in 2021 (Regione Lazio, 2021), regulates landscape management methods, indicating the relevant actions aimed at conserving, enhancing, restoring or creating landscapes. The Plan acknowledges the landscape as a vital component of the community's living environment and promotes its enjoyment.

In the case study area, among the Landscape Assets identified in the Map B "Landscape Goods, Art. 134, para. I, letters a), b) and c) of Legislative Decree 42/2004, scale 1:25,000", the following are highlighted for the purpose of "protecting areas of archaeological interest": the Salone quarries and Latomie (mp058_1962 and mp058_2029), the remains of an ancient bridge (mp058_2084), a rock tomb (mp058_2030), several areas of pottery fragments (mp058_2028, mp058_2031, mp058_2033) and an ancient quarry (mp058_2032) as individual elements; for the latter, a precise area (ma058_0124) is also indicated, for which a proposal for restriction is currently being studied.

In the Map C "Natural and Cultural Heritage Assets, Articles 21, 22, 23 of Regional Law 24/98, scale 1:25,000", the quarries are recognised as an important Complex of the Latomie di Salone (pv_138; pv_142) among the Natural and Cultural Heritage Assets, and among the Historical Monumental Heritage Assets, a roadman's house on the Via di Salone (spm_0437) and a fountain (spm_0435).

With regard to the entire area surrounding the river, which constitutes the heart of the study area, in the Map A "Landscape systems and contexts Articles 135, 143 and 156 of Legislative Decree 42/2004 Scale 1:25,000" designates it as a Natural Landscape of Continuity for the Landscape Plan. No value is ascribed to it from an agricultural perspective.

- Subsequently, an analysis was conducted at the local level. The present Master Plan of the Municipality of Rome, which was approved in 2008, was then subjected to scrutiny. However, in 2016, a "final redesign" was formulated, particularly with regard to the "prescriptive documents" examined in this study (Comune di Roma, 2016b). The documentation under consideration is entitled "Systems and Rules". The tables, which are presented at a scale of 1:10,000, stipulate the methodologies and regulations for the transformation of the municipal territory in its entirety, meticulously categorised according to city and system. This classification encompasses the following categories: "Historic city", "Consolidated city", "City to be renovated", and "City undergoing transformation". These categories pertain to settlement, environment, services, and infrastructure systems, respectively. With regard to the Settlement System, the area falls within the "city to be redeveloped" classification. Areas have been identified within it whose intended use is linked not to residential purposes but to commercial activities. With respect to the Environmental System, the area surrounding the river is predominantly designated as agricultural land, with the exception of the portion of territory encompassing the Salone quarries, for which there are plans to intervene with a project linked to the utilisation of public and private green spaces.
- Finally, the aspirations articulated during the River Contract process were duly considered. The Aniene River Contract was initiated in 2018 following the endorsement of a Statement of purpose, while the preliminary phase, involving the organisation of forums, public meetings and consultation tables, commenced in 2002. The conclusion of the final signing in 2022 signifies the culmination of an extensive and intricate participatory process, which has contributed to the dissemination of a perception of the river and its environs as a distinctive entity encompassing nature, culture and daily life. Concurrently, this process has facilitated the cultivation of an identity that is intrinsically linked to the river.

The Aniene River Contract is predicated on the attainment of four overarching objectives: namely, mitigation and adaptation to hydrogeological risks, environmental improvement, sustainable utilisation of environmental resources, and the promotion of tourism and recreation in the area. In particular, the initiatives concerning the study area, which have been planned but not yet implemented, include measures to extend the Aniene Protected Area from the Great Ring Road to Tivoli (BV.02), riparian and urban reforestation along the ecological

corridor of the Aniene Reserve (BV.03.c), systematisation, completion and participatory management of the recreational networks along the ecological corridor of the Aniene Reserve (BV.04.a), and creation of a cycle and pedestrian path along the left bank of the Aniene River from Cervelletta to Lunghezza (BV.04.n and BV.04.p) (Contratto di Fiume per l'Aniene, 2022).
Consequently, Tab.1 was devised, encompassing the elements pertinent to delineate the salient features of the case-study area. The following essay will provide a comprehensive overview of the relevant literature on the subject.

	CATEGORY	ELEMENT	DESCRIPTION
VALUE	**VN** **NATURE** ELEMENT	**The Aniene River**	The 120 km course of the Aniene River, from the Simbruini Mountains to the Tiber, is then followed by a substantial stretch that is included in the 'Valle dell'Aniene' Regional Nature Reserve, continuing on towards Tivoli.
	VL **LANDSCAPE** ELEMENT	**Roman Tuff Quarries "Latomie di Salone"**	Of considerable value (the discovery of the quarries from the description of the itineraries to the sharing of the routes in scenic landscapes, including the lakes). Classified as Geosite No. 66 of the Lazio Region: "Roman quarries of Tufo Lionato in Via di Salone".
	VA **AGRICULTURAL** ELEMENT	**Agricultural areas near the "Tenuta del Cavaliere"**	The geographical area under consideration is predominantly agricultural, albeit with ambiguous identification. The property is situated in close proximity to one of the two farms overseen by Roma Capitale, in conjunction with Castel di Guido.
DETRACTOR	**DA1** DETRACTOR RELATED TO **ANTHROPISATION**	**The Urban Residential Fabric**	The residential area known as 'Case Rosse' (Red Houses) is a prominent feature. The settlement, which began as a spontaneous development, was later established.
	DA2 DETRACTOR RELATED TO **ANTHROPISATION**	**The Industrial Fabric**	The Tiburtina area has historically been distinguished by the presence of industrial facilities, a phenomenon that can be partly attributed to its strategic location in proximity to the Aniene River, which has played a pivotal role in the transportation of goods.
	DA3 DETRACTOR RELATED TO **ANTHROPISATION**	**Road and Rail Infrastructures**	High-impact infrastructure: The railway in question is the Rome-Tivoli section of the Rome-Sulmona-Pescara railway, which was constructed in 1887. The Grande Raccordo Anulare (Great Ring Road), constructed in 1946, is a notable example of infrastructural development. The construction of the A24 Motorway commenced in 1990, encompassing the Tangenziale Est - Barriera di Lunghezza section.

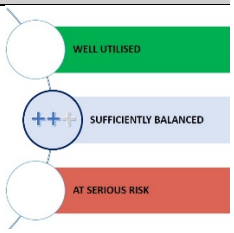
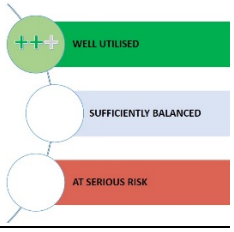
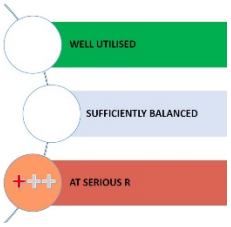
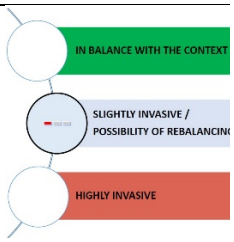
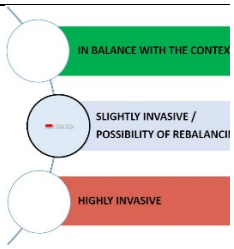
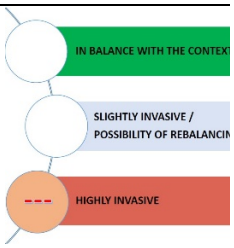
Tab.1 Elements involved to define main features (derived from Planning Tools and River Contract Proposals)

Furthermore, the NCPT model was employed to analyse the following elements, which are then reported in Tab.2:

CATEGORY	N	INDICATOR	DESCRIPTION
PROVISING	1	Harvested products	Impact on the production of food and timber
	2	Biodiversity	Impact on Biodiversity Action Plan (BAP) priority habitats and habitat connectivity
PERCEIVING	3	Aesthetic values	Impact on the visual amenity of a site or landscape
	4	Recreation	Impact on the availability and accessibility of public greenspace
REGULATING	5	Water quality regulation	Impact on water quality improving vegetation
	6	Flood risk regulation	Impact of vegetation on water storage capacities and water run-off
	7	Air quality regulation	Impact on vegetation contributing to air quality
	8	Local Climate regulation	Impact on cooling vegetation reducing the Urban Heat Island Effect (UHIE) - climate change adaptation
	9	Global climate regulation	Effect on carbon stored in soil & vegetation - climate change mitigation
	10	Soil contamination	Impact on risks to human health due to soil contamination

Tab.2 NCPT Elements involved to define main features (derived from Land Cover) 10 INDICATORS

These elements were subsequently documented in the VL_{CS} and VA_{CS} entries and the conclusions and assessments of this phase are shown in Tab.3.

	CATEGORY	ELEMENT	SCORE
VALUE	**VN$_{CS}$** **NATURE ELEMENT**	**The Aniene River** In the ***Regional Landscape Plan***, the buffer zone of the landscape restriction, which covers the river and its banks for 150 metres on both sides, is identified, but the coexistence of intrusive factors within it is ignored. In the ***Master Plan of the Municipality of Rome***, the river is merely indicated on the map. The initiatives of the ***Aniene River Contract*** are important, although they have not yet been funded.	
	VL$_{CS}$ **LANDSCAPE** ELEMENT	**Roman Tuff quarries "Latomie di Salone"** The ***Regional Landscape Plan*** places particular emphasis on the quarries and the numerous elements of archaeological interest that are located in the vicinity of the river. The ***Master Plan of the Municipality of Rome*** encompasses a range of activities for the utilisation of the sports lakes, with the private section being a notable component.	
	VA$_{CS}$ **AGRICULTURE** ELEMENT	**Agricultural areas near the "Tenuta del Cavaliere"** The ***Master Plan of the Municipality of Rome*** delineates the entire area surrounding the river as agricultural land. Conversely, the ***Regional Landscape Plan*** designates it as a natural landscape characterised by continuity.	
DETRACTOR	**DA1$_{CS}$** DETRACTOR RELATED TO **ANTHROPISATION**	**The Urban Residential Fabric "Case Rosse"** The ***Master Plan of the Municipality of Rome*** fails to address the impact of the large residential complex on the natural area.	
	DA2$_{CS}$ DETRACTOR RELATED TO **ANTHROPISATION**	**The Industrial Fabric "Tecnopolo Tiburtino"** The ***Master Plan of the Municipality of Rome*** identifies the entire area within the "Cities to be renovated" system, whose intended use is linked not to residential but to commercial activities.	
	DA3$_{CS}$ DETRACTOR RELATED TO **ANTHROPISATION**	**Road infrastructure: Connection to the A24 Motorway** In the ***Master Plan of the Municipality of Rome***, the presence of major motorway infrastructure is merely indicated on the map, with its associated influences being overlooked.	

Tab.3 Elements involved for the case-study area (CS = CASE-STUDY)

In the subsequent phase of DATA PROCESSING, the survey data were analysed using the NCPT method. As outlined in the methodology description, the data were divided by purpose, categorised as follows: PROVISIONING (indicators 1 and 2), PERCEIVING (indicators 3 and 4), and REGULATING (indicators 5 to 10). The results of this will be described after the contents of the project proposal have been presented. For this purpose, a comparison will be made between the initial state of the sites (before) and the final state once the project has been completed (after), in order to measure the change achieved.

The project proposal for the case-study area

The project is thus the result of a concept aimed at the enhancement of a fragmented area that is rich in potential. The objective of this initiative is to facilitate the integration of the fragments of Via Salone and Case Rosse through an approach that is not prescriptive, but rather encourages discovery, reflection, and the exchange of ideas.

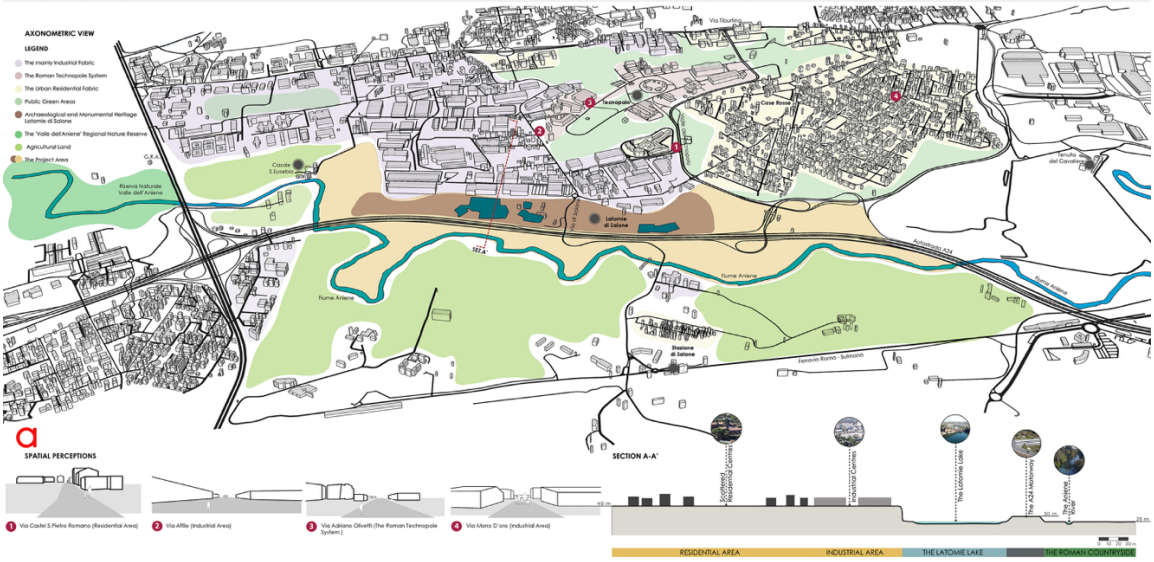


Fig.5a Current relations with the surrounding context

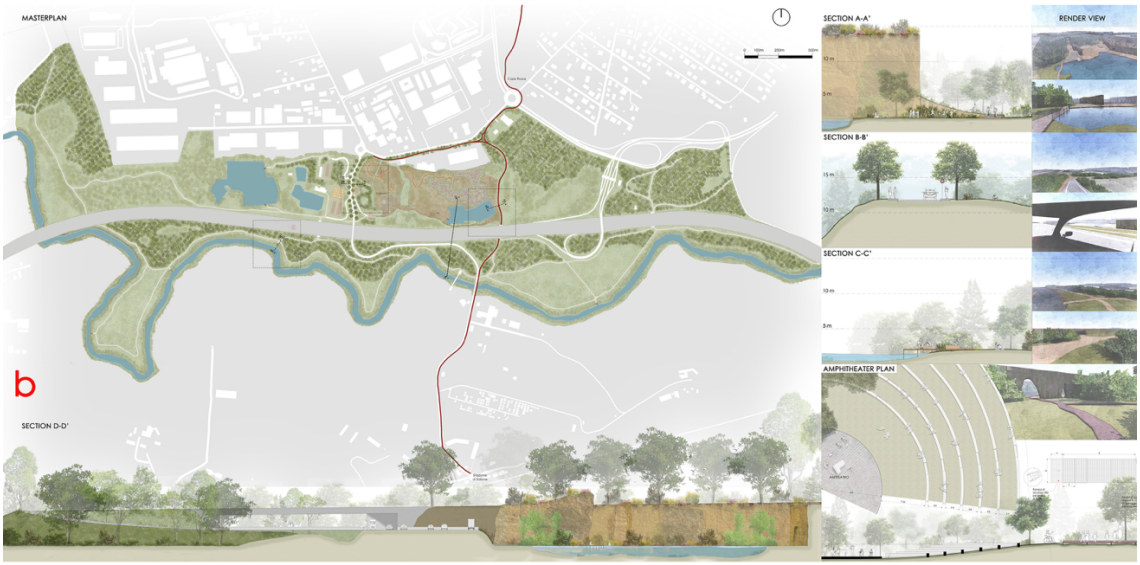


Fig.5b The project master plan

The project has been designated. The concept of "non-authoritarian encouragement to discover the Latomie" is a theoretical framework that aims to promote independent learning and personal growth in a non-coercive manner. The objective of the project is to promote the non-authoritarian exploration of the area, with a particular focus on the Latomie di Salone and the banks of the Aniene River, extending from Casale Sant'Eusebio to Tenuta del Cavaliere. This exploration is facilitated through the implementation of daily actions deemed essential for social functioning. The objective of the present study is, therefore, to assess the recovery and enhancement of a territory that has been fragmented over time by large infrastructure projects and uncontrolled building. This constitutes the core of the project, which is driven by the objective of unveiling the latent value of a region that, at present, appears to be significantly underutilising its full potential.

The analysis, as delineated in the methodology, is conducted on two levels: the broad level, which leads to an exploration of the wider context, and the local level, which allows for a detailed examination of the specific characteristics of the area, thereby addressing the challenge of integrating the various urban fabrics and the landscape.

A thorough analysis of the urban planning tools employed within the broader region has revealed that, over the course of approximately a century, the territory has undergone significant fragmentation as a consequence of urban planning and infrastructure decisions. Comprehension of this process is imperative for the understanding of the present and the capacity to imagine the future.

Local-level analyses yielded an in-depth understanding of the relationships between the Salone area and its environs, encompassing spatial perceptions, resources, and critical issues. The site visits facilitated a comprehensive understanding of the area's potential and the challenges it faces.

This location, which has been instrumental in preserving an age-old tradition, is further elaborated through the experience of the River Contract, a pivotal instrument in the revitalisation of the Aniene River's banks. An opportunity for recovery, but also for cultural rebirth.

Finally, the i-Tree method made it possible to assess the impacts in terms of ex-post ecosystem services, in order to estimate the extent to which the project proposal promotes the development of the context of the intervention.

Based on the above analyses, the project had two priority objectives: to increase greenery design, thereby improving ecological function, and to increase the perception and enjoyment of the sites.

Both following figures show the current state (see Fig.5a) and the planned state (see Fig.5b), respectively.

The following paragraph of the Results section therefore describes the EVALUATING phase.

4. Results and discussion

The current state of the area reflects the consequences of anthropisation processes. Some parts appear degraded and marginalised, characterised by abandonment, the accumulation of industrial waste and illegal dumping. The physical isolation of certain areas and their proximity to informal settlements have accentuated the perception of insecurity, transforming the territory into a vulnerable place from an environmental and social point of view. The agricultural system has also undergone a progressive weakening: the fields between the Great Ring Road, the Case Rosse industrial area, the motorway toll booth and the banks of the Aniene river are fragmented, partly abandoned and difficult to use. Incorrect agricultural practices and settlement pressure have triggered degradation processes that compromise soil functionality, often irreversibly.

Another critical issue is accessibility. Physical barriers, fences and closed underpasses limit internal connections, while the prevalence of private property hinders access to sites of high historical and archaeological value, such as the Latomie di Salone, the Casale di Sant'Eusebio and the Tenuta del Cavaliere. The result is an area marked by physical and social barriers, where cultural and natural potential remains hidden and difficult to exploit.

Conversely, the project constitutes a component of a comprehensive strategy for mitigating climate change. The increase in CO_2 and pollutants, which has been caused by anthropogenic emissions, has had consequences for public health and the urban climate. In this context, urban greenery plays a pivotal role in reducing temperatures, sequestering carbon and enhancing air quality. Trees are known as 'green lungs' due to their ability to retain fine particulate matter, absorb pollutants and accumulate carbon dioxide throughout their life cycle. Furthermore, through processes such as shading and evapotranspiration, they contribute to the mitigation of the so-called "heat island" effect, thereby enhancing the liveability of urban spaces. The presence of vegetation is therefore also crucial for soil protection, as it reduces erosion and increases the infiltration capacity of rainwater.

Finally, it should be emphasised that, from a design perspective, significant results have been achieved in terms of improving quality of life. The interventions are summarised in Fig.6a below: the first milestone

achieved is undoubtedly the increase in greenery. The main action (the Urban Forest) was aimed at designing the greenery of the large area with afforestation and the creation of a new mosaic of vegetation.
The second key element of the project was the creation of paths, in which nature also highlights the connection with the existing reserve (on the left), the archaeological site to emphasise the presence of the Latomie, and a network of cycle and pedestrian paths to increase the connection with the residential area of Case Rosse and the station providing access from the centre of Rome.

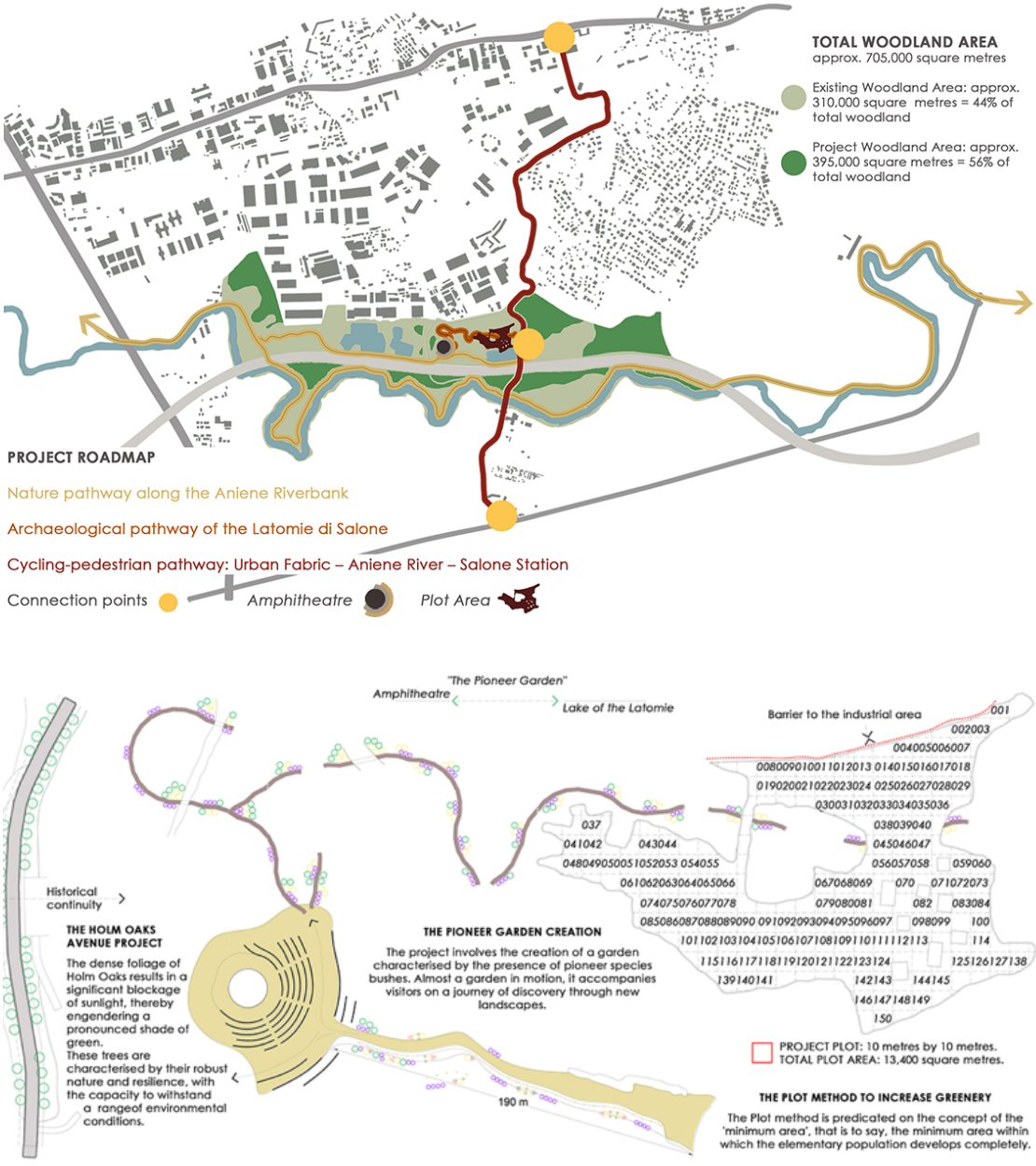
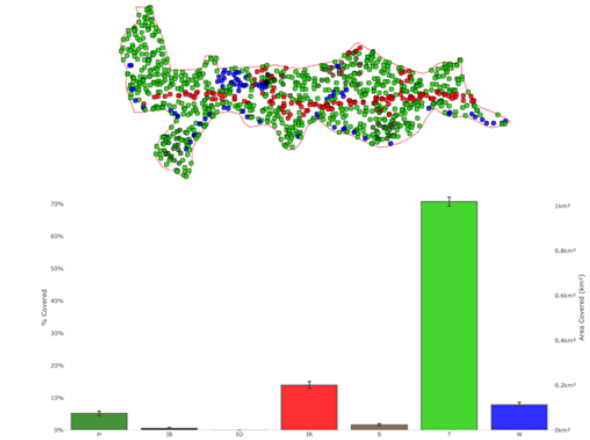


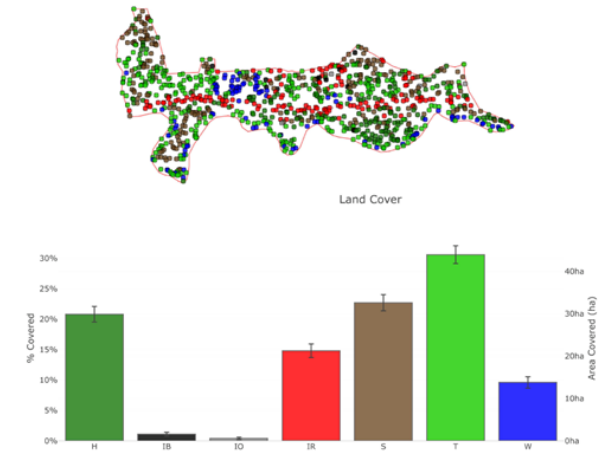
Fig.6 Areas with greater benefits. 6a. Overall view of the new connections, on the left with the existing reserve area, in the centre the area intended for recreation, which reconnects to the naturalistic system to the south and the settlement system to the north; 6b. The Amphitheatre - The Pioneer Garden - The Latomie Lake Network

These are nature pathways on compacted earth, which follow historic agricultural tracks and will connect the Aniene Valley Reserve to the Tenuta del Cavaliere estate. Inside the Latomie, the creation of an archaeological trail using modular and removable platforms will allow visitors to enjoy the site while protecting its heritage. An additional cycle and footpath will connect residential areas, the industrial area, the river and the Salone railway station, promoting sustainable mobility and slow enjoyment of the landscape.
The central part of the project involves creating the amphitheatre and the Pioneer Garden. This will be achieved by restoring the soil covering the Latomie through depaving — the demolition of the asphalt paving in the area

adjacent to the industrial buildings — and subsequently planting pioneer species. As regards the recreation area, the design methodology adopted is that of plots, based on the concept of minimum area. This approach allows the intervention to be divided into monitoring units, simplifying the operational phases and allowing precise control of ecological processes. In an initial artificial phase, the asphalt will be removed and replaced with topsoil, where cuttings and seeds will be placed. Subsequently, the natural process will guide the progressive spontaneous colonisation, stimulating biodiversity dynamics and initiating a cycle of ecological succession that will turn the area into a living laboratory of environmental regeneration (see Fig.6b).
The results of the study are presented in Tab.4.



		ANTE		
Abbr	**Cover Class**	**Points**	**Cover %**	**Area [km²]**
H	Grass/Herbaceous	208	20.80	0.29
H	Impervious Buildings	11	1.10	0.01
IO	Impervious Other	4	0.40	0.00
IR	Impervious Road	148	14.80	0.21
S	Soil/Bare Ground	227	22.70	0.32
T	Tree/Shrub	306	30.60	0.43
W	Water	96	9.60	0.13
Total		1,000	100	1.436



		POST		
Abbr	**Cover Class**	**Points**	**Cover %**	**Area [km²]**
H	Grass/Herbaceous	53	5.19	0.07
H	Impervious Buildings	6	0.59	0.01
IO	Impervious Other	0	0,00	0.00
IR	Impervious Road	143	13.99	0.20
S	Soil/Bare Ground	17	1.66	0.02
T	Tree/Shrub	723	70.74	1.02
W	Water	80	7.83	0.11
Total		1,022	100	1.44

Tab.4 Ante-Post Comparison (Integrated Ecosystem Services Assessment, i-Tree & NCPT-based)

All of the above actions were verified in terms of the benefits they would bring to the area in question. A comparison was made between the state of the sites and the project forecast, with the resulting data being generated using i-Tree Canopy. The findings indicate that the project will result in a reduction of more than 50% in air pollutants (PM10 and PM2.5), whilst also enhancing quality of life and promoting the implementation of plant and animal biodiversity, as shown in Tab.5a, 5b and 5c. These tables present a before-and-after comparison of the effects/benefits of the project.

	ANTE		POST	
Description	**Carbon (t)**	**CO_2 Equiv. (t)**	**Carbon (t)**	**CO_2 Equiv. (t)**
Sequestered annually in trees	105.46	386.70	243.82	894.00
Stored in trees (Note: this benefit is not an annual rate)	3,376.94	12,382.10	7,807.08	28,625.97

Tab.5a Tree Benefit Estimates: Carbon (Metric units)

		ANTE	POST
Abbreviation	**Description**	**Amount (kg)**	**Amount (kg)**
CO	Carbon Monoxide removed annually	38.38	88.72
NO2	Nitrogen Dioxide removed annually	171.58	396.67
O3	Ozone removed annually	1,922.17	4,443.83
SO2	Sulfur Dioxide removed annually	78.29	181.00
PM2.5	Particulate Matter less than 2.5 microns removed annually	97.03	224.33
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	483.14	1,116.97
Total		2,790.59	6,451.51

Tab.5b Tree Benefit Estimates: Air Pollution (Metric units)

		ANTE	POST
Abbreviation	**Benefit**	**Amount (kl)**	**Amount (kl)**
AVRO	Avoided Runoff	8.64	19.97
E	Evaporation	572.43	1,323.38
I	Interception	574.13	1,327.32
T	Transpiration	619.53	1,432.29
PE	Potential Evaporation	3,522.79	8,144.28
PET	Potential Evapotranspiration	2,507.06	5,796.02

Tab.5c Tree Benefit Estimates: Hydrological (Metric units)

Finally, Tab.6 correlates changes in land cover (from i-Tree Canopy) with the 10 ecosystem services analysed using the Natural Capital Planning Tool (NCPT) and highlights the changes that the project has produced.

NCPT CATEGORY	RELATIONSHIP WITH LAND USE (ante/post)	CHANGE	
1. Harvested Products	Not directly affected by the intervention.	≈	situation unchanged
2. Biodiversity	Greater habitat diversity thanks to increased vegetation.	↑	expected change
3. Aesthetic Values	A greener, more structured landscape improving visual perception.	↑↑	positive increase
4. Recreation	New green spaces increasing usability and quality of life.	↑↑	positive increase
5. Water Quality Regulation	Trees doubling the capacity to remove atmospheric pollutants.	↑↑↑	positive increase
6. Flood Risk Regulation	Tree covering helps locally, even if not compensating for hydraulic risk.	≈	situation unchanged
7. Air Quality Regulation	Trees doubling the capacity to remove atmospheric pollutants.	↑↑↑	positive increase
8. Local Climate Regulation	Reduction of bare soil and increase in trees improve permeability.	↑↑	positive increase
9. Global Climate Regulation	Increased shading and evapotranspiration, heat island mitigation.	↑↑	positive increase
10. Soil Contamination	Not directly affected by the intervention.	≈	situation unchanged

Tab.6 Relationship between Land Use and Ecosystem Services

A comparison of the radar charts indicates that the most significant impacts are in the categories of aesthetic values and recreation. This suggests that the project was strongly oriented towards improving the landscape perception of the area and increasing its usability by the community. Although to a lesser extent, there are positive effects on biodiversity and crop production, indicating a certain focus on enhancing the natural component. Key categories such as local and global climate regulation, air quality, water quality, flood risk regulation and soil contamination still show relatively low values, but an improvement can be seen compared

to the initial situation. Although these ecosystem benefits have not reached high levels, there is a positive trend indicating a first step towards strengthening the environmental functions of the area. (see also Fig.7).

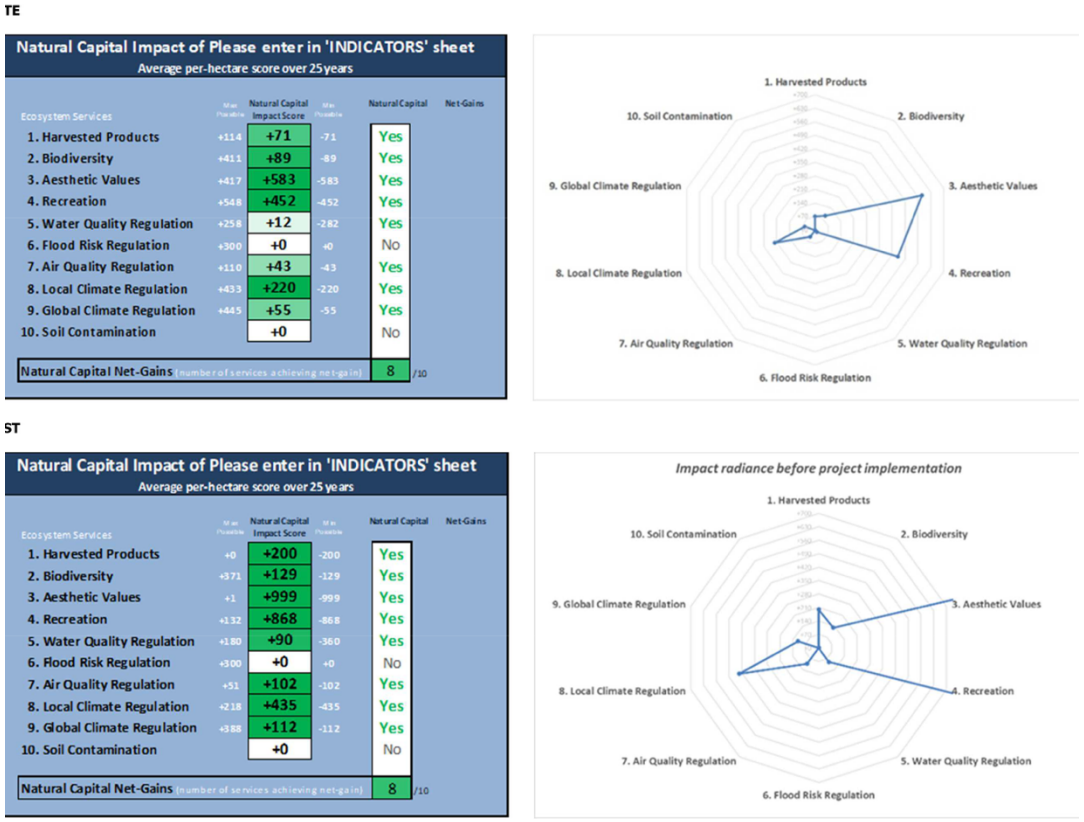


Fig.7 Report NCPT for the case-study area

The ex-post analysis highlights a clear improvement in natural capital following the intervention. Tree cover has more than doubled, significantly reducing bare soil and herbaceous surfaces. This has led to substantial gains in carbon capture and storage, air pollutant removal, and microclimatic and hydrological regulation. Cultural ecosystem services (aesthetic and recreational values) have also been enhanced, with expected benefits for quality of life and the social use of spaces. Only flood risk regulation shows no significant change. Overall, the intervention has generated a net and measurable gain in ecosystem services, contributing to environmental resilience and community well-being. These results highlight how nature-based interventions can effectively strengthen environmental resilience and generate tangible benefits for human well-being.
The following section seeks to provide a rationale for the outcomes observed by way of an examination of the individual interventions incorporated within the scope of the project (cfr. Tab.7).

5. Conclusion and remarks

The methodology described in this study was tested on a section of the Aniene River in the Municipality of Rome. The study was conducted with the aim of integrating the concepts of landscape restoration with the improvement of river areas.
The analysis of the area under study, based on site inspections and urban planning documentation, highlights a condition of profound fragmentation that has become stratified over time. This phenomenon can be attributed to the historical and functional evolution of the area, which has undergone a transformation from a natural landscape into a rural landscape, akin to the Agro Romano. Over time, the area has gradually become home to industrial and residential settlements, and more recently, a business centre.

ACTIONS	IMPACTS ON NATURAL CAPITAL CHANGES *		
	PROVISING INDICATORS (1-2)	PERCEIVING INDICATORS (3-4)	REGULATING INDICATORS (5-10)
AFFORESTATION 	**=/+**	**+/+**	**++++++**
Action_ Increase in green areas. Renaturalisation and enhancement of vegetation in sensitive areas (rivers, lakes) and ecological restoration of abandoned areas. This action has also led to an increase in **VN** value. **Action_** Recovery of agricultural areas no longer in use through the planting of trees and shrubs and soil regeneration. This action has also led to an increase in **VA** value**.**			
ARCHAEOLOGICAL PATHWAY 	**=/+**	**+/+**	**+=+++**
Action_ Archaeological pathway for visiting and accessing the tuff quarries, aimed at understanding the historic quarries, with a focus on accessibility and cultural enhancement. This action has simultaneously reduced the impact of Detractor DA2 and produced an increase in **VL** value**.**			
AMPHITHEATRE 	**=/=**	**+/+**	**=====**
Action_ Creation of the Amphitheatre within the sequence: Amphitheatre-Pioneer Garden -Latomie Lake. From here, connections branch off towards both the Aniene River and the Case Rosse settlement. This action has simultaneously reduced the impact of Detractor DA1 and produced an increase in **VL** value**.**			
NATURE PATHWAY 	**=/+**	**+/+**	**+=+++**
Action_ Creation of a nature pathway along the river, continuing on from the existing trail in the Valle dell'Aniene Regional Reserve. This action has also led to an increase in **VN** value**.**			
CYCLING-PEDESTRIAN PATHWAY 	**=/-**	**=/+**	**-=+--**
Action_ Cycle and footpath connecting the residential area of Case Rosse with the natural area (river, lakes and tuff quarries). Gentle connection (on foot/by bike) between residences and natural areas, promoting sustainable mobility and ecological use of the territory. This action has also reduced the impact of Detractor **DA1**.			
DEPAVEMENT 	**=/+**	**+/+**	**++++++**
Action_ Connection systems to overcome infrastructure, green mitigation for panoramic viewpoints and recovery of anthropised soil near the industrial area through depaving and planting of pioneer species cuttings capable of enriching the soil with organic substances over time. This action has also reduced the impact of Detractor **DA3.**			

* (+ Positive, = Neutral, - Negative)

Tab.7 Comparison between Actions and Effects

This succession of transformations has produced a significant landscape discontinuity, which has had an adverse effect on the legibility of the context and generated an uneven territory that is difficult to trace back to a unified system.

The causes of this fragmentation can be traced back to several levels. Geologically, this area is distinguished by the presence of formations of lionate tuff, accompanied by notable variations in elevation that disrupt the integrity of its topographical continuity. Human intervention has had a further impact on this balance. For centuries, the area was exploited as a quarry for building materials, leaving visible and persistent traces. In contemporary times, the construction of large-scale infrastructure projects has further segmented the space. During the 20th century, in response to the demands of mobility and economic development, the construction of the Rome-Tivoli railway, the Great Ring Road and the motorway took place, thereby establishing interconnected infrastructure that facilitated the operational efficiency of the urban system. However, this development resulted in a marked disruption to the cohesion of the territorial landscape.

The project aims to address these critical issues with the goal of recomposing the fragmented territory and restoring a new landscape coherence to the area. Consequently, it is hypothesised that the aforementioned actions have catalysed the regeneration of the area from both an environmental perspective, resulting in widespread renaturalisation, and from an urban and landscape standpoint, where there has been a diminution in the impact of expansive industrial zones and obtrusive large-scale artificial infrastructures.

Moreover, it is hypothesised that the methodology employed can be regarded as validating the project proposal outlined above. This methodology - which, as previously stated, has already been successfully implemented in situations where elements of significant landscape value coexist with intrusive and imposing detractors - can be re-proposed in situations presenting the same conflicts.

The i-Tree method, a software system designed to assess the benefits of planned interventions, has undoubtedly proved a valuable support. However, it is essential to note that integration of this method is necessary, given that a significant proportion of the intervention involves actions to increase the presence of green areas.

The Natural Capital Planning Tool (NCPT) is a decision support model designed to integrate the assessment of ecosystem services into land-use and urban planning processes. Unlike i-Tree Canopy, which focuses primarily on trees and biophysical effects, NCPT takes a broader approach, including ten categories of ecosystem services: provisioning, climate and hydrological regulation, biodiversity, risk reduction, recreational and cultural values, and landscape quality.

Its strength lies in its ability to conduct ex-ante and ex-post analyses, allowing the potential benefits or impacts of a landscape transformation to be estimated and compared with the actual effects subsequently observed. In this way, NCPT is not only an assessment tool but also a guide for the design of sustainability-oriented interventions.

In the case study considered, the application of NCPT confirmed the clear improvement in natural capital following the renaturalisation intervention. In addition to the environmental benefits, the analysis highlighted a strengthening of cultural services, such as recreational use, the aesthetic quality of the landscape and the improvement in the well-being perceived by the community. The only category that did not show significant changes was hydraulic risk regulation, an aspect strongly influenced by geomorphological and infrastructural factors.

The integration of i-Tree Canopy and NCPT therefore constitutes an innovative methodological model for the assessment of ecosystem services. The former provides accurate and quantitative data on the environmental functions associated with trees, while the latter broadens the perspective to include the social, cultural and regulatory dimensions of natural capital.

This synergy makes it possible to:

1. Rigorously quantify the environmental benefits deriving from landscape transformations;
2. Assess the overall impact of land use choices on ecological resilience and human well-being;

3. Orient urban and territorial planning towards nature-based solutions capable of generating multiple and lasting benefits.

The case study demonstrates how interventions to increase tree cover can produce a net gain in natural capital, translating into environmental, social and economic benefits. The integrated use of i-Tree Canopy and NCPT not only allows these changes to be monitored, but also to be leveraged within sustainable planning strategies. In an era characterised by climate crisis and increasing anthropogenic pressure, these tools are essential for promoting territorial policies geared towards resilience and collective well-being.

The necessary additions to the method in this work were identified in the introduction of parameters derived from the interpretation of current urban planning instruments, with particular emphasis on the landscape protection and enhancement plan, an instrument that characterises Italian legislation. However, it also contains interesting suggestions for situations that can also be found in other countries.

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Image Sources

Fig.1: Massera F., 2024

Fig.2: Massera F., 2024

Fig.3: Massera F., 2024

Fig.4: L.A.Co.S.T.A. Laboratory, 2024

Fig.5a: Massera F., 2024

Fig.5b: Massera F., 2024

Fig.6a: Massera F., 2024

Fig.6b: Massera F., 2024

Fig.7: NCPT Data Output, our elaboration 2024

Author's profile

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