# TeMA

Journal of
Land Use, Mobility and Environment

The Special Issue collects eight papers presenting methodologies, experiences, and techniques related to policies, best practices, and research on the potentialities of planning in the use of natural and agricultural territories, soil consumption, and the enhancement of territorial quality in response to climate change. The aim is to increase the territory's capacity to respond to critical events and enhance its resilience.

TeMA Journal offers papers with a unified approach to planning, mobility and environmental sustainability. With ANVUR resolution of April 2020, TeMA journal and the articles published from 2016 are included in the A category of scientific journals. From 2015, the articles published on TeMA are included in the Core Collection of Web of Science. It is included in Sparc Europe Seal of Open Access Journals, and the Directory of Open Access Journals.

*Special Issue 2.2023*

## Burn or sink
## Planning and managing the land

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

TeMA
Journal of
Land Use, Mobility and Environment

*Special Issue 2.2023*

# Burn or sink
# Planning and managing the land

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

TeMA is realized by CAB - Center for Libraries at “Federico II” University of Naples 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**
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples
web: www.serena.unina.it/index.php/tema
e-mail: redazione.tema@unina.it

Cover photo by Giuseppe Mazzeo. Rising wheat fields on the hills of Conza della Campania, Irpinia. January 31, 2023.

TeMA. Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include: engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science and complex systems.

With ANVUR resolution of April 2020, TeMA Journal and the articles published from 2016 are included in A category of scientific journals. From 2015, the articles published on TeMA are included in the Core Collection of Web of Science. TeMA Journal has also received the *Sparc Europe Seal* for Open Access Journals released by *Scholarly Publishing and Academic Resources Coalition* (SPARC Europe) and the *Directory of Open Access Journals* (DOAJ). TeMA is published under a Creative Commons Attribution 4.0 License and is blind peer reviewed at least by two referees selected among high-profile scientists. TeMA has been published since 2007 and is indexed in the main bibliographical databases and it is present in the catalogues of hundreds of academic and research libraries worldwide.

TeMA Journal of
Land Use, Mobility and Environment

*Special Issue 2.2023*

# BURN OR SINK
# PLANNING AND MANAGING THE LAND

## Contents

TeMA

Journal of
Land Use, Mobility and Environment

TeMA Special Issue 2 (2023) 123-142
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/10257
Received 1th August 2023, Accepted 6th November 2023, Available online 30th November 2023



# Analysis of strategic natural resources: the FEW Nexus model applied to Irpinia (Italy) and implications for regional planning

**Giuseppe Mazzeo**

Institute for Studies on Mediterranean (ISMed)
National Research Council (CNR), 80134, Naples, Italy
e-mail: giuseppe.mazzeo@ismed.cnr.it
ORCID: https://orcid.org/0000-0001-6204-9940

**Abstract**
Natural resources are strategic resources. They are becoming increasingly important in policies combating climate change. Moreover, their protection and enhancement are fundamental for actions of sustainable development. The paper analyses specific types of natural resources (soil, water and energy) and identifies their potential contribution to local development in a perspective of reduced environmental loads. General attention to the three systems of resources is evidenced by the development of research based on the FEW Nexus model which, since the 1970s, has explored the connections existing between them, as well as the development of parallel research lines. The latter can directly impact on regional planning and bring about necessary changes in currently applied plans so as to adapt them to evolving circumstances. A case study of interest is the area of Avellino, one of the inland provinces of Campania. The paper shows that the regional planning tool for the province only partially considers such resources, failing to assign to them any strategic importance. This may be considered a weakness both in regional planning and in land management because it excludes in advance, from analyses and forecasts, resources that can make a major contribution to the sustainable economic development of the province. To this end, the last section of the paper proposes changes in regional planning policy.

**Keywords**
Natural resources; FEW Nexus model; Sustainable local development; Regional planning.

**How to cite item in APA format**
Mazzeo, G. (2023). Analysis of strategic natural resources: the FEW Nexus model applied to Irpinia (Italy) and implications for regional planning. *Tema. Journal of Land Use, Mobility and Environment*, 123-142. http://dx.doi.org/10.6093/1970-9870/10257

## 1. Introduction

The meteorological events of 2022 and 2023 clearly highlighted some of the extreme consequences that climate change can cause on a regional basis. In 2022, the scant rainfall during the spring months, accompanied by a long period of much higher-than-average temperatures, reduced water availability for irrigation, resulting in the crisis of several agricultural production chains – those most dependent on water –, and led to the destruction of flora and fauna caused by summer wildfires. The symbolic image of the summer of 2022 was the low level of the River Po, whose flow reached all-time lows thanks also to other systemic phenomena, including the scarce flows of its main tributaries, the lowering of the level of Alpine lakes, and salt water intrusion from downstream. Contrasting with this prolonged drought was the severe flooding that affected the regions of the Marche in September 2022 and of the Emilia-Romagna in May 2023.

The alarm phase appears to have brought an end to the state of alert. This is typical of the normal approach of a community after a critical phase: choosing to ignore extreme phenomena instead of considering them as alarm bells and as a starting point for planning and structuring more sustainable management of natural resources.

Summer 2022 was also marked by a significant energy crisis. The sector has come under great pressure due to the war unleashed by Russia against Ukraine, even if previously there had been a series of speculative phenomena tending to increase the cost of raw materials required for energy production, especially gas and oil. The crisis has become an opportunity to think in depth on the energy question and on the different time frames on which it is measured: in the short to medium term there is a fundamental need to identify alternative energy sources to those from Russia; on a longer term basis, fossil fuels will have to be replaced with renewable sources so as to make individual countries self-sufficient and to take a decisive step forward in neutralizing emissions (Fistola et al., 2023).

This leads the reasoning back to the starting point, i.e., the severe drought and climate conditions of summer 2022 and 2023, with the aim to establish a very close systemic interrelation between all the processes linked to food and energy production and to the balanced use of water resources.

## 2. Literature review

This paper focuses on the relationship between natural resources, land use planning and management, and on the observation that resources are in a fragile state in the face of climate change. The scientific community pays considerable attention to the topic, which is being developed through several different lines of study, all worthy of further elaboration.

Among them we cite the FEW (Food-Energy-Water) Nexus model (Hoff, 2011; Zhang et al., 2019; Newell et al., 2019; Abdi et al., 2020), a theoretical framework used to analyze the interconnections and interdependencies among food, energy, and water systems (Fig.1). It recognizes that these three essential resources are strictly linked and that changes in one system can have significant impacts on the others. Furthermore, this model deepens the methodological and analytical tools to quantify the intensity of the relationships between them both locally and globally.

The main characteristics of the FEW Nexus Model include an interdisciplinary approach, an holistic perspective – which considers the entire lifecycle of food, energy, and water resources, from production and distribution to consumption and waste generation and which helps in identifying potential trade-offs and synergies between these systems –, and a systems thinking, which involves analyzing how changes in one component of the system can affect other components and the overall system.

Other characteristics are linked to environmental and geographical issues. The FEW Nexus Model recognizes that increasing global population, urbanization, and climate change are putting pressure on the resources, leading to scarcity and competition. Furthermore, the interactions among food, energy, and water systems can vary significantly based on geographic location and local conditions (D'Odorico et al., 2018). A potential answer is to achieve sustainability and resilience in the face of changing environmental and socioeconomic conditions. This involves identifying strategies to ensure the long-term availability of food, energy, and water resources while minimizing negative impacts on ecosystems and apply them at different scales.

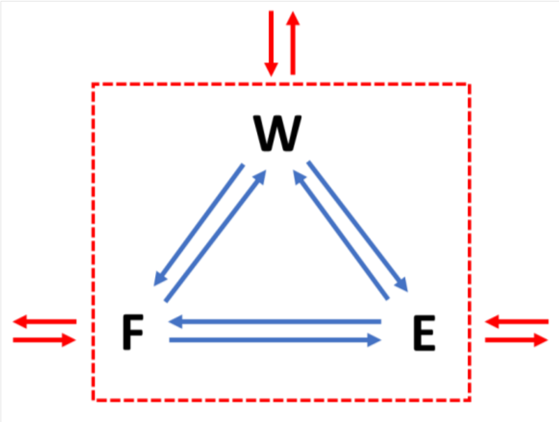


**Fig.1 FEW Nexus model: theoretical scheme**

The FEW Nexus Model is often used as a tool to inform policy and decision-making, with the aim to understand the complex interactions among these systems, and to inform choices to balance competing demands and promote sustainable resource management. In this way the FEW Nexus Model often involves engaging various stakeholders, including government agencies, industry representatives, NGOs, and local communities.
Last but not least, to build and apply the FEW Nexus Model effectively, access to accurate and up-to-date data is crucial, as is important to involve scenario analysis to explore potential future outcomes under different conditions and policy interventions.
Overall, the FEW Nexus Model provides a structured framework for understanding the complex interactions among food, energy, and water systems and is a valuable tool for addressing the sustainability challenges associated with these critical resources. For this model, the need to think in systemic terms derives from the interrelations between the three subsystems and from the evidence that population growth and its ever-greater shift towards urban systems increases the demand for these resources, in turn causing increased greenhouse gas emissions. The existence of relationships between these three subsystems means that changes in one of them have effects on the others, impacting, more generally, on climate change, environmental systems, socio-economic conditions and hence on policies and plans.
Another interesting line of research focuses on natural capital, defined as the stock of natural resources of an area (soil, air, water, living organisms) able to produce value through goods or services (Costanza & Daly, 1992; Moro, 1997; Dendena, 2018; Ministero dell'Ambiente, 2020). For this reason, natural capital must be the subject of particular attention.
Some types of natural capital provide communities with free goods and services, termed ecosystem services (Costanza et al., 1997; Daily & Matson, 2008; Turner & Daily, 2008; Scolozzi et al., 2012; Zoppi, 2020; Castellar et al, 2021). Two of these – water and soil – are the basis of economic and social systems and make community existence possible. To ensure that ecosystems continue to produce a flow of services, they need to be efficient and functional to avoid their degradation into non-renewable or inert natural capital. Hence the structure and variety of ecosystems is an important component of natural capital.
The presence of natural resources entails the need of proper planning and management with new rules and regulations able to ensure protection of the natural and agricultural environment, the reduction or cessation of soil consumption, and enhancement of environmental quality. The capacity of an area to respond to critical events resulting from climate change processes is thereby increased (Córdoba Hernández & Camerin, 2023).
If a geographical area has the ability to respond resiliently to the extreme events caused by climate changes, it is more capable of reducing potential damage to people and goods. The notion of resilience is connected to

the idea that an urban or rural system and its components can recover their functionality more quickly following negative events (Boyd et al., 2008; Molavi, 2018) and it is strictly connected to adaptation and mitigation processes (Muller, 2007). Resilience can be described in different ways but there are common factors that can be measured; it comprises diversity, flexibility, adaptive governance, and the ability to learn and to innovate, namely typical elements of processes related to innovation.

Climate change plays a specific role among the various causes of disastrous events that can affect a certain area. Climate change can cause rapid events, such as heavy rain, continuous events of medium duration, such as periods of drought, and continuous events of long duration, such as the average rise in temperatures. Based on an analysis of the scientific literature, Leichenko (2011) identifies four types of approaches and responses in terms of resilience: (1) ecological resilience; (2) reduction in hazard and risks from disasters; (3) the resilience of urban and regional economies; (4) the promotion of resilience through governance and institutions.

The ability of institutions to develop governance mechanisms that are most suited to respond to such problems, reducing risk for citizens, will be critical. According to studies in this regard, there is no single applicable system of governance, despite the presence of an extensive sample of good practices, and the best solution varies on a case-by-case basis (Ostrom, 2010).

## 3. Case study. Natural resources in the province of Avellino

The province of Avellino, sometimes referred to as Irpinia, is an inland province of the region of Campania in southern Italy (Figure 2). The area is rich in natural resources: it contains regional nature reserves and protected areas, its soil favours high quality agricultural production (Province of Avellino, 2004), and weather conditions are conducive to a significant generation of electricity from renewable sources. Furthermore, the main springs feeding the Apulian Aqueduct (Ciervo, 2016; Balacco et al., 2017) and supplying water to the Metropolitan City of Naples originate in southern Irpinia.


**Fig.2 Province of Avellino in the Italian peninsula**

Part of the province lies within the Alta Irpinia Pilot Area, one of the four inland areas selected by the Campania Regional Authority as part of the National Strategy for Inland Areas (SNAI). In 2017, the relative Strategy Document was approved by the Regional Authority (Regione Campania, 2017).

## 3.1 Soil, agriculture, food

The province of Avellino is 2,806.07 $km^2$. According to 2019 data, soil consumption in the province amounts to 7.3% of the total area, compared to a regional average of 10.3% (Munafò, 2020). There are significant differences between inland and coastal areas: for example, the Metropolitan City of Naples has an urbanized land percentage of 33.9%. The proximity of the regional average to the lowest figure is affected by extensive sparsely populated inland areas.

The most recent data from 2021 does not change the situation. According to the Webgis of ARPA Piemonte[1], soil consumption country-wide amounted to 7.13% of Italy's surface area, while the data for Campania and Irpinia are 10.49 and 7.36, respectively. In the latter there was a 47-hectare increase in soil consumption between 2020 and 2021 (Munafò, 2022), which brings the total amount of soil consumed to 20,536 hectares. Soil not consumed comprises basically natural and agricultural soils. The data relating to agricultural land are contained in the agricultural censuses. In 2013 the Campania Regional Authority, starting from these data, divided the region into 28 Rural Territorial Systems (STRs). 10 of them contain, in whole or in part, municipalities belonging to the province of Avellino, namely Colline del Fortore (STR3), Colline Sannite-Conca di Benevento (STR7), Colline dell'Ufita (STR8), Colline dell'Alta Irpinia (STR9), Colline dell'alta Valle dell'Ofanto (STR10), Piana Campana (STR13), Monte Partenio-Monti di Avella-Pizzo D'Alvano (STR18), Colline Irpine (STR19), Valle dell'Irno (STR20) and Monti Picentini (STR22). We note that these 28 STRs do not coincide with the 45 Territorial Development Systems of the Regional Land Use Plan approved in 2008.

According to the data published by the Campania Regional Authority in 2013, based on the Sixth Agricultural Census of 2011, the utilized agricultural area (UAA) amounted to 124,455.5 ha (34.92% of the province of Avellino, while the total agricultural are (TAA) was 150,162.3 ha, equivalent to 53.51% of the whole province. On the ISTAT website, the data relating to the 2010 Census are slightly different. The UAA accounts for 122,621 ha, while the TAA is 148,689 ha.

| STR | Municipalities in the STR (no.) | Municipalities in the STR and in the province of Avellino (no.) | Area of the municipalities in the province of Avellino ($Km^2$) | Area of STR in the province of Avellino (%) | Population of STR in the province of Avellino in 2011 (%) |
|---|---|---|---|---|---|
| 3 | 24 | 3 | 87.0 | 10.5 | 5.3 |
| 7 | 17 | 4 | 26.2 | 7.8 | 3.4 |
| 8 | 29 | 25 | 671.7 | 84.0 | 87.1 |
| 9 | 9 | 9 | 540.2 | 100.0 | 100.0 |
| 10 | 13 | 11 | 358.6 | 94.0 | 96.3 |
| 13 | 33 | 3 | 22.2 | 5.7 | 1,3 |
| 18 | 23 | 15 | 230.3 | 72.4 | 71.1 |
| 19 | 39 | 39 | 466.8 | 100.0 | 100.0 |
| 20 | 11 | 2 | 40.0 | 20.2 | 15.7 |
| 22 | 8 | 6 | 323.2 | 60.9 | 57.2 |

**Tab.1 Rural Territorial Systems (STRs) of the Province of Avellino**

1 https://webgis.arpa.piemonte.it/secure_apps/consumo_suolo_agportal/index.html

The Seventh National Agricultural Census took place in 2021[2]. To date, only regional data are available, and they show that between 2011 and 2021 there was an overall decrease in UAA of 5.74% (546,948 ha in 2010 vs. 515,544 ha in 2020).

Irpinia has extensive forest cover while its farmland is noted for its high quality products. Each of the Rural Territorial Systems is characterized by specific production and specific areas. For example, in the central part of the province there are internationally acclaimed winemakers, while eastern Irpinia is almost devoid of designation of origin products even in the presence of specific produce of great interest (Mazzeo, 2005). The exception is the Montella chestnut.

| STR | Municipalities in the STR and in the province of Avellino (no.) | Farms in the municipalities of the province of Avellino (no.) | Area of the municipalities in the province of Avellino (Ha) | Utilized agricultural area (UAA) (Ha) | Total agricultural area (TAA) (Ha) |
|---|---|---|---|---|---|
| 3 | 3 | 400 | 8,700 | 4,924.1 | 5,756.1 |
| 7 | 4 | 169 | 2,620 | 305.3 | 406.8 |
| 8 | 25 | 9,476 | 67,170 | 40,755.9 | 45,167.2 |
| 9 | 9 | 3,181 | 54,020 | 33,822.6 | 37,216.7 |
| 10 | 11 | 2,611 | 35,860 | 13,696.8 | 16,780.4 |
| 13 | 3 | 494 | 2,220 | 1,000.9 | 1,078.6 |
| 18 | 15 | 2,165 | 23,030 | 6,321.9 | 7,840.5 |
| 19 | 39 | 5,416 | 46,680 | 13,079.1 | 17,023.4 |
| 20 | 2 | 304 | 4,000 | 797.6 | 991.2 |
| 22 | 6 | 1,540 | 32,320 | 9,751.3 | 17,901.4 |
| TOTAL | 117 | 25,756 | 276,620 | 124,455.5 | 150,162.3 |

**Tab.2 Utilized agricultural area (UAA) and total agricultural area (TAA) in the Rural Territorial Systems (STRs) of the province of Avellino**

The local system of agricultural production must be framed within a broader horizon that sees agriculture being transformed into a sustainable sector able to reverse the current state in which it is viewed as a non-secondary source of emissions of climate-changing gases. In this regard, Community policies are very pressing. "The European Green Deal and its Farm to Fork Strategy treat agriculture as more than an economic sector: it also contributes to sustainability goals such as social well-being, ecosystem health, and food and nutrition security" (European Environment Agency, 2021).

## 3.2 Water

In terms of the organization of water resources, the provinces of Avellino and Benevento are part of the Optimal Territorial Area 1 (ATO-1) of Campania, known as the Calore Irpino. It forms part of the former Basin Authority of the rivers Liri, Garigliano and Volturno. It includes the areas pertaining to the land reclamation consortia of Ufita and Valle Telesina, as well as the territories of mountain communities, namely Alta Irpinia, Serinese-Solofrana, Ufita, Vallo di Lauro, Baianese, Partenio and Terminio-Cervialto (Fig.3).

The Plan of ATO-1 Campania dates to 2012. It shows that the province of Avellino has significant water resources deriving from the presence of numerous natural springs. The main springs are those of the upper Sabato valley (Serino), the upper Calore valley (Cassano Irpino and Alto Calore springs), and the upper Sele valley (Caposele). All these springs are fed by the mountain ranges of Terminio-Tuoro and Cervialto. Other springs are in the upper Solofrana valley (Bocche di Solofra), and in the Avella and Partenio mountains (Avella and Sirignano).

2 https://www.istat.it/it/censimenti/agricoltura/7-censimento-generale.

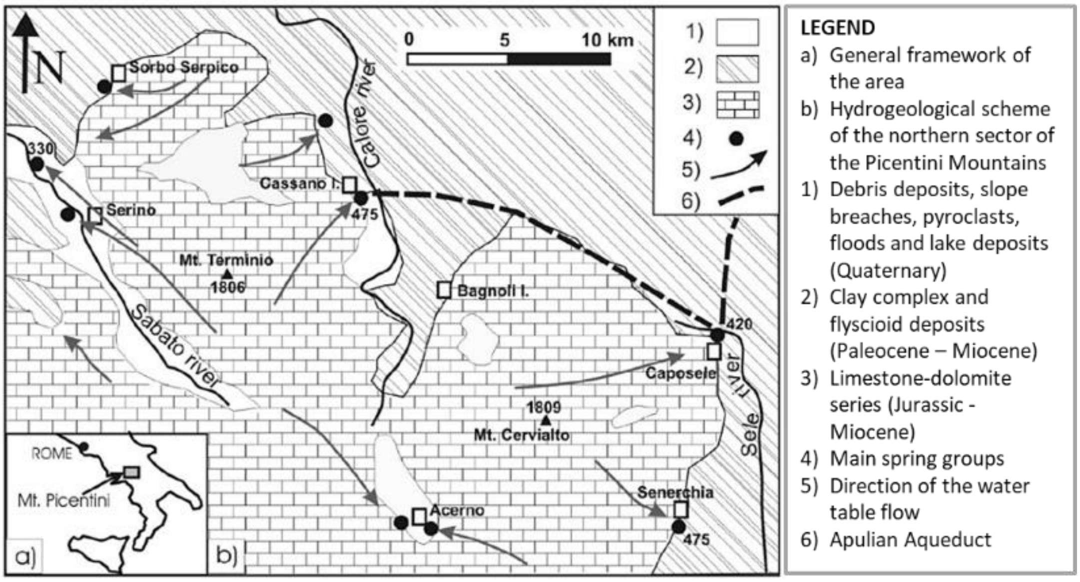


**Fig.3 Geological overview of the Picentini mountain area (Monte Terminio –Monte Cervialto) and hydrogeological scheme of its northern sector**

Most of Irpinia's water resources are used to supply drinking water to areas outside the province: the water of the Caposele and Cassano springs are channelled towards the region of Puglia, while the water of the Serino springs are channelled towards the metropolitan area of Naples (Fig.4). Overall, 91% of water resources come from springs and 9% from wells. Water production in 2012 was estimated at approximately 9,524 litres per second (Campania Regione, ATO-1, 2012).

Figure 4 shows the water balance of the ATO in 2012. It shows that 33% of the spring waters are used to supply drinking water for the ATO itself, while the remaining part (67%) is used by communities outside the province. The water resources drawn from wells are instead all allocated to the population of the ATO. Extra-regional water supplies (about 4% of the total) should be added to the overall balance.

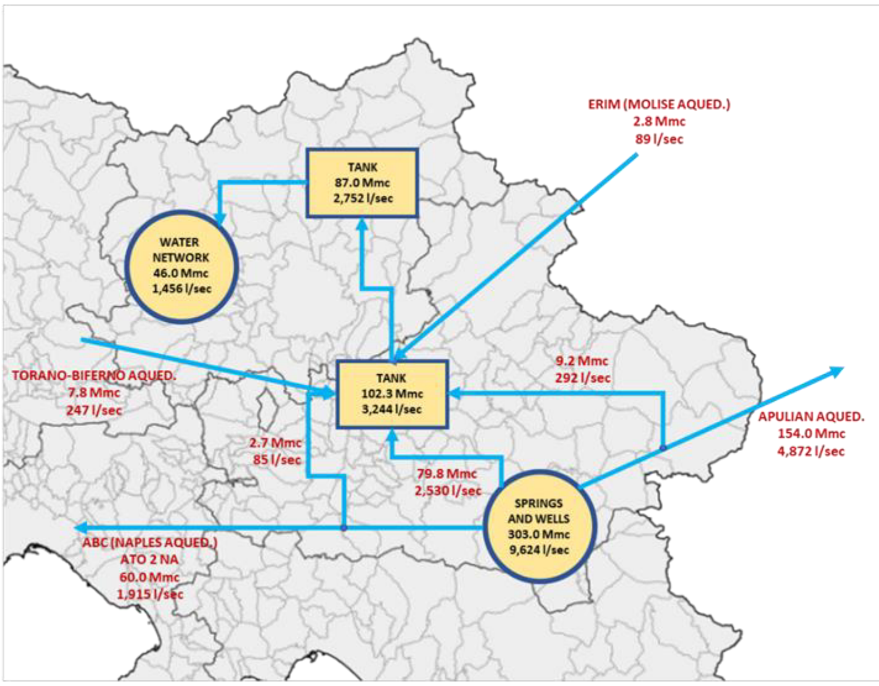


**Fig.4 Water balance at 2012**

Overall, the average flow rate available in the ATO-1 area should be 3,244 litres per second. In practice, given that water infrastructure censuses reveal average losses of 15% for the adduction network and 47% for the distribution network", the effectively distributed flow to users is approximately 1,458 litres per second (Regione Campania, ATO-1, 2012, 91). Tab.3 shows the total size of the flow rates within the area of the ATO-1.

| | Springs | Wells | Surface water | Total |
|---|---|---|---|---|
| Supplied water flow rate (l/s) | 3,965.2 | 1,955.5 | 0.0 | 5,920.7 |
| Mean derived flow rate (l/s) | 6,642.2 | 1,153.2 | 0.0 | 7,795.3 |
| Maximum derived flow rate (l/s) | 9,245.2 | 1,121.8 | 0.0 | 10,367.0 |
| Minimum derived flow rate (l/s) | 3,652.3 | 483.3 | 0.0 | 4,135.6 |
| Annual mean derived volume (mc) | 204,664,377.0 | 33,855,115.0 | 0.0 | 238,519,492.0 |

**Tab.3 Full data of the resources available in ATO-1**

The ATO-1 Plan highlights several critical elements. Despite the presence of numerous underground water bodies, the province's hydrological balance is negative, and it cannot be modified by using springs not yet connected to the water network. The latter, in fact, are modest or supply aqueducts outside the province, while the river waters are already excessively exploited by intensive agricultural and industrial activities. According to the Campania Regional Authority (Regione Campania, ATO-1, 2012, 65), in this context it is therefore essential to adopt measures to rationalize the management of water resources, aimed at partial recovery of the resource currently piped out of the region and focus on its regional distribution, as well as modernisation of existing works, to ensure the reduction of losses from aqueducts.

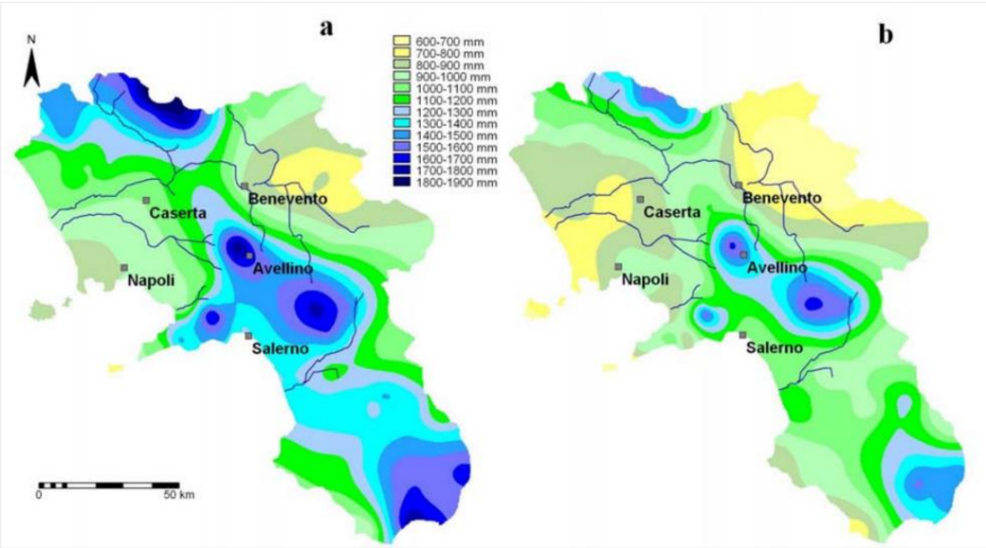


**Fig.5 Average annual rainfall (mm/year) for the period 1951-1980 (a) and 1981-1999 (b)**

An aspect of great importance is annual rainfall (Fig.5). Irpinian springs owe their water flows to winter and spring precipitation affecting the southern and western mountain areas. In this regard, Ducci and Tranfaglia (2005) showed that in the period 1981-1999 rainfall in Campania decreased by 15% compared to the previous 20 years. This decrease is not evenly distributed over the region, but has a greater impact in mountain and hill areas. Over the same period, the number of rainy days has decreased by a similar percentage.

The authors attribute this negative variation in the rainfall to global climate change. To support this hypothesis, they report that, in the same period, analysis of temperatures in Campania reveals an overall average increase of 0.3 °C, resulting from +0.2 °C in the flat coastal areas and +0.5 °C in inland and mountainous areas.

Returning to water resources, the two authors state that in Campania there have been decreases in flows from sources and lowering of the piezometric surface, important indicators of both the depletion of underground water resources and an increase in their exploitation. If this trend continues, they conclude that "a 70% decrease in groundwater resources could occur in the next 50 years, and groundwater management in Campania should be overhauled. In 2050, according to the scenario set out above, a population of several million people (population of Campania and Puglia, currently supplied with groundwater from Campania) may be in a critical situation"[3] (Ducci and Tranfaglia, 2005, 11).

## 3.3 Energy

Production of electricity from sustainable sources represents a sector with significant potential impact (Mazzeo, 2013). The inland areas of Campania and stretches of Molise and Puglia extending as far as the Adriatic coast account for some of the main production areas of renewables, namely solar and wind power. The plants built so far in Irpinia produce approximately 14% more energy from renewable sources than that actually consumed (1,513.7 GWh vs. 1,329.3 GWh), as can be seen from Tab.4 and Tab.5 (Terna, 2022). Wind power generation represents the dominant share of renewable energy production.

| **Source** | **Campania** | | **Province of Avellino** | |
|---|---|---|---|---|
| | **2000** | **2020** | **2000** | **2020** |
| Wind | 329.8 | 3,209.2 | 55.0 | 1,289.9 |
| Solar | 4.1 | 981.5 | 0.0 | 101.9 |
| Water | 1,916.8 | 844.0 | 16.5 | 10.7 |
| Thermoelectric | 2,906.9 | 6,708.7 | 0.0 | 111.2 |
| Total | 5,157.6 | 11,743.4 | 71.5 | 1,513.7 |
| % of regional total | = | = | 1.4 | 12.9 |

**Tab.4 Electricity generation by source. Gross production (GWh)**

The development of this production chain has also triggered a rise in local protests against the construction of new wind farms accused of generating a strong environmental impact, of being a vector of landscape fragmentation and, ultimately, of sometimes being based on poorly transparent business initiatives.

The current EU directive on the promotion of renewable energy (Directive 2018/2001) establishes that Member States must achieve by 2030 a share of energy from renewable sources equal to 32% of gross final consumption, and that the share of the transport sector must reach 14%. The Integrated National Plan for Energy and Climate (PNIEC, 2019) sets the Italian targets at 30 and 22%, respectively.

| **Sector** | **Campania** | | **Province of Avellino** | |
|---|---|---|---|---|
| | **2000** | **2020** | **2000** | **2020** |
| Agriculture | 212.5 | 311.0 | 8.0 | 12.4 |
| Domestic | 5,263.0 | 5,532.3 | 332.0 | 365.3 |
| Industry | 5,088.9 | 4,572.9 | 650.1 | 605.8 |
| Services | 3,783.8 | 5,407.8 | 242.1 | 345.8 |
| Total | 14,348.2 | 15,824.0 | 1,232.2 | 1,329.3 |
| % of regional total | = | = | 8.6 | 8.4 |

**Tab.5 Electricity consumption by sector (GWh)**

At the Community level, there is discussion on an acceleration of this process ("Fit for 55") that will raise the general target from 32 to 40% in 2030. This means that the focus on renewable energy can only grow further,

[3] Translation from the original text in Italian.

and will make it necessary to build new production plants, as well as boost research activities in the sectors of energy production, conservation and distribution.

### 3.4 Preliminary scenario

The Food-Energy-Water (FEW) Nexus model can be further enhanced through the development of a scenario analysis. This analytical approach aids stakeholders and decision-makers in exploring potential future outcomes and evaluating the potential consequences of different actions and policies, as suggested by Kosow & Gaßner (2008), Alcamo (2009), and Paltsev (2017).

The analysis starts from the current state of resources assuming possible evolutionary trajectories. The considerations are split into two sections: the first section expresses assessments to date, while the second section refers to a possible future scenario. Both the first and second use the same four types of qualitative indicators: (1) flows of goods; (2) quantity; (3) local impact; and (4) outlook. For each indicator, one opinion was expressed for two different states: the current state and the future state. Some judgments are followed by trend indications placed in square brackets. Figure 6 shows the results of the assessment both verbally and graphically. The building of the scenario is based on the data presented in the sections above, and on the hypothesis that in the near future there will be a strong step change in the decision-making system, such as to modify current area trends.

### Current state

At present the province produces food resources exported in significant quantities. Yet imports are also significant. The local impact of this resource can be considered significant, even if it does not yet express all its potential in terms of impact on the province. The outlook is positive.

Since the energy produced is higher than that consumed in the province, the latter may be said to be a net exporter even if the quantities are not significant. Although the local impact of this resource is limited in economic terms, it is critical from the social point of view due to opposition from some local communities. The outlook is positive.

The province is a net water exporter, even if in this case the exported quantities are decidedly greater and more significant than those consumed locally. Of the resources analysed, water is the most important and strategic, especially in consideration of its impact on some communities outside the province. Prospects for the future are stable.

### Potential forecast

Turning to the outlook, the considerations that can be hypothesized give rise to substantially different scenarios from those relating to the current state. As regards food, import/export flows between the province and outside areas will continue. Quantities could change significantly: they could grow if agriculture gains weight within land use development policies. This could have a high local impact both in economic and social terms. The positive outlook could consider the negative impacts of climate change or other events that could create critical situations within one or more agricultural production sectors.

The energy sector confirms the judgment on flows, with a province that can strengthen its position as a net exporter. Due to its characteristics, it should significantly increase the amount of energy produced. The local impact of the sector is more nuanced, which should be taken into due account within future investment policies. Local impact means the possibility that energy will be used locally to develop specific economic sectors, but also the possibility that local communities can self-produce and market increasing amounts of energy. The prospects, however, appear positive.

CURRENT STATE

| | FLOWS OF GOODS | QUANTITY | LOCAL IMPACT | OUTLOOK |
|---|---|---|---|---|
| FOOD F | Import/Export | Significant | Significant | Positive |
| ENERGY E | Export | Limited | Limited | Positive |
| WATER W | Export | High [Steady] | Significant | Neutral |

POTENTIAL FORECAST

| | FLOWS OF GOODS | QUANTITY | LOCAL IMPACT | OUTLOOK |
|---|---|---|---|---|
| FOOD F | Import/Export | Significant [Growing] | High | Positive [Critical] |
| ENERGY E | Export | Significtant [Growing] | Significant | Positive [Neutral] |
| WATER W | Export | High [Reduction] | Significant | Negative [Critical] |

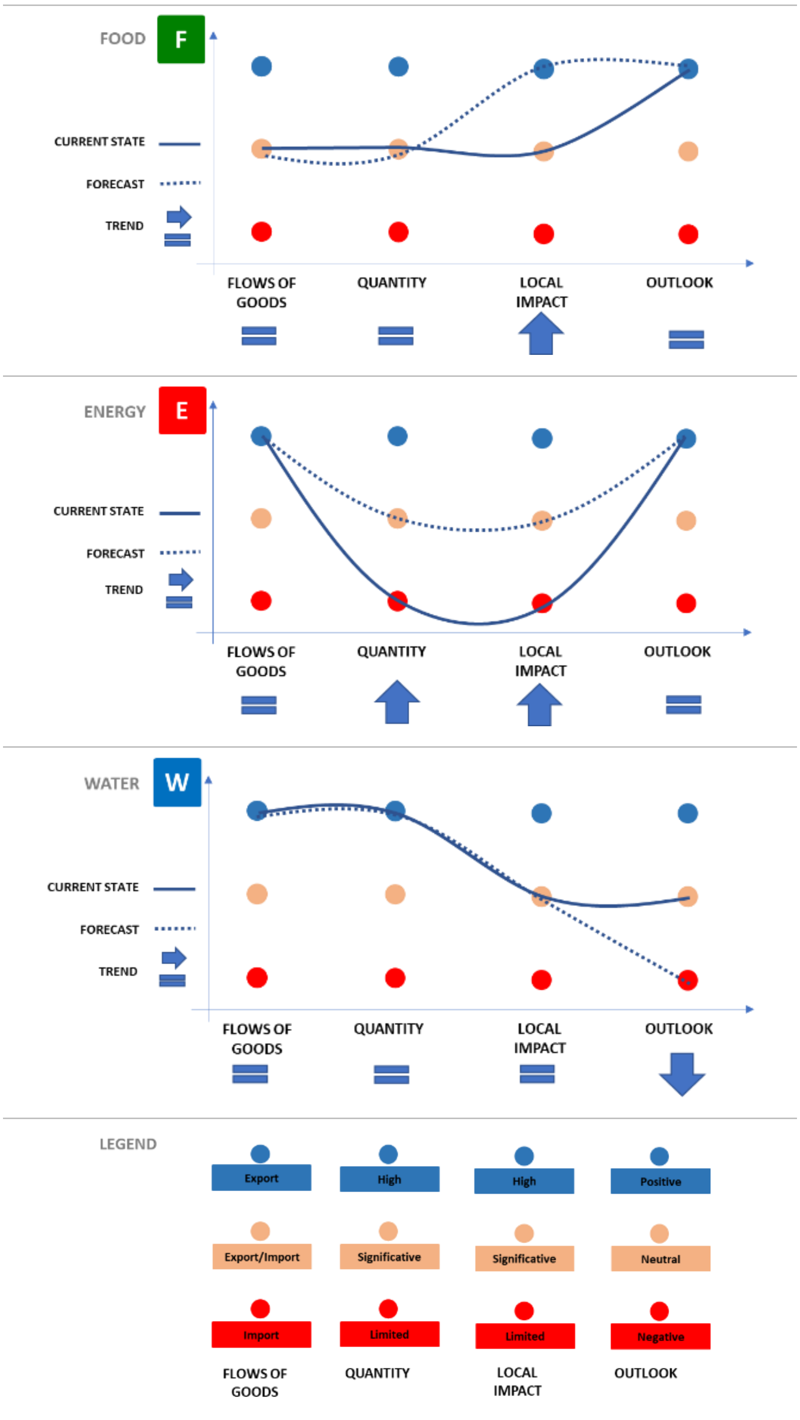


**Fig.6 State and scenario qualitative indicators as applied to the case study of the FEW Nexus model**

Finally, the water sector confirms the status of Avellino as an exporting province, even if there has been a reduction in spring flows in recent decades as a result of changing climatic conditions and lower rainfall. The resource will continue to have a significant local impact, which will grow if sustainable water use becomes the basis of economic development. In the case of this resource, the outlook can be considered negative and potentially critical because significant reductions in water supplies from springs due to climate change cannot be excluded. Hence the urgent need to draw up policies that are much more attentive to the use of the resource.

The scenario presented earlier is qualitative and should be considered as the initial step of a future research, aimed at deepening the data and at developing the scenario structure that is useful for applying territorial policies and plans.

# 4. Discussion. Towards new topics of the regional plan

## 4.1 The current regional plan for the province

Planning addresses the necessity of incorporating sustainability and resilience elements into the tools (Colucci, 2015). These elements must have an environmental focus, guiding urban and land-use systems toward active management of natural capital and ecological impact neutrality (Griggs et al., 2013). They should also encompass social aspects. In this context, a particular challenge affecting inland areas, such as the province of Avellino, is their livability. This extends beyond overall environmental quality (which is crucial) and includes the quality of services provided to the resident population, enabling them to lead their best possible lives.

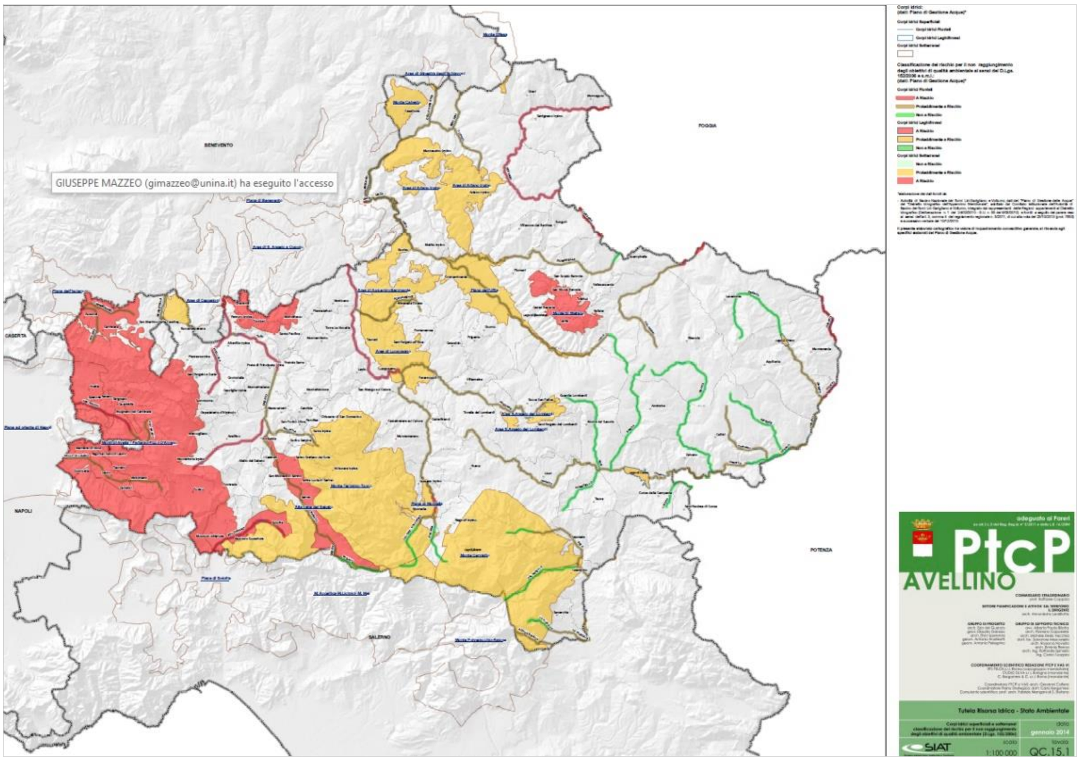


**Fig.7 Regional Coordination Plan of the Province of Avellino. Table QC 15.1 "Protection of Water Resources, Environmental Situation". The table is based on data from the Water Management Plan of the Liri, Garigliano and Volturno River Basin Authority**

These considerations are contained in the Territorial Coordination Plan (PTCP) of the Avellino Provincial Authority, approved in 2014. According to the Provincial Authority (2004), ensuring that people live better

means offering them appropriate services, thereby avoiding depopulation of marginal lands and concentrations of population only in the largest urban areas.
The purpose of the plan is to organise the province so that the system of services and production activities operating within it can support the existing population and, if possible, lead it to increase in the future. To combat the demographic crisis pre-existing territorial strengths need to be enhanced and improved.
Interesting for the purposes of this paper are the PTCP guidelines in relation to the issues of energy, agricultural resources and water. Within the guidelines for compatible development of business and industry, one of the aims is energy saving to be implemented through three types of tools: integration in the plan of environmental improvement policies, and development of renewable sources; the development of guidelines to be implemented in municipal urban plans and building regulations (Gargiulo & Russo, 2017); identification of criteria and areas for implementation of energy districts.
The plan devotes specific attention to agricultural and agroforestry resources, sectors always considered by regional plans. In particular, the provincial plan serves to protect and enhance area resources (Mazzeo, 2021). In the case of the Avellino PTCP these objectives are the protection of the agricultural landscape and the development of responsible tourism.
The issue of water resources is less present in the plan (Fig.7). There is no mention of the strategic importance of such resources or of their representing the basis for the construction of policies to improve the environmental conditions of the population. When mentioned, the water issue is dealt with as a secondary theme, in support of other objectives. For example, when the plan suggests the creation of greenways it argues that ecological corridors to be conserved or strengthened are identified through a process of analysis of the hydrographic network. Furthermore, the plan states that "interventions can be designed by placing water, present in abundance along the entire network of the ecological corridors, at the centre of the choices and as a project variable. The characteristics of the area and the strong presence of water, in the form of waterfalls, springs, rivers, lakes, fountains, pools etc., creates the conditions for a 'environmentally sustainable' quality system. If water is life, waterways are the arteries of our province and of our landscapes" (Provincia di Avellino, 2014, 18).
The transition from description of resources to identification of projects to implement is further testimony of the scant consideration given to resources in the plan. Only two projects are concerned with the resources mentioned. The first are urban and energy redevelopment plans, which the Provincial Authority promotes for the benefit of municipalities. Starting from energy analysis of the urban fabric of the municipal area, the plans identify and encourage energy redevelopment of buildings and neighbourhoods (Provincia di Avellino, 2014, 105). The second group of projects concerns river redevelopment projects basically promoting tourism in the province, to be implemented with an action called "Irpinia: land of water".

## 4.2 New regional planning and the challenge of resources

Classical planning defines land use methods, urban loads, functions, and interrelationships between spaces and functions, with little attention to the impacts that such forecasts may have on primary area resources, such as water, food and soil. Such plans fail in these basic aspects: they lack a vision of the systemic impacts of sectoral policies, while a rigid system of actions and procedures persists, and they unfold along separate lines that do not intersect (Pahl-Wostl, 2017).
The need for a substantial change in pace is evident from the analysis of Avellino provincial planning (but the reasoning can probably be extended to many other plans). When preparing guidelines for management of a geographical area such as a province or region, effective evaluation of its own characteristics is of fundamental importance. Based on these, we structure the system of actions that is best suited to it. This is essential to avoid miscalculations that can lead to worse results than those we wish to rectify.
In an area such as Irpinia, the basic conditions require targeted actions able to achieve at least two important results. The first is to better preserve the system of existing resources, to be considered strategic because

they are used to obtain the necessary goods. To ensure that such resources continue to be used in the future, they must be taken into consideration in all land management policies and in all plans, from the regional level to the project level involving major environmental changes (Mazzeo & Polverino, 2023).

The second result would be to reverse the trend in depopulation and the reduction in existing services and in life quality (Friedman et al., 2023). In other words, it is necessary to interrupt the vicious circle of a declining population and the scrapping of services, which leads to the overall impoverishment of the province. To curb population loss, policies for inland areas need to be underpinned by a significant economic fabric. This means starting from the system of resources present in the province, to identify actions for resource conservation and enhancement, and to develop ongoing economic activities that can generate income, thereby reversing the processes of depopulation. At the same time, the limited usefulness of haphazard activities should be borne in mind: such action is able to concentrate attention on the environment for limited periods without translating into long-term benefits.

To this end, the FEW Nexus model can be useful thanks to its specific characteristics: systemic attention to three types of strategic resources; the highlighting of relationships between such resources; the ability to link resources and typical functions connected with regional planning, such as domestic and production sectors; finally, the ability to reveal how such resources may be connected with areas outside the province (Fig.8).

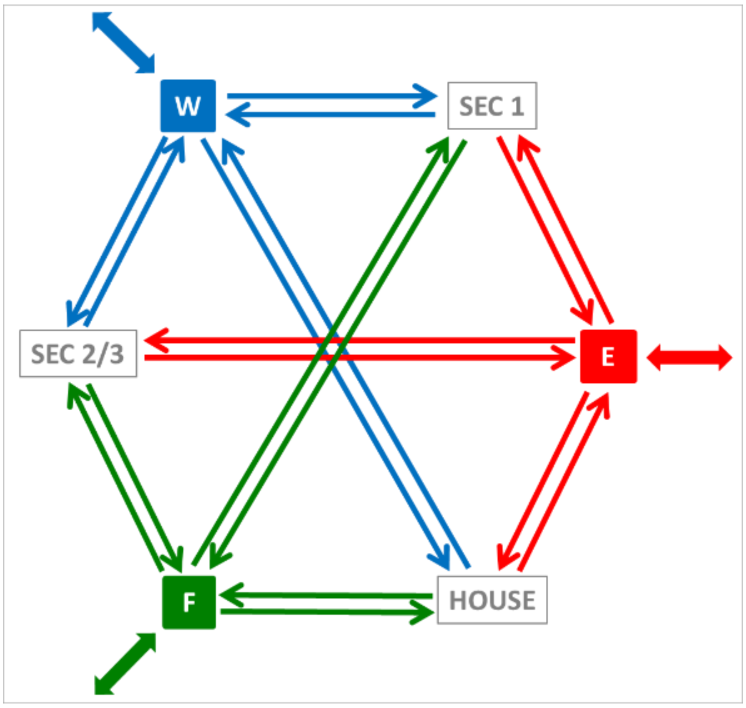


**Fig.8 FEW Nexus model and relations with main planning sectors (house and economic sectors)**

Redefining the connections between land use planning and natural resources entails giving new meanings to the plan (Fig.9). The latest generations of plans are distinguished by some specific characteristics such as landscape protection, soil consumption reduction or elimination, rewilding, urban regeneration, renewable energy production, and buildings with low carbon footprints.

All the above aspects are important for the plan to be able to confer greater sustainability. However, it is necessary to take a step forward and ascertain the possibility of the plan, with its general systemic vision, becoming the tool that sets the balance between consumption and natural resource use. If water, food and energy are three fundamental assets of an area, various situations can arise:

- the area exports all three resources;
- the area imports all three resources;

- the area is an importer of one or two resources; conversely, it is also an exporter of one or two resource types.

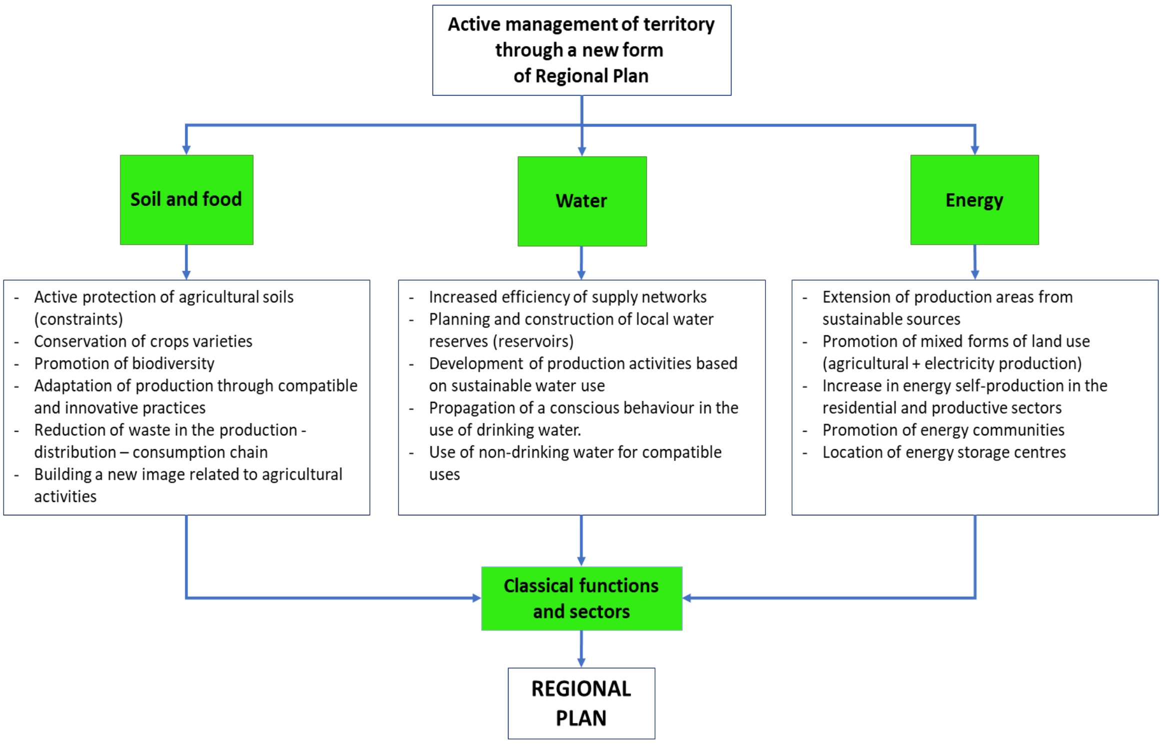


**Fig.9 New strategic elements of the regional plan**

In the various cases, the resources take on different values and affect land use differently. In any event, sound management of these resources becomes a strategic way to increase the area's resilience and reduce its overall carbon footprint.

Another aspect to consider is the need for the plan to envisage scenario analysis (Önkal et al., 2013; Meissner & Wulf, 2013). A plan devised today unfolds in the next decade; therefore, it needs to consider alternative development scenarios. Construction of such scenarios, based on the strategic resources present in the area, creates a new type of land use plan in which visions of the future are identified and worked towards through specific actions.

Active management of a region therefore means giving the right weight to new elements. They must be the backbone of land-use planning which will have to expand its range of action from the simple regulation of land use to the ways in which this use is brought about.

The new form of planning should be capable of achieving three objectives:

- increasing awareness of how the protection of natural capital can translate into an economic advantage and how it can affect settlement trends. Each of the components (water, soil, energy and others) has characteristics that can have a significant impact on the region and can lead to the construction of ecological districts that, in turn, can generate significant economic and settlement impacts;
- clarifying the meaning of natural resources, and modifying the perspective with which they are normally considered, especially highlighting the benefits resulting from usage patterns that contribute to resource enhancement and that have a positive impact on environmental sustainability, on the quality of the area in question and on liveability;
- drawing up guidelines to update land-use planning tools in terms of effective application of the principles of sustainability and neutrality of the local carbon footprint and as a contribution to the parallel process of decarbonisation (European Environment Agency, 2000; United Nations, 2015; Ulpiani et al., 2023).

## 5. Conclusions

The study represents an initial step in research intended to be developed in the near future. It requires theoretical and practical elaboration. The connection between food resources, energy, and water resources needs to be explored further with the aim of investigating the existing connections in relation to the following aspects: 1) the impact of climate change on these natural resources and 2) the ability to use climate change to modify behaviors, tools, and methodologies for sustainable resource utilization.

There is also a need to delve into the role of scenarios in constructing interrelationships. Scenarios, despite their inherent uncertainty, build knowledge that contributes to refining models for predicting changes. This knowledge can be directed towards the identification and test of a model of the relationship between resources that have so far been considered autonomous and analysed separately; the application of a systemic analysis, which involves exploring the relationships and intensity of flows generated due to these interconnections; and the investigation of the impacts of climate change on resources by determining the share of impact resulting from these interrelationships.

The optimal use of the natural resources of an area can represent the basis for building sustainable development strategies. Natural resources are strategic resources and will become increasingly vital over time. Their conservation, their careful use and their regeneration moves in the direction of EU policies for the enhancement of the natural heritage and decarbonization of the economy and urban areas.

Attention to such resources is highlighted on a scientific level by in-depth investigations performed by various fields of study such as the FEW Nexus model, analyses of natural capital and of ecosystem services. They testify to the growing importance of the link between the socio-economic structure and the physical basis for such resources, a link that allows land-use systems to continue evolving towards higher levels of sustainability.

Several insights may be drawn from the case study, based on in-depth analysis of the three systems considered by the FEW Nexus model. With regard to soil and agri-food production, the Irpinia case study shows a lower trend in soil consumption than that occurring in other areas of Campania. Yet the agricultural landscape needs to be preserved, as well as land not used for agriculture which is of fundamental importance for other resources (such as water). However, the Irpinia agri-food chain has further development potential, especially in eastern areas of the province. It is therefore necessary to investigate the characteristics and conditions for the development of new certified production areas, to be included in the national quality agricultural production system which represents a major part of the Italian economy (Basile et al., 2016).

The importance of water resources is evident, as is the need for them to be at the core of local and national policies. The water resources of the Irpinia basin should be subject to great care and attention. Yet they are still considered an infinite resource to be exploited in other areas, conferring few benefits on local communities and with little attention to distribution efficiency. Water is a resource used by millions of inhabitants in coastal Campania, as well as in Puglia and Basilicata, which represents natural capital that will become increasingly strategic with the exacerbation of climate change processes (Bates et al., 2008). Sustainable management of such resources means less water waste (both in extraction and in use), higher levels of safety and quality, and creation of innovative production systems in different sectors, from agriculture to tourism. It means using water where it flows, as well as where it is required. It is a strategic resource in terms of economic development and also of national geopolitics.

The management of water resources is closely linked to processes of climate change. The latter causes both direct effects (lowering of piezometric levels and decrease in flow rates) and indirect effects (infiltration of surface water and pollutants) upon groundwater resources. In addition, the rise in temperatures leads to an increase in consumption and hence greater extraction from aquifers. According to Ducci and Tranfaglia (2005), in this context, the management of drinking water resources in Italy and Campania (where in 2004 groundwater accounts for 86.4% and 99.7%, respectively, of drinking water) is a critical issue, since it must cope with increasing anthropogenic pressure, and hence with increasing drinking water demand, and with decreasing groundwater resources due to climate change.

Finally, energy production is to be considered a factor affecting development, like agriculture and water. Clean energy represents the future of this sector especially in consideration of the European policies to eliminate harmful emissions over the next few decades (European Commission, 2018). Clean energy already means new way to build communities (Gaglione, 2023) and energy autonomy for the province of Avellino. However, it could become a resource to be exported in ever greater quantities and to use for siting innovative production chains able to create a district economy in the area concerned.

Furthermore, international scenarios accentuate the strategic nature of the energy sector and the necessary national and European autonomy. Autonomy depends both on the reliability of suppliers and on the increase in production capacity from renewable sources. This second line of action is fundamental to reduce greenhouse gas emissions, hence to positively impact climate issues in the medium and long term, but it also plays a significant role in the freedom of action of a nation in moments of energy crisis.

Starting from in-depth knowledge of such systems and from the relationships existing between them and the area in which they act, new guidelines may be drawn up for regional planning, which must change to keep abreast of new attention to land use and to natural resources. Such planning for the near future must increasingly become strategic, changing from a static to a dynamic structure that accompanies evolving land use, employing tools for the various scenarios envisaged.

## References


Abdi, H., Shahbazitabar, M., & Mohammadi-Ivatloo, B. (2020). Food, Energy and Water Nexus: A Brief Review of Definitions, Research, and Challenges. *Inventions*, *5* (56), 14. https://doi.org/10.3390/inventions5040056

Alcamo, J. (Ed.) (2009). *Environmental Futures: The Practice of Environmental Scenario Analysis*. Amsterdam: Elsevier.

Balacco, G., Carbonara, A., Gioia, A., Iacobellis, V., & Piccinni, A.F. (2017). Evaluation of Peak Water Demand Factors in Puglia (Southern Italy). *Water*, *9* (2), 96. https://doi.org/10.3390/w9020096

Basile, G., Diana, P., & Vitale M.P. (Eds.) (2016). *La definizione identitaria di un territorio rurale. Benessere e antichi mestieri nell'Alta Irpinia*. Milano: FrancoAngeli.

Bates, B., Kundzewicz, Z.W., Wu, S., & Palutikof, J. (Eds.) (2008). *Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change*. Geneva: IPCC Secretariat.

Boyd, E., Osbahr, H., Ericksen, P., & Tompkins E. (2008). Resilience and 'Climatizing' Development: Examples and policy implications. *Development*, *51*, 390-396. https://doi.org/10.1057/dev.2008.32

Castellar, J.A.C., Popartan, L.A., Pueyo-Ros, J., Atanasova, N., Langergraber, G., Säumel, I., Corominas, L., Comas, J., & Acuña, V. (2021). Nature-based solutions in the urban context: terminology, classification and scoring for urban challenges and ecosystem services. *Science of the Total Environment, 779*, 146237. https://doi.org/10.1016/j.scitotenv.2021.146237

Ciervo, M. (2016). Beni comuni: accesso alla risorsa e giustizia sociospaziale. Il caso dell'Acquedotto Pugliese, SpA in house. In AA.VV. *Commons/Comune, geografie, luoghi, spazi, città.* Memorie Geografiche della Società di Studi Geografici. 14, 537-543.

Colucci, A. (2015). The Potential of Periurban Areas for the Resilience of Metropolitan Region. *TeMA - Journal of Land Use, Mobility and Environment*, 103-122. https://doi.org/10.6092/1970-9870/3655

Córdoba Hernández, R., & Camerin, F. (2023). Assessment of ecological capacity for urban planning and improving resilience in the European framework: An approach based on the Spanish case. *Cuadernos de Investigacion Geografica,* 49. https://doi.org/10.18172/cig.5638

Costanza, R., & Daly, H.E. (1992). Natural Capital and Sustainable Development. *Conservation Biology*, *6* (1), 37-46. Retrieved from: https://www.jstor.org/stable/2385849. (Accessed: June 30, 2023).

Costanza, R., d'Arge, R., de Groot, R., Farber S., Grasso, M., Hannon, G., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P., & Belt, M. van den (1997). The value of the world's ecosystem services and natural capital. *Nature*. *387*, 253-260.

Daily, G.C., & Matson, P.A. (2008). Ecosystem services: From theory to implementation. *PNAS, 105* (28). https://doi.org/10.1073/pnas.0804960105

Dendena, B. (Ed.) (2018). *Capitale naturale. Ecologia, economia e politica per società sostenibili*. Milano: Fondazione Giangiacomo Feltrinelli.

D'Odorico, P., Davis K.F., Rosa, L., Carr,J.A., Chiarelli, D., Dell'Angelo, J., Gephart, J., MacDonald, G.K., Seekell, D.A., Suweis, S., & Rulli, M.C. (2018). The Global Food-Energy-Water Nexus. *Review of Geophysics, 56* (3), 456-531. https://doi.org/10.1029/2017RG000591

Ducci, D., & Tranfaglia, G. (2005). L'impatto dei cambiamenti climatici sulle risorse idriche sotterranee in Campania. *Geologi. Bollettino dell'Ordine dei Geologi Della Campania*, *1* (4), 13-21.

European Commission (2018*). A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy. COM (2018) 773 final*. Brussels: European Commission.

European Environment Agency (2000). *Sustainable Development Goals and the environment in Europe: a cross-country analysis and 39 country profiles*. Copenhagen: European Environment Agency.

European Environment Agency (2021). *Rethinking agriculture. Briefing no. 25/2021*. Copenhagen: European Environment Agency. https://doi.org/10.2800/090009

Fiorillo, F., & Ventafridda, G. (2009). Le portate delle sorgenti di Cassano Irpino e Caposele (Campania) durante periodi siccitosi. *Geologi e territorio*. *4* (8).

Fistola, R., Gaglione, F., & Zingariello, I. (2023). The small smart city: renewable energy sources in little town of Italy. *Tema. Journal of Land Use, Mobility and Environment*, 16 (1), 183-199. http://dx.doi.org/10.6093/1970-9870/9850

Friedman, E., Solecki, W., Troxler, T.G., & Paganini Z. (2023). Linking quality of life and climate change adaptation through the use of the macro-adaptation resilience toolkit. *Climate Risk Management*, *39*, 100485. https://doi.org/10.1016/j.crm.2023.100485

Gargiulo, C., & Russo, L. (2017). Cities and energy consumption: a critical review. *TeMA - Journal of Land Use, Mobility and Environment, 10* (3), 259-278. https://doi.org/10.6092/1970-9870/5182

Gaglione, F. (2023). Policies and practices to transition towards Renewable Energy Communities in Positive Energy Districts. *TeMA - Journal of Land Use, Mobility and Environment*, *16* (2), 449-454. https://doi.org/10.6093/1970-9870/10054

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M.C., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N., & Noble, I. (2013). Sustainable development goals for people and planet. *Nature*. *495*, 305-307. https://doi.org/10.1038/495305a

Hoff, H. (2011). *Understanding the Nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus*. Stockholm: Stockholm Environment Institute.

Kosow, H., & Gaßner, R. (2008). *Methods of Future and Scenario Analysis: Overview, Assessment, and Selection Criteria*. DIE Studies, 39. Bonn: Deutsches Institut für Entwicklungspolitik gGmbH.

Leichenko, R. (2011). Climate change and urban resilience. *Current Opinion in Environmental Sustainability*, *3*, 164-168. https://doi.org/10.1016/j.cosust.2010.12.014

Mazzeo, G. (2005). Lo sviluppo dell'agricoltura di qualità in Irpinia. *Urbanistica Informazioni*. *201*, 83-84.

Mazzeo, G. (2013). City and Energy Infrastructures between Economic Processes and Urban Planning. *TeMA - Journal of Land Use, Mobility and Environment*, *6* (3), 311-324. https://doi.org/10.6092/1970-9870/1929

Mazzeo, G. (2021), *Sulla pianificazione territoriale in Italia. Cronache, testimonianze, prospettive*. Milano: FrancoAngeli.

Mazzeo, G., & Polverino S. (2023). Nature-based solution for climate change adaptation and mitigation in urban areas with high natural risk. *TeMA - Journal of Land Use, Mobility and Environment, 16* (1), 47-65. https://doi.org/10.6093/1970-9870/9736

Meissner, P., & Wulf, T. (2013). Cognitive benefits of scenario planning: Its impact on biases and decision quality. *Technological Forecasting & Social Change*, *80*, 801-814. https://doi.org/10.1016/j.techfore.2012.09.011

Ministero dell'Ambiente (2020). *Terzo rapporto sullo stato del capitale naturale in Italia. 2019. Comitato per il capitale naturale*. Roma: Ministero dell'Ambiente. Retrieved from: https://www.minambiente.it/pagina/terzo-rapporto-sullo-stato-del-capitale-naturale-italia-2019. (Accessed: January 20, 2023).

Molavi, M. (2018). Measuring Urban Resilience to Natural Hazards. *TeMA - Journal of Land Use, Mobility and Environment, 11* (2), 195-212. https://doi.org/10.6092/1970-9870/5485

Moro, B. (1997). *Capitale naturale e ambiente*. Milano: Franco Angeli.

Muller, M. (2007). Adapting to Climate Change: Water Management for Urban Resilience. *Environment and Urbanization, 19*, 99-113. https://doi.org/10.1177/0956247807076726

Munafò, M. (Ed.) (2020). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici. Edizione 2020.* Report SNPA 15/20. Roma: ISPRA.

Munafò, M. (Ed.) (2022). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici. Edizione 2022.* Report SNPA 32/22. Rome: ISPRA.

Newell J.P., Goldstein, B., & Foster, A. (2019). A 40-year review of food–energy–water nexus literature and its application to the urban scale. *Environmental Research Letters, 14*, 073003. https://doi.org/10.1088/1748-9326/ab0767

Önkal, D., Sayım, K.Z., & Gönül, M.S. (2013). Scenarios as channels of forecast advice. *Technological Forecasting & Social Change*, *80*, 772-788. https://doi.org/10.1016/j.techfore.2012.08.015

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change, 20* (4), 550-557. https://doi.org/10.1016/j.gloenvcha.2010.07.004

Pahl-Wostl, C. (2019). Governance of the water-energy-food security nexus: A multi-level coordination challenge. *Environmental Science and Policy*, *92*, 356-367. https://doi.org/10.1016/j.envsci.2017.07.017

Paltsev, S. (2017). Energy scenarios: the value and limits of scenario analysis. *WIREs Energy and Environment, 6* (4), 242. https://doi.org/10.1002/wene.242

PNIEC (2019). *Piano Nazionale Integrato per l'Energia e il Clima*. Roma: Ministero dello Sviluppo Economico, Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Ministero delle Infrastrutture e dei Trasporti.

Provincia di Avellino (2004). *Studi propedeutici al Preliminare del Piano Territoriale di Coordinamento Provinciale*. Assessorato alla Pianificazione Territoriale. Avellino: De Angelis Editore.

Provincia di Avellino (2014), *PTCP Avellino, Relazione generale*. Retrieved from: http://old.provincia.avellino.it:8090/web/guest/p.t.c.p. (Accessed: September 20, 2023).

Regione Campania, ATO-1 (2012). *Piano d'Ambito. Rapporto ambientale. Aggiornamento 2012*. Retrieved from: http://www.atocaloreirpino.it/area-tecnica/piano-d-ambito/documenti-pda-2012.html. (Accessed: January 20, 2023).

Regione Campania (2013). *Il territorio rurale della Campania. Un viaggio nei sistemi agroforestali della regione attraverso i dati del 6° Censimento Generale dell'Agricoltura*. Napoli: Regione Campania, Assessorato Agricoltura.

Regione Campania (2017). *Delibera della Giunta Regionale no. 305 del 31/5/2017, Strategia Nazionale Aree Interne – Approvazione del documento di strategia d'area dell'Alta Irpinia*. BURC n. 50 del 22/6/2017.

Scolozzi, R., Morri, E., & Santolini, R. (2012). Pianificare territori sostenibili e resilienti: la prospettiva dei servizi ecosistemici. *Territorio, 60*, 167-175. https://doi.org/10.3280/TR2012-060027

Terna (2019). *Statistiche Regionali 2018*. Roma: Terna.

Terna (2022), *Pubblicazioni statistiche*. Retrieved from: https://www.terna.it/it/sistema-elettrico/statistiche/pubblicazioni-statistiche. (Accessed: June 15, 2023).

Turner, R.K., & Daily, G.C. (2008). The Ecosystem Services Framework and Natural Capital Conservation. *Environmental Resource Economy, 39*, 25-35. https://doi.org/10.1007/s10640-007-9176-6

Ulpiani, G., Vetters, N., Melica, G., & Bertoldi P. (2023). Towards the first cohort of climate-neutral cities: Expected impact, current gaps, and next steps to take to establish evidence-based zero-emission urban futures. *Sustainable Cities and Society, 95*: 104572. https://doi.org/10.1016/j.scs.2023.104572

United Nations (2015). *Transforming our World: The 2030 Agenda for Sustainable Development*. A/RES/70/1. New York: United Nations. Retrieved from: https://sdgs.un.org/2030agenda. (Accessed: April 16, 2023).

Zhang, P., Zhang, L., Chang, Y., Xu, M., Hao, Y., Liang, S., Liu, G., Yang, Z., & Wang C. (2019). Food-energy-water (FEW) nexus for urban sustainability: A comprehensive review. *Resources, Conservation & Recycling, 142*, 215-224. https://doi.org/10.1016/j.resconrec.2018.11.018

Zoppi, C. (2020). Ecosystem Services, Green Infrastructure and Spatial Planning. *Sustainability, 12* (11), 4396. https://doi.org/10.3390/su12114396

## Image Sources

Fig.1, 2: Author's elaboration;

Fig.3: Fiorillo & Ventafridda (2009);

Fig.4: Author's elaboration on data Campania Region, ATO-1 (2012);

Fig.5: Ducci & Tranfaglia (2005);

Fig.6: Author's elaboration;

Fig.7: Regional Coordination Plan of the Province of Avellino. Table QC 15.1;

Fig.8, 9: Author's elaboration.

## Table Sources

Tab.1, 2: Regione Campania (2013);

Tab.3: Regione Campania, ATO-1 (2012). Area Plan, Annex C (Analytical tabs on the consistency of infrastructures);

Tab.4, 5: Terna (2022).

## Author’s profile

**Giuseppe Mazzeo**

Researcher at the National Research Council, Institute for Studies on the Mediterranean (CNR-ISMed) in Naples. The research activity is carried out in cooperation with the Department of Civil, Architectural and Environmental Engineering (DICEA) of University of Naples Federico II. Research fields are regional planning, strategic environmental assessment, urban planning and regeneration. Through teaching contracts, he held courses in the urban planning sector at the Federico II and Parthenope universities in Naples.