From Global to Local Scenarios of Climate Change Impact on Natural Resources. The Role of Regional Planning in an Inner Area of South of Italy

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Abstract. The global scenarios associated with climate change predict a rise in temperatures over the coming decades, with serious consequences in terms of economics and quality of life. The scenarios outlined by the IPCC and the European Environment Agency foresee the Mediterranean basin as one of the areas potentially most affected by these phenomena. The paper, starting from the global scenarios, hypothesizes a local scenario in a region of significant relevance in Southern Italy, the Province of Avellino. Due to its implications, the paper proposes to use the scenarios as a primary tool in the building of regional planning for this area.

Keywords: Climate change · Scenario analysis · Mediterranean basin · South of Italy · Regional planning

1 Introduction and Structure of the Paper

Climate change, given the high probability of negative impacts stemming from it, has become a central issue in shaping the majority of national and international medium to long-term policies, especially concerning natural resources. This leads to an increasing role of scenarios envisioning future transformations, starting from the fact that they already influence current local events and situations, as the growing frequency of extreme weather events and the damages they cause to territories.

The policies pursued by states, based on scientific considerations from supranational bodies – in particular, on the various reports of Intergovernamental Panel on Climate Change (IPCC) –, are directed towards mitigation actions (addressing the causes of climate change) and adaptation actions (addressing the current response to risks). However, these policies cannot swiftly reverse the trends of rising temperatures, hence negative impacts must still be anticipated in the near future.

However, it is to emphasize the tension surrounding the concept of climate change, mitigation, and adaptation. The international debate reflects the complexity and urgency

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of addressing this global challenge. Starting from the condition that there's often disagreement on the severity and causes of climate change, which can hinder consensus on appropriate actions, the disputes on mitigation arise over how to reduce greenhouse gas emissions effectively and fairly. This involves balancing the responsibilities of developed and developing nations, as well as considering economic impacts and technological feasibility. At the same time the dispute about adaptation revolves around actions to adapt to the impacts of climate change, such as rising sea levels, extreme weather events, and shifts in agricultural patterns. Other questions arise about resource allocation, equity, and the role of governments versus local communities.

The interest in adaptation has increased significantly because anthropogenic climate change appears unavoidable and mitigation agreements are difficult to achieve. But the discourse over climate change adaptation can be critical. Taking it for granted as a strategy for coping with climate change simplifies the political and economic contexts in which this strategy could be applied, and it might also unintentionally subvert the vulnerable communities it wants to benefit. This because adaptation strategy is favoured by neoliberal policies, which shift responsibilities for social and environmental problems to the individual [1].

Many cities and territories around the world are increasingly developing plans and policies for either mitigation and adaptation to climate change. This approach can be problematic and result in trade-offs because efforts aimed at enhancing mitigation may hinder achieving adaptation aims, and viceversa. Mitigation measures may have negative impacts on adaptation by increasing exposure to risks. In contrast, adaptation measures may increase greenhouse gas emissions by, among other things, reducing efficiency and increasing energy demand [2].

Other emphasize the lack of clarity and multiplicity among and between these concepts allows them to continue to be widely adopted in different sectors of society [3]. In addition, limited information and insufficient resources are inherent challenges for climate policy, and policy makers must cope with actions to design and implement adaptation policies under conditions of scarcity. Also, if adaptation policy will be designed under these conditions, the perspective calls for greater attention to the social justice implications in the policy design process [4].

Overall, these tensions underscore the need for collaboration, innovation, and compromise on a global scale to address climate change effectively. It requires navigating diverse interests and perspectives while prioritizing the long-term health of the planet and its inhabitants.

Attention to natural resources assumes particular relevance in the mitigation and adaptation perspective. They provide a range of fundamental services for life on the planet and are studied from various viewpoints, focusing on one or more of them at a time.

The aim of the paper is to apply a scenario analysis, albeit in preliminary form, on the possible impacts of climate change on a territory (the case study) characterized by natural resources that need to be preserved and protected for their strategic importance, and on the responses in terms of territorial governance.

The paper starts from an analysis of the general scenarios proposed by the latest IPCC report and their relevance for the Mediterranean area (Sect. 2). Section 3 highlights the

case study (the Province of Avellino, Italy) analysing some key indicators of the territory. These indicators are strategic for the territory, but they are also the most exposed to adverse scenarios related to climate change. Section 4 presents a local scenario concerning the case study. Finally, recommendations for the future regional planning follow (Sect. 5).

2 IPCC Scenarios

The IPCC Synthesis Report, presented in 2023, highlights a series of evidence and scenarios characterizing the current state and foreseeable evolution of climate change [5].

Evidence and forecasts are grouped into three temporal situations:

- Actual state.
- Long-term scenario.
- Short-term responses.

Then, the IPCC develops a specific scenario for the Mediterranean area, which is reported in the final part of the chapter.

2.1 Actual State

Human activities, primarily through greenhouse gas emissions, are the cause of global warming, with the global surface temperature reaching 1.1 °C above 1850–1900 levels during the period 2011–2020. Global greenhouse gas emissions continued to rise during the period 2010–2019, with contributions stemming from unsustainable energy production, land use, lifestyle and consumption patterns, and production models among regions, countries, and within countries and individuals. Human-induced climate change is already influencing a range of extreme weather and climate events in every region of the world. This has led to widespread negative impacts on food and water security, human health, economies, and society, with associated losses and damages to nature and people (Fig. 1).

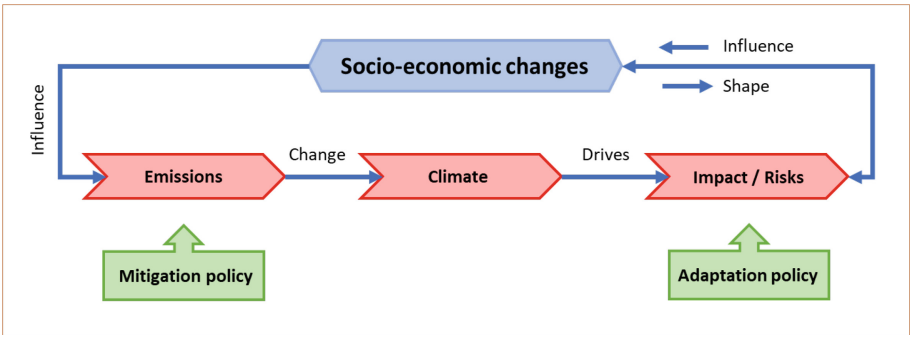

Fig. 1. The cause-effect chain joining the emissions and the impacts for climate change [5]

The responses of the international community have seen the signing of climate agreements and the of growing national ambitions for climate action. They, along with increasing public awareness, are accelerating efforts to address climate change across multiple levels of governance. Mitigation policies have contributed to a decrease in global energy and carbon intensity. Low-emission technologies are becoming increasingly accessible, with many low or zero-emission options now available for energy, buildings, transportation, and industry. Adaptation planning and implementation progress have yielded multiple benefits, with effective adaptation options having the potential to reduce climate risks and contribute to sustainable development.

However, current mitigation and adaptation actions and policies are not sufficient as there are gaps between global ambitions and the sum of declared national ambitions. In terms of mitigation, projected global greenhouse gas emissions for 2030 would lead to warming exceeding 1.5 °C over the course of the 21st century. This would make it more challenging to limit warming to below 2 °C. Gaps persist in adaptation, with many initiatives prioritizing short-term risk reduction but falling short of substantial adaptation.

2.2 Long-Term Scenario

The future warming will be driven by future emissions. It will affect all major components of the climate system, as each region will undergo multiple and concurrent changes. Many of the climate-related risks will increase compared to assessments made in past years, and the long-term impacts are hypothesized to be many times greater than those currently observed. The multiple climate and non-climate risks will interact, resulting in overall and cascading damages across all sectors and regions.

With increasing warming, adaptation actions will become more limited and ineffective. At higher levels of warming, losses and damages will increase, and additional areas will reach adaptation limits. This will increase vulnerability, exposure, and risks, although long-term planning may have beneficial effects if it includes flexible, multisectoral, and inclusive adaptation actions.

Regarding mitigation processes, the report emphasizes that limiting global warming caused by humans requires net anthropogenic CO_2 emissions to reach zero. On the other hand, pathways even with temperature increases of 1.5 °C and 2.0 °C entail rapid, profound, and immediate reductions in greenhouse gas emissions across all sectors. However, the windows of opportunity needed to ensure a liveable and sustainable future for all are rapidly closing (Fig. 2).

2.3 Short-Term Responses

In the short term, it is necessary to implement deep and rapid mitigation actions and accelerate adaptation efforts. This way, the risks of climate change to humans and ecosystems can be reduced. Models that limit warming to 1.5 °C and 2.0 °C must be immediately implemented. They foresee global greenhouse gas emissions peaking in the early years of the second decade of the 2000s followed by rapid and deep reductions.

Accelerated implementation of adaptation actions will enhance well-being by reducing losses and damages. Rapid and sustained mitigation actions entail higher initial

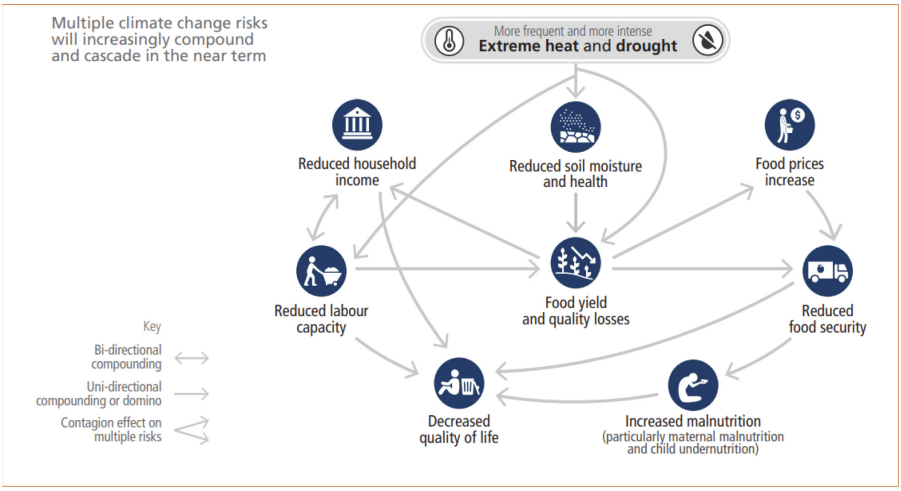

Fig. 2. Example of complex risk, where impacts from climate extreme events have cascading effects on food, nutrition, livelihoods, and well-being of smallholder farmers [5]

investments but will reduce future adaptation costs and improve co-benefits associated with sustainable development. Nevertheless, even in the short term, extreme events will increase, interacting with each other. Continuing with current development patterns means increasing the exposure and vulnerability of ecosystems and people to climate risks.

2.4 Scenarios for Mediterranean Region

Climate change strongly interacts with other environmental problems in the Mediterranean Basin, resulting from urbanisation, land use change, overfishing, pollution, biodiversity loss and degradation of land and marine ecosystems [6]. Main phenomena are:

- surface temperature in the Mediterranean region is 1.5 °C above the pre-industrial level;
- increasing of high-temperature extreme events;
- variable trends in precipitation across the basin;
- more frequent and intense droughts, especially in the north Mediterranean;
- warming of the sea surface by 0.29 °C–0.44 °C per decade since the early 1980s with stronger trends in the eastern basin;
- acceleration of the rising of sea level;
- increasing of sea acidity.

Climate change is the main cause of a growing number of impacts across the entire basin. These impacts include multiple consequences as longer and/or more intensive heat waves, droughts, floods, sea acidification and sea level rise, such as cascading impacts on marine and terrestrial ecosystems, as well as on land and sea use (agriculture, forestry, fisheries, tourism, recreation, etc.) and human health.

In the next future climate change is projected to intensify throughout the region. Air and sea temperature and their extremes are likely to continue to increase more than the global average.

The report underlines some of the expected main changes: the growing warming on land, the decrease of precipitation, the growing rainfall extremes in the northern part of the region, the growing of droughts. "Due to its particular combination of multiple strong climate hazards and high vulnerability, the Mediterranean region is a hotspot for highly interconnected climate risks. The main economic sectors in the region (agriculture, fisheries, forestry, tourism) are highly vulnerable to climatic hazards, while socioeconomic vulnerability is also considerable" [6, 2235].

3 Case Study. Natural Resources in the Province of Avellino

This paper focuses on the use of scenarios to build relationship between natural resources and land use planning. Natural resources are in a fragile state in the face of climate change and the scientific community pays considerable attention to the topic, which is being developed through several different lines of study.

The following analysis use three types of resources: food, water and energy. They are fundamental natural resources, and also the topic of the FEW (Food-Energy-Water) Nexus model [7–9], a theoretical framework used to analyse the interconnections and interdependencies among these resources. 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 province of Avellino is an inland province of the region of Campania in southern Italy (Fig. 3). The area is rich in natural resources: it contains regional nature reserves and protected areas, its soil favours high quality agricultural production [10], and weather conditions are conducive to a significant generation of electricity from renewable sources. Furthermore, the main springs feeding the Apulian Aqueduct [11] and supplying water to the Metropolitan City of Naples originate in southern Irpinia.

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 [12].

3.1 Soil, Agriculture, Food

The province of Avellino is 2,806.07 km^2. Soil consumption for Campania and Irpinia are 10.49 and 7.36% of surface area, respectively (for Italy the value amounts to 7.13%). The total amount of soil consumed to 20,536 hectares [13]. Soil not consumed comprises basically natural and agricultural soils.

Irpinia has extensive forest cover while its farmland is noted for its high-quality products [10]. For example, in the central part of the province there are internationally acclaimed winemakers.



Fig. 3. Province of Avellino in the Italian peninsula

3.2 Water

In terms of the organization of water resources, the provinces of Avellino and Benevento are part of the optimal territorial area ATO-1 of Campania, known as the Calore Irpino. ATO is the acronym of Ambito Territoriale Omogeneo, a territory on which integrated water services are organized. The Plan of (ATO-1) Campania [15] shows that the province of Avellino has significant water resources deriving from the presence of numerous natural springs. 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 East (Puglia and Basilicata), while the water of the Serino springs are channelled towards the metropolitan area of Naples. 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.

The water balance of the ATO-1 in 2012 (Fig. 4) shows that 33% of the spring waters are used to supply drinking water for the ATO-1 itself, while the remaining part (67%) is used outside the province.

Overall, the average flow rate available in the ATO-1 area should be 3,244 L per second. In practice, given that water infrastructure censuses reveal average losses of

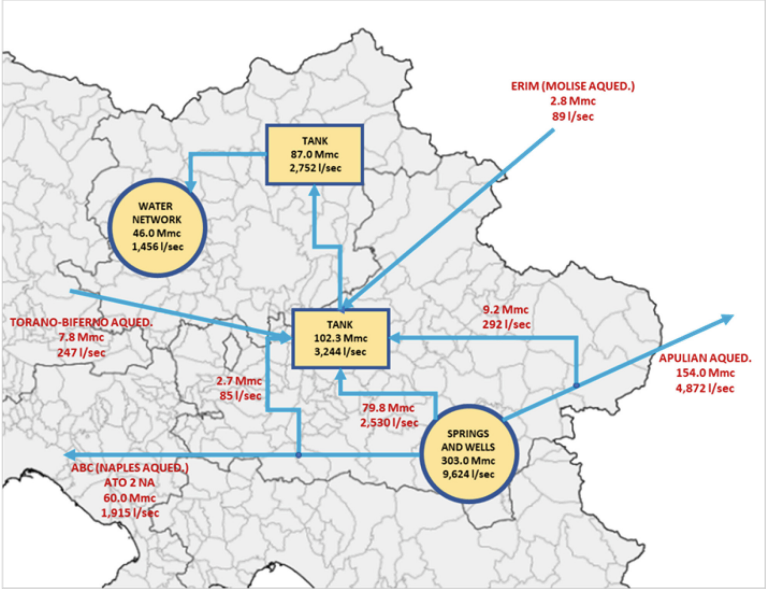

Fig. 4. Water balance of ATO-1 of Campania (2012) [15]

Table 1. Full data of the resources available in ATO-1 [15].

Flow rate	Springs	Wells	Surface water	Total
Supplied water (l/s)	3,965	1,955	0.0	5,920
Mean derived (l/s)	6,642	1,153	0.0	7,795
Maximum derived (l/s)	9,245	1,121	0.0	10,367
Minimum derived (l/s)	3,652	483	0.0	4,135
Annual mean derived volume (mc x 1,000)	204,664	33,855	0.0	238,519

15% for the adduction network and 47% for the distribution network, the effectively distributed flow to users is approximately 1,458 L per second. Table 1 shows the total size of the flow rates within the area of the ATO-1.

3.3 Energy

Production of electricity from sustainable sources represents a sector with significant potential impact [16]. 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) [17]. Wind power generation represents the dominant share of renewable energy production.

4 Local Scenario

The analysed natural resources can be the main topic for the development of a scenario analysis, with the aim to aid stakeholders and decision-makers in exploring potential future outcomes and evaluating the potential consequences of different actions (plans) and policies, as suggested by [18, 19], and [20].

4.1 Elements Influencing the Scenario

The construction of the scenario begins with the identification of the elements that can influence future trajectories in some way. These impactful conditions can be internal and external to the territory. Below, they are related to the three resource systems.

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 and the European Green Deal and its Farm to Fork Strategy consider that it will contribute to sustainability goals such as social well-being, ecosystem health, and food and nutrition security [21]. Climate change, however, may negatively impact the expansion of areas designated for agriculture and the yield per hectare of crops.

Regarding water, the plan of ATO-1 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. According to the Campania Regional Authority [15], 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.

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 a paper [22] showed that in the period 1981–1999 rainfall in Campania decreased by 15% compared to the previous 20 years. This decrease 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. In the same period, 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. Furthermore, in Campania the water resources have been decreased in flows from sources and lowering of the piezometric surface. 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

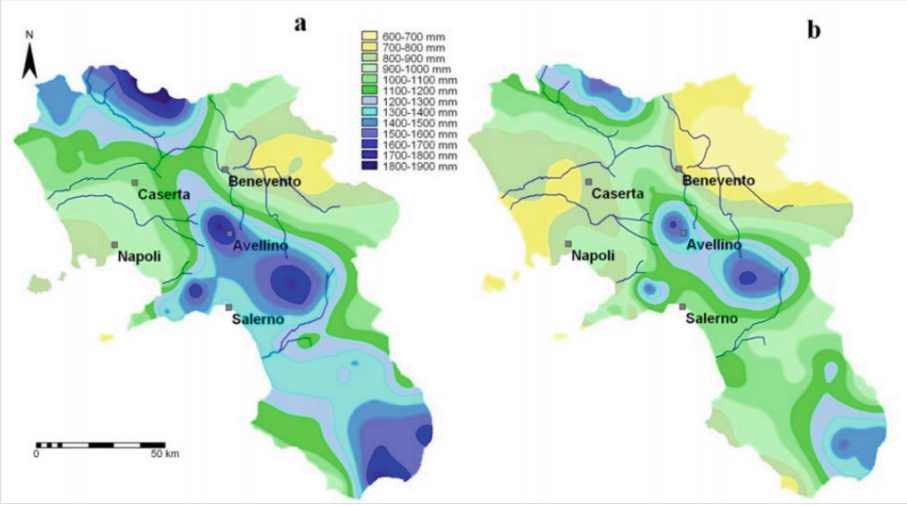

Fig. 5. Average annual rainfall (mm/year) for the period 1951–1980 (a) and 1981–1999 (b) [22]

and Puglia, currently supplied with groundwater from Campania) may be in a critical situation" [11, 22].

Regarding the energy, 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 European 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 [23] sets the Italian targets at 30 and 22%, respectively.

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 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.

4.2 The Scenario

Taking what has been said into consideration, the scenario is split two sections: the first starts from the current state of resources, while the second assumes possible evolutionary trajectories and it 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 of goods; (3) Local impact; and (4) Outlook. For each indicator, one opinion was expressed for the current state and the future state. Some judgments are followed by trend indications placed in square brackets. Figure FF 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 (Fig. 6).

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.

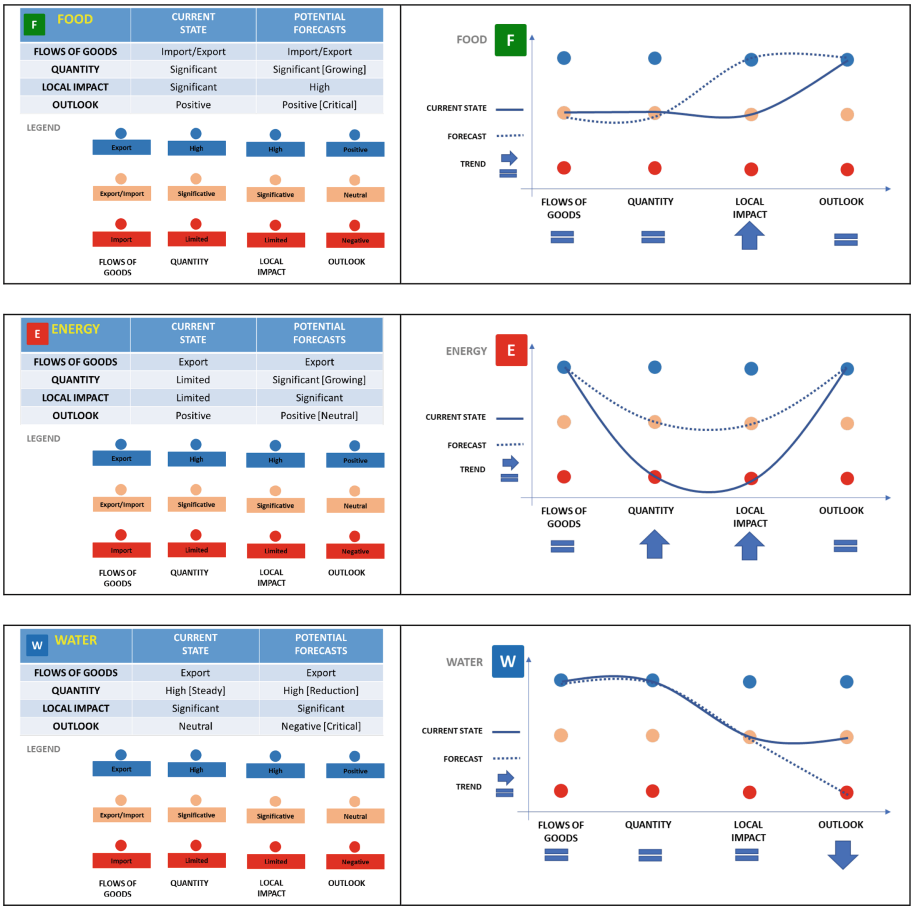

Fig. 6. State and scenario qualitative indicators as applied to the case study of the FEW Nexus model [24]

5 Recommendation for the Future Regional Planning

Planning addresses the necessity of incorporating sustainability and resilience elements into the tools [25]. These elements must have an environmental focus, guiding urban and land-use systems toward active management of natural capital and ecosystem services [26, 27]. 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. These considerations are contained in the Territorial Coordination Plan (PTCP) of the Avellino Provincial Authority, approved in 2014. According to the Provincial Authority [28], 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.

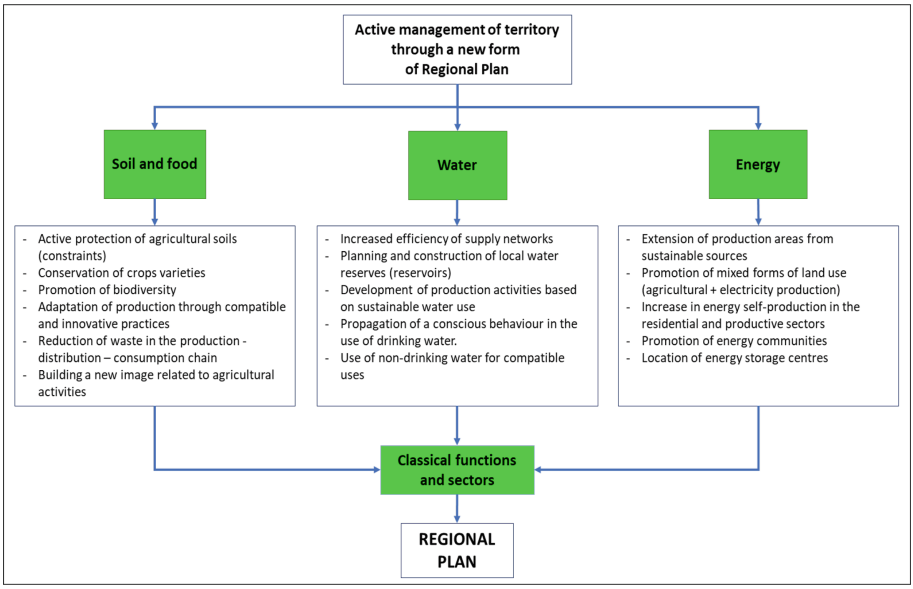

Fig. 7. New strategic elements for a regional plan of the province

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 [29].

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).

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 [30]. The second result would be to reverse the trend in depopulation and the reduction in existing services and in life quality [31].

To this end, the plan to use must respond to specific characteristics: 1) systemic attention to the strategic resources; 2) the highlighting of relationships between such resources; 3) the ability to link resources and typical functions connected with regional

planning, such as domestic and production sectors; 4) finally, the ability to reveal how such resources may be connected with areas outside the province.

Redefining the connections between land use planning and natural resources entails giving new meanings to the plan (Fig. 7). 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 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.

Another aspect to consider is the need for the plan to use scenario analysis [32, 33]. 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.

6 Conclusions

The paper has underlined the role of scenarios in constructing interrelationships among different temporal state of a region. 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.

Starting from in-depth knowledge of the natural resources 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.

The new form of planning should be capable of achieving three objectives [24]:

– 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 [34–36].

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