from Nexus Thinking to Nexus Doing

REXUS

MANAGING RESILIENT NEXUS SYSTEMS THROUGH PARTICIPATORY SYSTEMS DYNAMICS MODELLING

D6.1 BASELINE DESCRIPTION

WP6 – PILOT IMPLEMENTATION

www.rexusproject.eu

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With contributions from all pilot area teams

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Executive Summary

REXUS seeks to better understand the Water-Ecosystems-Food-Climate (WEFC) Nexus at European and global scales with significant heterogeneity of case studies. It is being implemented in five strategic pilot areas in Europe and Latin America, with the goal of promoting Nexus resilience and of supporting stakeholders in the implementation of REXUS solutions.

This document provides an overview and details of the characteristics of the five REXUS pilot areas. As such, it describes their primary water, agriculture, energy, environment, and climate features, relevant policies and current governance, water sources and uses, land uses, energy generation infrastructures. It also describes their challenges, stakeholders, innovation demand, technical and organisational infrastructure and knowledge capacities, and innovation supply. REXUS aims to respond to the fundamental needs of the pilot areas, so this document highlights the requirements of the stakeholders.

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I. INTRODUCTION

A. Purpose and scope

Project objective

The objective of REXUS is to analyse the Water-Energy-Food-Climate (WEFC) Nexus, co-develop, and validate solutions and tools that facilitate the transition to resilient systems with the help of Dynamic Systems. REXUS combines Earth Observation (EO) and different data to support Ecosystem-based Adaptation (EbA) by promoting participatory decision-making and policy development approaches. In addition, it is working towards meeting the Sustainable Development Goals (SDG).

Purpose and scope of the document

This report aims to integrate the description of the pilot areas in a general way and to provide an overview to the different Work Packages (WP). In this task lays the foundation for implementing REXUS solutions in the pilot cases. It is being developed in close interaction with stakeholders from the Learning and Action Alliances (LAA´s) communities. The baseline description of the pilots includes two chapters, the first is an overview, and the second part is a detailed description of each of the pilot cases.

B. Gender mainstreaming

Natural resources management and governance have a significant gender dimension, a fact that fully translates into the WEFC nexus. According to a large body of research and practical experience, effective, efficient, and equitable management of resources is only achieved when women and men are equally involved in consultation processes as well as in the management and implementation of any related solutions.

The Key importance of gender mainstreaming in natural resources management, and thus the nexus, can be understood even better through recalling the two opposite principal underlying cultural paradigms:

The *hierarchy paradigm* perceives humankind at the top of a pyramid dominating and owning all natural resources, and thus, entitled to exploit them. This in turn leads very often to over-exploitation and the decline of natural resources (in quantity and/or quality), provoking the perception of “peak resources” and “not enough”. In this mindset, humankind is also structured as a hierarchical pyramid, where women are more often than not perceived to be at lower levels than men in that social pyramid.

The *community paradigm* perceives all living beings as in a circle, sharing all resources freely and openly. This goes hand in hand with a strong sense of responsibility for the benefit of all (implying that this brings also benefits to the individuals). This in turn fosters the concept of resources stewardship, which is an important step towards sustainable management of resources. In this worldview, all human beings are seen of equal value and with equal rights. This includes gender equality.

Our behavior is marked and determined by the paradigm we adhere to. Current resources management is essentially based on the hierarchy paradigm. Any attempt to make it more sustainable and resilient needs to be oriented by the community paradigm. Gender mainstreaming is a key part of that step.

Therefore, the objective of Gender Actions in REXUS is fourfold:

1. to achieve a common understanding within the consortium of the importance of gender mainstreaming in all nexus domains and of the facts behind this statement.

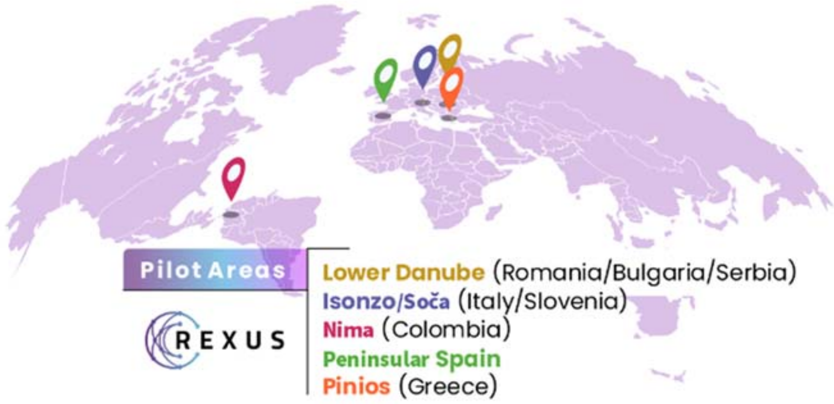
2. to apply from the very beginning the principles of gender mainstreaming to all project aspects and activities (i.e., walk our talk).

3. to provide statistics on women and men working in the project, at consortium member and stakeholder organizations levels, and to develop strategies to achieve true Equal Opportunity conditions.

4. to keep monitoring and evaluating progress with the partners, and with their assistance perform a gender analysis wherever possible.

Due to the specific demographic of the European nexus-related sectors, there is a very strong gender bias in the samples accessed in interviews, surveys and any stakeholder activities. Consequently, it will not be possible to perform a gender analysis proper (i.e., disaggregation of sample and separate analysis of each gendered sample). However, an effort is being made to bring in the voices and votes of women stakeholders and to distill as much gender-disaggregated information as possible from any stakeholder input.

C. Pilot area teams



The pilot area teams are listed below.

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II. PILOTS OVERVIEW (FACTSHEETS)

PINIOS RIVER BASIN – GREECE

PENINSULAR TERRITORY OF SPAIN

NIMA RIVER WATERSHED – COLOMBIA

ISONZO/SOČA RIVER – ITALY, SLOVENIA

LOWER DANUBE – ROMANIA, BULGARIA, SERBIA

1. Pinios River Basin, Greece

Bringing together a range of stakeholders to tackle the Water-Energy-Food-Climate (WEFC) Nexus issues in the Pinios River Basin

Considering all the complexities of sectoral interdependencies, the REXUS project aims to develop a sustainable framework that integrates the whole Nexus. The Pinios River Basin (PRB) is one of the most productive basins in Greece in terms of agricultural production, with a significant impact at the regional and national levels. The absence of efficient water resources management manifests in high water consumption and overexploitation of groundwater. In addition, population growth and the expansion of tourism have increased water needs. Energy production is also essential, with two large hydropower plants operating and small hydropower plants expanding. In a further development, photovoltaic plants are also being established, in most cases replacing agricultural land, and large capacity new wind farms are planned. Finally, Climate Change impacts considerably, increasing the likelihood of devastating floods and extreme droughts.

General Characterisation

- Area: 11,000 km²; Delimited by rugged relief.
- Agricultural land: 45 %.
- Arable crops: Cereals, cotton, and other annual crops cover over 65% of the total arable land of Thessaly Water District (1st designated nitrate vulnerable zone of Greece since the 90´s).
- Water demand for agricultural irrigation: Approx. 92 % (1292 hm³).
- Groundwater constitutes the main source, although surface water is also contributing significantly to water requirements.

Water Framework Directive (WFD):

River Basin Management Plan Outcomes

- 3 out of the 27 groundwater bodies characterized by bad chemical quality and 10 by bad quantity status.
- 4 of the 69 surface water bodies in bad ecological status, 4 surface water bodies with chemical status below good.
- Intensive groundwater abstraction led to aquifers' over-exploitation in the past, triggering in parts of the basin significant subsidence due to matrix compaction that affected land infrastructures considerably.
- The water budget in large parts of the basin is deficient, leading to exploitation of non-renewable water resources, thus posing significant risk for water availability in the near future.

REXUS Goals

The REXUS project will contribute to all the Nexus domain's challenges.

Water: Restore the status of water bodies, sustaining a sufficient quantity and quality of water to meet the needs of water users. Likewise, environmental flows to ecosystems must be maintained improving adaptability to climate change (floodland droughts).

Energy: Maintain/increase energy production through renewable resources to reduce emissions. Satisfy the energy needs of various uses (agricultural, industrial, domestic, etc.).

Food: Considering the high socio-economic impact on agriculture, maintaining production is one of the most critical challenges. Production costs must be optimized to achieve the viability and improve the competitiveness of agriculture, while promoting the quality elements of products produced in harmony with the environment, to increase their added value in the market.

Climate: Reduce the vulnerability of productive sectors and especially agricultural production to climate impacts. Resilience is also the keyword in this critical sector.

How will REXUS work?

Scientific and Participatory approach

The critical issue to be addressed is to improve the understanding of the NEXUS by providing sustainable and viable solutions with the involvement of stakeholders from all sectors, levels, and functions with the firm conviction that this is the right way to manage "our NEXUS". In addition, REXUS will show how technologies help shape scientifically justified and reliable pathways to sustainability and demonstrate the need for systematic, high frequency monitoring as a vital tool to safeguard the correct implementation of solutions. Successful implementation of solutions must go through detailed analysis of the pilot´s needs.

Future perspective: Call to Action

"*Active stakeholder engagement is a one-way road to realize our vision, and a unique opportunity to make viewpoints known, and share experiences, knowledge, and different problem-solving approaches to common challenges. Their guidance to the envisaged solutions and critical review of the project's research team proposals is of utmost essence. Smart, pragmatic, and acceptable solutions need to be shaped after hearing all the voices on ideas and the needs to be met, thus holistically understanding the environment the stakeholders want to live in. Stakeholders help us shape the big picture of the NEXUS, and we help stakeholders co-create sound solutions. Our action plan facilitates connectivity and networking with other stakeholders and the scientific community in the pilot area and beyond. In turn, the research team shares knowledge, technical guidance, and scientific support to the day-to-day work and operations, enhancing capacities where needed and requested. In the end, our overall actions aim at promoting real solutions for the sustainability of our living environment.****"***

SWRI Team

SWRI Soil and Water Resources Institute

Country pilots Regional Teams

The Soil and Water Resources Institute (SWRI) is one of the 11 research institutes of the Hellenic Agricultural Organization DEMETER in Greece that specializes on the protection and management of soil and water resources. SWRI is involved in resource management and policy support-oriented projects, focusing on environmental modelling, applying state-of-the-art technological solutions and sensors in environmental monitoring, developing, and proposing good agricultural practices, performing climate change impact assessment and environmental impact assessment in agriculture, and managing soil resources in agricultural areas. SWRI is one of the founding partners and the operator of the Pinios Hydrological Observatory (PHO), which is included in the International Long-Term Ecological Research (ILTER) sites and the European Network of Hydrological Observatories (ENOHA). SWRI also manages national river discharge monitoring network operating in the framework of the WFD 2000/60/EU.

2. Peninsular Territory of Spain

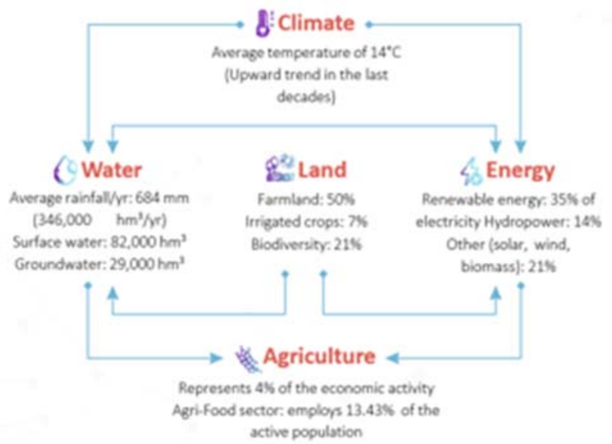
Overcoming administrative barriers for effective Water-Energy-Food Nexus management

The potential for Nexus resource conflicts in Peninsular Spain is intensified by unequal availability of water between the more water-rich northern regions and the arid southern regions, high demand for water for irrigation, and significant nuclear and hydroelectric power production. This is threatening the effectiveness of national and regional policies, including national and regional climate adaptation plans.

Working in close collaboration with national, local, and river basin authorities, REXUS aims to evaluate the Water-Energy-Food-Climate Nexus on a national scale and devise solutions that cut across administrative barriers and can be effectively integrated into national planning.

General Characterisation

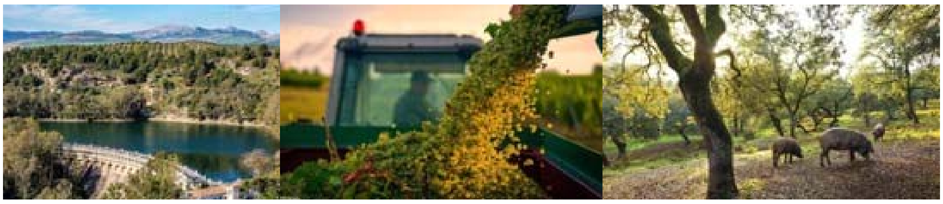
Peninsular territory of Spain
Total population 47,394,223
Area Spain: 505,944 km²
Peninsular Territory: 493,475 km^2



Pilot within the Pilot: Jucar River Basin

The Jucar River Basin, on the South-East Mediterranean coastal area, has been selected because of its location in a scarcity risk area.

- Surface area: 42,735 km²
- Population: > 5 million
- Climate: Mediterranean
- Precipitation: Around 500 mm, oscillating between maximum annual values of 780 mm for the wet years and just over 300 mm for the dry years.
- Land-use: Agriculture (80%), urban (16%), and Industry
- and Energy (4%).



REXUS Goals

The main goal of the REXUS project in the Spanish Pilot Case is to help overcome administrative barriers that lead to fragmented natural resources management, by providing a comprehensive Nexus framework that will allow implementing exemplary practices in Nexus management (from Nexus thinking to Nexus doing).

Objectives:

- Water-Energy-Food-Climate Nexus interactions. REXUS will examine specific policies focused on one sector, analysing their impact on other Nexus sectors for possible direct or indirect positive or adverse effects.
- In light of the analysis of Nexus dynamics between sectors, REXUS will provide a blueprint for sustainable practices on a national scale that involve the entire Nexus.
- REXUS will seek to overcome administrative fragmentation between regions and watersheds. In Spain, many entities perform effective management separately, but it is necessary to integrate them. Therefore, REXUS will work by bringing together different stakeholders.

How will REXUS work?

- Stakeholder Engagement
- Participatory System Dynamics Modelling (PSDM) development
- Integrated Modelling
- Earth Observation (EO) and Climate Risk Assessments
- Policy Analysis
- Identification and planning of feasible Ecosystem based Adaptation
- Socio-Economic analysis

How will the Nexus be analysed?

Through the Learning and Action Alliances (LAAs)

The active cooperation of different stakeholders from the Ministry of Agriculture, Fisheries, and Food (MAPA), the Ministry for Ecological Transition and Demographic Challenge (MITECO), River basin authorities, down to small farmer communities, will improve the understanding of the Nexus and contribute to the development of strategic decision making. A community willing to learn and grow in resource management issues will be formed. In addition, the LAA proposes to foster discussions with the other pilot cases of the REXUS project throughout the project, following a process of problem identification, evaluation of possible solutions, and finally validation of results.

Future perspective: Call to Action

"As a Mediterranean country, Spain will be hit hard by climate change. To protect natural resources and the economic sectors that crucially depend on them, we need to integrate Nexus cross-sectoral dynamics in national, regional, and basin level policy, otherwise management efforts may cancel each other out and imperil our best efforts to ensure resilience. REXUS will provide an inventory and analysis of the Nexus at the national level with regions and watersheds. It will link national and regional climate adaptation plans and will help introduce resilience and Nexus thinking/action in upcoming policy measures (WFD 3rd cycle implementation, CAP post-2020/ green deal, climate emergency). This effort will only succeed thanks to the unique insights and first-hand experience of the different stakeholders, who will validate Nexus analysis and help forge a consensus for more effective and resilient coordination"

AgriSat Team

Country pilots Regional Team

The leader in the Spanish case is AgriSat. AgriSat is a company born among people who work in the field, with a mission to combine solid agronomic knowledge with leading-edge technology to help the farm and water sectors around the globe to become more sustainable and resilient. It has also been participating in or leading many EU-funded projects in these sectors.

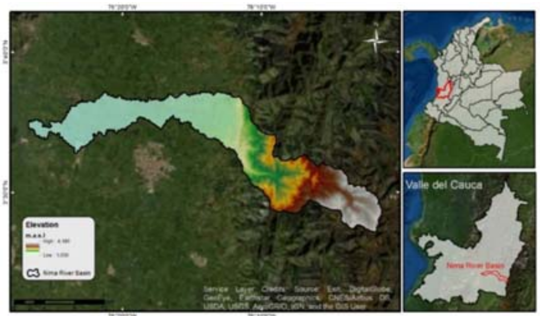
3. Nima River Watershed, Colombia

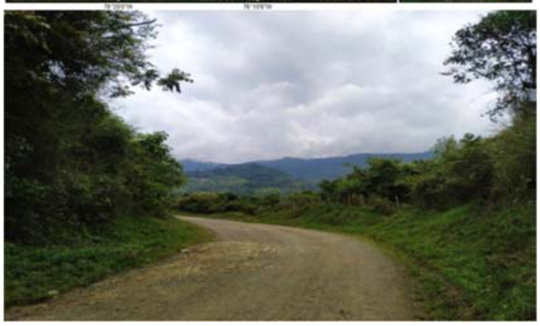
Participatory System Dynamics Modelling (PSDM) will support understanding of the Water-Energy-Food-Climate (WEFC) Nexus

The Nima River flows into the Amaime River, one of the Cauca River's main tributaries, one of the most important rivers of Colombia. Nima's downstream area is surrounded by agricultural landscapes composed mainly by sugarcane crops. The upstream mountainous zone has conservation priorities such as: Pristine Paramo ecosystem, in addition to Andean ecosystems with several endemic and endangered species of fauna and flora. There is an intersection area between the upstream and downstream areas mainly covered by livestock farming activities.

General Characterisation

Location: Cauca River Valley in the Central Andes of Colombia.
Elevation: Ranges between 1,050 and 4,100 MASL ("Las Hermosas National Natural Park").
Relevance: Key to guaranteeing water supply to 9 aqueducts in the municipality of Palmira for 312,519 inhabitants, a hydroelectric plant, and an irrigation district that benefits 6,900 ha of sugarcane in the downstream area.
Dry seasons: January/March & June/September.
Rainy seasons: April/June & September/December.
Precipitation: 1,500 mm/year (lower middle areas) - 2,100 mm/year (Upper areas).
Average temperature: 8-24 ºC.
Agriculture: Sugarcane 39.4 %.
Other land uses: Natural Forest (21.0 %), Extensive cattle ranching (17.9 %), Paramo vegetation (10.3 %).





REXUS Goals

REXUS aims to address most of the current challenges in the NIMA Basin

- Water Use Efficiency: There is a need to increase water use efficiency in the intensive sugar cane cropping system.
- Nature-based Solutions (NbS): The watershed would benefit from NbS to address the threat for forest and paramo areas at the highlands, resulting from intensive livestock breeding.
- Agricultural Management Practices: There is a need to explore other crop systems and alternatives to reduce environmental impacts of agriculture and livestock in this watershed and use efficiently water sourced by upstream areas.
- Policy Assessment: There is a need to regulate material extraction from the Nima river, since it increased the risk of river overflow.
- Water Quality: There is a need to improve the pollution of water bodies, which the community has recognized as a key concern.
- Climate Risk Assessment: A 1.5°C temperature and 10% precipitation increase by 2040 is projected in the Municipality of Palmira, which might increase drought and flooding risks over the watershed.

How will REXUS work?

The REXUS project will build a conceptual framework that will identify suitable measures for the watershed's challenges in the short, medium, and long term. In the first year, REXUS partners will try to prioritize and analyse the challenges and issues in the watershed. In the second year, the creation of the modelling framework will take place, and finally, in the last year of the project, a scenario analysis in the Nima Watershed will be conducted. The approach throughout the project will be participatory and based on the Learning and Action Alliances (LAAs).

How will the Nexus be analysed?

Applying Participatory Systems Dynamic models (PSDM)

PSDM will play an essential role in the LAAs in understanding the complexity of the Nexus. PSDM will complement the Nima watershed planning process, which is part of the territorial planning of the municipality of Palmira. Specifically, PSDM will support an environmental participative diagnostic of the watershed with stakeholders from different sectors, private, public, local community in order to build a territorial participative prospective of the natural resources, through a scenario analysis in the Nima Watershed.

Future perspective: Call to Action

"There are many environmental challenges ahead that will substantially impact our society. That is why we expect from the REXUS project to achieve an environmental diagnosis through a participatory approach of the Nima watershed, that highlights the main environmental problems and needs; the potential Nature-based Solutions (NbS) to address environmental conflicts and challenges; subsequently, it is essential to build a local stakeholders' vision of the future on natural resources, following the approach and guidelines of the Land Management Plan of Palmira."

Dr. Marcela Beltrán, CIAT

Alliance

Country pilots Regional Team

CIAT (International Centre for Tropical Agriculture) collaborates with hundreds of partners to help developing countries make farming more competitive, profitable, and resilient through smarter, more sustainable natural resource management. CIAT helps policymakers, scientists, and farmers respond to some of the most pressing challenges of our time, including food insecurity and malnutrition, climate change, and environmental degradation. CIAT's global research contributes to several of the United Nations' Sustainable Development Goals and cuts across four key themes: big data, climate-smart agriculture, ecosystem action, and sustainable food systems.

4. Isonzo/Soča River, Italy-Slovenia

Overcoming transboundary management challenges by applying the integrating Water-Energy-Food-Climate Nexus

Assessing the Water-Energy-Food-Climate Nexus in transboundary river basins represents a significant challenge. In these contexts, there is heterogeneity in environmental data, flood risk management plans, climate change assessment methodologies, and resource views of the Nexus, which often prevents the implementation of effective basin-scale strategies. The case study of the Isonzo/Soča river basin, which crosses between Italy and Slovenia, represents an exciting ground to demonstrate the effectiveness of the solutions developed in the REXUS project. It also presents an opportunity for the District Basin Authority of the Eastern Alps (AAWA) River District, to understand the impact of the Water-Energy-Food-Climate Nexus in its basin planning activities following Directives 2007/60/EC and 2000/60/EC.

General Characterisation

- Transboundary River: 140 km - Originates in the Alpine Valley of Trenta in Slovenia.
- Basin area: Approx. 3400 km².
- Climate: Mediterranean influenced, partly humid.
- Needs to be addressed: Protection of Ecosystem Services (ES) and proper management of water resources; otherwise, water abstraction affects biodiversity and water availability for irrigation communities.
- Nexus Linkages:
  Water- Energy-Ecosystems → Fluvial continuity of the river.
  Water-Energy-Food → Irrigation.
  Water-Energy → Groundwater pumping, hydropower, and cooling of thermal power plants.
- The mountainous section of the Isonzo/Soča ends at Solkan-Salcano (Nova Gorica), on the border between Italy and Slovenia.
- Challenges: There is a lack of shared framework focusing on nexus issues for the whole basin.

REXUS Goal

- Provide valuable scenarios to estimate the impact of climate change on the area and current strategies (e.g., flood prevention, etc.), also in the view of the next updates of the current management plans.
- Finding and testing best solutions/best practices to ensure sustainability, e.g., flood risk reduction measures, including environmental value within projects, and transition of Nature-based Solutions approach, instead of standard grey infrastructure.
- Find a balance between various water uses (flood/food/energy), e.g., a balance between flood security and economic development.
- Estimate the future behaviour of the economy to help decision-makers (socio-economic assessment).
- Connect renewable energy production to existing agricultural infrastructures and, in parallel, to improve river continuity by increasing drought resistance. Furthermore, it is necessary to account for water resources for optimal use.

How will REXUS work?

- International coordination and cooperation: Broadening the scope of cross-border cooperation and identifying shared priorities.
- Improve Transboundary Management: Monitoring, verification, and exchange through *knowledge sharing*.
- Accounting and Efficient Resource Allocation: Agriculture and hydropower production are crucial activities for the basin's economy in both countries and represent the central pressures on water resources. Therefore, it is essential to optimize the use of resources and infrastructure.
- Participatory approach: An integral vision of the basin and the definition of areas of common interest for regional development is urgently needed. Climate change is expected to significantly affect the WEF resources of both nations, impacting current agreements.
- Promote progress in line with the Water Framework Directive 2000/60/EC and Floods Directive 2007/60/EC. The participation of AAWA in the project will strengthen its capacity in hydrologic and hydraulic modeling for flood risk mapping and drought. AAWA will be involved in use case design, stakeholder engagement user requirements, the validation scenario and evaluation methodology, demonstrations, and testing.

Future perspective: Call to Action

"It is important to identify barriers to the implementation of policy actions and political resistance mechanisms resulting from institutional fragmentation. It is also necessary to define water management strategies for policymakers, analysing priorities, pressures, synergies, and trade-offs, especially between energy production, irrigation, and flood risk reduction. Finally, REXUS will propose transboundary water management strategies and tools to assess the effects of climate change, estimating how resources and flood management will be affected and how to NbS approaches; these tools will consider ecosystem services to support management strategies."

Autorità di Bacino Distrettuale delle Alpi Orientali (AAWA)

Country pilots Regional Team

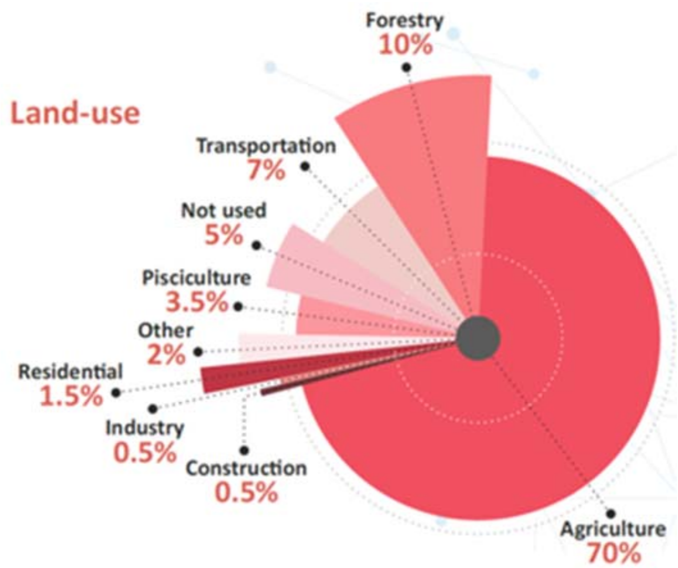
District Basin Authority of the Eastern Alps (AAWA) will be the REXUS partner responsible as domain expert of the Isonzo/Soča River Basin pilot area and the primary stakeholder. AAWA is a Public Body accountable for managing the rivers in the Eastern Alps River basin district, which covers the northeast regions of Italy and the transboundary river basins between Austria, Slovenia, and Switzerland. AAWA oversees the catchment planning, including remedial measures to reduce hydraulic and geological risks and the protection and sustainable use of water resources. It coordinates the activities to be implemented on a basin-scale, such as safeguarding the quality and quantity of water resources, attaining the best possible balance among the contrasting water use, study the schemes necessary to prevent, in particular, disastrous events, droughts, and floods.

5. Lower Danube, Romania-Bulgaria-Serbia

Integrating solutions through participatory approaches:
Enhancing Lower Danube´s Water-Energy-Food-Climate Nexus resilience

The REXUS project aims to assess the Water-Energy-Food-Climate Nexus of the European Lower Danube River system through an integrated analysis, working with stakeholders to overcome administrative barriers, to improve the local population's living conditions. The Lower Danube area faces significant challenges, such as the continued exploitation of the Danube River resources, especially for navigation, hydropower production, and the higher water quotas for agricultural irrigation, especially during periods of drought. As a result, the water level may drop below the safety margin. Therefore, local communities may be forced to rely on groundwater resources, which are also limited, for drinking water supply.

General Characterisation



Total population > 1.2 million inhabitants.

Area: 236,930 km^2 (29% of the total Danube basin area of 817,000km^2).

Climate: Temperate (rains occur throughout the year, hot and dry summers, annual average temperature 11.5ºC).

Precipitation: West to East decreasing trend, from over 600 mm/y to less than 500 mm/year in the East Romanian Plain and about 350 mm/year in the coastal region.

REXUS Goal

The main challenge to overcome is the continued overexploitation of the Danube river's water resources. A critical factor to be included in the WEFC Nexus analysis is sustainable exploitation, as it generates less impact on the natural environment and improves ecosystem services. Activities related to flood risk management, such as cost-benefit analysis, economic, social, and environmental impact assessment, and land use planning, require better coordination by Nexus stakeholders. REXUS plans to bring together key stakeholders from government institutions, such as ministries and national administration, local administrations, NGOs, insurance companies, and citizens, with the aim of overcoming some of the expected bottlenecks, such as lack of transparency, high bureaucracy, and divided decision-making, through the implementation of REXUS project measures.

How will REXUS work?

The REXUS project integrates methodologies and techniques such as Stakeholder Engagement, System Dynamics Modelling (SDM), Earth Observation (EO), climate risk assessment, socio-economic and policy analysis.
One of the critical aspects is Stakeholder Engagement which is essential for the project's development and is built on two principles:

- Building local relationships: The active cooperation of stakeholders from national institutions, such as the Ministry of Agriculture, Ministry of Water and Forests, Ministry of Transport, Ministry of Regional Development and Tourism, National Meteorological Administration, Romanian Waters National Administration, and Environmental Guard, as well as Lower Danube River Administration, local administrations and NGOs, down to small farmers and citizens, improve the understanding of the REXUS project and contribute to the development of strategic decision making.
- Active pilots' participation: Cross-fertilisation with the other REXUS pilots will take place throughout the project stages to share a standard view on the proposed solutions and validate them.

Future perspective: Call to Action

"The challenge for the future is to maintain a dynamic balance between the development of human activities, industry, and the natural environment in the Danube Basin.
Most of the land along the riverbank is now under the administration of private owners, which presents an important challenge to initiatives that the local authorities may have concerning the maintenance and development of the pilot area."

Albert Scrieciu, Geoecomar

Country pilots Regional Team

GeoEcoMar is a research and development institute created in 1993 under the Romanian Ministry of Education and Research coordination. GeoEcoMar represents the focal point of national excellence in research and consultancy on marine, coastal, fluvial, lacustrine geology, geophysics, and geo-ecology. Due to its technical capabilities and scientific performance achieved in a short period, the centre has become since 1996 an "Institute of National Interest", its primary research focus being the complex study of the Danube River-Danube Delta-Black Sea macro-geosystem. An essential part is to improve the state of the Danube River ecosystem by actively participating in research projects to develop better solutions for the threats facing the macro-geosystem.

III. PILOTS DESCRIPTION

PINIOS RIVER BASIN – GREECE

PENINSULAR TERRITORY OF SPAIN

NIMA RIVER WATERSHED – COLOMBIA

ISONZO/SOČA RIVER – ITALY, SLOVENIA

LOWER DANUBE – ROMANIA, BULGARIA, SERBIA

1. Pinios River Basin (Greece, GR)

1.1. General characterization

The Pinios River Basin (PRB) is in central Greece (Figure 1), and it is one of the most productive basins of Greece and the national WFD pilot basin, while it covers an area of approximately 11,000 km^2. PRB presents highly diversified geological, hydrological, and hydrogeological conditions. At the same time, the absence of rational water resources governance and management generally manifests in high-water consumption and groundwater over-abstraction for irrigation. Agricultural land constitutes the primary land cover for PRB (45% of total PRB area). In contrast, agriculture constitutes the primary water consumer for Pinios River Basin since about 92% of total water consumption (1292 hm^3) is allocated to irrigation. Recently increasing energy costs for pumping and irrigation systems contribute to Nexus challenges. The Thessaly plain has been one of Greece's 1^{sts} designated nitrate vulnerable zones since the late 1990s. Environmental flow is hardly satisfied at the middle and downstream river sections, mainly due to river water abstractions for irrigation.

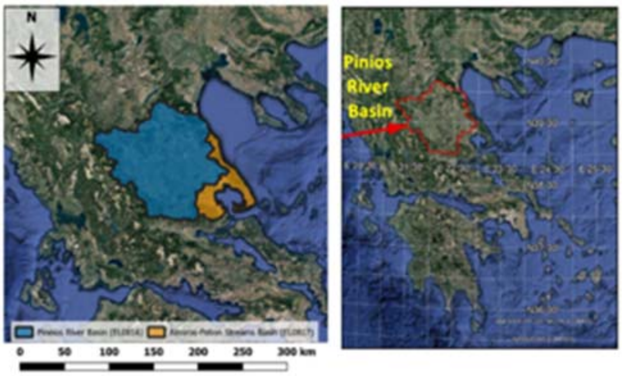


Figure 1. Pinios River Basin (Greece). Source: Soil and Water Resources Institute (SWRI), 2021.

1.2. Major developments

Water

Water resources management in PRB was marked by the development of groundwater resources exploitation that started in the late 1960s and lasted until the late 1980s. This development was made irrationally, and this is proved by the decreasing groundwater levels observed in most groundwater systems found in PRB, as demonstrated in Figure 2. Moreover, during this period, collected irrigation and drainage networks were constructed to serve the irrigation needs of plain areas. These irrigation networks were fed by both surface water from Pinios River and groundwater. In their majority, the irrigation networks constructed from the 1960s to 1980s were open canals. When possible, closed pipe irrigation networks have been built in the last decades to reduce the high-water losses of open canal irrigation networks. The two large dams that have been constructed at the western part of PRB (Plastiras and Smokovo dams) significantly affected the development of agriculture since they provide irrigation water in a significant amount of the west of Thessaly plain.

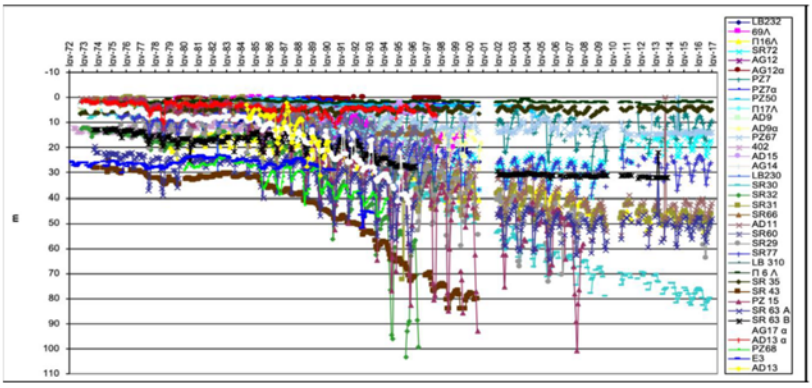


Figure 2. Groundwater level variation in selected wells located in PBR. Source: Soil and Water Resources Institute (SWRI), 2021.

Agriculture

The development of the agricultural and water sector in PRB was evolving in parallel. Even though agriculture was traditionally the significant productive activity in the plain areas of PRB, it was significantly expanded and intensified mainly because of water exploitation development, including groundwater exploitation and irrigation networks construction. Therefore, similarly to the trends in Figure 3 for the whole country, irrigated agricultural land has almost tripled from 1960 to 2000.

Fruits' processing is gaining a share of the financial activities of the region. Likewise, dairy products' units are growing. Some of them are taking significant and impressive development steps in expansion nationwide. Extensive processing, selection, standardization, packaging, storing, and exporting have been developed to address primary production effectively. To this end, an emerging with systematic steps and a focus on high-quality market activity extends in the standardization and production of high-quality cotton fibre. Thessaly hosts the only accredited unit for cotton fibre properties assessment and characterization. It attempted to create and host a hub to produce high-quality fibres for high-end garment production companies.

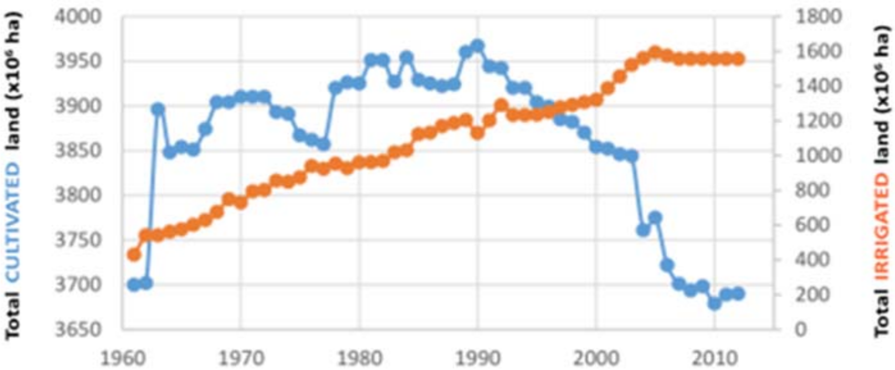


Figure 3. Evolution of agricultural and irrigated land area in Greece. Source: FAOSTAT, 2021.

Energy

The first milestone for developing the energy sector in PRB is constructing the Plastiras dam in 1959, which produces about 160 GWh/y. This dam also serves a significant part of the irrigation and domestic water needs of the western part of PRB. Smokovo dam constructed in the late 1980s mainly serves irrigation and domestic water supply, but it is also considered one of the basin's significant infrastructures for energy production. Compared to the dams mentioned above, the last 10 to 15 years are marked by developing smaller renewable energy resources infrastructures in the PRB. More in detail, photovoltaic power plants have started to be constructed in PRB in the middle 2000s. In contrast, their development has increased after 2010 and is mainly due to Law 3851/2010, which partially allowed the installation of photovoltaic power plants in agricultural land. Due to the higher precipitation and subsequently higher surface runoff, small hydroelectric power plants are being installed at the western part of PRB, while wind power plants are also increasing.

Environment

Several environmental issues developed simultaneously with the intensification of agriculture. Nitrate pollution resulting from irrational agricultural practices has been identified since the 1980s. In comparison, the large plain areas of both eastern and western Thessaly basins have included the nitrate vulnerable zones of Greece since the late 1990s. Moreover, the Government ranked 3 out of the 27 groundwater bodies in PRB as of bad chemical quality status according to the most recent river basin management plan (RBMP). Except for the water scarcity observed in some areas in PRB due to overexploitation, other environmental issues caused by overexploitation were locally regarded, such as landslides. According to the most recent RBMP, 10 out of the 27 groundwater bodies in PRB were of lousy quantity status. Other environmental issues have also been observed in PRB expanding progressively with the expansion of agriculture and industry.

Climate

According to Loukas (2010), the period 1988-1993 was the driest recorded for PRB, which affected PRB and the Mediterranean Basin.

1.3. Challenges

Nexus-related challenges

Regarding water, the ultimate challenge is to improve the irrational water resources management. Therefore, the REXUS project must contribute to maintain sufficient water quantity and quality; satisfy the needs of all the competitive water users; maintain the environmental flow for ecosystems; adapt to the decreased water availability indicated by the CC scenarios; and deal with climate extremes (floods but mainly with droughts). The conflicts of water-related to the other sectors of the WEFC Nexus are summarized as follows:

- Water supply and distribution is directly affected by the energy supply.
- Food production is increasing, thus increasing water demand.
- Water availability is vulnerable to climate conditions, water infrastructure risk due to climate extremes.
- High water abstraction may lead to infrastructure destruction.

A significant challenge is maintaining or increasing energy production through renewable resources to decrease emissions (transgression to the post-lignite era is a critical symbolic target of the State). At the same time, it is challenging to satisfy the energy needs of several uses (agricultural, industrial, domestic, etc.). The conflicts of the energy sector related to the other sectors of the WEFC Nexus are briefly presented below:

- Increasing water demand is connected to increasing energy demand.
- Hydroelectric energy production is directly connected to water availability.
- The increasing food production is rising energy demands.
- Climate change can potentially increase water demand, thus energy demand.

The ultimate challenge is to maintain the agricultural production of the most productive basin in Greece. Production costs must be optimized to keep agriculture viable and competitive. There are some conflicts identified for the food sector related to the other sectors, which are:

- Food production is related to irrigated agriculture and thus to water availability.
- Photovoltaic parks are substituting agricultural land, thus decreasing food production.
- Agriculture is vulnerable to climate change, and consequently, food production.
- The air temperature increase may increase physiological stress to the crops and reduce production.

As it concerns climate, it is essential but challenging to reduce the vulnerability of productive sectors in PRB and especially agricultural production to climate impacts and prepare/adapt to climate change impacts.

Actions to meet Sustainable Development Goals

Considering the case of PRB and the context of the REXUS project, the most relevant SDGs are 7, 12, 13, and 15, and the corresponding more relevant targets are:

Target 6.4: by 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

Target 6.5: by 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

Target 6.6: by 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes.

Target 6.b: support and strengthen the participation of local communities in improving water and sanitation management.

Target 12.2: by 2030, achieve the sustainable management and efficient use of natural resources

Target 13.1: strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

Target 13.2: integrate climate change measures into national policies, strategies, and planning.

Target 15.1: by 2020, ensure the conservation, restoration, and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains, and drylands, in line with obligations under international agreements.

Considering all the above targets, the priority actions must focus on:

- Increasing water use efficiency considering climate change impacts in a sustainable and integrated way will also include the ecosystems perspective.
- Measures acceptability by the community and therefore demonstrate a high possibility of implementation. This can be achieved by the active engagement of the end users/stakeholders in the action's development process.

1.4. Key stakeholders

At the higher and lower administrative/organizational/managerial level, the key stakeholders that we potentially are involved in the context of the REXUS project are presented in Table 1 and Table 2:

Table 1. High-level stakeholders in the Pinios River Basin.

Stakeholder	Description
Secretariat General for Natural Environment and Water, Ministry of Energy	Responsible for water management at the national level and can provide the regional and national water resources management aspect. They require the improvement of water resources management on multiple levels.
PPC-SA Hellas – Department of Hydroelectric Production	Responsible for developing hydroelectric energy production in Greece. They require the efficient development and operation of hydroelectric power plants in the basin. Since they hold strong hydrologic expertise, they can provide the energy aspect while incorporating the water resources management aspect.

Table 2. Lower-level stakeholders in the Pinios River Basin.

Stakeholder	Description
Municipality of Agia	In charge of domestic water management, they also supply irrigation water management through a network of groundwater wells. They can provide a representative domestic and irrigation water supply structure while requiring an efficient and seamless supply of water to their community.
Local Land Reclamation Organizations	Responsible for irrigation water supply in large portions of agricultural land in PRB. They can provide the point of the most common administrative structure of irrigation water management in Greece. What they require is a seamless supply of irrigation water to the farmers throughout the cultivation period.
Agricultural Cooperative and Farmers	They are the major water users in PRB since agriculture consumes about 95% of total water abstractions in the basin. They can provide the aspect of the primary water user in the basin, but they are also connected to the food aspect while they require sufficient irrigation water for their crops.

1.5. Policy

Relevant policies for all nexus domains

The most significant relevant policies related to water management are presented and briefly analysed below:

The Water Framework Directive (WFD) 2000/60/EU: It constitutes the holistic and innovative effort to protect and manage Water Resources that has emerged after a long period of discussion and negotiation between the countries of the European Union. Greece was fully harmonized with WFD with the Law 3199/2003 and Presidential Decree 51/2007. 1st version of RBMPs for Water Districts of Greece was developed and approved in 2014, while the 1st revision was approved by 2017.

Directive 2006/118/EC for the protection of groundwater against pollution and deterioration and Directive 2014/80/EU amending Annex II of Directive 2006/118/EC. The corresponding directives are implemented together with WFD 2000/60

Directive 91/676/EEC protects waters against pollution caused by nitrates from agricultural sources, which was incorporated in the Greek law according to the Ministerial Decision 16190/1335/1997. It is of deep concern for PRB since Thessaly plain was one of the first two areas in Greece recognized as nitrate vulnerable zones. Despite the action plan developed in the early 2000s, nitrate pollution in Thessaly plain is still significant.

Environmental quality standards (EQS) for priority substances have been determined by the provisions of Directive 2008/105/EC, harmonizing in Greece with the Ministerial Decision 51354/2641/E103/2010.

Law 3851/2010 includes provisions for the location of Renewable Energy Sources (RES) facilities while prohibiting the installation in agricultural parcels, which are characterized as high productivity agrarian land, any activity other than agricultural exploitation, and the production of electricity from RES stations, including photovoltaic stations. However, Law 4015/2011 temporarily prohibits the installation of photovoltaic stations on high productivity lands.

Directives 2010/75/EU & 2015/2193/EU introduce strict emission limits (mainly, but not only for SO2, NOx, and PM2,5 pollutants) for power plants. These limits create significant difficulties in complying with existing units at a reasonable cost and are an essential additional limiting parameter. Finally, other indirect restrictions are introduced by both the Waste Framework Directive 2008/98/EC as amended by Directive 2018/851/EU and Directive 2019/944/EU.

Directive 2009/28/EC: The policy measures for the further development of RES in electricity generation are implemented to achieve the target for the participation of electricity generated by RES in gross electricity consumption in 2020, as formulated during the harmonization of Directive 2009/28/EC in Greek law. The policy measures for the further development of RES in transport through biofuels have been launched to achieve the goal of the penetration of a share of energy from RES in transport, as defined respectively in the harmonization of Directive 2009/28/EC in Greek law.

Directive 2018/844/EU: The adoption of new regulatory measures (in the context of the revision of Directive 2010/31/EU with Directive 2018/844/EU) will aim to shape the appropriate framework and create incentives to maximize the number of buildings that will exceed the minimum energy efficiency requirements.

- Other: Bathing Waters (Directives 76/160/EEC, 2006/7/EC); Natura 2000 sites (Directives 92/43/EEC - 2009/47/EC); Drinking-Water (Directives 80/778/EEC, 98/83/EC); Major Accidents (Seveso) (Directive 96/82/EC); Environmental Impacts of Projects / Activities (Directives 85/337/EEC, 97/11/EC); Sludge for treatment plants (Directive 86/278/EEC); Urban Wastewater Treatment (Directive 91/271/EEC); Plant protection products (Regulation (EC) No 1107/2009 - Directive 91/414/EEC); Prevention - Pollution Control (Directive 96/61/EC).

Degree of implementation and conformity:

The legal framework for all policies mentioned above is in place, shaped, and in several cases reformed-updated and revised to comply with evolving EU regulatory framework and account for suggestions and input by the stakeholders. The basin was the reference area where the national methodological framework for the assessment and characterization of the groundwater bodies' status was developed and the pilot for the development of the initial methodological framework for the implementation of the Nitrates Directive (NVZs, Action Plans, and Code for Good Agricultural Practice). This is also one of the first basins in the country to initiate a systematic well inventory, registration of abstraction works, and installation of water meters. Furthermore, the basin has a long (but not very successful) tradition in groundwater monitoring (and surface water monitoring), being the first basin in the country to implement an extensive and systematic groundwater resources development project initiated in the mid-1960s with preliminary studies and concluded in 1970s. An ill-tempered tradition had been developed for years due to frequent and largely not focused subsidies offered to promote irrigated agriculture to succeed food sufficiency and primary sector production increase.

Despite entering the period of the second revision of the WRMP at basin scale by the WFD's schedule, public participation lacks representativeness and impact on shaping measures and, therefore, acceptability. The deliberation period is limited, and data collection and processing would merit a more systematic approach and more time. The national water resources monitoring program is in operation but needs significant upgrade and justification that is currently being elaborated. Due to administrative constraints and the financial ordeal Greece had gone through, long delays have been experienced in the past leading to disruption of the program twice.

Nitrates directive is based on the designation of NVZs delineated in a simplistic way that needs to be upgraded. When developed, the methodology covered the era's needs under the lack of data and time but now needs considerable upgrades. Code for good agricultural practice also needs to be upgraded, and the same goes for the action plans. The latter need to be assessed for their efficiency, reviewed, and re-established. It is essential to restart the program for monitoring the implementation of the measures and carefully study their results. Overall, there is a great need to sensitize stakeholders to the correct direction, inform them, and partner to problem-solving. Currently, most farmers save on fertilizers and water consumption because of their costs, not the environment.

The energy sector also lacks coordination. Aeolic and solar parks are installed and the interest to install small hydropower units is excellent. However, coordination and holistic consideration are missing. To install solar panels infertile land and reduce land productivity, probably reduce natural recharge, disregard impacts on biodiversity, overlook financial aspects on payback values and feasibility for the investor.

Interdependency between water and ecosystem is overlooked, but its importance has started gaining attention. There is a solid hydraulic connection between groundwater and surface water bodies. In several instances, terrestrial ecosystems feed groundwater and surface water bodies to a minor extent. Often, over-abstraction takes place without consideration of such dependencies. Ecological discharge is not well-defined and certainly not always respected.

The principle of recovering the cost of actions to re-instate the baseline status was approached regarding environmental cost calculations. Environmental costs occur as a legal framework but have not been implemented yet. The "per hectare" charge still broadly applies irrespective of the actual volume of water used. One of the three national studies upon which the whole irrigation cost model was to be developed had been elaborated in this basin. The financial crisis and the regional agricultural unions' impact on national politics have impeded the cost recovery policies.

Finally, there is a lack between the ownership of the resource and the engineering work used to utilize the resource. This is still not well comprehended by the stakeholders. Hence, well ownership is still mistaken for resource ownership. The essential cost acknowledged and accepted in collective irrigation networks is represented by the operational and investment cost. Environmental, recovery, alternative use, prices are not conceived. They are mainly unknown thus unaccepted not only by end-users but to a large extent also to decision-makers and regulators at the regional level.

Side effect in policy implementation

Reviving of dried Lake Karla: Lake Karla occupied a large part of the southern extent of eastern Thessaly plain and was dried in the 1930s as part of the health advancement policy of the era (compact malaria) and in the framework of agricultural development (increase agrarian land and make the land for settlements of refugees from the Asia Minor catastrophe in the 1920s). In the past 15 years, it was thought that the lake might be partially revived and act as a habitat and source to irrigate surrounding fields. The reservoir struggles to fill, and a large dam was constructed with a long canal to augment its supply, and water is constrained from the downstream parts leading to shortages in hydrologically dry years. High toxicity levels were reported in the first years of reviving, leading to massive deaths of fish and birds due to anoxic conditions washout of heavy metals and organic molecules from the lake’s bed (heavily cultivated in the past with large agrochemical inflows). It appears to be a venture that may eventually work out but needs to carefully balance water uses from the lake and to the lake.

Cost of Water: The financial crisis and refusal to take upon political costs have resulted in long delays in developing an irrigation water cost model to establish a legal framework and even more to implement it.

Nowadays, the model is a legal act, and the cost is calculated for the region; however, shifting from cost to price is not entirely successful. Moreover, the measure is not imposed due to a lack of coordinated and systematic information, education, promotion, co-design, and decision with local government and stakeholders. Many farmers have either refused to install water meters or removed them. Many farmers see registration of their abstractions' works (wells, boreholes, spring captures, etc.) as an indirect way to be enforced to pay extra taxes. Still, because of this lack of trust, it is estimated that registration of the works is no more than 60% of actual existing jobs. The sole reason for forwarding massively to registrations is the need to ensure electrification of their pumps at the special low farming rate.

In line with the European Food Safety Authority (EFSA) scientific guidance and the legal framework of the EU, the number of registered and authorized drastic compounds for plant protection use in member states is reducing on an annual basis. Substitutes to banned compounds are often less efficacy and with higher costs. Thus, environmental safety is promoted, agrochemical input reduced, biodiversity species protected, but agricultural production faces survival issues due to high costs and decreased productivity.

Biological production lacks coordinated action from the legal point of view and the imposition of characteristics and regulations that safeguard good natural conditions. Moreover, the lack of coordinated action at this level does not allow for extensive biodiversity recovery and enrichment.

Reduced water use costs only recently became part of the official policy supported by the structural funds to help farmers shift to higher productivity and digitize their enterprise. Despite this, because water use charges are imposed mainly based on the irrigated land extent and not on the water volume used, water users do not have a pressing incentive to cut down water consumption in their properties. Imposed costs relate only to operational expenses, such as [PLEASE ADD] and not to other expenses.

In line with the implementation of the WFD, basin management plans have been prepared and revised. The nature of the measures is very austere and leaves no room for developing activities to protect water bodies from further deterioration and improve their recovery. There are many cases in which the measures applied are too generic. These distortions have been corrected in the first revision of the management plans, but some issues still need to be addressed. Also, management issues related to the need for high-quality irrigation water downstream, just before the Pinios River flows into the Aegean Sea, have not been considered because the area lacked sufficient data for the first phase of the draft management plan analysis. Consequently, local stakeholders did not freely take coordinated initiatives considering the plethora of needs and the consequences of overexploitation of the river's water. In addition, management practices imposed through temporary earthen detour dams may seriously impact flash floods that cannot be ruled out, especially under climate change.

A mix of different water uses characterizes most of the water bodies identified within the PRB, and, in most of them, the most sensitive one is domestic use. By the WFD principles, measures are designed to efficiently manage the resources needed to protect the most sensitive water efficiently. However, this imposed severely and, to a large extent, unreasonable restrictions on potential investments reducing the possibility of enhancing their development and productivity. Thus, financial welfare and perhaps social coherence.

Wind generator parks are expanding and the power they produce is increasing in line with the green development goals, the targets set by the EC for expansion of renewable energy sources, the national policy for the post-lignite era, and the international treaties for a progressive shift non-fossil fuel. There are growing concerns about the potentially conflicting role of this source of renewable energy as they cause many aesthetic issues (please add cit., or examples). Moreover, the large installation areas disturb local societies and wildlife (that seeks calm conditions away from the mountain fringes close to populated areas) and they generate alterations to bird habitats and airways, and to microclimate conditions. Finally, concerns to wind generator parks, regard the post-operation life era i.e., the re-instate phase (removal of the infrastructure, equipment, etc.).

1.6. Relevant documents and Governance systems

Planning documents

Table 3. Main planning documents for the Pinios River Basin.

Document	Description
River Basin Management Plan (RBMP)	Developed in WFD 2000/60 implementation, it constitutes the most critical document for water resources management and planning in PRB. Its first version was approved in the year 2014, while it was revised in the year 2017.
Action plan against nitrates pollution of agricultural origin	Action plans were developed for all the nitrate pollution vulnerable areas in Greece in compliance with the Nitrates Directive 91/676/EEC. The most recent version of the action plans was compiled in the year 2019.
Code for good agricultural practice	In compliance with the 4th Article of Nitrates Directive (91/676/EEC), the excellent farming practices code for protecting waters from agricultural-induced pollution was developed in 2015.
Floods Risk Management Plan	In compliance with the Floods Directive (2007/60/EC), the Floods risk management plan for Thessaly Water District was developed in 2018.
Climate change impact report of the National Bank of Greece	Developed for the whole country in 2011, this document introduces a wide range of aspects for socio-economic planning in the context of climate change.

Governance systems

At regional level, the principal actors managing and coordinating (?) water governance are the Directorates for Water for each of the fourteen Water Districts of Greece. The Directorate of Water constitutes the bond between the local water resources management stakeholders (municipalities, local domestic, and irrigation water supply authorities) and the national ones. The reference document for water resources management is the River Basin Management Plan (RBMP), which was introduced by WFD 2000/60.

The Hellenic Republic Asset Development Fund manages high-value assets, usually not including agricultural land. The national cadastral services, in principle, deal with land management. However, agricultural land is monitored by the Greek payment authority for Common Agricultural Policy aid schemes. This may cause issues in scheduling and revising potential large-scale changes in land use management.

Administrative boundaries of public services, that define their jurisdiction, in many cases not coincide with naturally defined boundaries (watersheds, river basins, etc.). Hence, even though jurisdictions are clearly defined for management and decision-making on natural resources, issues still exist due to bureaucratic procedures that may delay or stall decision-making and development attempts. Lack of coordinated actions is profound in several cases, and precisely because of the long and complex administrative chin of activities, management does not always follow quick and decisive routes.

Bottlenecks:

- Bureaucracy with lack of specific deadlines for action-taking.
- Lack of information and clarity to citizens on rules and regulations.
- Low level of public participation in decision making.

- Decision-making and actual management roles are shifted to the top levels of management, excluding local and regional bodies. This gives the excuse to local society to quarrel for exclusion and refusal to comply with regulations and, on the other hand, allow the managerial level to use.
- Local stakeholders believe they are overlooked and obliged to comply with measures not discussed with them .and not recognise the final issues identified within the region.
- Lack of specialization is profound across the regional services, with very few exceptions. This, in turn, reflects that those acute issues related to the management of natural resources and the environment may not be pointed out, relayed, and channelled in an effective way across the pyramid of decision making. Moreover, digital tools that may develop by third parties may not be utilized, kept updated, and yield results for the region. Often such tools get obsolete without being used.
- Lack of systematic regional-based action of natural resources management (monitoring, etc.) to feed into the national monitoring grid and the basin-scale management plans.
- Considerable gap between farming and consultation. In essence, field agriculturalists and general geotechnical scientists monitor and enhance the implementation of national guidelines and policies. Hence, an extension service to assist farmers with environmentally friendly and biodiversity-oriented services is not existing.
- Support and liaison systematically between the state and the farmers on funding opportunities need to be further developed. Administrative bureaucracy needs to boost up to reduce the considerable time required between application, approval, funding, and audited completion of a venture.

1.7. Basic climate and soil data

Climate characteristics in Pinios River Basin present significant spatiotemporal variation since (Loukas et al. 2007):

- The average annual precipitation varies between 400 mm at the plain central part to more than 1850 mm at the western mountainous part of the basin.
- Climate at the western and central part of PRB is continental, while at the eastern part is Mediterranean.
- During the summer period (June to August) rainfall is rare for the whole PRB.

Soil categories: *Entisols (Xerofluvents)*: These soils are formed on alluvial deposits, and therefore they are located close to rivers; *Inceptisols (Xerochrepts)*: These soils are slightly developed with cambic horizon and are mainly found at some distance from rivers; *Alfisols (Xerlafs)*: They are found in higher elevation, during the present a well-developed argillic horizon; *Vertisols (Xererts)*: They are very fertile but heavy soils since they are found in floodplains, and therefore, they present high clay content.

1.8. Current and emerging water sources and uses

Table 4 presents the water demand per sector as indicated in the most recent version of River Basin Management Plan (RBMP). Irrigation constitutes the primary water consumption in PRB since it requires about 92% of the total annual water demand.

Table 4. Annual water demand per dominant sector/water use.

Sector/Water use	Annual water demand (hm³)
Irrigation (Excluding water volumes from deficit irrigation)	1,226
Domestic water	94
Livestock	13
Industry	9
Total	1,342

Accordingly, the distribution of the above water demand to the corresponding water sources is presented in Table 5. Groundwater constitutes the dominant water source, and at the same time, it indicates a higher deficit. The annual water deficit is approximately 35% of total water extraction, thus meaning the necessity for improving water resources management in PRB.

Table 5. Annual water extraction per water source.

Water Source	Annual current water extraction (hm³)	Annual sustainable water extraction (hm³)	Annual deficit (hm³)
Groundwater	920	620	300
Surface water	235	160	75
Reservoirs	185	165	20
Deficit irrigation	-	-	80
Total	1340	945	475

1.9. Current and emerging land uses, major crops, and farming systems

The approximate land use distribution in PRB according to CORINE land cover is presented below. Half of PRB areas are covered by forests and semi-natural areas, followed by agricultural land, which holds more than 40% of the total PRB area (Table 6).

Table 6. Major land cover distribution according to the CORINE land cover data.

Land Cover Class	% Of total PRB area
Artificial Surfaces	2.05
Agricultural areas	44.74
Forest and seminatural areas	52.76
Wetlands	0.35
Water bodies	0.10

According to 2017 national data report by the Greek Payment Authority of Common Agricultural Policy (OPEKEPE), the total cultivated land in Water District of Thessaly was roughly 603,000 ha. Table 7 presents the estimated area of each of the arable and perennial crops. Noteworthy, just three arable crops, cereals, cotton, and alfalfa, cover over 65% of the total arable land of Thessaly Water District.

Table 7. Arable and perennial crops distribution in Water District of Thessaly (EL08).

Crop Name	Area (ha)	% Of Total Arable Land
Arable Crops		
Tomatoes	4,307	0.70
Vegetables	4,725	0.77
Legumes	12,560	2.05
Alfalfa	83,078	13.58
Biodiesel	1,835	0.30
Cotton	143,815	23.51
Maize	35,478	5.80
Cereals	198,007	32.37
Perennial Crops		
Olive Groves	28,879	4.72
Orchards	14,237	2.33
Nut trees	11,909	1.95
Vineyards	4,743	0.78

1.10. Energy generating infrastructure

Plastiras dam constitutes one the most significant hydroelectric power generation facilities infrastructures, and it serves to produce about 160 GWh/y. Other smaller hydroelectric power plants were found in PRB, while energy production through photovoltaic power plants is expanding in the last decades.

There is a lack of data for energy demand in PRB. Therefore, the corresponding estimations will be made in the context of the REXUS project. Nevertheless, a description of the national situation is the following. Greek economy relies on fossil fuels (carbon, oil, and natural gas) and is highly dependent on primary energy imports. Table 8 presents the total Greek energy consumption per sector/per source in 2020. Transportation constitutes the dominant energy consumer in Greece (36.7% of total energy consumption), followed by domestic consumption (24.3%), industry (22.8%), and trade and services (13%). The main problems of the energy sector in Greece are related to the deficiencies in the energy infrastructures and to the high cost of energy made substantial by the dizzying unpaid bills of (PPC) (approximately 2.7 billion euros in 2019).

1.11. Demographic data at pilot scale

This chapter analyses the demographic characteristics of the pilot area of Pinios River Basin. Table 10 presents the percentage of each prefecture participating in Pinios River Basin, while Table 11 contains the total population and distribution per age and gender in the same area, referred to 2011. The information is obtained by the census data of the National Social Security Institute.

Table 8. Energy consumption of Greece per sector and source in 2018. Source: Eurostat.

Energy consumption per sector	
Industry	22.8%
Households	24.3%
Trade and services	13%
Transportation	36.7%
Agricultural	1.8%
Other	1.4%
Energy consumption per source	
Biomass, Biofuels	5.1%
Hydroelectric	2.1%
Wind	2.3%
Solar	2.6%
Heat (Pumps) and another RES	1.4%
Oil	47.6%
Natural Gas	17.2%
Carbon	19.3%
Electricity	2.4%

Table 9. Characteristics and weaknesses of the energy sector in Greece.

General	High energy dependence High dependence on fossil fuels
Electricity sector	Structural imbalances, especially in the field of electricity supply Limited competition due to lack of access of new entrants to low cost primary energy sources High energy cost in the wholesale market Weak connection of the wholesale market with the retail electricity market Large amounts of the overdue debts to PPC
Energy infrastructure	The interconnections of the autonomous island systems with the mainland braiding system are not completed Delay in the development of "intelligent" electricity distribution networks and in the installation of "smart" meters
Natural gas	Not completed coverage of the country by natural gas network Relatively small retail market and hysterical compared to the EU average for connected households

Table 10. Area and population of each prefecture that participates in Pinios River Basin

Prefecture	% Of Prefecture belonging to Pinios river basin
Larissa	91%
Magnesia	19%
Trikala	76%
Karditsa	75%
Pieria	8%
Grevena	5%
Fthiotida	18%
Kozani	2%

Table 11. Population and distribution per age and gender in PRB in 2011. Source: National Social Security Institute

	Age groups	Population		Age groups	Population		Age groups	Population
Total	0-9	51265	Males	0-9	26201	Females	0-9	25064
	10-19	53392		10-19	27530		10-19	25862
	20-29	57320		20-29	29474		20-29	27846
	30-39	72457		30-39	36849		30-39	35608
	40-49	72892		40-49	36800		40-49	36092
	50-59	67254		50-59	33965		50-59	33290
	60-69	59123		60-69	28851		60-69	30272
	70+	89125		70+	39309		70+	49816
	Sum	**522829**		**Sum**	**258979**		**Sum**	**263850**

1.12. Major economic activities / industries, employment

Table 12 presents the employment status of the population in PRB according to census data from the National Social Security Institute for the year 2011. Moreover, Table 13 illustrates the employees by sector of economic activity in PRB.

1.13. Organizational infrastructure, Innovation capacities and Data

Technical and organizational infrastructure

Water resources management (WFD, GWDD, National grid): Strategic management of water resources is carried out at national level by the central government, namely the General Directorate for Water, which belongs to the General Directorate for Natural environment and Water of the Ministry for Environment and Energy (which means that specific General Directorates strategically manage all strategies on energy, environment, and resources for each sector). At regional level, water resources management is carried out by the Water Directorates acting at a multi-regional level (i.e., at more than one identified Water District). Therefore, regional water management is lead by different administrative levels.

Table 12. Employment status of the population in PRB in 2011. Source: National Social Security Institute

Total			522,829
Financially active	Total		202,226
	Employees		164,395
	Unemployed	Total	37,831
		Former employees	23,926
		New	13,905
Financially inactive	Total		320,603
	Students		82,859
	Retired		133,525

	Rentier	701
	Household	63,398
	Other	40,119

Table 13. Employees by sector of economic activity in PRB in 2011. Source: National Social Security Institute

Total	202,226
Agricultural, forestry and fisheries	36,823
Mines and quarries	331
Processing	18,824
Activities of electricity, natural gas, steam, and air conditioning	1,036
Water supply, wastewater treatment, waste management and reconstruction activities	1,180
Constructions	14,046
Wholesale and retail trade - repair of motor vehicles and motorcycles	32,642
Transportation and storage	6,838
Activities of accommodation services and catering services	13,926
Information and communication	1,867
Financial and insurance activities	3,032
Real estate management	251
Professional, scientific, and technical activities	9,132
Administrative and support activities	3,398
Public administration and defense - mandatory social insurance	20,383
Education	18,968
Activities related to human health and social care	12,807
Arts and entertainment	1,842
Other service activities	3,677
Household activities as employers	1,203
Activities of non-governmental organizations	20

Theoretically, water resources management plans are compiled at the Water District administration level, and practice adopted only in few regions of the country for the coming review of the programs. Thessaly is not one of them. Therefore, the study will be prepared by the central governmental services with the liaison of the Water Directorate of Thessaly. The latter will be then responsible for the implementation of the designed measures, focusing on specific measures to address the issues present within the general framework. Lower-level management bodies include the departments of hydro economy and environment. Municipalities are involved in licensing abstraction works, in collecting paperwork, and in forwarding it to the Water Directorate. Irrigation water management is assigned to the irrigation organizations, which are utilities responsible for managing the collaborative networks. Private works exist, but irrigation networks are not allowed to be constructed and they have to operate in the jurisdiction of the combined networks unless the network cannot cover the water demands entirely. Licensed volumes calculation is based on obsolete legal acts that need to be updated (usually, they overestimate the required volumes primarily to cater for cultivation). No actual monitoring-policing of consumed books takes place. Public Utility services operate at the municipality level to cater to domestic water supplies and domestic effluent treatment plants. Industrial water use management is performed by the managing staff of each industrial area across the country, including the Thessaly basin (Pinios River Basin). A private entity performs industrial areas and ventures' parks under a central management board according to national regulations.

Nitrates Directive: It is implemented (based on an obsolete NVZ delineation approach that needs review and update) by the regional authorities and coordinated by the central governmental services. The delineation of the NVZs is a responsibility of the Ministry for the Environment and Energy, which liaises with the Ministry for Rural Development and Food on the compilation of the Code for Good Agricultural Practice and the specification of Action Plans to be followed. Regionally based services of the Ministry for Rural Development and Food are assigned to monitor their implementation is assigned. Currently, monitoring is carried out based on randomly selected fields samples in the NVZs domain where residual N concentrations are examined. Results of this exercise are assessed along with N inputs and nutrients concentrations in water receptors as deduced from the results of the national monitoring grid.

Environmental management-protected areas: The Natural Environment and Climate Change Agency (NECCA) is supervised by the Ministry of Environment and Energy. It was formed in 2020, being the successor of the National Centre for Environment and Sustainable Development with administrative and financial autonomy. NECCA aims to implement the policy set by the Ministry of Environment and Energy for (i) the management of protected areas in Greece and biodiversity conservation, and (ii) the promotion and implementation of actions for sustainable development actions and climate change. Regarding the conservation of protected areas, NECCA (a) coordinates the implementation of the policies for protected areas; (b) conducts scientific research and studies; (c) prepares a Five- Year Action Plan; (d) monitors the implementation of the Priority Actions Framework; (e) organizes a dedicated web portal; (f) undertakes support for natural state monitoring networks; (g) implements programs and (h) cooperates with European and international organizations, public and private scientific and productive bodies, and non-governmental organizations for the management of protected areas. Regarding the promotion of sustainable development and climate change, NECCA: (a) collects and treats data on environment and climate change; (b) supports MEEN to meet the obligations of Greek administration towards the European Environment Agency implementing plans and preparing reports as required by the national, European, and international law; (c) implements environmental programs, projects, and actions; (d) acts to disseminate environmental policy and (e) cooperates with all stakeholders and raise public awareness for the environment and sustainable development.

Agriculture management: At regional level, the Directorates for Agricultural Economy and Livestock operate to manage and assist the primary sector and they oversee facing the sector issues. Their contribution is vital when staffed by scientific excellence and professionalism.

Innovation capacities

The University of Thessaly performs R&D projects and provides services in water and land management, improvement of agricultural practices, and promotion of aquaculture. Energy-related applications are also supported in the primary agricultural sector.

The Technical and Geotechnical Chambers of Thessaly support and promote management practices with a degree of innovation and they provide large-scale development ideas and attempts. Nevertheless, to SWRI´s knowledge, there is no specific innovation structure. Public services structures that may be actively involved in supporting such activities are in operation, at least in their organizational charts.

Private and public entities show state-of-the-art adaptations in their activities, pushed by the needs of their tasks and having been approached and offered such solutions by innovation services, not necessarily confined within the basin’s boundaries.

Models and data

The water balance model mGROWA (Herrmann et al. 2013) developed for PRB is available to be implemented for the REXUS project. Two consecutive parts constitute the distributed modeling approach of mGROWA. The first, physically based part of the model includes the simulation of the water balance and runoff formation on the ground surface, including the root zone of the soil. The second empirical part simulates the separation of the total runoff into groundwater recharge and direct runoff. The latter includes the diffuse water fluxes occurring near-surface in the unsaturated zone. A representation of the modeling scheme followed in mGROWA is demonstrated in Figure 4.

The available recorded, measured, monitored, and simulated data available for PRB are described below:

- Climatological Data: Daily precipitation data from 42 meteorological stations covering 1958-2010, while daily minimum and maximum air temperature data for 8 of those stations are also available. Furthermore, interpolated monthly data of precipitation, air temperature, and ETo is available in ASCII grid format with a grid cell size of 100 x 100m.
- Simulated water budget constituents: Monthly grids (ASCII grid format) simulated with mGROWA for the period 1970-2010 of total runoff, direct runoff divided in interflow, drainage runoff and
- Runoff from urban areas, groundwater recharge, actual evapotranspiration, and crop-specific irrigation needs.
- River discharge data: Historical time-series monthly river discharge in several points of the main river course and its tributaries.
- Crop distribution on field-scale for the year 2017, as registered by the responsible Greek authorities.
- Digitized geological data from the geological map of Greece (1:500,000 scale).
- Terrain, land cover, and soil data are available from public domain sources.

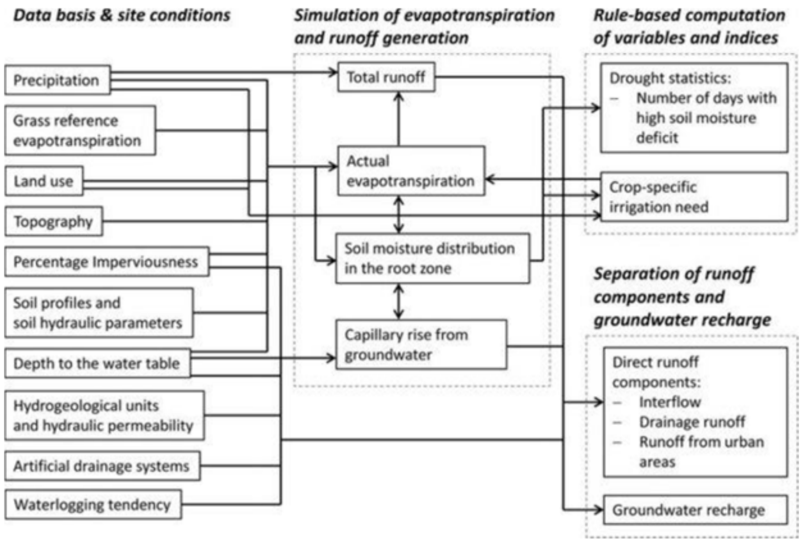


Figure 4. Data basis and general modelling scheme of the mGROVA model. Source: Hermann et al. 2016.

1.14. EU &/or national projects where the pilot was an important test case

2014-2018, FP7, MARS: Managing Aquatic ecosystems and water resources under multiple stress. The effects of multiple stressors in rivers, lakes and estuaries were investigated in the context of the MARS project. Formerly, rivers and lakes were impacted by intense, single stressors, e.g., organic pollution or acidification. They were replaced by a complex mix of stressors resulting from urban and agricultural land use, waterpower generation and climate change. One of the pilot areas was PRB.

2015-2018, HORIZON 2020, FATIMA: Farming Tools for external nutrient inputs and water Management. According to the project's website, FATIMA addresses effective and efficient monitoring and management of agricultural resources to achieve optimum crop yield and quality in a sustainable environment. It covers both ends of the scale relevant for food production, namely, precision farming and sustainable agriculture in integrated Agri-environment management. It aims at developing innovative and new farm capacities that help the intensive farm sector optimise their external input (nutrients, water) management and use, with the vision of bridging sustainable crop production with fair economic competitiveness. PRB constituted one out of the eight pilot areas.

2015-2019, International virtual topic-network on modelling and managing catchments in Mediterranean basin, Forschungszentrum Jülich and SWRI. This project aims to apply the fully distributed hydrologic model mGROWA in PRB and investigate potential climate change effects in water resources. The above model application will be used for the REXUS project.

2015 – today, Pinios Hydrologic Observatory (PHO). PHO was primarily developed to provide deep knowledge of water balance at the river basin scale and improve understanding of the effective hydrodynamic mechanisms, thus improving hydrological modelling and ultimately sustainable water resources management (Pisinaras et al. 2018). Through its detailed and high-frequency data, accompanied by a solid connection to the local stakeholders, PHO can provide significant input to the REXUS project.

2016-2021, Innogrow Interreg. Regional policies for innovation-driven competitiveness and growth of rural SMEs. Rural economy SMEs face challenges in adopting innovation to increase their competitiveness. Regional policies need to correspondingly support the diffusion of innovative solutions and new business models that will increase productivity and access to new markets. INNOGROW regions are called to play an essential role in supporting the modernisation of their existing rural SMEs and the proliferation of innovative start-ups.

2019-2022, Interreg, Re-Source: Providing services for management of natural resources. The Re-Source project tries to improve the transnational governance capacity concerning the following three fields: 1) irrigation water management, 2) good agricultural practices, and 3) soil erosion risk management. PRB constitutes one of the pilot areas.

2019-2023, HORIZON 2020, ATLAS: Agricultural Interoperability and Analysis System. The goal of ATLAS is the development of an open interoperability network for agricultural applications and to build up a sustainable ecosystem for innovative data-driven agriculture. One of the sectors that ATLAS is working with is irrigation, and Soil & Water Resources Institute is responsible for the corresponding tasks.

2021-2023, LENSES: LEarning and action alliances for Nexus EnvironmentS. LENSES aims to contribute to improved water allocation enhanced food security while preserving ecosystems and aiding climate change adaptation by supporting the operationalisation of the Nexus paradigm (from Nexus Thinking to Nexus Doing) in the Mediterranean region. It will do so by a collective learning process, which integrates the concepts of sustainable Nexus management (progressing Sustainable Development Goals, SDGs) with a resilience-oriented approach, leading decision-makers in accepting uncertainty as an integral part of management and decision-making. LENSES will be implemented in 6 demonstration pilot sites distributed across the Mediterranean basin, focusing on different water and land uses, mainly food production through agricultural activities, forest and natural ecosystems conservation, and other activities (such as tourism and industrial production).

2021-today, Water for Tomorrow, Athenian Brewery. A project financed by the Athenian Brewery promotes Sustainable Development in practice through the emergence of solutions for the proper management of water resources in Greece. During the implementation of the “Water for Tomorrow” Program, the scientific team will apply the integrated methodology for the Innovative Systems Transformation (Systems Innovation Approach), aiming at the active involvement of the productive and institutional partners in all stages of the design of the solutions will lead to a sustainable model of water resources management in Thessaly.

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2. Peninsular Spain & Jucar River Basin (Spain, ES)

2.1. General characterization

The Peninsular Territory of Spain

The territory of Spain is 505,944 km^2, with a population of 47 million. The average annual rainfall is 684 mm, equivalent to 346,000 hm^3/yr, average runoff is 220 mm, with an average yearly volume of water resources of 111,000 hm^3, of which 82,000 hm^3 are surface water, and 29,000 hm^3 are groundwater. Agriculture represents approximately 4% of the economic activity, and if the entire Agri-Food Sector is considered, it employs up to 13.43% of the active population. About 50% of the territory is covered by farmland, while 7% is dedicated to irrigated crops. Spain has one of the most extensive territories in the EU protected by biodiversity (21%). Climate Change plays a vital role in agriculture. The increasing temperatures and decreasing rainfall with periods of drought provoke water stress episodes on crops, leading to yields below the threshold of economic profitability. Regional governments have declared Climate Emergency. Over the last 20 years the central administration has developed an ambitious irrigation modernization program for surface water irrigation schemes to increase water efficiency. The high solar radiation throughout the year, a favourable wind regime, and a developed infrastructure of water reservoirs had urged the development of renewable energies' production in the last decades. Renewable energy represents 35% of electricity production, with hydropower around 14%, and the rest (solar, wind, biomass) represents 21%.

REXUS targets only the peninsular territory. Water resources in the Peninsular Territory of Spain are managed in 15 Autonomous Communities and 15 River Basin Districts (RBD), which are responsible for the design, planning, and supervision of the use of these resources (Figure 5). Socioeconomic problems and different geographic distributions generate political conflicts, so solutions that guarantee equal rights and environmental sustainability must be implemented.

Figure 5. 15 Spanish mainland Autonomous Communities (left) and 15 Spanish mainland River Basin Districts (right). Source: Universidad Castilla-La Mancha, 2021.

Jucar River Basin (JRB)

The Jucar River basin is located in the South-East part of Spain on the Mediterranean shore (Figure 6). It comprises nine water resources systems with a total surface area of 42,735 km^2, a population of 5,048,249 permanent inhabitants, and an equivalent total population of 5,476,578. The Jucar River Basin District has a Mediterranean climate; the total annual precipitation is around 500 mm, oscillating between maximum annual values of 780 mm for the wet years and just over 300 mm for the dry years. The main sectoral uses are agriculture (80%), urban (16%), and Industry and Energy (4%). To fulfil these demands and maintain water flows for natural environment, all types of water resources are considered: surface/ground water and water transfers from other basins and non-conventional water (desalination and treated wastewater). The basin has good monitoring networks for surface and groundwater linked to an Automatic Hydrological Information System (SAIH), with historical datasets from 1989. The Albufera protected wetland has its own control network, and marine intrusion is also monitored.

The Jucar River Basin Authority (JRBA) is an autonomous body established under the Ministry of Ecological Transition and Demographic Challenge (MITECO). It was created in 1934 and constituted in July 1935. The JRBA oversees WFD implementation and reporting. The key stakeholders involved in participatory management are the JRBA itself, the key water users (irrigation communities, urban water suppliers, energy providers, and industries), as well as water infrastructure managers (desalination plants, wastewater treatment plants, water transfers), Regional Government, environmental associations, and data providers.

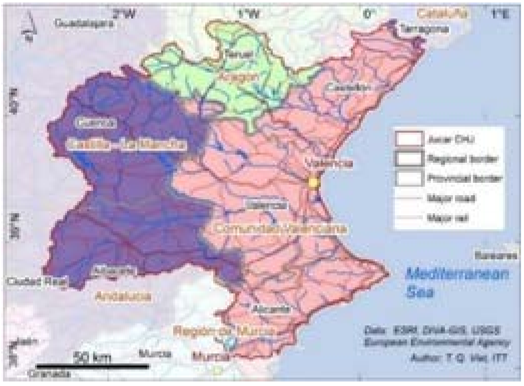

Figure 6. Jucar River Basin. Source: Environmental European Agency, 2021.

2.2. Major developments

Water

When we refer to the latest developments in water resources issues, we must mention the "National Hydrological Plan (PHN)" by the Ministry for the Ecological Transition (MITECO) and the "DSEAR plan, 2018". During the last two decades, Spain has undergone a substantial transformation with the development of Water Reuse through the National Plan (DSEAR plan, 2018). The DSEAR plan seeks to ensure sustainable management of water resources based on the integral water cycle. However, these advances are insufficient to address the significant challenges facing the sector.

The Water Directorate General (WDG) Plan for all the River Basin Districts (RBD) is based on a continuous adaptive process in each district, reviewed and updated every six years. One of the phases comprises and develops flood risk management plans, and we are currently in the third phase of the National Hydrological Plan (PNH, 2001), which seeks to make the sector more attractive, encouraging investment and increasing the interest level of all parties by improving the management of the water cycle. In addition, the PNH seeks to enhance the understanding between the different River Basins.

The situation requires a lot of measures, investment, and technical knowledge. At the end, public administrations cannot address these complex issues, so the gap is too broad to obtain the expected results. At least 3,500 measures must be implemented in the areas of wastewater treatment, sanitation, and reuse. For all these reasons, the seven Governance Objectives (GO) have been defined: to design a prioritization mechanism for the measures (GO1), to strength administrative cooperation (GO2), considering state's interest (GO3). To improve energy efficiency (GO4), finance and recovery (GO5), to promote water reuse (GO6), and to promote innovation and technology transfer (GO7).

Treated and reused water would show that in the scope of 2004 and 2016, the proportion of reused water surpassed 400 hm^3, even reaching values over 500 hm^3. According to the Ministry of Ecological Transition, the volume of water used in the 2017/2018 campaign was 382 hm^3, which is a severe problem in this sector, far from any objective of the National Reuse Plan. There is a structural problem as not all basins work efficiently, and only some of them contribute positively to the sustainable allocation of water resources.

Agriculture

Government's position is to achieve the Sustainable Development goals (SDG) proposed by the European Union. Therefore, the Ministry of Agriculture, Fisheries, and Food is implementing the National Irrigation Plan (PNR), where the topic of Food Security to improve water allocation and development in the energy sector is essential. The increase in the world population means an increase in food demand. It constitutes one of the biggest challenges, supplying the population through sustainable practices that contribute positively to biodiversity, water allocation, preservation of ecosystems, and adaptability. For all this, the Ministry of Agriculture works together with the Common Agricultural Policy (CAP), making complex decisions that seek to boost the agricultural sector, on the other hand, the National Government pursues the achievement of the SDG following the guidelines of the PNR (Figure 7).

Before mitigating, it is essential to understand that we must quantify agricultural systems at different scales with exhaustive studies. For the development and assurance of food, the private sector supports the other agrarian systems with technology and quantification of the various properties of ecosystems. More and more companies are investing in this sector, not counting those already established, providing satellite images and studies that guarantee an efficient allocation of resources.

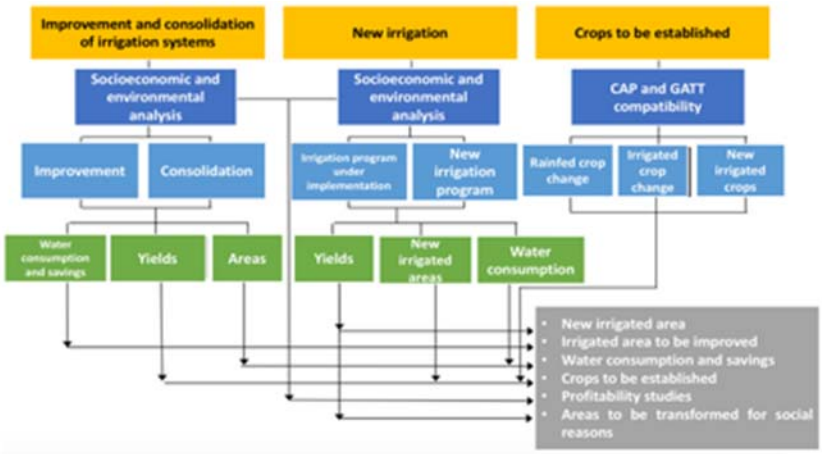

Figure 7. Methodology of the National Irrigation Plan. Source: MAPA, PNR.

Energy

Spain is rich in natural resources that allow renewable energy production, as the sun and wind are abundant and suitable land is available for the plants. Spain has cutting-edge solar and wind energy technology, and the national energy policy strongly encourages renewable energy to reduce its dependence on energy imports.

Regarding energy developments in the country, the National Integrated Energy and Climate Plan (PNIEC) 2021-2030 plays a significant role through the Institute for Energy Diversification and Saving (IDAE). This plan reduces greenhouse gas (GHG) emissions through renewable energy and energy efficiency. The strategies include renewable energies, energy efficiency, employment and wealth, self-consumption, intelligent systems, sustainable mobility, measures for industries and infrastructure rehabilitation.

The sectors that consume the most power, these are industry (textile, food, and beverage, paper, chemical, minerals, construction, wood, etc.), transportation (roads, rail, maritime, air, pipelines, etc.), and various uses (agriculture, fishing, commerce, residential, etc.) (IDAE). The 2018 Final Energy Consumption Balance Sheet by IDAE shows that more than 50% of the total energy consumed comes from petroleum products (e.g., diesel, gasoline, kerosene, among others). Only for a lower extent they come from renewable energies. This is a call to look for new energy sources if objectives have to be achieved.

Water is fundamental for energy generation; therefore, hydroelectric power is relevant. The contribution of this sector to total energy production is around 10-14%. At the European level, Spain ranks third and fourth in hydroelectric power plants in terms of power. The reservoir capacity of Spanish dams is slightly more than 55,000 hm^3, and electricity consumption in the different water cycle processes is around 7% of the total energy demanded.

The National Integrated Energy and Climate Plan (2021-2030) expects to achieve an emissions reduction level of 23% compared to 1990. To meet the GHG emissions target for 2030, sectors subject to emissions trading (ETS) and diffuse sectors are expected to contribute 61% and 39%, respectively.

Environment

The Ministry for the Ecological Transition (MITECO) has been made the most progress on environmental issues, and plans vary by sector, as each affects the ecosystem differently. The strengths focus on recovery, transformation, and resilience plans. Some of the advances and processes being seen are:

Water: Hydrological planning, enhanced sanitation and purification systems, river restoration, irrigation management, water quality and status, water resources assessment, protection of national hydrological reserves and SEPRONA (Nature Protection Service) actions.

Biodiversity and Forests: The first report reflects the state of natural heritage and biodiversity in Spain up to 2020, a year that has been very significant for biodiversity conservation.

Quality and Environmental Assessment: Air quality viewers, environmental liability regulations, environmental risk analysis software application, environmental assessment, zoning for wind and photovoltaic renewable energies, emissions inventories, waste management, and monitoring of environmental indicators with the help of the European Environment and Information Agency.

Coasts and marine environment: In this point, the actions refer to the mapping of marine and costal zones, flood control, strategies for protecting the coast and protecting the marine environment, adaptation to climate change. Currently, the “Mar Menor” protection is a priority for the state.

Environmental education: The latest in this topic is the work program for 2022 of the environmental education action plans for sustainability (PAEAS).

Climate

There are many plans that Spanish state is making today to combat climate change. We can add the efforts being made to achieve goal number 13 of the 2030 agenda, which is the one that refers to climate change. As mentioned above, Spain is working to improve environmental adaptation. As a first step, the accounting of different indicators is essential, secondly, proceeding to implement measures by putting in place different plans. These plans seek to promote environmental care by accounting for emissions carbon footprint, improving adaptation to climate change, and keeping society informed clearly and transparently.

2.3. Challenges

Nexus-related Challenges

Challenges at the policy level (policy and implementation).

The main challenge of the REXUS project in the Spanish Pilot Case is to move from comprehensive analysis to implementing exemplary practices in Nexus management (Nexus thinking to Nexus doing).

Conflicts:

- Agriculture-Ecosystems-Energy-Climate Nexus. In general, the implementation of specific policies has a positive impact on one of the different systems of the Nexus but may directly or indirectly affect other essential factors. It is these types of relationships that we must study. Sustainable practices that involve the entire Nexus must be provided.
- Between regions and watersheds. In Spain, many entities do a well-done job, but separately, it is necessary to integrate each of them, so we must work involving each of the different stakeholders.

The work of REXUS is:

- Provide an inventory and analysis of the Nexus (at the national level with regions and Watersheds).
- Link national and regional climate adaptation plans.
- Help introduce resilience and Nexus thinking/action in upcoming policy measures (WFD 3rd cycle implementation, CAP post-2020/green deal, climate emergency).

Agriculture is the main link in the Spanish Water-Energy-Food-Climate Nexus. It is the largest user of the country's water resources and consumes a significant amount of energy. Specifically, irrigated agriculture consumes more than 60% of the national blue water resources and accounts for more than 40% of total agricultural energy use. Hence, one of the challenges and needs is to account for the water and energy footprint.

In addition to all the above, maintaining and increasing food production is essential while facing a significant challenge, climate change, and the scarcity of water resources.

Spain is the driest country of all the members of the European Union (EU), with an average annual rainfall of over 600 mm. However, the distribution is uneven, with some regions receiving less than the 350 mm mark the threshold of a semi-arid climate. Water resources are abundant only in the northwest of the country. There, have always been recurrent droughts, and climate change is expected to aggravate the situation.

Actions to meet Sustainable Development Goals:

Spain is committed to the 2030 Agenda and the Sustainable Development Goals (SDG). The implementation of the SDG will be coordinated by the Central Administration of the Government of Spain, regional governments, and local entities.

Messages were delivered on the importance of the 2030 Agenda in their policies: universal health coverage, gender equality, renewable energies, ecological transition, employment policy, international governance, solidarity, and commitment to human rights, as well as the eradication of child poverty, the reduction of inequalities and the fight against climate change.

Considering the Nexus and the REXUS project, the most significant SDG are:

SDG 6. Clean Water & Sanitation: We will work on water resources management with the different river basins in Spain. The main challenge of this pilot case is water stress and water quality assurance (water bodies are at risk due to high N levels). Spain is considered in water stress by SDG indicator 6.4.2 (43% of available freshwater resources are withdrawn annually).

SDG 13. Climate Action: It is no secret that Climate Change is a reality. We will continue to insist on the fight against climate change following the commitment of the Paris Agreement to limit the increase in global temperature.

SDG 15. Life on Land: This is one of the essential points for the Spanish pilot case, as it seeks to protect ecosystems, fight desertification, and stop soil degradation.

As well as:

SDG 2. Zero Hunger: Agriculture is fundamental to end hunger. Currently, the country wants to ensure food security by promoting sustainable agriculture. Task 2.3. Supporting smallholder farmers Task 2.4.

SDG 7. Affordable & Non-Polluting Energy: It is essential to promote new energy sources; currently, fossil fuels are the core of the Spanish energy system. The shift towards clean energy production will bring about changes in the Environment, Ecosystems, and Emission Reduction.

2.4. Key stakeholders

In the case of the Spanish pilot, the key stakeholders are:

National ministries in charge of national policies and plans:

- MITECO - Ministry for Ecological Transition and Demographic Challenge.
- MAPA - Ministry of Agriculture, Fisheries, and Food.
- Ministry of Social Rights and Agenda 2030.

Regional governments and water authorities responsible for adapting national policies to the regional scale:

- Jucar Hydrographic Confederation
- 13 River Basin Authorities. (Hydrographic Confederations-CCHH).
- 15 Regional Governments (devolved competencies); The most relevant Autonomous Communities (CCAA) in the REXUS project are Castilla La Mancha and Valencian Community.
- Provincial Councils of Valencia and Albacete.

Institutional entities at the National Level:

- National Federation of Irrigation Communities of Spain (FENACORE).
- Institute for Energy Diversification and Saving (IDAE).
- Spanish Agricultural Guarantee Fund (FEGA).
- Energy utilities: Iberdrola, Endesa, Naturgy, Galp, Acciona.
- Water utilities: Canal de Isabel II.

Local stakeholders:

- Individual farmers and farmers' associations.
- Irrigation communities and water user associations (CCRR): Central Irrigation Board Mancha Oriental (JCRMO).

2.5. Policy

Relevant policies for all Nexus domains

The country is currently facing a set of environmental challenges, for example, water stress. Implementing sustainable practices is necessary to achieve a development that includes the economic, social, and environmental sectors, including the whole Water-Energy-Food-Climate Nexus. AgriSat is committed to the development of technologies that facilitate beneficial policy decisions for Ecosystem Services. It has improved in different aspects, but it is not enough. We will work with a participatory approach with autonomous communities and hydrological basins following the Spanish Strategy for Sustainable Development.

Another critical point is that Spain is the first country to include water footprint analysis in government policymaking in the context of the EU Water Framework Directive (BOE 2008). In September 2008, a regulation was approved that incorporates water footprint analysis as a technical criterion for preparing river basin management plans to be drafted in the context of the EU Water Framework Directive (WFD 2000/60/EC).

Below, we highlight some relevant Climate Laws and Decrees:

- Article 28 of the Water Law approved Royal Legislative Decree 1/2001, of July 20, attributes to the Governing Board of the Basin Organizations the competence to "*declare the groundwater bodies at risk of not reaching well quantitative or chemical status*."
- The Hydrological Planning Regulation (RD 907/2007); Royal Decree 1/2016, of January 8, approving the revision of the Hydrological Plans of the river basin districts.
- Directive 2000/60/EC, of October 23, establishes a framework for Community action in water policy, referred to as the Water Framework Directive (WFD). Royal Decree 849/1986, of April 11, 1986, incorporates aspects of the WFD.
- Law 22/1988, of July 28, 1988, on Coasts.
- Royal Decree 817/2015, of September 11, establishing the criteria for monitoring and evaluating the status of surface waters and environmental quality standards, and with Royal Decree 1075/2015, of November 27.
- Law 21/2013, of December 9, on environmental assessment, guarantees maximum ecological protection and gives new impetus to sustainable development by analysing the significant effects on the environment of plans, programs and projects before their adoption, approval, or approval authorization.
- United Nations Convention on the Protection and Use of Transboundary Watercourses and International Lakes, held in Helsinki on March 17, 1992; the OSPAR Convention for the Protection of the Marine Environment of the Northeast Atlantic, done in Paris on September 22, 1992, and the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention), Protocol on the Protection of the Mediterranean Sea against Pollution from Land-Based Sources, approved in 1996 and ratified by Spain in 1999, has been in force since 2008.
- At the state level, to guarantee cooperation in applying water protection regulations, the Committees of Competent Authorities in Royal Decree 126/2007, of February 2, are created in the river basin districts with intercommunity basins referred to in this Royal Decree.
- The hydrological planning takes into account the documents derived from the Common Strategy for the Implementation of the Water Directives promoted by the European Commission and, in particular, the Communication, dated November 14, 2012, from the Commission to the European Parliament, the

Council, the Economic and Social Committee and the Committee of the Regions, entitled "A Blueprint to Safeguard Europe's Water Resources" and the new guidance documents recently prepared or updated, especially the "WFD Reporting Guidance 2016", adopted by the European Water Directors in June 2014.

Side effect in policy implementation

The National Government manages River Basins. There are other basins that, as they cover more than one autonomous community, are driven by the corresponding autonomous community, which may cause problems of communication with specific agreements measures to be implemented. Therefore, this case is complex to address and requires a participatory approach from all parties. In addition, the plans need long-term governmental support; otherwise, evaluation and mitigation will be affected by constant political or administrative changes in state, regional or municipal institutions.

Another aspect to note is that the European Commission ensures compliance with water obligations, and Spain is in an evaluation period; the Commission might impose sanctions. We are currently in the third cycle of the national hydrological plan, where the measures adopted are expected to have a positive effect and meet the requirements.

We highlight the most relevant policies/directives that in some cases have reached the courts of justice of the European Union in water matters: Directives 91/271/EEC, of May 21, on urban wastewater treatment and 91/676/EEC, of December 12, on the protection of waters against pollution caused by nitrates used in agriculture.

Thanks to the hydrological basin plan, the Jucar River Basin has detected some groundwater bodies at risk that do not reach good quantitative status, requiring immediate measures to improve water quality to not affect final users.

2.6. Relevant documents and Governance systems

Planning documents

The central government governs the basins Appling the same plans with different measures. Here we will focus on the Jucar River Basin. The Jucar River Basin must complete the planning process every six years, with the closing years being 2009, 2015, 2021, etc. During these six-year periods, the JRB must reach different objectives present within the plans. This analysis compared documents corresponding to previous cycle plans.

Legislative framework:

- Hydrological Basin Plan. Royal Decree 1664/1998.
- Hydrological Basin Plan of the Jucar River Basin District. Cycle 2010-2015. Royal Decree 595/2014.
- Hydrological Plan of the Jucar River Basin Demarcation. Process 2016-2021. Royal Decree 1/2016.
- Hydrological Plan of the Jucar Hydrographic Demarcation. Cycle 2022-2027.
- Monitoring reports of the hydrological basin plan.

Other relevant plans: Special and Eventual Drought Alert Plan; Flood Risk Management Plan; and Groundwater Bodies Exploitation Plan.

One of these successful outcomes is the JRB's Drought Management Plan, launched in 2013 and implemented during the 2015 drought. The use of long- and short-term modelling and decision support systems (DSS) has played an essential role in developing drought management strategies.

Governance systems

There is not a unique governance model, but strong and stable institutions ensure compliance and service delivery. Political and economic systems must be based on natural resource management, bringing various benefits and contributions. Different resource governance institutions must be tailored to the needs of regions and address multiple challenges in a localized manner. Governments must work together with society, so it is necessary to use understandable language. Likewise, government decisions must consider the welfare of the population by being clear and transparent to achieve economic, social, and environmental benefits.

Governance in Spain seeks to ensure that service tariffs cover their short, medium, and long-term investments, guaranteeing the resources for the proper operation and maintenance of these capital contributions. Institutions in charge of the governance of natural resources are some of our leading stakeholders, such as MITECO (Ministry for the Ecological Transition and the Demographic Challenge) and MAPA (Ministry of Agriculture, Fisheries and Flood).

2.7. Basic climate and soil data

Peninsular Territory

In Spain, we can find clay soils in the vast plains of the two Castilla's, the Ebro and Guadalquivir plains; limestone soils in the Pyrenees to the Basque Country, Valencia, and Gibraltar; siliceous soils from Galicia to Madrid and western Andalusia, composed of primary materials: granite and slate. The primary Spanish soils (Travernier 1985, MITECO) are: Andosols, Arenosols, Cambisols, Fluvisols, Histosols, Leptosols, Luvisols, Planosols, Podsol, Ranker, Solonchak, Vertisols, Xerosols.

In terms of temperature an upward trend can be seen in the last decades. Since 1961, the warmest years have been 2020 and 2017. Year 2020 has been extremely warm, with an average temperature of 14 ºC, increasing by 1.0 ºC compared to the reference period (1981-2010). Concerning precipitation: year 2020 had average cumulative rainfall of 606 mm, 5% below the reference value (1981-2010).

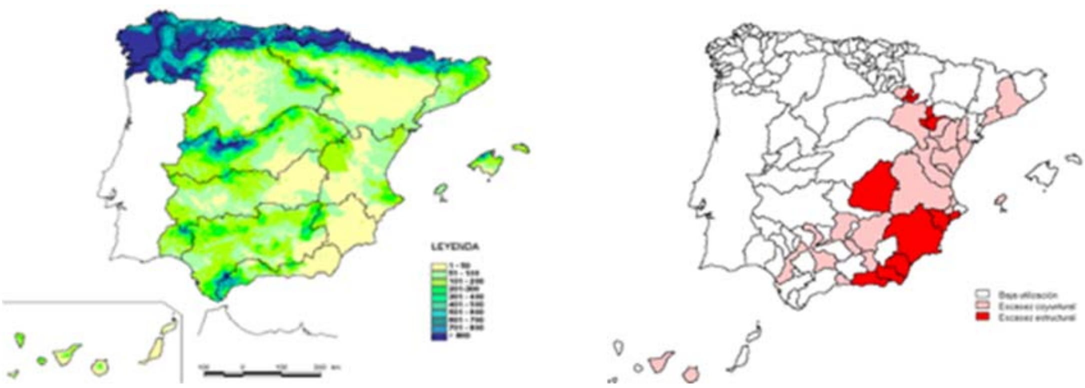

Figure 8. Average annual rainfall mm (left), Surface annual runoff mm (middle), Risk of scarcity (right). Source: MITECO, 2021.

Jucar River Basin

The climate of the JRB is the Mediterranean, with warm summers and mild winters. The highest temperatures are recorded in July and August, with more than 40 ºC, coinciding with droughts. During October and November, there can be episodes of heavy rainfall of short duration. Average annual temperatures range between 14-16.5 ºC, and average yearly precipitation is around 500 mm. However, there is enormous spatial variability with values of 300 mm, while other areas exceed 750 mm.

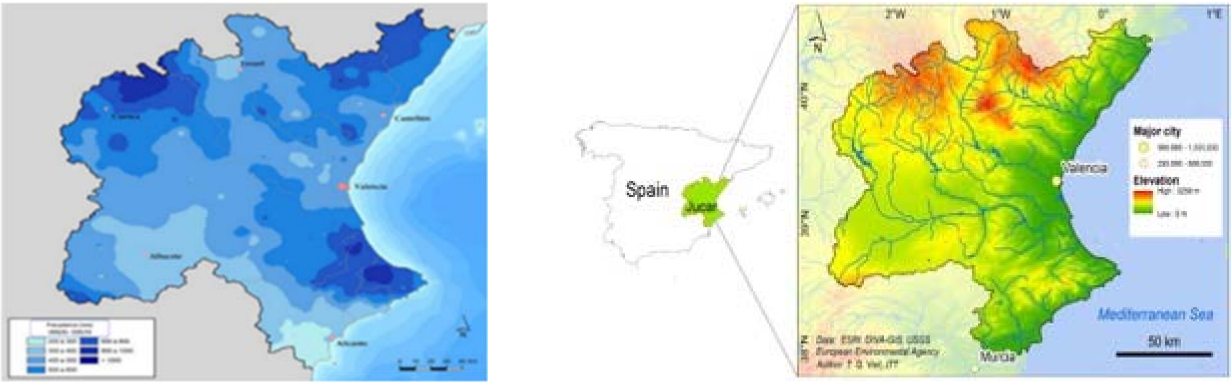

Figure 9. Average annual precipitation (left) and Elevation (Right) of the Jucar River Basin. Source: MITECO & Institute for Technology and Resources Management (ITT), 2021.

The JRB comprises mountainous areas and a coastal zone characterized by flat lowlands. The highest peak in the basin is Peñarroya, located in the Iberian System (IBS) with an altitude of 2,024 m (Figure 9). The IBS is a mountainous system that acts as a barrier that favours rainfall in these regions. In addition, the Turia, Mijares, and Jucar rivers, whose watersheds cover approximately two-thirds of the entire JRB, originate in this mountain system.

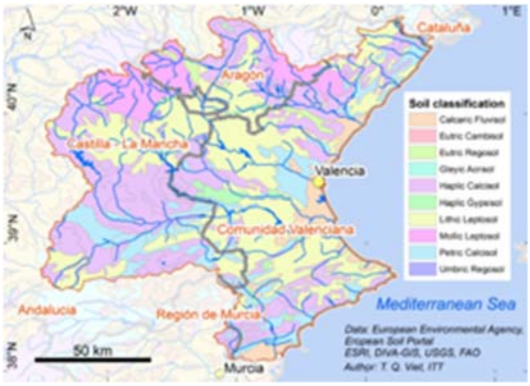

Figure 10. Jucar River basin soil Classification. Source: MITECO and ITT, 2021.

In Figure 10, we can observe the different types of soils in the Jucar River Basin. We highlight alternating limestone, sandstone, clay, marly limestone, sand, and gravel with clay content. These soils are characteristic of arid or semi-arid climates and close to the sea.

At the geomorphological level, the formation of lagoons and wetlands that stand out in this territorial and geographical area is worth mentioning. The “Albufera” of Valencia, the “marjal Pego-Oliva,” the “Prat de Cabanes-Torreblanca,” and the “Salinas de Santa Pola” are included in the RAMSAR list of wetlands of international importance. In general, both types of sites are defined as extensive flood plains fed by groundwater and, to a lesser extent, by surface water. The “Albufera” Valencia Natural Park is critical in migrating birds from Europe to Africa. Its natural reserve has a total area of 21,120 hectares.

2.8. Current and emerging water sources and uses

Jucar River Basin

Regarding irrigation systems, we can highlight that the basin is responsible for at least 370,000 hectares. The main water courses are the Jucar, the Turia, the Serpis, the Mijares, and the Vinalopó. Fifty percent of the available water resources come from groundwater sources, and reuse plays a crucial role in different sectors (Table 14).

Table 14. Characterization of the Jucar River Basin. Source: MITECO, 2021.

Characterization	Total
Surface	42,735 km^2
Rivers	304
Municipalities	789
Lakes	19
Bodies of Groundwater	90
Dams	27
Water Canals	95/1,172 km
Waterwheels	708
Desalination Plants	7
Hydroelectric Plants	60
Wastewater Treatment Plants	291
River Nature Reserves	10
Population	> 5,000,000
Irrigation Communities	> 500
Irrigation Systems	370,000 ha
Discharges of treated wastewater	375 hm^3
Water needs	3,132 hm^3/year
Estimated water resources in natural regime	3,329 hm^3/year

The main rivers in the territorial scope of the JRB are Cenia, Mijares, Palancia, Turia, Jucar, Serpis, and Vinalopó. However, the Júcar and Turia rivers, with 497,5 and 280 km, respectively, are the most important. The watercourses that make up the leading river network have a markedly Mediterranean flow regime, characterized by drier periods in summer and increased flow during autumn.

Within the JRB, 90 groundwater bodies and 26 impermeable water bodies or aquifers of local interest have been defined. Groundwater covers a total surface area of approximately 40,520 km^2, distributed in five autonomous communities: Comunidad Valenciana (49.7%), which includes the entire province of Valencia and part of the provinces of Castellón and Alicante; Castilla-La Mancha (37.9%), with the partial presence of the regions of Cuenca and Albacete; Aragón (12.1%) with part of the province of Teruel; Cataluña (0.2%) with a minimal amount of the end of the province of Tarragona; and the Region of Murcia (0.1%) in Yecla.

2.9. Current and emerging land uses, major crops, and farming systems

Water sources and uses: There are two main blocks in the water chain: upstream and downstream. The former are those processes that capture water from rivers, reservoirs, and wells. Desalination plants are also part of this block; the destination is for agricultural irrigation, industry, and electricity generation (cooling processes). The downstream systems include drinking water purification, distribution, and sanitation; the use can be domestic, for services, municipalities, industry, and construction. Another phase of the downstream systems is the treatment of reused water, and its primary use is for agricultural irrigation, leisure areas, and industry. It should be highlighted that high-water consumption reached in 2014 about 32.9 billion m^3, and showing a downward trend in recent years, falling almost 7% between 2008-2014. This is a result of improved efficiency in irrigation systems and changes in consumer habits.

Agriculture: Due to social-economic issues and poverty risks, the population of the rural areas is decreasing. Families leave aside agriculture for the city because of the lack of guarantees and opportunities. Most farms in the national territory are small, so the small producer needs support from the relevant administrations; they must also guarantee essential services and adequate educational systems. Spain has respected European policies since 1986, where it is governed by the Common Agricultural Policy (CAP). The amount of productive agricultural land has increased thanks to irrigation systems that improve over time.

The most important crops are vegetables, fruits, and cereals, accounting for almost three-quarters of the agricultural production. Cereals such as wheat and barley are the main crops in Spain and are cultivated in the area of Castilla y León, Castilla-La Mancha, and Andalusia; Rice crops in Valencia and southern Catalonia; Corn in the north; Tobacco in Extremadura; Beet (sugar) in the Duero and Guadalquivir Valley; Olive trees mainly in the south; Citrus fruits in the regions of Valencia and Murcia; In addition, vegetables such as tomatoes, onions, potatoes, among others, are produced. Spain is one of the leading producers of wine and oil globally, and the principal areas in which they are grown are Rioja, Penedés in Catalonia, Valdepeñas in Castilla la Mancha, the Duero Valley in Valladolid, Malaga, and Jerez.

Livestock: In terms of livestock, pork leads the production, followed by poultry, beef, and lamb. The areas and most livestock farms are in Castilla y León, Aragón, and Catalonia. Sheep and dairy cows are raised in the coastal regions and the dry interior of the south.

Forestry: Forests cover more than a third of the total area, with many of them in the Cantabrian Mountains. Forestry contributes to the primary sector only with a small economic fraction, and the government has currently initiated reforestation efforts.

Fishing: The fishing sector has two essential ports located in Vigo and La Coruña. Moreover, it represents approximately 1% of GDP, with fish being fundamental in the diet. Fishing catches have decreased, and farmers have opted for fish farming as an alternative.

Energy: Energy is essential for production, processing, and marketing. Given the high demand for agricultural products, the sustainable use of resources and energy efficiency in each process (water pumping, machinery, greenhouses, transportation, processing, conservation) is essential. A relevant fact to highlight: Water catchment for agricultural use in Spain accounts for 23% and distribution for 13% of electricity consumption related to water use.

Data from the National Statistics Institute (INE) (Table 15):

Table 15. Data on Land use in Spain 2019. Source: Statistics National Institute (INE), 2021.

Category	Total
Agricultural land	52.4%
Rural region	50,596 thous ha
Inland Waters	655 thous ha
Other lands	5,213 thous ha
Total area for equipped for irrigation	3,923 thous ha
Area	505,957 km^2
Land area	499,603 km^2
Forest zone	185,636 km^2
Arable land (% of land area)	23.8%
Permanent farmland (% of land area)	9.8%
Forest Zone (% of land area)	37.2%

Table 16.% Distribution of assets by economic sector, data by quarters (service is connected to agriculture). Source: INE, 2021.

Category	2020 Q4	2020 Q3	2020 Q2	2020 Q1	2019 Q4	2019 Q3	2019 Q2	2019 Q1
Agriculture	4.2	4.1	4.2	4.1	4.2	4.1	4.3	4.4
Industry	12.5	12.6	13.1	12.8	12.6	12.8	12.7	12.7
Construction	6.2	6.1	6.1	6.1	6.2	6.1	6.1	6.2
Services	69.5	70.2	70.9	70.4	70.4	70.1	69.9	69.6
Unemployed looking for their first job or have left their last job more than one year ago	7.5	7	5.7	6.5	6.6	6.8	6.9	7.1

Table 17. Major crops in Tonne production in Spain. Source: INE, 2021

Product	Tonnes
Olives	9,819,570
Barley	9,554,160
Wheat	8,322,510
Grapes	6,983,260

Product	Tonnes
Tomatoes	4,768,600
Maize	3,842,520
Orange	3,639,850
Sugar beet	2,87,0910
Potatoes	2,010,930
Tangerines	1,978,580

Regarding crop groups, herbaceous crops predominate in the upper areas of the Jucar River basin (especially in "La-Mancha plain") and the Albufera Natural Park (intensive rice crops). The most significant proportion of woody crops is in the coastal areas, with citrus being the main crop.

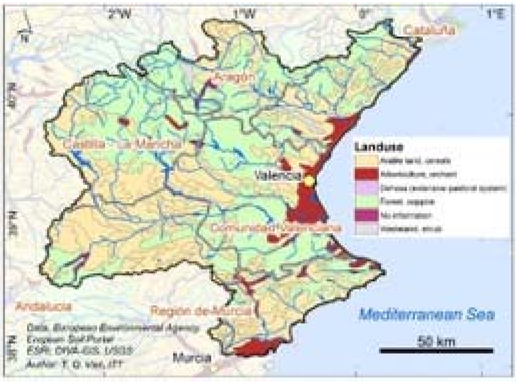

Figure 11. Land uses in the Jucar Hydrographic Demarcation. Source: European Soil Portal, EEA.

2.10. Energy generating infrastructure

In Spain, the Secretary of State for Energy coordinates the competences identified within the energy strategies. There are various institutions to ensure the sustainable development of the energy sector (e.g., IDAE, ENRESA, CORES); these institutions publish different energy plans. For 2015, the energy utilization in Spain was 87,739 Kilotons of oil equivalent (kT), 0.7% more than in 2014. Figure 12 shows the final energy consumption throughout the last twenty years.

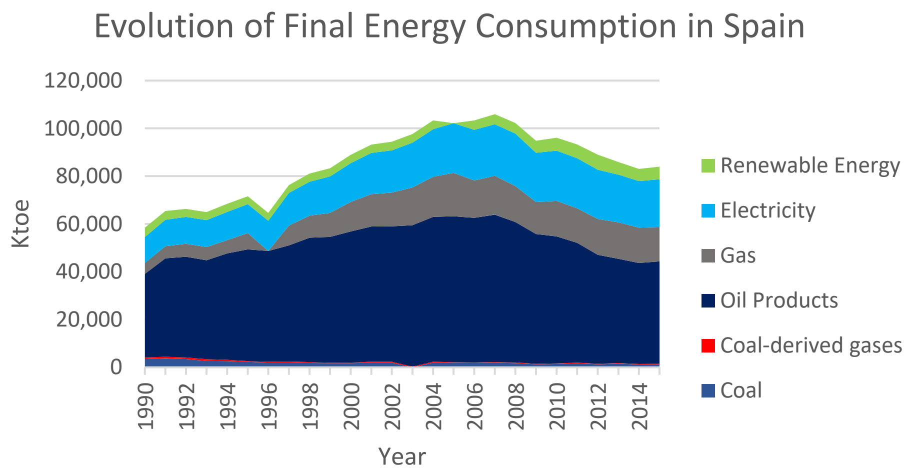

Figure 12. Evolution of final Energy Consumption in Spain. Source: Ministry of Industry, Energy and Transition (2015)

The Basin has enormous potential in term of energy production. The Cortes - La Muela complex is one of the largest pumped hydroelectric power plants (HPP) in Europe. It has several plants that supply between 200,000 and 400,000 families per year. These reservoirs are built on the Jucar River in the Valencian Community (Cortes de Pallás). The total installed power is 1750-1720MW in turbination and 1520-1200MW in pumping, representing national and European levels. The installed electric power capacity in the region has doubled in the last decade due to the development of wind and thermal energy systems, mainly biomass and cogeneration. In 2012 the power installed in the basin was 13,313 MW, 12.11% of the total power installed in Spain. Of this power, 8% corresponds to nuclear energy, 36% thermal management, and 56% renewable energies (38% wind, 7% solar, and 11% hydroelectric). The accompanying diagram (Figure 13) shows the evolution of the installed power in the Jucar basin lately up to 2012.

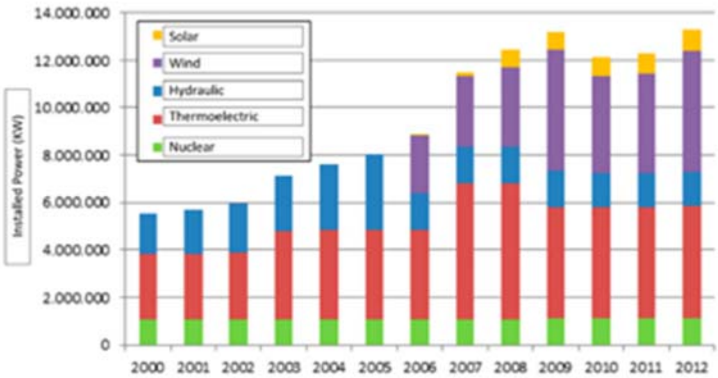

Figure 13. Evolution of installed capacity in the JRB. Source: MITECO, 2014.

Production in 2012 was about 34,000 GWh, of which 27.6% corresponds to nuclear, 37.5% is of non-nuclear thermal origin, 25.6% to wind, 4.8% to solar, and 4.5% to hydroelectric.

In general terms, it is essential to highlight the role of hydroelectric power in respond to energy demand. This type of energy - the most capable in terms of starting, stopping, and rapidly varying the load supplied - is the only one that can guarantee precise monitoring of the demand curve and immediate response to sudden variations in the energy supplied.

The installed power and turbine flow data of the hydroelectric power plants located in the JRB in operation, grouped by the operating system, are presented below (Table 18). It should be noted that hydroelectric production is a non-consumptive use.

Table 18. Distribution of installed power capacity and turbine flow in hydroelectric power plants in the JRB. Source: MITECO, 2021.

Production Systems	Units	Installed power	Turbine Flow (m^3/s)
Cenia-Maestrazgo	0	0.00	0.00
Mijares-Plana de Castellón	22	65.02	19.21
Palancia-Los Valles	1	0.30	0.00
Turia	22	57.37	22.93
Júcar	58	1,273.01	106.08
Serpis	4	1.54	7.41
Marina Alta	0	0.00	0.00
Marina Baja	0	0.00	0.00
Vinalopó-Alacantí	1	0.17	0.00
Total	108	1,397.40	155.63

2.11. Demographic data at pilot scale

This sub-chapter analyses the demographic characteristics of the pilot area of Spain. According to 2018 data by the OECD, Spain (47,354,173) was the fourth most populous country in the European Union behind Germany (83,160,874), France (67,347,238), and Italy (59,449,527). Table 19 presents the population by gender in each autonomous community, while Table 20 contains the population by age.

Table 19. Demographic data distributed by gender. Source: Statistics National Institute, 2021.

Autonomous Communities	Men	Women
Andalucía	4,170,605	4,293,806
Aragón	656,056	673,335
Asturias	486,066	532,718
Baleares	584,298	587,245
Canarias	1,076,185	1,099,767
Cantabria	282,559	300,346
Castilla y León	1,178,846	1,216,072

Autonomous Communities	Men	Women
Castilla - La Mancha	1,023,740	1,021,481
Cataluña	3,826,964	3,953,515
Comunitat Valenciana	2,492,121	2,565,232
Extremadura	526,288	537,699
Galicia	1,300,153	1,401,666
Madrid	3,243,793	3,536,095
Murcia	756,699	754,552
Navarra	327,226	333,971
País Vasco	1,079,452	1,141,052
Rioja	157,835	162,079
Ceuta	42,542	41,66
Melilla	44,162	42,914
Total	23,255,590	24,195,205

Table 20. Population and distribution by age. Source: Statistics National Institute, 2020.

Years	Both genders	Years	Both genders	Years	Both genders
0-4	1.981.692	35-39	3,391,000	70-74	2,212,176
5-9	2.325.443	40-44	3,996,212	75-79	1,747,869
10-14	2.523.498	45-49	3,895,525	80-84	1,273,071
15-19	2.389.021	50-54	3,668,449	85-89	996,416
20-24	2.360.667	55-59	3,364,857	90-94	435,917
25-29	2.583.973	60-64	2,912,674	95-99	111,312
30-34	2.839.403	65-69	2,424,312	100	17,308
Total			47,450,795		

Jucar River Basin

The total population of the JRB is 5,565,000 inhabitants; if we subtract the seasonal population associated with tourism and second homes, the permanent population would be around 5,162,163 inhabitants, which means a population density of 120 inhabitants per km^2, higher than the national average (93.66 hab/km^2). Even so, the most significant urban concentration is in the coastal areas of the JRB. Inland cities such as Albacete, Cuenca, Teruel, and those located in the valleys of some rivers stand out.

Table 21. Regional distribution of the population of the territorial JRB scope. Source: MITECO, 2021.

Province	Permanent Population	Total population (including seasonal population)
Albacete	290,138	295,792
Alicante	1,488,346	1,663,941
Castellón	597,176	683,885
Cuenca	133,528	140,067
Tarragona	23,985	25,583
Teruel	53,628	57,646
Valencia	2,575,362	2,698,086
Total JRB	5,162,163	5,565,000

2.12. Major economic activities / industries, employment

The following figure shows the countries' gross domestic product (GDP). This is a standard measure of the added value created by producing goods and services in a country. According to the World Bank, for 2017 Spain had a value of US$28,100.59/inhabitant; for 2018, it had US$30,349.75/inhabitant; in 2019, it decreased to US$29,555.32/inhabitant; and for 2020, it had a GDP/capita total of US$27,063.19/inhabitant (Figure 14).

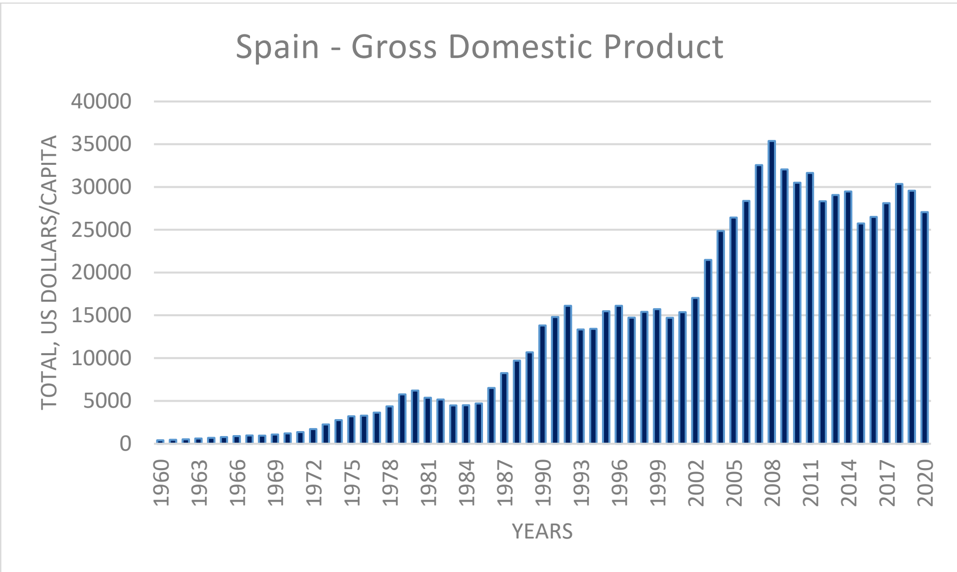

Figure 14.Gross Domestic Product in countries. Source: World Bank (2021).

The most significant sectors in terms of industrial activity in the Jucar River Basin are non-metallic mineral products, textiles, clothing, leather, footwear, food, beverages, and tobacco. The most crucial industrial activities are in the exploitation systems of the Turia, Jucar, and Vinalopó-Alacantí rivers. The most important sectors in the JRB are: services and tourism sector; industry is the second most important sector, followed almost equally by agriculture and energy. Agriculture is the economic activity that occupies almost half of the territorial scope of the Demarcation. The Jucar River Basin District has an irrigated surface area of approximately 390,000 ha. This surface area is mainly concentrated in the Plana de Castellón, Valencia and the lower Turia basin, the Mancha Oriental, the Ribera, the lower Jucar basin, and the irrigated lands of the Vinalopó and Monegre valleys.

2.13. Organizational infrastructure, Innovation capacities and Data

Technical and organizational infrastructure

Many institutions are working on the Water-Ecosystems-Food-Climate Nexus. The main responsible for ensuring sustainable development is the Ministry for Ecological Transition and Demographic Challenge. Regarding the water sector, which is where we will put our focus, it is distributed as follows: Municipalities are responsible for 10% of direct water management (processes such as abstraction, storage in reservoirs, and water transport), 34% control by Public Administrations (AAPP), 22% by joint ventures delegated at regional level with 50% market share of the private sector as well as the public sector, and finally, 34% are private companies specialized in infrastructure management.

After the European Water Framework Directive (WFD) approval, the aim is to quantify water resources and the different water quality indicators to identify problems derived from human activities. The main challenge for effective management is increasing inter-administrative and inter-sectoral cooperation. The new EU CAP focuses this time on greater integration with the objectives of the WFD. The success of the WFD depends on understanding and strengthening the whole Nexus and the different relationships of the autonomous communities with the River Basin Districts (RBD).

Innovation capacities

According to the National Statistics Institute (INE), the R&D spending between 2018 and 2019 increased by 4.2%. The communities with the highest% of domestic R&D expenditure over GDP are Basque Country (1.97%), Community of Madrid (1.71%), Community of Navarra (1.67%), Catalonia (1.52%), and the Community of Castilla y León (1.35%). Innovation measures are required in the different sectors: primary (i.e., agriculture, livestock, fishing), secondary (i.e., industry, construction, energy, mining), and tertiary (commerce, banking, services, public services, hotels and restaurants, transport, communication, telecommunications, etc.). The demand for innovation goes through the improvement of infrastructures and technologies related to the different systems.

Land: Better allocation of resources by implementing technologies that generate higher yields and meet the needs (soil studies, quantification of soil quality indicators, accuracy in nutrients, biofertilizers).

Water: Improvement of infrastructures and processes. Improvement of governmental relations between the different river basins. The efficiency of the water cycle. Investment dynamism in the sector (improvement of materials in power plants and processes in the water cycle, irrigation).

Energy: Indispensable the change of energy sources, construction of sustainable practices and zero GHG emissions (improvement in electromagnetic induction processes; change of fossil fuels; wind, hydraulic, solar energy; no waste, allowing to take advantage of environmental resources without depleting them; improvement of reservoirs and dams). The PNIEC divides investments into the following broad categories: i) energy savings and efficiency, ii) electrification of the economy, iii) grids, iv) renewable energies, and v) other measures.

Environmental: Fulfilment of the 2030 zero-emissions agenda. It involves all the different sectors. Zero GHG. (Quantification of Carbon Footprint and Water Footprint). Quantification and mitigation. We need to address

Climate Change from local levels. With the implementation of the above innovations, the climate and the environment will benefit. The information on investment in the non-energy diffuse sectors comes from the Spanish Climate Change Office (OECC).

Strategies: The development of transport, telecommunications, and energy networks; enterprises' productive environment and competitiveness. R&D in terms of environmental protection, equality in employment; local economic development; investments in favour of the rehabilitation of peripheral and isolated areas.

2.14. EU &/or national projects where the pilot was an important test case

Many research projects are being carried out in Spain. Below, we mention some of them, interested in improving systems involving the Nexus and related to the REXUS project.

B-FERST – Horizon 2020 (2019-2024): The project seeks to improve the waste chain by creating circular chains and ensuring crop sustainability by developing eight innovative bio-based fertilizers.

SIEUSOIL – Horizon 2020 (2019-2022): It aims to develop sustainable soil management practices. A research platform consisting of advanced crop and soil sensing tools, data modelling and fusion, digital soil mapping, and farm management information systems will be developed to maximize land productivity and socioeconomic benefits while minimizing environmental impact. In the Albacete region, variable ranges are being worked with.

FATIMA – Horizon 2020 (2015-2018): In this project, innovative agricultural tools were established to help the farm sector, building relationships between economic growth and sustainable development, optimizing input management and productivity.

DIANA – Horizon 2020 (2016-2019) is a project that enables authorities to optimize the identification and inspection of unauthorized water abstractions for irrigation and significantly improve the monitoring and evaluation of their water management policies and practices, both under standard and special conditions.

APOLLO – Horizon 2020 (2016-2019) is a project that provides a set of farm management advisory services (tillage scheduling, irrigation scheduling, crop growth monitoring, and crop yield estimation) specifically designed to meet the needs of smallholder farmers.

LENSES: LEarning and action alliances for Nexus EnvironmentS – Prima project (2021-2023): aims to contribute positively to biodiversity, improved water allocation, food security by preserving ecosystems and enhancing adaptability. It also has a resilience-oriented approach to advancing the Sustainable Development Goals (SDGs); it will seek to improve understanding of the Water, Ecosystems, and Food Nexus through joint, active, and inclusive engagement.

LifeTRivers: Project on temporary rivers. The Jucar Hydrographic Confederation (CHJ) participates in a European LifeTRivers project together with the University of Barcelona (UB), the Catalan Water Agency (ACA), and the Spanish National Research Council (CSIC), whose main objective is to improve the knowledge and valorization of temporary rivers.

Life Albufera project for the integrated management of artificial wetlands to comply with the Water, Habitats and Birds Framework Directive. The Jucar Hydrographic Confederation (CHJ) participates as co-financier in a European Life Albufera project coordinated by the Polytechnic University of Valencia (UPV) and in which the Spanish Ornithological Society (SEO/BirdLife), the Global Nature Foundation (FGN), and Acció Ecologista Agró participate as partners. The public company Acuamed and the Biodiversity Foundation have also participated in the co-financing.

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3. Nima River Watershed Pilot Case (Colombia, CO)

3.1. General characterization

The Nima River is a tributary of the Amaime River that drains into the Cauca River, one of the most important rivers of Colombia. This watershed (16,739 ha) is in the southeast of the Department of Cauca Valley, in the mountains of the Colombian Andes (Table 22). The altitude ranges from 1,050 to 4,100 m.a.s.l., and the average temperature ranges from 8 ºC to 24 ºC. The annual precipitation varies across the watershed, from 1,500 to 2,100 mm yr^{-1}, and is distributed along the year following a bimodal rainfall pattern. Nineteen tributary streams drain into the Nima River, and the average streamflow of the Nima river is 2 m^3s^{-1}. As a typical Andean catchment, it is characterized by two main landscapes units: a mountainous upstream area that is key to the provision of water-related ecosystem services for downstream users and a flat downstream area dedicated mainly to agricultural activities and that benefits from the water provided by the upstream region. About 8,700 ha are under different conservation categories (national Natural Park, regional Natural Park, forest reserves, and areas with strategic ecosystems). This watershed is of high importance as it supplies with water the municipality of Palmira (312,519 inhabitants), a hydropower plant, and an irrigation district that benefits 6,900 hectares dedicated mainly to sugar cane grow – a crop that has played an essential role in the economic development of the region since colonial times. Given the importance of the watershed for the municipality of Palmira, the municipality acquired the land protected as areas with strategic ecosystems (Figure 15).

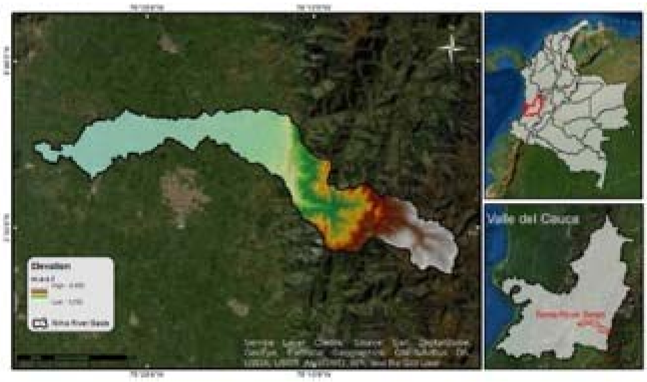

Figure 15. Location map of Nima River Watershed. Source: CIAT, 2021.

3.2. Major developments

Water

The Nima river watershed supplies water to most of the township's municipalities and aqueducts, the drinking water treatment plant in the township of Barrancas. The watershed has 11 water intakes (9 for the municipality's aqueducts; 1 for the hydroelectric plant, in charge of a private company for energy production (CELSIA); 1 for the irrigation district) (see Figure 16 and Table 25).

Agriculture

Almost 40% of the surface is destined to the sugarcane crop, followed by natural forest (21.0%) and extensive cattle ranching 17.9% of the total area of the watershed (see Table 24 and Figure 19).

Energy

The two hydroelectric power plants in the Nima River Watershed date back more than 50 years. The "Nima I" plant began operations in 1914 with 1 unit of 2MW. On the other hand, the "Nima II" plant started operations in 1942 with two 2.35 MW units. Currently, they can process more than 6000 KW/hour.

Environment

There have been significant developments in public land-use planning instruments for conservation and protection in the Nima River Watershed. This began in 1963 when the Palmira administration, the municipality's public companies, and the Regional Environmental Authority (C.V.C., Corporación Autónoma Regional del Valle del Cauca) took over surveillance of the watershed.

Subsequently, the C.V.C. carried out the first basic studies on the watershed between 1971 and 1973, which allowed the elaboration of a development and management plan. This plan highlights the importance of the Nima River in the development of the territory and declares the Nima Regional Natural Park as a Municipal Reserve. Moreover, in 2006, 3,037 hectares were incorporated into the Valle del Cauca Protected Areas System along with the purchase of land by the Nima River Protection Committee (Dirección de Gestión del Medio Ambiente, 2021). This managed to isolate the cattle frontier in the fundamental parts of the watershed.

In 2014, the Municipal System of Protected Areas (Sistema Municipal de Áreas Protegidas, SIMAP) was created, which indicates the protected or declared areas of national and regional order. It also considers the land acquired by the municipality of Palmira for the conservation and protection of parks and natural reserves of civil society.

The Nima watershed have several protected areas such as Las Hermosas National Park, La Albania-La Esmeralda Natural Reserve, Santa Teresa-Los Cuervos Reserve, and 16 reserves of the civil society (Cristal, Bélgica, San Rafael, El Moral, Villa Rica, Yarumal, Campo alegre, El Entamborado, El Laurel, El Recreo, El Silencio, El Tenjo, La Aurora, La cascada, Perú, Peñalisa). See RUNAP (parquesnacionales.gov.co).

3.3. Challenges

The challenges, mentioned for Amaime watershed that comprises the Nima watershed, are (CVC 2013):

- The need of stop the extension of the agricultural and livestock frontier at the Paramo area.
- The desire to establish protective forest covers in the high part of water bodies.
- The community recognized an inadequate solid residues management that pollute water bodies.
- To replace chemical by organic inputs to fertilize and pests' control and preserve natural resources in the watershed.
- The need of regulation of material extraction from the Nima river, because the border has been modified increasing the risk of river overflow.
- Regulation in sugar cane burning as locals live near the plantations.

After a meeting with the municipalities of Palmira, the Board agreed on the main challenges, and the most relevant ones faced by Nima-Watershed are:

- The sugar cane cropping system is intensive and uses supplemental irrigation during the dry season. There is a need to increase water use efficiency in this system.

- The sector has supported implementing projects oriented to conserve water regulation functions of the high Andean ecosystems. Despite this, the watershed requires more conservation, restoration, and sustainable use to balance hydrological, biophysical, and socioeconomic asymmetries that need to be addressed to maximize the water-related benefits provided by this watershed.
- There is a need to explore other crop systems and agricultural management alternatives to reduce the environmental impacts of agriculture in this watershed and efficiently use water sourced by upstream areas.
- Incentive mechanisms are required to align land use/management decisions in the watershed to common environmental and socioeconomic goals of actors in this watershed. One of the main goals is to secure future water supply for the human population and ensure water availability for agriculture and industry (including the hydropower generation industry).

3.4. Key stakeholders

The key stakeholders in the pilot area are:

- Municipalities of Palmira: Responsible for updating land use plans of its jurisdiction.
- Asoamaime (Asociación de usuarios del río Nima y Amaime).
- Regional Environmental Authority (C.V.C., Corporación Autónoma Regional del Valle del Cauca).
- Water Supply companies of Palmira (Aguas de Palmira, Aquaocciente).
- Emurfit Kappa –Cartón de Colombia (Owner of forest plantations for paper production).
- CELSIA: Private company for energy production.
- Landowners.
- Asocaña (sugarcane producers' association).
- CENICAÑA (Sugarcane Research Center).
- Las Hermosas National Natural Park.
- Nima Regional Natural Park.
- La Albania-La Esmeralda Natural Reserve.
- Rio Amaime Natural Reserve.
- Reserves of the civil society (Cristal, Bélgica, San Rafael, El Moral, Villa Rica, Yarumal, Campo alegre, El Entamborado, El Laurel y el Recreo, El Silencio, El Tenjo, La Aurora, La cascada, Perú, Peñalisa).

3.5. Policy

Colombian environmental planning is defined at the article 80 of the Colombian Constitution, that states: "*The state will plan the management and use of the natural resources to guarantee its sustainable development, protection, restoration or substitution*". The fundamental laws for environmental planning are:

- *Law 99 (1993)-Environmental policy framework*: this law establishes the creation of the Ministry of Environment and Sustainable Development and the organization of the National Environmental System (SINA in Spanish). This law defines the environmental regional corporations whose labour is: 1)

Implementation of environmental policies at the regional field, 2) the environmental authority exercise and territorial, and 3) territorial planification and ordering.

- *Law 152 (1994)-Developmental plan law*: the purpose of the law is to establish procedures and mechanisms for the preparation, approval, execution, monitoring, evaluation, and control of the development plans. The developmental plans should include strategies, programs, and projects criteria to estimate environmental costs and benefits and to define actions that guarantee a suitable environmental offer to future generations.
- *Law 388 (1997)-Developmental territorial law*: this law establishes the general framework of territorial development in the municipalities and districts of Colombia. The law guides the territorial development by use of space regulation, transformation, and occupation, in accordance with socio-economic development strategies, in harmony with the environment and historical and cultural traditions.
- *Law 373 (1997)- Efficient use and saving of water*: every regional and municipal environmental plan must incorporate necessarily a program for the efficient use and saving of water. The program for the efficient use and saving of water is a set of projects and actions that must be prepared and adopted by entities such as aqueduct, sewerage, irrigation and drainage services, hydroelectric production, and drainage services.
- *Law 1523 (2012)-National policy of disasters risk management*: this law establishes the national system of risk and disasters management that mandate the inclusion of risk diagnosis and analysis process in the regional and municipality planning.
- *Law 164 (1994)-United Nations Convention Framework on the Climate Change*: this law establishes the generation of national and regional programs to mitigate and adapt to climate change.
- *Law 1930 (2018)-Paramos law*: it establishes the guidelines to ensure the integrity, preservation, restoration sustainable use, and knowledge generation of Colombia paramos which are recognized as strategic ecosystems that have a special protection category.
- *Decree 1076 2015*: it regulates instruments for planning, ordering, and managing hydrographic basins and aquifers.
- *CONPES 3242 (2003)-Institutional Strategy for Environmental services sale for climate change mitigation*: it promotes Colombia's participation in the verified reductions of greenhouse gas emissions market, through the establishment and consolidation of an institutional framework.

3.6. Relevant documents

The available planning documents are presented below:

- **Regional Environmental Management Plan 2015-2036 (PGAR in Spanish):** It is an environmental planning instrument that indicates the desired environmental scenario for the Valle del Cauca department through three strategies:
  1) *Integral watershed management*: execute actions aimed at conservation, restoration, and sustainable use of natural resources and ecosystems.
  2) *Implement and strength practices and environmentally sustainable techniques*: implementing techniques to decrease pollution and prevent, mitigate, and reverse environmental deterioration.
  3) *Risk management and adaptation to climate change*: achieve a coordinated work in prevention and emergencies attention in the face of extreme events (CVC 2015).

- **Management and Territorial Ordering Plan of Amaime River Watershed (2013):** It establishs strategies and actions to improve the governance of water resources and other natural resources in the watershed (CVC 2013).
- **Territorial Ordering Plan 2012 (POT):** It is a planning tool for the physical development of the territory. It is defined as the set of objectives, guidelines, policies, strategies, goals, programs, and actions adopted to guide and manage the physical development of the territory and the use of land. It indicates the paths of the different possible urban actions that can be undertaken (Alcaldía de Palmira, 2012).
- **Management plan for the protected areas:** They are the management plans for the majority of the protected areas of Colombia**.**
- **Integral Plan for Adaptation to Climate Change (in Spanish PIACC) (Municipality of Palmira):** It is a tool to promote adaptation and mitigation measurements accordingly with local conditions (Alcaldía Municipal de Palmira 2019).

3.7. Basic climate and soil data

The Nima River Watershed has a bimodal rainfall regime, with few variations, due to the Pacific equatorial current's convergence of the northeasterly and southeasterly winds. This bimodal rainfall period includes two dry seasons (January-March; June-September) and two rainy seasons (April-June; September-December) per year. Likewise, precipitation ranges from 1,500 mm/year (lower middle part) to 2,100 mm/year (upper part).

The soil types that make up the Nima River Watershed are shown by the percentage of area in Figure 16, which shows the five predominant soil types present in the Watershed: MR (16.2%), MN (11.2), PL (8.7), OS (7.2) and VC (7.2). In this case, the MR, OS, and VC soils are found mainly in the high areas of the Watershed, while the MN and PL soils are in the low and the flat regions.

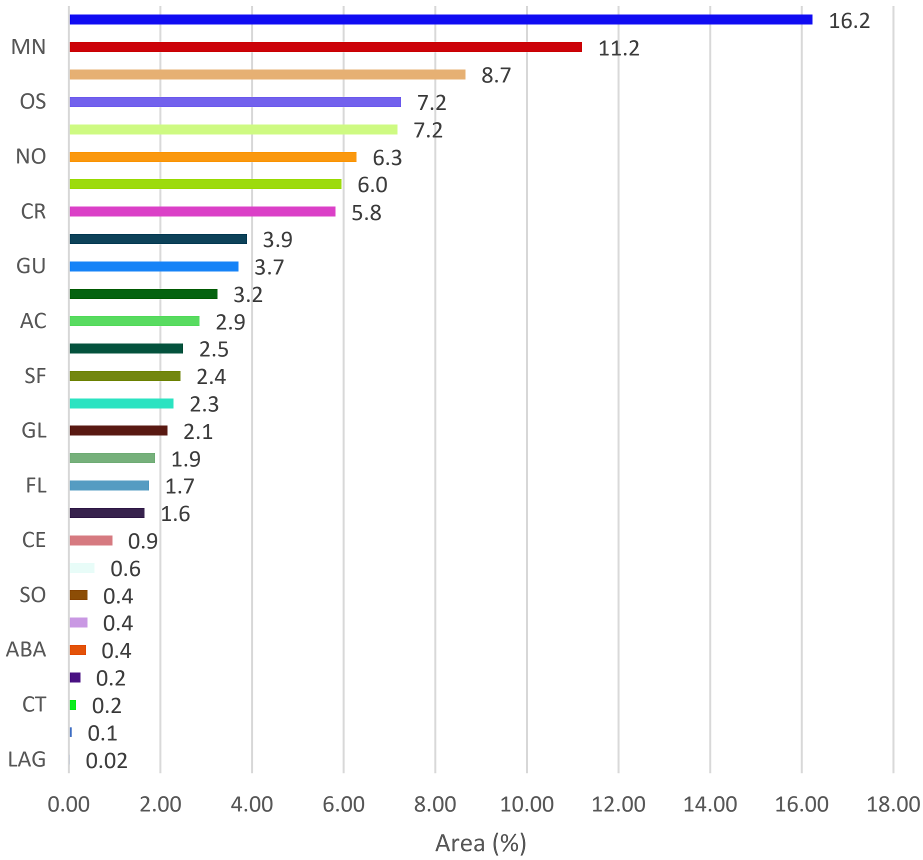

Figure 16. Soil types in the Nima river watershed. Source: CIAT, 2021

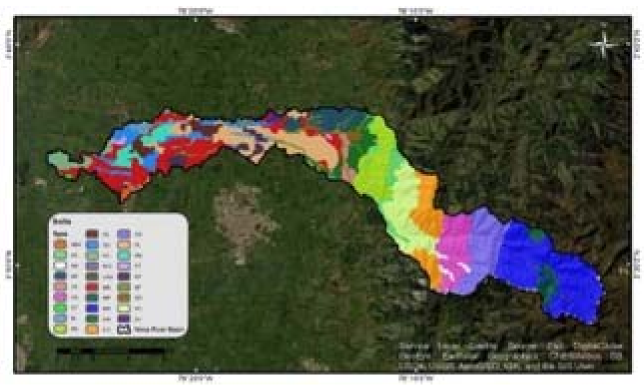

Figure 17. Soil ma Units - Nima River Watershed. Source: CIAT

3.8. Current and emerging water sources and uses

The watershed has nineteen tributary drainages that drain into the Nima River with an average flow rate of 2 m^3s^{-1}, as shown in the following table:

Table 22. Hydrography of the Nima River Watershed. Source: CVC & UN, 2008

No	Sub-basin	Flow	Area (ha)
1	Represa de Santa Teresa	700	3,050
16	Aguazul	635	1,811
12	Los Negros	400	1,799
2	Los Cusumbos	284	584
15	Las Mirlas	237	446
19	Los Cuervos	196	480
5	La Esmeralda	173	386
17	Amberes	128	355
14	Los Añascos	96	274
6	Careperro	89	187
13	San Emigdio	89	360
3	El Rincón	85	834
4	La Albania	73	300
18	Los Aguacates	36	268
10	Los Naranjos	24	155
11	Los Olivos	13	240
8	Las Mercedes o Las Bellas	12	129
7	Los Amores	2	149
9	El Cofre	2	331

Water supply and quality conditions are directly affected by anthropogenic activities in influence of the Nima River, as this river mainly provide the municipality's aqueduct. Likewise, the Nima river watershed supplies water to most of the township's municipalities and aqueducts, the drinking water treatment plant in the township of Barrancas, and the hydroelectric plants. Therefore, the watershed has 11 water intakes (9 for the municipality's aqueducts; 1 for the hydroelectric plant, in charge of CELSIA; 1 for the irrigation district).

Table 23. Nima River Watershed Intakes. Source: CIAT, 2021.

ID	Water Intake	Type	Admin.	Drainage
1	Nima I y II	Hidroeléctrica	Calucé	-
2	Barrancas	Auxiliar	Barrancas	-
3	Tenjo	Acueducto veredal	Tenjo	Q. Las Mirlas
4	Tenjo Careperro	Acueducto veredal	Tenjo	Q. Careperro
5	Calucé	Acueducto veredal	Calucé	Q. Los Naranjos
6	Parte baja de Tenjo	Acueducto veredal	Tenjo	Q. El Caimo
7	San Emigdio	Acueducto veredal	San Emigdio	Q. El Caimo baja
8	Quisquina	Acueducto veredal	Quisquina	Q. El Silencio
9	El Olivo	Acueducto veredal	El Olivo	Q. El Olivo
10	Los Chochos	Acueducto veredal	Los Chochos	Q. Los Chochos
11	Minidistrito de riego	Riego	Las Mercedes	Q. Las Mercedes

The Nima River Watershed supplies drinking water to the entire urban population (295,000 inhabitants, approx.) together with the communities settled in Palmira (3,937 inhabitants, approx.) in the rural area of the municipality of Palmira.

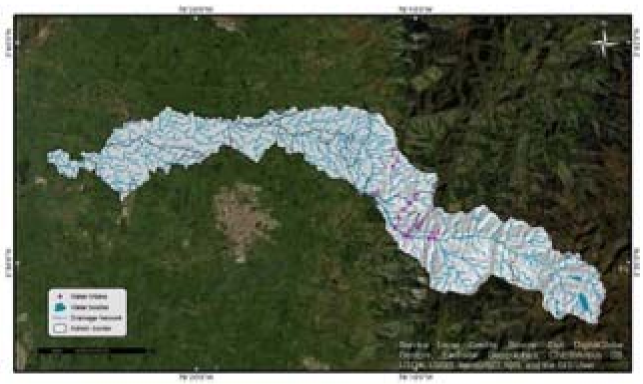

Figure 18. Water network and water intakes in the Nima River Watershed. Source: Uribe, Estrada and Jarvis, 2009.

Water from the Nima River to the aqueduct intake (Barrancas) is used for human consumption in the urban area of Palmira. The sugar mills capture the surplus for irrigation of their sugar cane crops. In general, the water demand amounts to 6,900 hectares for irrigation of agro-industrial production and to support livestock, poultry, pork, and sugarcane production (Dirección de Gestión del Medio Ambiente, 2021).

There is no information on water demand in the Nima river watershed. The information available is for the Anaime River watershed, which encompasses the Nima river watershed. This information for the Anaime River is available at CVC.

3.9. Current and emerging land uses, major crops, and farming systems

Land uses and land cover in the Nima river watershed are shown in Table 24. Sugarcane cultivation continues to be predominant with 39.4%, followed by natural forest with 21.0% and extensive cattle ranching with 17.9% of the total area of the watershed. These uses are spatially distributed in different zones of the Watershed (Figure 19) (Uribe et al.,2009).

Table 24. Land use and land covers in the Nima River Watershed. Source: CIAT

Land cover class	Area (%)
Sugar cane	39.4
Natural forest	21
Livestock	17.9
Moorland vegetation	10.3
Planted forest	3.9
Coffee/Banana	1.8
Stubble	1.6
Transient crops	1.6
Infrastructure	0.9
Guadua forest	0.8
Urban areas	0.4
Permanent crops	0.2
Water bodies	0.1

For example, sugarcane cultivation is in the flat and low areas, in contrast to other crops such as coffee/banana and permanent crops in the middle zone of the Watershed. On the other hand, the forest zone is located mainly in the high zones with Páramo vegetation, natural forest, Guadua forest, and planted forest. This helps in conserving the fundamental zones of the Watershed and reduces the advance of cattle ranching in the middle zones. Additional information on land use (2014) is available at SIAC.

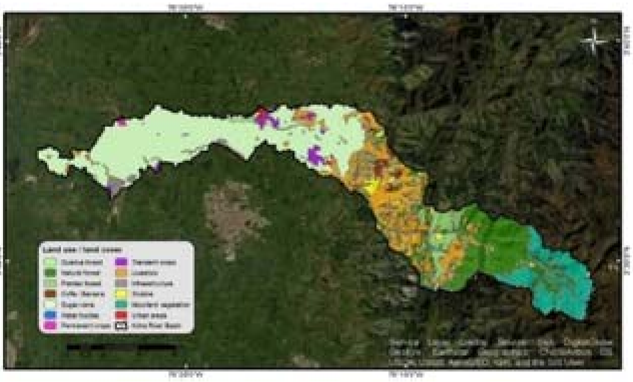

Figure 19. Land use and cover map - Nima River Watershed. Source: CIAT, 2021.

3.10. Energy generating infrastructure

The Nima River Watershed provides the most significant water for agricultural, industrial, and power generation uses. This is mainly generated at "the Nima I" and "Nima II" plants, located in Calucé, in the middle zone of the watershed (Figure 20). Nima II has a 6.4 Mm^3 reservoir called Santa Teresa, located in the upper part of the Watershed (CELSIA, 2013). The plants are managed by CELSIA and generate between 6,000 and 7,000 KW/hr of electrical energy, allowing electricity to reach most of the population centers in the watershed (Dirección de Gestión del Medio Ambiente, 2021). However, electricity coverage in the middle part of the watershed reaches up to the village of Los Tambos, which means that Socorro, La María, and Aguazul do not have electricity. Therefore, these sectors supply the demand of their farms using solar panels.

Figure 20. Hydroelectric Power plant: Nima I (left) and Nima II - Santa Teresa DAM (right). Source: CIAT, 2021.

Figure 21. Energy infrastructure - Nima River Watershed - Cuenca del rio Nima (location is estimated). Source: CIAT, 2021.

3.11. Demographic data at pilot scale

The Nima River Watershed has approximately 10,456 inhabitants in its population centers (Table 25). Amaime is the population center with the most significant number of inhabitants and is located in the watershed's lower middle zone (Figure 22). In contrast, the smallest is Calucé, with 286 inhabitants, and is in the upper-middle area between Potrerillo and Tenjo. In general, most of the population centers are grouped in the middle zone of the watershed.

The road infrastructure in the watershed determines access to these population centers. Most of the centers are accessed by tertiary or auxiliary roads, except for Tienda Nueva and Amaime, located near primary highways.

Table 25. Nima River Watershed Population. Source: Office of Commerce in Palmira. Source: CIAT, 2021.

Jurisdiction	Population
Amaime	3,604
Tienda Nueva	2,328
Tablones	1,684
Potrerillo	1,632
Boyacá	630
Tenjo	292
Calucé	286
Total	10,456

Figure 22. Towns and road infrastructure in the Nima River Watershed. Source: CIAT, 2021.

Jurisdiction boundaries and roads maps at 1:25:000 are available and can be downloaded at SIGOT.

3.12. Major economic activities/industries, employment

According to Palmira's environmental management department, the Nima river watershed has economic activities such as:

- *Sugar cane*: it is established in the lower part of the watershed (Tienda Nueva, Tablones, Boyacá, Amaime) with approximately 5,000 ha cultivated in sugarcane.
- *Extensive cattle ranching*: established mainly in the middle part of the watershed (Potrerillo, Calucé, Tenjo, la Zapata, and Ayacucho) with approximately 3,000 ha dedicated to dual-purpose cattle ranching.
- *Commercial forests*: located in the upper middle part of the watershed with approximately 800 hectares of Eucalyptus and pine trees for paper pulp production.
- *Coffee and bananas*: mainly in the Corregimiento de Potrerillo (Quisquina and Los Robles), Calucé (El Olivo), and Tenjo, with a total estimated 30 hectares.
- *Horticultural crops*: beans, peas, cabbage, and corn. These have a total area of approximately 5 hectares throughout the watershed.
- *Livestock production*: Poultry farms are mainly located in Calucé. They produce eggs for incubators with more than 100,000 birds.
- *Sources of employment*: Most watershed inhabitants are employed in the urban zone, commuting every day and supplement their income with livestock and backyard farming activities. They also work in the sugar, poultry, coffee, and manufacturing sectors.

3.13. Organizational infrastructure, innovation capacities and Data

Technical and organizational infrastructure

The infrastructure available in the urban centers of the Nima river sub-watershed is shown in Table 26. This table indicates whether each population center has the types of infrastructure (health, educational, ecclesiastical, police, water).

Table 26. General infrastructure available per urban center. Source: Dirección de Gestion de Medioambiente,2021.

Town	Health	Education	Ecclesiastical	Police	Water
Amaime	yes	Yes	yes	-	-
Tienda Nueva	yes	Yes	-	yes	-
Potrerillo	yes	Yes	yes	-	-
Tablones	-	Yes	-	-	yes
Boyacá	-	Yes	-	-	yes
Tenjo	yes	Yes	yes	-	yes
Calucé	-	Yes	-	-	yes

On the other hand, Table 26 shows the available road infrastructure, which portrays the connectivity of the population within the watershed. The presence of auxiliary trails has a higher proportion compared to road infrastructure.

Table 27. Road infrastructure. Source: CIAT, 2021.

Type	Description	Km
1	Primary road	32.9
2	Secondary road	14.1
3	Terciary road	6.9
4, 5, 6	Auxiliar road (crops, farms, etc.)	366.6
7	Trials	278.1
Total		698.6

Regarding water infrastructure, most of the population centers in the Nima River watershed have an aqueduct. However, there are deficiencies in the infrastructure for water discharge and treatment, mainly lacking sewerage and wastewater treatment plants (WWTP). In addition, the areas that have septic tanks are deficient. Therefore, the drainage canals are used to discharge water from homes or directly into the tributaries of the Nima River watershed. The following table (Table 28) represents a detailed description of the available infrastructure by village:

Table 28. Water and land infrastructure by town center. Source: CIAT, 2021.

Town	No. Predios[1]		Water supply	Sewerage Sewage	PTAR	Septic tanks	Drainage canal
	Residential	Non residential					
Amaime	643	221	-	yes	-	-	-
Tienda Nueva	250	228	-	sectorized	no	-	yes
Potrerillo	278	123	-	no	no	no	yes
Tablones	231	248	yes	yes	-	-	-
Boyacá	136	40	yes	yes	no	-	-
Tenjo	31	36	yes	no	-	deficient	yes
Calucé	39	57	yes	no	no	deficient	-

Types of available models and data

The water balance model was developed for the Nima river watershed using the SWAT model. This model relates the use of land, water, and sediment through territorial units that present similar conditions, which produce a particular impact on the quantity and quality of water in the watershed (Uribe et al., 2009). These units are called Hydrological Response Units (HRU) and allow us to identify which areas contribute most to sediment and water flow. (Note: this modelling exercise was not calibrated given the absence of observed water flow and sediments data).

The hydrological modelling used the following information:

- *Land uses*: land cover classification based on Landsat images from 2001 to 2003. These images were adjusted with a land-use layer at a scale of 1:500,000 due to clouds.
- *Digital Terrain Model (DTM)*: the digital terrain model was calculated from STRM (90m) provided by CIAT.
- *Daily precipitation data*: data without null values from daily precipitation stations were used. In addition, a virtual station was created using the MarkSim model with a 1km resolution to adjust minimum flows in the watersheds.
- *Climatic data*: stations with daily temperature data were used. In addition, there were records of wind speed, daily maximum, and minimum temperature, solar radiation, and dew point.
- *Soils*: soil survey (granulometry, depth of horizons, and percentage of rock fragments in the profile) at IGAC scale 1:500,000. From these data, the parameters of bulk density, available water in the soil, saturated hydraulic conductivity, and each soil unit's hydrological group were derived.

3.14. EU &/or national projects where the pilot was an important test case

Impact of land use on the flow and sediments generation: The case Tulua-Morales, Guabas, Sabaletas, Amaime, Nima, Bolo, Fraile, Desbaratado, and Palo basins have been involved in the project. This study was leaded by The Nature Conservancy (TNC) and CIAT.

Deltares has collaborated with the CVC through the creation of the **tool HERMANA**, a new instrument to enable sustainable water resources management for the Valle del Cauca was launched (https://www.deltares.nl/en/projects/tool-for-integrated-water-management-herramienta-para-el-manejo-integral-del-agua-hermana/).

Ecological restauration project at the middle area of Nima watershed. The project carried out the restoration of three corridors between fragments of sub-Andean Forest. It involved the setting up of a nursery with native species, the planting of 45,000 trees of native species, and the recovery of approximately 19 ha of riparian corridors that benefited 1,200 ha of forest. This project was led by The Colombian Alexander von Humboldt Institute in 2007.

Fauna and flora inventories at Amaime river dry forest relicts. This Project was led by Wildlife Conservation society. (Inventarios de Fauna y Flora en Relictos de Bosque en el Enclave Seco del Río Amaime, Valle del Cauca (gbif.org)).

The study Payments for environmental services and control over conservation of natural resources: The role of public and private sectors in the conservation of the Nima watershed, Colombia (Rodríguez-de-Francisco & Budds 2015

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4. Isonzo/Soča River Pilot Case (Italy & Slovenian, IT-SI)

4.1. General characterization

The Isonzo/Soča river originates in Val di Trenta with springs at an altitude of 935 m.a.s.l. and flows into the Adriatic Sea, near Monfalcone, where it forms a delta that tends, over time, to move from west to east. The Isonzo/Soča basin subtends a total area of approximately 3,400 km^2 of which is about 1,150 Km^2, one third, within the Italian territory and the remaining within the Slovenian one. The river has a purely torrential character collecting and discharging the waters of the southern side of the Giulie Alps, which separate this basin from the Sava one. The main river's right tributaries are the Coritenza, in Slovenian territory, and the Torre, which flows almost entirely in the Italian part; on the left, the Isonzo/Soča is fed by Idria and Vipacco, with their respective basins included totally and almost totally in Slovenian territory. The Italian portion of the Isonzo/Soča basin coincides for more than 90%, with the sub-basin of the Torre. The sectoral study on river hydraulic safety have been referred to this sub-basin. The hydrographic system of the Torre basin, which at the confluence with the Isonzo/Soča consists of an area of approximately 1,060 Km^2, is complex and articulated and is characterized, in addition to the main shaft of the Tower, by the auctions of the left tributaries: Malina, Natisone, and Judrio and from the auctions of their main contributors: Ellero for Malina, Alberone, Cosizza and Erbezzo for Natisone, Corno and Versa for Judrio (Figure 23).

Figure 23. Isonzo/Soča river basin. Source: AAWA, 2021.

4.2. Major developments

Water

Water management in the Slovenian part of the basin is strongly affected by its geology, particularly by diffuse karst. Water management in these karst regions is complex. Groundwater behaves similarly to surface water flows and can be affected by distant and difficult to locate sources of pollution. In addition, the self-purification capacity of the water, compared to non-karst regions, is very limited due to the lack of adequate natural filters.

These characteristics of the basin give the watercourse a typically torrential natural flow. At the same time, in the scarcity phase, they guarantee an outflow that is always relatively strong due to karst inputs and spring snowmelt. Since the interior of the river basin is sparsely populated, with the exception of a small number of pastures (the Trnovo forest and the Nanos and Hrušica plateaus), the waters of the surrounding karst regions of the river basin do not experience large-scale pressure. However, many vineyards in the karst region could exert environmental pressure.

As for the qualitative aspect, the water balance data for the period 1971-2000 show that the overall water supply for the Slovenian part of the basin is relatively stable and secure. However, there is a shortage of surface water during the summer months. Occasional droughts cause crop damage and yield losses, but the subway aquifers, which constitute most of the drinking water resources, are rarely noticeably affected.

The mountainous section of the Isonzo/Soča basin ends at Solkan-Salcano (Nova Gorica), on the border between Italy and Slovenia. As for the Italian part, water resources management depends on the Isonzo/Soča river flows and they are modulated and regulated by a series of artificial barriers built on Slovenian territory between Most na Soči and Solkan for hydropower purposes. The average daily reach on an annual basis, recorded in the last five years at Ponte Piuma di Gorizia, is about 70 m^3/s. About the non-constant releases from the Solkan dam, the flow in the shortage regime varies considerably during the day, with average increases in the water draw of 60-80 cm during the day and the consequent decrease in the evening and night. The reach of 12 m^3/s minimum, provided for by international agreements signed after World War II between Italy and the then Yugoslavia, can lead to critical situations if not properly managed, especially at times of maximum water scarcity. This water regulation system applied in Solkan strongly influences the whole hydrological and diversion system of the river section in Italy.

On the Italian side, there are some essential intakes for irrigation and hydroelectric canals (such as those belonging to the irrigation network of the Consorzio di Bonificazione Della Pianura Isontina), which are strongly affected by the change in daily flows operated by the managers of the Slovenian hydroelectric power plant. Finally, the well-known Canale de 'Dottori distracts Monfalcone most of the river's flow, so it does not make it flow towards its natural outlet to the sea Punta Sdobba.

Figure 24. Solkan Dam on the Isonzo/Soča river. Source: AAWA, 2021.

Agriculture

The most important agricultural products of the Slovenian valleys of the Isonzo/Soča river basin are fruits (especially peaches, apricots, and cherries), which are concentrated in the Vipava valley, and grapes for wine production. Other essential agricultural products are early vegetables (lettuce, potatoes, cabbage, carrots, onions, garlic, and strawberries) due to favourable climatic conditions and a more extended vegetation period than Slovenia's continental areas.

Grape crops are mainly located in the territories cultivated by the Consorzio di Bonifica della Pianura Isonontina in the southeast of the basin. In Italy, the most important production is wine in the Isonzo/Soča plain, with the Isonzo/Soča e Collio DOC brand. In addition, cereals, fruit, and olive oil are also grown to a lesser extent. It is also worth considering that agricultural activities are important from an economic and social perspective and an environmental conservation perspective for the people living in the area.

Energy

The electricity market has been liberalized in Italy and Slovenia since the 2000s, following the European Directive 96/92/EC to regulate the internal electricity market. Each country has adopted this directive with a specific national law. They have a national free market and can exchange electricity with neighbours where the necessary infrastructure exists.

The price of electricity varies significantly depending on the season, the day of the week and the weekend, but mainly during the day, with a peak in the evening hours in both Slovenia and Italy.

In Italy, Terna4 manages the transmission network, while ENEL Distribuzione and other local operators manage the distribution network. Also in Slovenia, the national grid operator is ELES5 and there are several electricity distribution companies: SODO, Elektro Celje, Elektro Gorenjska, Elektro Ljubljana, Elektro Maribor, Elektro Primorska, as well as some closed distribution systems.

Environment

The area's environmental problems are due to the close interconnection between climate change, water, land use and land consumption, and the impact of agricultural and industrial activities on water resources.

There have been severe cases of flooding, the most critical flood in the last 50 years in the Isonzo/Soča basin occurred on the 24^{th}-25^{th} December 2009, when the maximum flow in the Salcano (SLO) section of 2,288 m^3/s was reached, and flooding occurred on both the Italian and Slovenian sides. In the Vipacco stream, a tributary of the Isonzo/Soča river, the waters had washed away some houses in the Italian town of Gradisca d'Isonzo.

On the same stream the situation during a more recent flood (September 2010) was much more critical, as the flows in transit were lower than the flow capacity at several points of the watercourse (Figure 25).

Figure 25. Flooding in Gradisca di Isonzo/Soča (IT) after the flood event of December 2009. Source: Civil Protection of Friuli Venezia Giulia Region, 2010.

The vegetal material carried away by the floodwaters, and retained by the trees present, has considerably reduced the hydraulic sections damaging especially the municipality of Savogna d'Isonzo, the village of Rupa, and the village of Gabria up to the confluence with the Isonzo/Soča river (Figure 26).

Figure 26. Flooding in the Slovenian Part of the Vipava\Vipacco River in occasion of the flood of 2009 and 2010. Source: AAWA, 2021.

For the Slovenian part of the basin the situation with the highest flood risk is related to the Vipacco/Vipava river basin, a tributary of the Isonzo/Soča river. This is one of the areas most profoundly influenced by human activity in Slovenia. Several catastrophic floods have occurred in recent years due to changes in rainfall patterns, one of the consequences of climate change. With the regulation of the Vipava River, flood protection in the upper part of the basin has improved. However, flooding has become more frequent due to faster runoff to the lower part of the basin.

To face flood occurrence a reservoir was designed. The large Vogrščček reservoir has a volume of 8.5 million m^3 of water (both lower and upper reservoir). Vogrščček is designed to supply water for irrigation in the lower Vipava Valley, accounting for 84.5% of the total usable volume (6.8 million m^3). Although planned, not all adequate irrigation systems were constructed. The current capacity of Vogrščček is only 1.8 million m^3 per year, which corresponds to the possible irrigation of 1,400 ha of agricultural land. However, its operation is not optimal (leaks in the barrier, low water level causing low pressure for optimal irrigation), and only approximately 1.3 million m^3 of water per year (1,000 ha of agricultural land) is used for irrigation.

The Slovenian Ministry of Environment and Spatial Planning considers the environmental status of the river and its tributaries to be of "very good" quality at gauging stations. Despite this, the most critical river is the Vipava River with several nutrients exceeding the permissible limits, due to agricultural activities. The ecological status of the lower part or the river is deteriorated due to high levels of nutrients and specific pollutants.

In the Italian part, the ecological status of the water bodies is good/sufficient in general. However, the water structure is affected by numerous forms of anthropogenic pressure (agriculture and energy production).

A final environmental aspect concerns heavy metal pollution, in particular mercury. Mercury is transported to the Isonzo/Soča by the Hydrizza River, a major tributary, which passes through Idrica, where mercury mines were active for 500 years until 1996. The danger of this insoluble mercury is that it is slowly converted into soluble methyl mercury and can thus enter benthic organisms and in the entire food chain.

Climate

The climate of the area can vary significantly throughout the basin. Climate projections suggest increasing temperatures: "in the period 1951-2000, the mean annual air temperature in Slovenia increased by 1.1 ºC, and during the last 30 years, warming exceeded the 1.5 ºC limits" (Kajfež-Bogataj, 2005).

Analysis of water balances in Slovenia from 1971 to 2000 shows changes in precipitation levels, with an increasingly pronounced precipitation peak in autumn and a decreasing amounts in the other seasons. Although annual precipitation levels show no trend, they tend to be less evenly distributed throughout the year.

The basin has experienced extreme and persistent low flow events during the summer months and relatively short but extreme discharge peaks during heavy rains, resulting in devastating floods.

Projections of climate change in Slovenia published by the Slovenian Environment Agency in 2008 suggest that the average annual temperature in the Vipava valley could increase by about 1.3 ºC by 2030. The increase in temperature is accompanied by a precipitation reduction in summer and an increase in winter. In addition, summer precipitation tends to decrease with shorter but more intense rainfall with thunderstorms and torrential downpours, resulting in rapid surface runoff of precipitation water with little infiltration into the soil.

As for the Italian part, the reference study is carried out at the AAWA Eastern Alps River district scale and shows a similar trend to that of the Slovenian counterpart. In the context of the TRUST project, the Mediterranean Centre for Climate Change, financed with Life+ funds by the European Commission, has shown an evolution of the climate in the district's territory for the next 100 years consistent with the forecasts provided by European climate models.

The climate models show a warming trend, with a substantial temperature increase in the southern regions of Europe and a marked winter temperature increase in the northern European regions. Even with an average global temperature increase of less than 2 ºC, the European climate appears to deviate significantly from the current climate in the coming decades. For precipitation, signs of change are less clear and vary from region to region. However, there is some agreement in identifying an increase in precipitation in northern Europe and a decrease in southern regions.

As for mean sea level rise, increases are expected between 0.29 and 0.55 meters in the RCP2.6 scenario, between 0.36 and 0.63 meters in the RCP4.5 scenario, and between 0.37 and 0.64 meters in the RCP6.0 scenario, and between 0.48 and 0.82 meters in the RCP8.5 scenario. As for the predicted change in extreme events, there will be a marked increase in extreme events in Europe, particularly heat waves, droughts, and heavy rainfall. Regarding the RCP4.5 scenario and the territory of northern Italy, the frequency of extreme precipitation is expected to increase in the period 2071-2100.

Regarding the forecasts on the variation of the average number of heatwaves for the summer season (May-September) for the period 2071-2100 compared to the period 1971-2000, with reference to the scenario RCP4.5 and the territory of Northern Italy, for the period 2071–2100, an increase of 1 or 2 heatwaves is expected compared to the period 1971-2000.

As for the expected variation in the duration of drought periods, the territory of northern Italy, especially that of the Eastern Alps district, does not seem to be affected by significant changes. If an increase in extreme wave events is expected on the coasts of northern Europe, the projections are not very clear or consistent for the Mediterranean. As for the district's territory, by the end of the century, the average surface warming could reach about 5 ºC compared to current values. Compared to the evolution of the average daily precipitation measured for the whole district, the results obtained from the scenario simulations seem to indicate that, in the district, changes in precipitation could occur in the form of a relatively moderate negative trend. The negative trend is visible and of equal magnitude in summer and winter. The region is characterised by a slight reduction in precipitation (around -0.5 mm/day towards the end of the century).

4.3. Challenges

The assessment of the Nexus is fundamental to achieve the objective of a sustainable growth model. The most relevant conflicting use of resources in the basin concerns the competition for water for upstream hydropower production and downstream irrigation.

The part of the Isonzo/Soča river downstream of the Solkan dam has suffered from the oscillation of the discharge flow caused by the Solkan hydroelectric power plant since its construction in 1984. This aspect has immediate repercussions on the flooding risk. This fluctuation causes a significant variation in the river level, thus endangering the water status. On the Italian side, the Isonzo/Soča represents the primary water source for irrigation. When a low quantity is discharged, it becomes difficult, or impossible, to use irrigation infrastructures.

The transboundary issue had its roots in 1975 when Italy and Slovenia signed the "Osimo Agreements". Today, each country gives a different interpretation of the agreement. One part of the agreement, which is still in force today, involves the management of the water of the Isonzo/Soča river. Slovenia claims that the "Osimo Agreements" obliged to release an average flow equal to 25 m^3/s per day. At the same time, Italy argues that Slovenia must continuously discharge a water flow at least equal to 25 m^3/s. After signing the Agreements, the most important result was the construction of the Solkan plant in Slovenia, near the border. At the same time, Italy was to build a replenishment basin (a dam) to balance the daily fluctuation. Italy has never built a balancing dam.

The origins of mismanagement and disagreement lie in the past. The position of the border has changed considerably over the last century. It was not always a transboundary river; after the First World War, the whole basin was included in the Italian territory before becoming part of the Austro-Hungarian Empire. After World War II, the upper Isonzo/Soča basin was assigned to Zone B of the Treaty of Paris in 1947 and became part of Yugoslavia in 1954. Zone A, which included the foothills and the coastal plain, became Italian, so the border became the current one. Several bilateral agreements between Italy and Slovenia facilitate continued cooperation between the two countries. However, a shared framework for basin-wide management that focuses specifically on Nexus issues is lacking. A comprehensive vision for the basin is urgently needed to consider climate change, which creates fractures in the current arrangements.

The central Nexus challenges in the area can be summarized as follows:

- Understand the status of the current flood and water management plan in relation to climate changes and provide applicable scenarios to estimate the impact of climate changes in the area and with respect to current strategies.
- Find and test best solutions/best practices to ensure sustainability. For example, in the case of flood risk reduction measures, consider environmental value within projects and consider Nature-Based Solutions (NBS) approaches instead of traditional grey infrastructure.
- Finding a balance between various water uses (flooding/feedwater/energy). For example, find a balance between food security and economic development.

- Estimating the future behaviour of the economy to help decision-makers.

The REXUS project can help achieve these objectives by:

- Identifying obstacles to implementing policy actions (political resistance mechanisms in the area (fragmentation, transboundary issues).

- Defining water management strategies for policymakers by analysing priorities, pressures, synergies and trade-offs (especially between energy production, irrigation, and flood risk reduction).
- Propose transboundary water management strategies.
- Provide tools to assess the effect of climate changes and estimate.

4.4. Key stakeholders

A preliminary list of potential key stakeholders has been identified. It can be modified during the project based on the developments:

- AAWA (Water Authority of the Oriental Alpes River District) – the water basin authority for the Italian part of the Isonzo/Soča basin.
- Friuli Venezia Giulia Region (the administrative Region where the Italian Part of the Isonzo/Soča basin falls).
- Friuli Regional Environment Agency (Arpa FVG).
- ISPRA (Italian National Institute for Environmental Protection and Research).
- The Italian ministry of environment.
- Slovenian Ministry of environment.
- Environmental authority for Slovenia (ARSO).
- Land reclamation consortiums and other drainage authorities.
- Energy authorities.
- Farmers associations.

4.5. Policy

The European Union developed a necessary framework for water, starting by adopting an international agreement to increase water quality, address climate change, and ensure access to clean water. The challenge posed by this regulation is that this topic requires very diverse expertise to be addressed.

Article 191 of the Treaty on the Functioning of the European Union, i.e., "*Community policy on the environment shall contribute to preserving, protecting and improving the quality of the environment through prudent and rational utilisation of natural resources*", is one of the first pillars of the Treaty, and follows the polluter pays principle to mitigate.

The most important assumption found in European water legislation is that "*water is not a commercial product like any other, but a heritage to be protected, defended and treated as such*" (Directive 2000/60/EC).

The genesis of the European Water Policy can be found in the conclusions of the Ministerial Seminar on Community Water Policy held in Frankfurt in 1988, which reported the need for common legislation on ecological quality. In 1988, the Council submitted a proposal following the conclusions of the Ministerial Seminar on Community Water Policy, which led to the declaration on groundwater held in The Hague in 1991. Since 1991, Community legislation has recognised the need to prevent the deterioration of freshwater quality and quantity.

With the resolutions on the 25th February 1992 and on the 20th February 1995, the Commission called for a specific action program to protect groundwater from pollution caused by certain substances. Another important resolution was adopted in 1995 concerning wetlands, recognised as necessary for their role within the ecosystems.

The most important act, at European level, to protect water against pollution is the Water Framework Directive (WFD) (2000/60/EC). The Directive presents a broad discussion on environmental and water quality protection issues. As reported in Article 1 of the Directive, the main objectives are:

- Establish a framework for protecting inland surface waters, transitional waters, coastal waters, and groundwater.
- Prevent further deterioration and protect and improve the status of aquatic ecosystems.
- Promote sustainable water use based on the long-term protection of available water resources.
- Further protect and improve the aquatic environment through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing out of discharges, emissions, and losses of priority hazardous substances.
- Ensure progressive reduction of groundwater pollution and prevent further pollution.
- Contribute to mitigate the effects of floods and droughts.
- Sufficient supply good quality surface water and groundwater.
- Significant reduce groundwater pollution.
- Protect terrestrial and marine waters.

The WFD promotes an innovative approach based on the river basin concept to drive actions to achieve the stated objectives by introducing a management plan for all the water-related actions implemented in the basin.

The river basin management plan must consider all aspects of the water environment, from drinking water protection to the achievement of the rivers' good ecological status. It must considers that the objectives set for the river basin have to be achieved within the required timeframe and that the cost-effectiveness of the various possible measures, based on an economic analysis of water use in the river basin, have to be assessed. The Commission incorporated in the WFD the concept of a river basin authority responsible for implementing all the measures required by European law.

The WFD applies to all water bodies, from rivers, lakes, sea, and groundwater to rivers or artificial channels. The Directive required all Member States to achieve good ecological status by 2015 and to achieve the others environmental objectives by 2021 and 2027 (second and third cycle).

Good ecological and chemical status are defined in the Directive and must consider both the quality of the biological community and the hydrological and chemical characteristics of the water bodies. Any use of water that could lead to a degradation of the ecological status must be avoided. Some exceptions relate only to navigation, hydroelectric power plants, floods, and other consequences of emergencies. For groundwater, the degree of protection must be total. The basin plan must also considers all actions to avoid changes in chemical properties, ecological status, and quantity. Each water abstraction is considered a pressure that must be accounted for in the plan and mitigated.

The second water directive was established in 2007, namely the Floods Directive (FD) (2007/60/EC). Article 1, reported below, sets out the scope of the Directive: "*The objective of this Directive is to establish a framework for the assessment and management of flood risks, to reduce the negative consequences for human health, the environment, cultural heritage and economic activity associated with floods in the community*".

The first milestone of the Directive was the initial identification of flood-affected areas. Each basin organization had to develop a risk management plan for each flood-affected area and update it every six years. Flood risk management plans should address all aspects of flood risk management, focusing on "*prevention, protection, preparedness, including flood forecasting and early warning systems*" and considering the characteristics of the river basin or sub-basin. Moreover, "*Flood risk management plans may also include promoting sustainable land-use practices, improved water retention and controlled inundation of certain areas in the event of flooding*" (Floods Directive, 2007/60/EC)

The Flood Risk Management Plans prepared for each basin by the competent authority must include:

- Flood risk maps.
- A description of the appropriate flood risk management objectives.
- A summary of the measures and their prioritization to achieve the appropriate flood risk management objectives, including measures adopted under Article 7 and flood-related measures adopted under other Community acts. Moreover it has to include the (1) Council Directives 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment; (2) the 96/82/EC of 9 December 1996 on the assessment of the effects of certain public and private projects on the environment, and on the control of risks inherent to accidents involving dangerous substances; (3), Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of specific plans and programs on the environment; and (4) the Directive 2000/60/EC.
- In the case of shared river basins or sub-basins, a description of the methodology, defined by the Member States concerned, and the cost-benefit analysis used to assess measures with transnational effects.
- In the case of transboundary river basins, the flood risk management plan must be shared by the involved States.

Other legislative developments in the European Union that should be considered are related to water quality:

- The Environmental Quality Standards Directive (2008/105/EC).
- The Marine Strategy Framework Directive (MSFD, 2008/56/EC).
- Directive 2006/7/EC.
- The Groundwater Directive (2006/118/EC).
- The IPPC Directive.
- The Seveso Directives.
- Nitrates Directive.
- Urban Wastewater Treatment Directive.

Other legislative acts:

Several bilateral agreements between Italy and Slovenia (e.g., the 1975 Osimo agreement) facilitate continued cooperation. However, a shared framework for basin-wide management that focuses specifically on Nexus issues is lacking. A comprehensive basin-wide vision is urgently needed to consider climate change, which could create fractures in the current arrangements.

4.6. Relevant documents

- PGRA: Flood risk management plan according to the EU 2007/60 directive.
- PAI: Basin Management plan according with the Italian law 183/89.
- PGA: Water management plan according to the EU directive 2000/60/EC.

All those documents are managed by AAWA.

4.7. Basic climate and soil data

The area of Slovenia represents mainly the mountainous part of the Isonzo/Soča basin, and it is subject to a Mediterranean climate interacting with continental climatic conditions. The climate is moderated by the occasional inflow of continental air masses through the mountain barrier from the northeast. This is especially relevant in the Vipava River basin, open to the west towards the Adriatic Sea.

Summers are hot and dry, with occasional droughts, and winter is usually mild and rainy, with frequent winds. The wind is characterise to be dry, cold, and often comes with gusts exceeding 100 km/h and occasionally can exceed 200 km/h, causing damage to crops and infrastructure.

The area most affected by the wind is usually the upper part of the Vipava valley, extending from Ajdovščina to Podnanos. The valley floor rarely experiences freezing temperatures, and snow is also a rare phenomenon.

The average annual temperature for 1981-2010 on the valley floor is 12-13 ºC.

Temperatures decrease with altitude; at the annual level, they are 2 ºC lower on the karst plateau and 6 ºC lower in the highlands of the Trnovo Forest Range. The warmest month is July, with an average temperature (1981-2010) of 22 ºC, and the coldest month is January, with an average of 3 ºC. The average annual precipitation in the upper part of the Vipava valley is about 2,000 mm per year, and in the lower part and the Vipava hills, about 1,500 mm per year.

As far as the Italian part is concerned, climate and precipitation of Friuli Venezia Giulia Region, which includes the entire Italian Isonzo/Soča basin, are determined by several factors. The main factors are: its geographical location in the temperate and boreal belt, with latitude between 45° and the 47° parallel; the presence of longitudinal alpine and pre-alpine reliefs that constitute a climatic barrier to the north; and the influential presence of the Adriatic Sea, from which warm and humid air masses originate. These factors determine climatic differences that are also significant in some areas of the Friuli Venezia Giulia region. In general, there is a temperate maritime climate in the plains and hills, with low average temperatures and steep annual excursions, and abundant and well-distributed rainfall; in the mountainous area.Alps protect the plains from the cold, dry winds from the north.

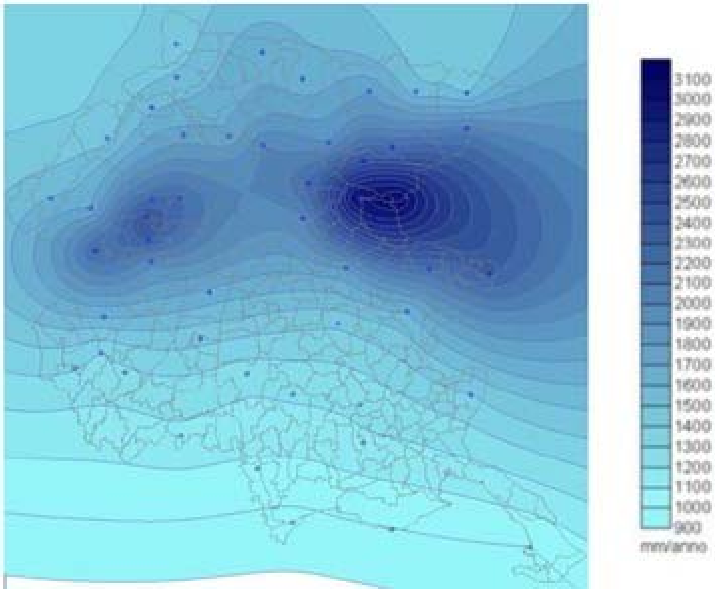

Figure 27. Maps of yearly rainfall from 1960 – 2004 for the Friuli Venezia Giulia Region. The eastern peack of precipitation value, the maximum for the whole Italy, fells in the Isonzo/Soča river basin (Source Rodriguez, 2009).

The Carnic Prealps make it difficult for warm, humid air to enter the interior valleys from the southeast, and the low-lying Julian Prealps are responsible for the abundance of rainfall in the easternmost sector of the Region. The rainfall pattern of the Isonzo/Soča river basin is of the alpine sub-coastal type, with a summer minimum less pronounced than the winter and an absolute maximum generally in autumn. The pluviometry of the basin is complex and is characterized by essential variations in space. The rainfall increases considerably when passing from the plain to the Julian Alps, although it also presents high values in the plain. In the alpine belt (which roughly coincides with the southern slopes of the Julian Alps), the average annual rainfall reaches values among the highest in Italy and even in Europe, with heights between 2,400 and 3,100 mm.

The pre-alpine belt comprises practically all of the Julian Pre-Alps and the Bainsizza and Tarnova karst plateaus and has lower annual precipitation values, ranging between 2,000 and 2,500 mm. Going further down the valley, the upper plains and the mountainous fringe is characterized by annual precipitation between 1,400 and 1,800 mm. The coastal strip and the low plain are, without a doubt, the least rainy area of the basin: annual precipitation totals reach values of 1,000-1,400 mm on average, with increases from the coast to the interior plain. In the thirty years 1961-1990, the smallest wet year was characterized by total precipitation of around 800 mm, while in the wettest (1965), the total precipitation was between 1,400 and 1,800 mm.

Regarding the monthly rainfall variability, the least rainy month is February, with an average, estimated in the previous thirty years, of 70-100 mm, followed shortly after by January and March. The wettest months are June (average 100-140 mm), November (110-140), September, and October. The minimum total monthly rainfall assumed values between 0 and 20 mm. At the contrary, during the autumn season, the maximum average monthly rainfall recorded values between 300 and 350 mm.

The upstream mountain area of the basin, mainly in Slovenia, is composed by tertiary and quaternary alluvial sediments where the soil is quite fertile. The mountain range that envelops the valley in the north is a massive Mesozoic limestone accretion, covered by a thin and unstable layer of flysch. For this reason, landslides are standard on the steep slopes during heavy rainfall events. The elevated but lower plateau in the south is a composed by pure limestone from the Mesozoic era. Both limestone plateaus lack surface water, and all the water sinks into ground creeks and canyons, only to emerge just above the impermeable valley bottom. The downstream part of the basin represents the plain called in Italian 'Pianura Isontina'. It is almost entirely made up of Quaternary alluvial deposits of the Corsicans d'acqua Torre, Judrio, Versa and Isonzo/Soča. These streams of water at their outlet in plains have deposited very coarse materials and sediments downstream gradually finer, thus leading to the formation of two distinct zones in terms of characteristics, grain size, and permeability of deposits:

- The Upper Plain upstream of the springs line, limited to the north by hills of the Collio and the south from the Karst plateau, is made up of materials mostly coarse and very permeable.
- The Lower Plain, downstream of the springs line, limited to the east from the Karst plateau and to the south from the sea, is made up of clayey or sandy-clayey, whose permeability is very high low or low none.

Upper and Lower Plains are separated by the springs line, which generally trends from North-West to South-East. Along this strip, the groundwater emerges from the Upper Plain that rises progressively towards the valley for the decrease in permeability of the filter medium following the decrease particle size of alluvial deposits. The emergence of these waters is also favoured by the presence, along the resurgence area, of impermeable clayey horizons that support the groundwater upstream (Cucchi et al., 1999; Fontana, 2006). All-mountain rivers disperse a large amount on their way of water in the Upper Plain. These sub-river and lateral losses are so elevated that some rivers, such as the Torre and the Judrio, remain without cash flow for most of the year. These infiltration waters, together with the rainy ones, to those of runoff of the hilly reliefs and those coming underground from the rocky masses, form the aquifer water table of the Upper Plain. Towards the valley, they grafted from the south into the High Plain of the extensive clayey lenses that, in the Lower Plain, lead to the establishment of a multi-layer complex with a sequence of overlapping aquifer systems, confined or semi-confined (Vatta, 1992; Stefanini & Cucchi, 1976; Cucchi et al., 2002). Upstream of the springs line, some artesian aquifers o very deep pseudoartesian (up to 200 m from the ground level in San Pier d'Isonzo) receive contributions from the nearby karst limestone massif of the Isonzo/Soča Karst.

4.8. Current and emerging water sources and uses

The main water uses in the basin, related principally with hydropower production, are shown in the following map (Figure 28).

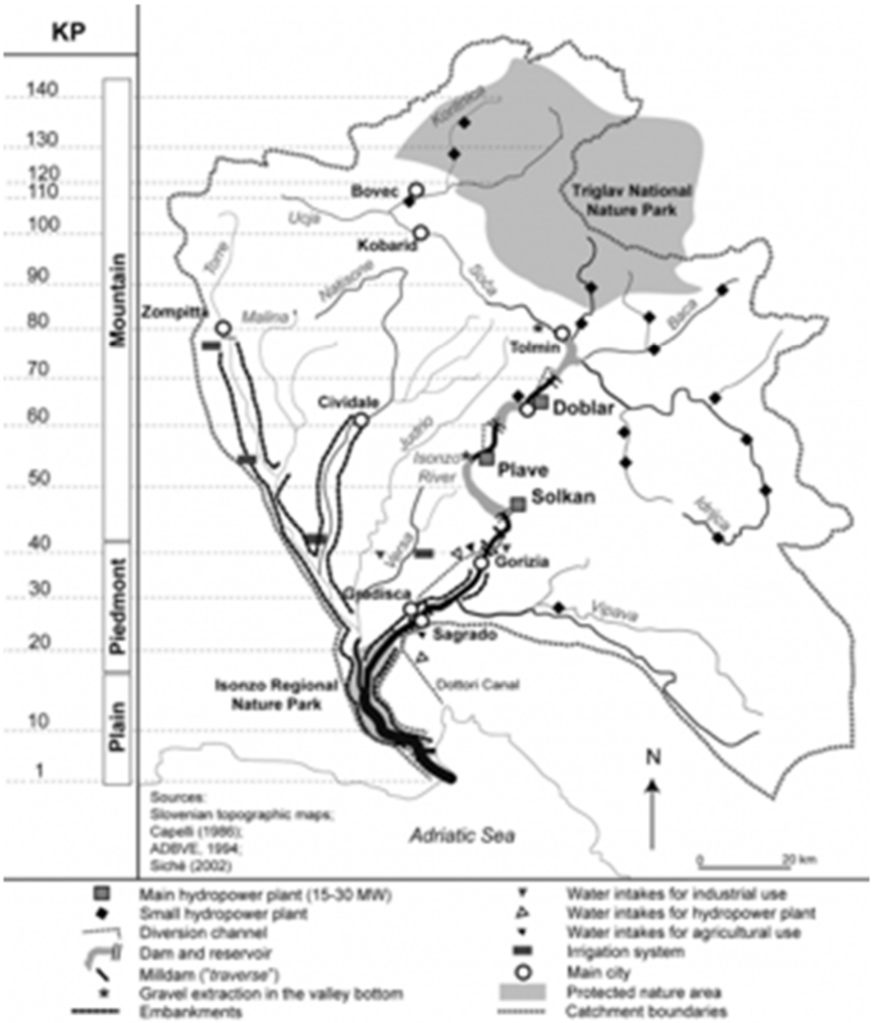

Figure 28. The main water uses in the Isonzo/Soča basin. Source: Mei, 2015.

For the Slovenian part, detailed water use, and balance data are currently available only for the Vipacco River basin, which is on the main Isonzo/Soča sub-basin. In this area. The total annual runoff of the basin is approximately 545 million m^3. Regarding authorized water withdrawals (or abstractions), we distinguish between two terms:

- *Water use* describes the total amount of water withdrawn from its source to be used. Uses of surface water include small hydropower plants, aquaculture, fisheries, saw/mill, water used by technological plants, and individual water supply.
- *Water consumption* is the portion of water use that is not returned to the original water source after being withdrawn. In 2013, the total water consumption from surface waters through granted water permits amounted to around 33.5 million m^3, around 6% of all water available from surface waters.

Municipal public utility services provide drinking water for households (Komunala Nova Gorica d.d. Nova Gorica, Šempeter-Vrtojba, Miren-Kostanjevica,Renče-Vogrsko, Komunalno stanovanjska družba, Ajdovščina, Vipava, and Ajdovščina) obtaining it from springs (e.g., Hubelj). The total granted withdrawal in the Vipava river basin in 2013 amounted to around 6.2 million m^3 through water permits. Additional 0.08 million m^3 were allocated to individual water supplies. Combined, the two uses present more than 99% of all water consumption from springs. An additional granted amount of 3.9 million m^3 was allocated to aquaculture. The water use from groundwater sources other than springs is low. In 2013 only 7,000 m^3 of withdrawal was granted through water permits for individual water supplies, and additional 64,000 m^3 for technological purposes. There were no concessions awarded for groundwater use in 2013.

In the Italian part, the Soil Reclamation Consortium of the ‘Pianura Isontina’ (Isonzo’s plain in Italia) intercepts water from Isonzo/Soča for irrigation and industrial usage through two derivation channels (Figure 29): one in Gorizia, in the Piedimonte district and the other one in the Sagrado Municipality.

Figure 29: Main water interceptions on the Italian Part of the Isonzo/Soča river, of the irrigation network and the hydroelectric plants. Source: Rodriguez, 2009.

The area is characterized by two irrigation basins identifiable in the districts of the discontinued Consortia, having their own hydraulic characteristics: the basin of the former "Agro Cormonese-Gradisca" and that of the former "Agro Monfalconese" each of them underlies a user territory. The average values of the flows derived from the Isonzo/Soča basin for these two irrigation districts are reported in the following table (Table 29).

Table 29. Average Irrigation intakes for the Isonzo/Soča river for the two districts of Alta Pianura Isontina Soil Reclmation Consortium. Source: Rodriguez, 2009.

Derivation barriers	Location	Average water flow [m^3/s]	Concessionaire
Agro Cormonese barrier	Piedimonte (GO)	6.354	Consorzio di Bonifica Pianura Isontina
Agro Monfalconese barrier	Sagrado	8.51	Consorzio di Bonifica Pianura Isontina

Being the basin of the former Agro Cormonese-Gradisca, the system derives its waters for irrigation and industrial purposes in the municipality of Gorizia in Piedimonte through a dam and a reservoir of approximately 180,000 m^3. It takes them to the basin through the main channel and a network of secondary channels of about 40 km.
Regards the basin of the former Agro Monfalconese, the system derives its waters for irrigation-industrial purposes from the Isonzo/Soča river in the municipality of Sagrado and brings them into the basin through the main channel and a network of secondary channels for the total development of about 22 km.
The total irrigated area of the Soil Reclamation Consortium of the 'Pianura Isontina', including the two above mentioned basins, is 9,833 ha and is divided as follows (Table 30), according to the main types of irrigation systems:

Table 30. Irrigated area in the Isonzo/Soča Plain (Alta Pianura Isontina Soil Reclmation Consortium: Source: AAWA.

Irrigation system	Irrigated area (ha)
slider irrigation system (superficial channels)	1,909
sprinkler irrigation	7,924
Total	9,833

The irrigation infrastructure is composed by the following elements:

- 1 derivation from Isonzo/Soča river in Gorizia for the 'Agro Cormonese-Gradiscano'.
- 1 derivation from the Isonzo/Soča river in Sagrado for the 'Agro Monfalconese'.
- 1 pumping well in Cormons.
- 13 pumps.
- 2 lifting and supply stations.

The features of the main intake points on Isonzo/Soča are shown in the following table:

Table 31. Features of the main intakes on the Isonzo/Soča river downstream of Solkan dam. Source: AAWA.

Intake point	Location	Concessionaire	Type	Average derived flow (l/s)	Maximum derived flow	Nominal Power (Kw)	Drop (m)
Texgiulia (ex-sbarramento Enel)	Gorizia - loc. Straccis	Texgiulia	Industrial and Hydroelectric	495	790	2688.5	5.54
Patt (on Agro Cormonese barrier)	Gorizia - loc. Piedimonte	Patt (Fantoni)	Industrial and Hydroelectric	193	240	794.7	4.2
Agro Cormonese Barruer	Gorizia - loc. Piedimonte	Pianura Isontina land reclamation consortium	Irrigual	63.54	Maximum 206.74		
			Industrial and Hydroelectric	143.2		1,925	13.7
Nuova Torcitura di Sagrado (ex-sbarr Snia)	Sagrado - loc. Poggio	Nuova Torcitura di Sagrado	Industrial and Hydroelectric		140	412	
Agro Monfalconese barrier	Sagrado	Pianura Isontina land reclamation consortium	Irrigual	85.1	Maximum 215		
			Industrial and Hydroelectric	129.9		2,112.5	TOT. 16.35

Agricultural production is not feasible without irrigation, even if the precipitations are not scarce. For that reason, the irrigation district is strictly dependent on its unique source: the Isonzo/Soča river. The river survival of the Isonzo/Soča is connected and dependent on the management of the hydroelectric dams located in Slovenia. Therefore also, the need for irrigation is affected by this management.

The Italian area is subject to significant daily challenges due to the particular use of the hydroelectric reservoir of Salcano. This involves a daily change in flow rate and level of the Isonzo/Soča river in the Italian territory, such as making irrigation difficult in the northern part of the area (Agro Cormonese) and critical in the southern part (Agro Monfalconese).

Significant difficulties regard the release of the minimum vital flow in correspondence with the derivations, as required by Italian laws. The minimum requirement necessary for irrigation purpose, for the survival of the fish fauna, for the protection of the river environment as well, and for acceptable exploitation for hydroelectricity should be equal to a continuous daily and night flow of about 25 m^2/sec., a fact that has rarely happened in recent years. As part of the agreements between Italy and Slovenia, a system for regulating the river's flow was defined, which guaranteed Italy, at the Sagrado intake, 21.5 m^3/s water that is needed for industrial and irrigation purposes. Water releases in the Italian territory occur with wide fluctuations (Figure 30), which do not allow regular use of the irrigation service in the area. Slovenia interprets the agreement as it is obliged to provide a guaranteed average daily flow rate, but not with a constant flow, as the irrigation service provided by the Consortium would require, therefore often causing irrigation dysfunctions.

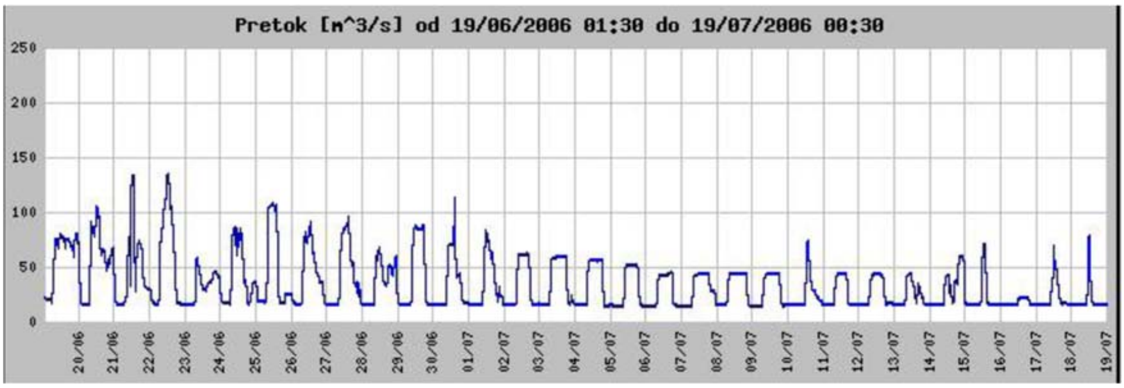

Figure 30: Discharge regimen on the Isonzo/Soča river downstream Salcano for the particular dry summer of 2006. (Souce ARSO – Slovenian- http://www.arso.gov.si/vode/podatki/amp/Hg_30.html).

During the daytime slot, when the hydroelectric energy produced has a higher value than the night one, the Slovenian private company Soške Elektrarne puts the turbines to produce energy by releasing a consistent quantity into the river water. In the nocturnal zone, the water is retained in the reservoir with a modest release, less than 15 m^3/s, which raises many problems.

4.9. Current and emerging land uses, major crops, and farming systems

In the basin a major part of the land is covered by forests and cropland and a smaller part by cities and water bodies, as in the following picture.

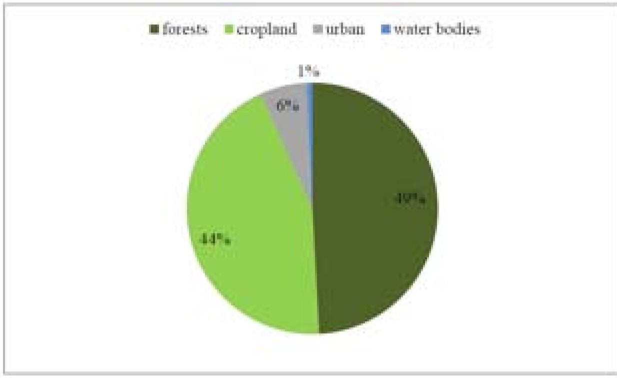

Figure 31: Land cover and use in the basin. Source: AAWA, 2021.

A large part of the river basin is covered by forest in the Slovenian area, mainly on the slopes and higher altitudes around the central valley; the second primary land use is agriculture, mainly in the flatland around the Vipava River and its tributaries. Land use has changed relevantly in the last decades.

For example, a comparison between land use in 2002 and 2015 in the Vipava basin, one of the most important sub-basins of the Isonzo/Soča, show noticeable changes. During this time, 2.1% of the river basin area was transformed from arable land to grassland and urban area, and 3.5% of the area that formally was grassland developed into forest and shrubland.

The most important agricultural products in the Slovenian valleys of the Isonzo/Soča basin are fruits (especially peaches, apricots, and cherries), concentrated in the Vipava Valley and grapes for wine production. Other essential agricultural products are early vegetables (lettuce, potato, cabbage, carrot, onion, garlic, and strawberries) due to favourable climate conditions and a vegetation period that is significantly longer compared to the continental parts of Slovenia.

In Italy, the most important production is wine on the Isonzo/Soča plain, with the Isonzo/Soča e Collio DOC brand. The grape crops are mainly located in the territories cultivated by a Consortium (Consorzio di Bonifica della Pianura Isonontina) in the southeast part of the basin. Furthermore, are farmed cereals, fruits, and in minor quantity olive oil. Moreover, in the piedmont are present grazing land.

The entire area is also rich in protected areas, especially in the Slovenian part. Here there is one national park: Triglavski Narodni Park, and the entire River Soča, on the Slovenian side, is protected as Natural Monument. Idrijca and Vipava, with their tributaries, are not included in the same monument but are protected under different categories as separate entities.

The mouth of the Isonzo/Soča is also protected as a Regional/Provincial Nature Reserve. Finally, Valle Cavanata, on the Adriatic Coast, is a Special Protection Area under Ramsar Convention.

4.10. Energy generating infrastructure

Firstly, it is necessary to distinguish between the two countries. On the Slovenian side the only type of power plants present is hydroelectric and most of them have a high installed capacity. Whereas in Italy this type of production is less relevant and are also installed thermal utilities. The Soške elektrarne Nova Gorica (SENG) company owns all the hydropower plants on the Slovenian part and these are listed, with their main features, in the following table (Table 32).

To understand the relevance of this basin for the overall country, the total average electricity production is compared with the Slovenian net production and final consumptions. Data for the overall Slovenia are taken from the Statistical Office web site.

Table 32. Relevance of the Soča basin for Slovenia energy production. Source: AAWA, 2021.

Relevance of the Soča basin	
Respect to the net Slovenian average production	8.7%
Respect to the hydroelectric average production	32.9%
Respect to the average final consumption of Slovenia	10.1%

Table 33. Major Hydro-Power Plants in Slovenia side of the Soča river. Source: AAWA, 2021.

HHP	Operation start	Installed turbine power [MW]	Annual electricity production [GWh]	Maximum height: [m]	Rated discharge: [m³/s]
Avče (PHPP)	2009-10	185	553	521	40
Solkan	1984	32	105	75.5 (min)	180
Doblar 1	1939	30	150	153	75
HPP Doblar 2	2002	40	199	48.5	105
Plave 1	1940	15	80		68
Plave 2	2002	20	116	27.5	105
TOTAL of big HPP		322	1203		

Table 34. Small Hydro-Power Plants in Slovenia side of the Soča river. Source: AAWA, 2021.

HHP	River/ tributary	Operation start	Installed turbine power [MW]	Annual electricity production [GWh]	Maximum height: [m]	Rated discharge: [m³/s]
Gradišče	Vipava	1922	0.15	0. 55	12	2.74
Možnica	Koritnica	1911	0.53	2.3	27	3
Tolmin	Tolminka	1995	0.109	0.6	5.4	4.3
Podmelec	Bača	1931	0.425	1.4	12	5
Marof	Idrijca	1932	0.44	1.7	12.7	0.9
Trebuša	Trebušica	1985	0.76	2.1	110	2.06
Mesto	Idrijca	1909	0.2	0.7	16.3	0.4

HHP	River/ tributary	Operation start	Installed turbine power [MW]	Annual electricity production [GWh]	Maximum height: [m]	Rated discharge: [m³/s]
Mrzla Rupa	Idrijca	1989	0.648	1.6	239	2.7
Hubelj	Hubelj	1931	2.1	10	110	2.5
Ajba	Soča	2008	0.25	1.4	10.2-11.7	
TOT of small HPP		5.612	20.4			
TOT from HPP (big+ small)		327.612	1,223.40			

The basin is quite important for the national electricity balance and in particularly it represents more than one third of the national hydroelectric production which in turn also quite significant in the global electricity supply. As reported by Mei (2015) the hydroelectric power plants are responsible for the 26.3% of power supply in Slovenia, the third source behind nuclear power plants (37.4%) and thermal power plants (36%).

On the Italian side of the basin are present three thermal power plants, as shown in Table 35.

Table 35. Thermal Power Plant on the Italian side of the Isonzo/Soča Basin. Source: Mei, 2015.

Name	Installation year	Installed capacity [MW]	Annual Production [GWh]	Fuel	Owner
Torviscosa CCGT	2006	790	4,174	Natural gas	EDISON
Elettrogorizia CCGT	2005	49.9	225	Natural gas	ElettroGorizia S.p.A.
Monfalcone TPP	1965	976	3,800	Coal/Oil/ Biomass	A2A
TOT TPP		1,815.9	8,199		

The Torviscosa power plant uses a considerable amount of freshwater (3,885,900 m^3) extracted from the wells owned by the Caffaro Company (the industrial utility which receives the vapour produced). The principal water employment is for producing demineralised water, instead the cooling system (wet-dry tower) helps to not increase the water consumption.

Despite the Elettrogorizia plant consumes much less freshwater (on average 31,500 m^3 per year) because it has a lower installed capacity and it uses a closed loop for demineralised water production. Thus, the main water use is for filling up the recovery heat generator, since there is an air cooling system. In this case the intakes come from the local supply water network (Cecotti, 2006)

Finally, the Monfalcone group, even if is not exactly located within the basin boundaries, should be related with the water uses in this area because it consumes in average 1.6 million cubic meters of fresh water withdrawn mainly from the Valentinis Channel, closed to the Isonzo/Soča mouth. However, the intake is not so significant due to the use of sea water in the cooling system (EMAS, 2012).

In the end, considering their fresh water uses, the thermal power plants are not fundamental in the water management of the river.

Instead the hydroelectric exploitation represents the main water use on the Italian side (73.6%), followed by irrigation (25.2%), and fishing (0.9%), while other uses represents only the 0.3% (Mei, 2015). However, this type of water uses is less important than in Slovenia, due to the nature of the territory, which is characterized by piedmont and plain.

The next table (Table 36) show the group of small hydro plants located within the Italian basin area which are connected to the national grid.

Table 36. Grid-connected Hydro-Power Plant on Italian side of the Isonzo/Soča river. Source: Mei, 2015.

Name	River/ tributary	Installation year	Installed turbine power [MW]	Annual average production [GWh]	Maximum height: [m]	Rated discharge: [m³/s]	Owner
Hydra Poggio barrier	Isonzo/Soča		0.4	2.6		14	Hydra srl
Consorzio di Bonifica Pianura Isontina	Isonzo/Soča and Canale Dottori	1905-7	1.5	11	16.3	12.99	Edipower
TOT of HPP			1.9	13.6			

On the Italian side other small hydroelectric utilities, listed in Table 37, exist, although they are owned by industrial companies and not connected to the grid.

Table 37. Off grid hydro power plants on the Italian. Source: Mei, 2015.

Intake point name (not official)	Location	Installed capacity [kW]	height [m]	average water flow [m^3/s]
Texgiulia barrier	Straccis (GO)	2,688.5	5.5	49.5
Patt barrier	Piedimonte (GO)	794.7	4.2	19.3
Agro Cormonese barrier	Piedimonte (GO)	1,925	13.7	14.3
Nuova torciutura Sagrado barrier	Poggio (Sagrado)	412		14

The importance of the basin, for electricity production, respect to the whole Italian nation is shown in table 38. The national data on production and consumption are taken from the annual report of the grid transmission company (TERNA, 2012). As is possible to see from the data, the relevance of italian part Isonzo/Soča river in the national production is modest compared to the Slovenian part.

Table 38. Relevance of the Isonzo/Soča basin for Italian energy supply. Source: Mei, 2015..

Relevance of the Isonzo/Soča basin		
Total: HPP+TPP	respect to the net production	2.96%
	respect to the final consumption	2.59%
HPP	respect to Italian hydroelectric production	0.50%
	respect to the total Italian production	0.08%
TPP	respect to the Italian thermoelectric production	4.00%
	respect to the total Italian production	2.88%

Additionally, in Italy the hydro power production is not as relevant as in Slovenia, representing only the 15% of the production, which is capitalized by the thermoelectric production (72%, Mei, 2015). In general, from the previous tables, it is possible to understand that Italy relies on a lower base on the basin, than Slovenia, from an electricity perspective. This is especially evident when the hydroelectric production is considered, which result to be the most important for this study.

Ultimately, it is evaluated also the importance of the Slovenian electrical production for Italy, to better analyse the situation, understanding the Italian dependency. Indeed, in table 39 is evident how Slovenia is the principal electricity exporter of Italy and this amount of electricity is not negligible since it represents more than one percent of the total final consumption.

Table 39. Italian electricity dependency from Slovenia. Source: Mei, 2015..

Italian indicators	
Net electricity import over the total final consumption	1.5%
Net electricity import from Slovenia [GWh/y]	3,732
Import from Slovenia over the total final consumption	1.1%
Import from Slovenia over the overall import	76.9%
Total electricity consumption indicator [MWh/person]	0.778
Electricity import from SI indicator [MWh/person]	0.063

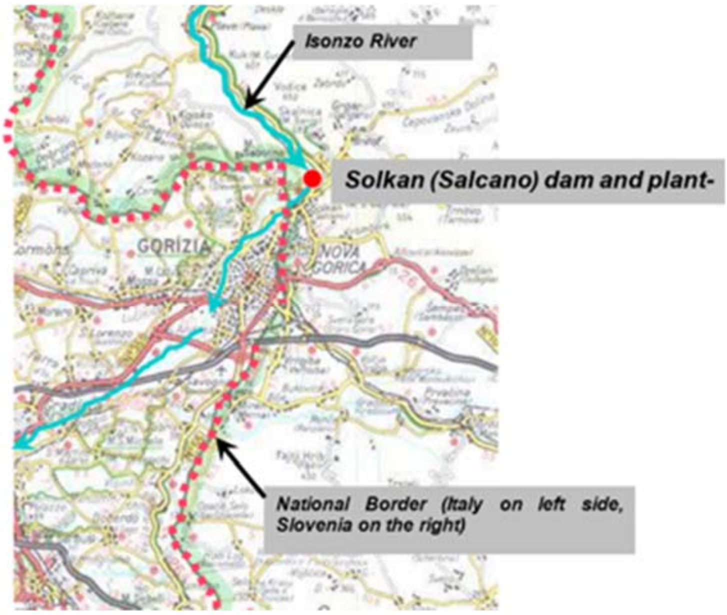

Figure 32: Location of the Solkan Dam. Source: AAWA, 2021.

The following table (table 40) summarizes the principal technical characteristics of the Solkan hydropower plant.

Table 40. Main features of the Solkan Hydro Power Plant. Source: Mei, 2015.

Installation year	Installed capacity [MW]	Annual average production [GWh]	Type of turbine	Permissible storage volume oscillation [m^3]	minimum inlet flow [m^3/s]	maximum inlet flow [m^3/s]	Nominal height [m]
1984	32	105	3xKaplan	1,150,000	12.5	180	75.5

Through the analysis of the water flow data and the comparison with the electricity selling price on the Slovenian market (Mei, 2015), it is easily understood that the electricity production is maximized during the peak cost hours of the day. To do so the water must be stored during the low-cost hours causing though a low flow discharged downstream.

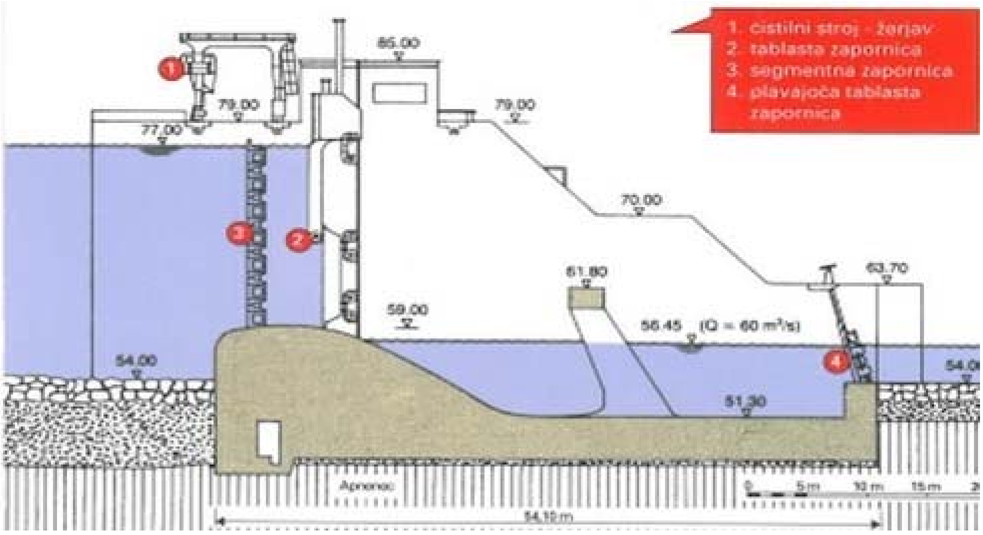

Figure 33: Schema of the Salcano Dam. Source: Mei, 2015.

A comparative analysis (Mei, 2015) of the water flow discharged in 2012 by the dam shows a similar average trend for the water flow and for the electricity price (Figure 34), confirming the the Solkan power plant works mainly when the is more convenient for the electricity company. Indeed,the water flow is directly proportional to electric power produced.

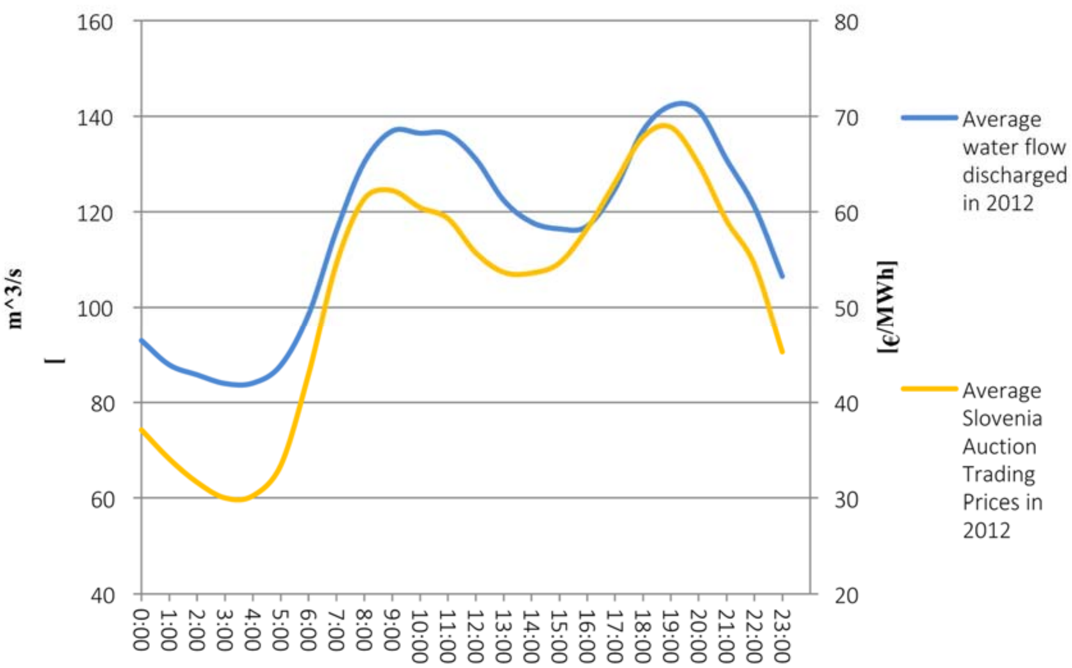

Figure 34 comparison of the water flow discharged by the Solkan dam and the Slovenian electricity selling price in 2012 (Medi, 2015). Source: AAWA, 2021.

Finally, the relevance of this power plant for the two Countries is presented (Table 41).

Table 41. Relevance of electricity production of the Solkan hydropower plant for Italy and Slovenia. Source: Mei, 2015.

Solkan annual average production	
Slovenian net electricity production (2011)	0.7%
Slovenian final consumption (2011)	0.8%
Average hydroelectric production on the Slovenian side of the Soča basin	8.6%
Slovenia export to Italy (2012)	2.7%
Italian electricity final consumption (2012)	0.04%

This hydro power plant is more important for Slovenia, on a national scale. However, it also produces a consistent amount of the electricity imported by Italy. Therefore, it is possible to conclude that both countries rely on this utility even though in a differ manner.

4.11. Demographic data at pilot scale

Some Basic population data from the basin can be found on the following table. As is clear from the data, even if the Slovenian part of the basin is twice the size of the Italian one, the latest counts almost double of the population of the Slovenian counterpart. For this reason, the density of population in the Italian Part of the basin is four time greater than the Slovenian one. This result is not so surprising considering that the Italian part of the Isonzo/Soča rivers included urbanized plain, whereas the Slovenian is mostly mountainside. The most of the population is the Slovenian part is mostly located in the Vipava Valley.

For both parts of the basin, the density of population is lower than the respective national Averages.

Table 42. Demographic data. Source: AAWA, 2021.

	Surface (km^2, AAWA)	Portion of basin/Respective Country surface area	Population 2012 (Mei, 2015)	Part of basin / Respective Country population	Density of the Population in the basin (Ab/mq)	Average Density of Population in the respective Nation (ab/mq)
Italian Part of the **Isonzo/Soča** Basin	1097.1	0.36%	178183	0.30%	**162.4**	**197.1**
Slovenian Part of the **Isonzo/Soča** Basin	2302.9	11.36%	98664	4.80%	**42.8**	**101.4**
Total Basin	3400		178183			

The population density is quite high at in the plains of the Italian part of the basin and in the bottom of the valley and lower on the slopes that enclose the valley of the Vipava River in Slovenia. The lowest density of population in the basin, for both the countries in in the mountain part.

4.12. Major economic activities / industries, employment

The main economic activities in the riparian basin are connected to water. In the Slovenian part, they are related to tourism, especially the water activities around the river and hydroelectric production. The industry is present in all major cities of the Vipava Valley (e.g., Ajdovščina, Vipava, Šempeter, Nova Gorica), although it is more condensed in the lower part of the basin. The town of Ajdovščina developed along the Hubelj watercourse. In Ajdovščina, there are two crucial food processing factories. Other important industrial sectors in the valley are electronics, construction, and transport services. During the past decade, the number of newly established micro, small, and medium-sized companies are increasing as people are developing new income opportunities, following the abandonment of agricultural activities and decreasing employment opportunities in large industrial complexes.

In the Italian part, the area's economy is greatly affected by the geographical position, which is marginal compared to the Italian market. At the same time, the presence of political borders and the proximity to the large port of Trieste favours international trade and promotes the transit function. The industrial revolution, the spread of modern roads and means of transport, new reclamation and irrigation techniques, new cultivation practices and new settlement models have levelled the most original aspects of agricultural landscapes, which tend to evolve towards a is the only type of modern agriculture, mechanized and chemicalized according to productivity and oriented towards the market. The most common crop is maize, potatoes, sugar beets and wheat. Over half of the commercial agricultural production is the result of cattle breeding, which has benefited from a strict genealogical selection and more rational forms of management, which have allowed significant increases in production yields: the most consistent sector is the bovine one, followed by from swine, which is practised by an increasing number of specialized companies; fish farming has had significant development, especially in the lagoons and along the Trieste coast. The industries are located along the main rail-road and fluvial-maritime communication routes, with concentration along the tremendous central axis that connects the outlet centres of the pre-Alpine valleys, near the underground resources and in the forest and agricultural areas. Agricultural and livestock production required localization in the areas of most outstanding specialization of food industries and influenced the establishment of some tanneries and the footwear industry. The craft traditions have favoured the development of various manufacturing activities (textile and wood industry, cutlery, ceramic processing), and the attraction of the consumer market has led many industries to locate themselves in the centres and industrial areas where there was demand. Of semi-finished products and capital goods: the textile industry has attracted the production of looms and other textile machines, and the shipbuilding industry has attracted the steel and mechanical industries. River basins also feed the production of hydroelectricity. The most developed sector of the tertiary sector comprises trade, which feeds on domestic demand and international traffic: commercial activities are divided between the various levels of the urban centres according to their rank.

4.13. Organizational infrastructure, Innovation capacities and Data

AAWA can provide experts in hydrology, hydraulic, and environmental issues, and the correspondent ICT. AAWA has in place a hydrological-hydraulic model of the basin and a database for the environmental variables. AAWA experienced the usage of satellite data to derive the use of soil and the presence of floods and other hydrological variables (snow cover, humidity, etc.).

4.14. EU &/or national projects where the pilot was an important test case

VISFRIM (INTERREG Italy-Slovenia) (2019-2022): Monitor, analyse, and forecast natural phenomena and processes in the environment, and reduce natural threats to people and property for the Isonzo/Soča basin

GREVISLIN (INTERREG Italy-Slovenia) (2018-2022): Understanding the role and potential for green infrastructure in the conservation and improvement of the condition of habitats and protected species along the rivers.

EOPEN - H2020 (2017-2020): Knowledge on how to fuse Copernicus big data content with other observations from non-EO data, aiming at interactive, real-time, and user-friendly visualisations and decisions from early warning notifications

AQUA3S - H2020 (2019-2022): Understanding citizen exposure to water related disasters and exploring risk reduction measures for vulnerable communities.

Visfrim, Grevislin and Aqa3s are ongoing projects, and no outputs are currently available; EOPEN provided algorithms and knowledge to derive flooded areas from satellite observations.

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5. Lower Danube Pilot Case (Romania, Bulgaria & Serbia, RO-BG-RS)

5.1. General characterization

The Danube River is the second-longest river in Europe, running through 10 countries flowing for 2,850 km until it reaches the Black Sea. The Romanian section covers almost a third of the surface area of the basin, and over a third of the river's length flows through the country. Indeed, Romania represents 29% of the surface area of the whole Danube Basin, with a length of 37.7% of the Danube River flowing through its territory (Figure 35).

Figure 35. Danube River map. Source: http://railwaystays.com)

Its basin supports a lot of activities such as transport, industry, energy, agriculture, and tourism. These activities are vital for the local, national, and European economy, but at the same time generate a series of pollutants that are finally deposited in the Danube Delta and in the Black Sea.

Anthropic interventions along the Danube River water course, such as the construction of the hydropower plants "Iron Gates I" and "Iron Gates II" and the alterations along its banks through embankment, have generated high banks erosion processes as well as changes of the riverbed with negative impact on navigation. The negative effects induced by anthropic interventions coupled with climate change impact have intensified the flooding and drought events, as explained in the following sub-chapter.

The challenge for the future is to maintain a dynamic balance between the development of human activities and the natural environment in the Danube Basin.

Most of the land along the riverbank is now under the administration of private owners and this hinders even more any incentive that the local authorities would have regarding the maintenance and development of the areas.

Considering the large area covered by the pilot area in progression with the high number of urban areas, accumulation lakes, old/inexistent drainage infrastructure, riverbank consolidation works, and an inexistent plan developed, especially for sustainable economic friendly solutions, the risk of catastrophic damage to the local communities, is extremely high.

5.2. Major developments

Water

Hydrology: Usually, during a year, the following variation can be observed: maximum flow in April-May-June and minimum flow in September-October, in between there is inserting an autumn increase (November) and a winter decrease (January-February). Danube water is frozen on its all width only in very frosty winters. Usually, the ice bridge form at middle January, and its longest recorded duration was of 54 days in 1954.

According to its chemical composition, the Danube water is carbonated-sulphurated-chlorinated, but its degree of mineralization is reduced, around 300 mg/l. Therefore, the water can be used for human consumption after treatment, for irrigations, or for industry.

The study area is susceptible to severe droughts especially in the summer season. Droughts result from a combination of meteorological, physical, and human factors. Their primary cause is a deficiency in rainfall and the timing, distribution and intensity of this deficiency in relation to existing storage, demand and water use. Temperature and evapotranspiration may act in combination with insufficient rainfall to magnify the severity and duration of droughts. Moreover, due to land use changes, water demand, and climate, the droughts in future may become more frequent and more severe.

Floods: One of the most severe threats in the Romanian pilot area are the recurring floods. Since the development of grey infrastructure along the riverbanks flash floods travel at an increased speed along the Danube and most of the old floodplains, which now are used for agriculture, are flooded on a regular basis (Figure 36).

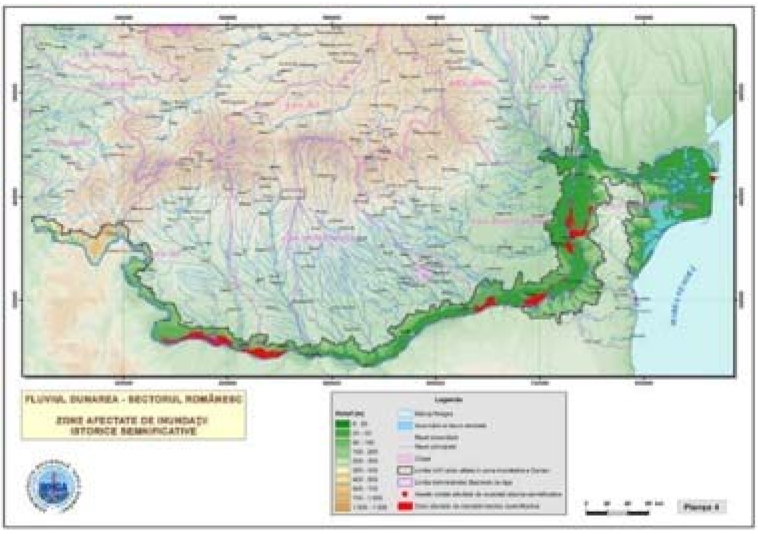

Figure 36. Danube River, Romanian Sector, Historical flooded areas. Source: Danube River, Flood Risk Management Plan, 2021.

For example, in 2006 a major flood has been recorded near the Rast town, which had an extreme impact on the whole region.

In 2006 the floods in the Rast region were severe, leading to loss of life and substantial damage to the infrastructure, agriculture, and the town itself. After the rebuilding effort Rast town was split in two, Old Rast and New Rast. Old Rast remained near the riverbank and still has a very high vulnerability to floods while New Rast has been developed to a distance of approximatively 3 km from the Old Rast to decrease the flood risk factor. Such events could be prevented with by taking the necessary precautions in the development of the area.

Agriculture

Most of the studied area has been used for agriculture, especially on the Lower Danube sector, where the former floodplain area is located.

Because of the large quantities of sediments that are brought by the river, the land is extremely fertile and during the communist period a large area was prepared for agriculture by installing different types of irrigation systems and drainage pumps.

Nowadays, the land is owned either by private owners or by associations that plant different crops according to a rotation schedule. Although a large irrigation system and drainage pumps were built in the communist era (up until 1989) the status of all the local improvements is very poor, only a very small percentage have been repaired by private interested parties.

Energy

One of the largest dams in Europe, that acts as a hydroelectrical plant is located in Romania. In 1964 a joint-venture project between the governments of Romania and Yugoslavia started to build the “Iron Gates I” hydropower plant.

After the completion of the first project, “Iron Gates II” started, in 1977, with the cooperation of the same partners, wanting to upgrade the energy production capacity of the Danube River. Nowadays the two hydropower plants are managed by Serbia and Romania.

The plants have undergone since a number of upgrades that have increased the energy output and are currently providing an important quota of the energy demand.

After the completion of both projects, one major aspect has been observed: the decrease of a very large percentage of the natural sediment flow towardsthe Danube Delta and the Black Sea.

Environment / Land use

Most of the area in the pilot area can be characterized by 3 major land uses:

- Inhabited areas, cities, and villages (human settlements).
- Agricultural areas.
- Pastures.

Along the Danube River, one of the major economic entity, there is a high percentage of establishments. In the pilot area there are several among the major cities and rural areas. Most of the settlements are distanced a few hundred meters up to a kilometer from the Danube, with the exception for those that have ports where the infrastructures have been developed up to the riverbank.

Between all the populated areas, most of the land is being used for agriculture and pastures since this area is very fertile and produces a very good yield. The land along the riverbank is currently under the administration of private owners and this hinders the incentive possibility that local authorities would have regarding the maintenance and the development of the areas.

Romania has considerable land resources; 62% of which are agricultural, 27% forest, 3.7% waters and 6.9% other uses (data referred to 2000). The agricultural and arable land per capita range between 0.6 and 0.4 ha and is significantly and unevenly spread, with the highest proportion located in the plains (80% agricultural).

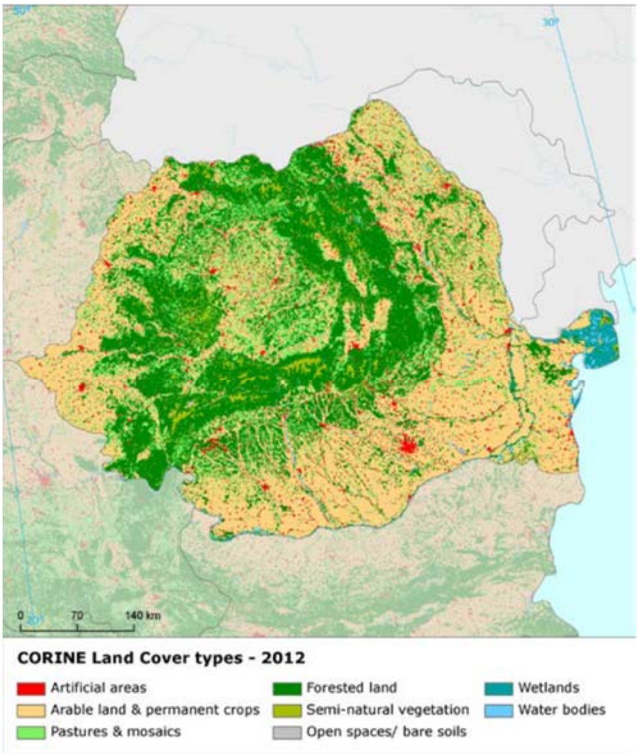

Figure 37. CORINE land cover Types. Source: GeoEcoMar, 2021.

	Artificial areas	Arable land & permanent crops	Pastures & mosaics	Forested land	Semi-natural vegetation	Open spaces / bare soils	Wetlands	Water bodies	TOTAL [hundreds ha]
Land cover 2006	**12649**	**94117**	**42199**	**75650**	**6643**	**251**	**3188**	**4048**	**238745**
Consumption of initial LC	11.8	165.5	57.4	465.5	4.4	0.6	0.1	6.6	712
Formation of new LC	125.2	46.6	10.5	464.0	0.0	0.0	54.4	11.2	712
Net Formation of LC	**113.4**	**-118.9**	**-46.9**	**-1.5**	**-4.4**	**-0.6**	**54.3**	**4.6**	**0**
Net formation as % of initial year	*0.9*	*-0.1*	*-0.1*	*0.0*	*-0.1*	*-0.2*	*1.7*	*0.1*	
Total turnover of LC	**137.1**	**212.0**	**67.9**	**929.5**	**4.4**	**0.6**	**54.5**	**17.7**	**1424**
Total turnover as % of initial year	*1.1*	*0.2*	*0.2*	*1.2*	*0.1*	*0.2*	*1.7*	*0.4*	*0.6*
Land cover 2012	**12762**	**93998**	**42152**	**75649**	**6638**	**250**	**3242**	**4053**	**238745**

Figure 38. Summary balance table 2006-2012. Source: GeoEcoMar, 2021.

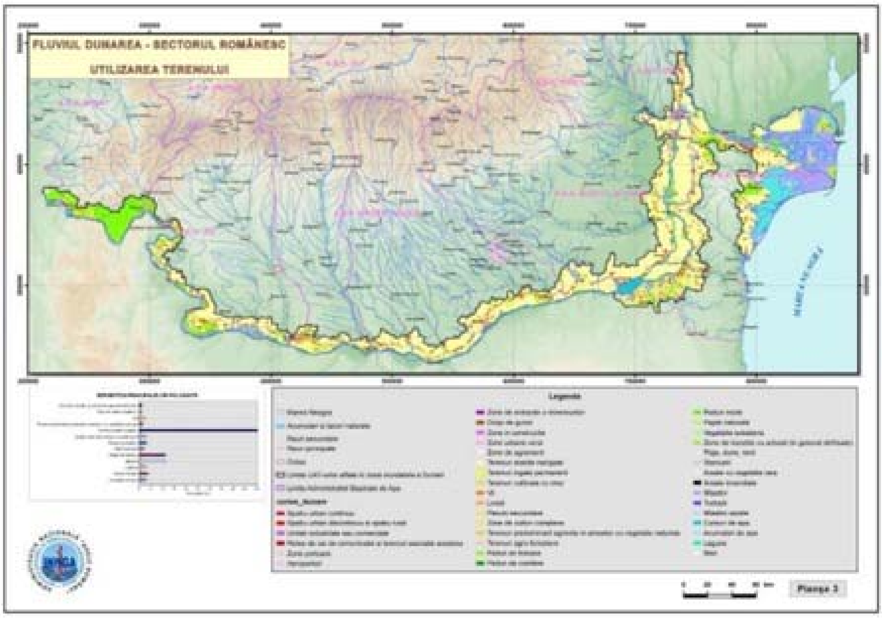

Figure 39. Danube Romanian Sector, Land use map. Source: Danube River, Flood Risk Management Plan (ANAR), 2021.

The yearly Romania's water resources (about 135 bill m^3) comprise: the Danube River (52%), inland rivers (36%), and groundwater (12%). According to the water balance, in 2017, a water volume of 6.86 bill m^3 was abstracted and used for different purposes: 16.9% for human use (drinking water), 59.5% for industry (excluding hydropower), and 23.6% for agriculture (including irrigations) (ICPDR).

In the region, along the Danube riverbanks, several Natura2000 sites can be found. These sites are strongly protected from human intervention and are strictly monitored.

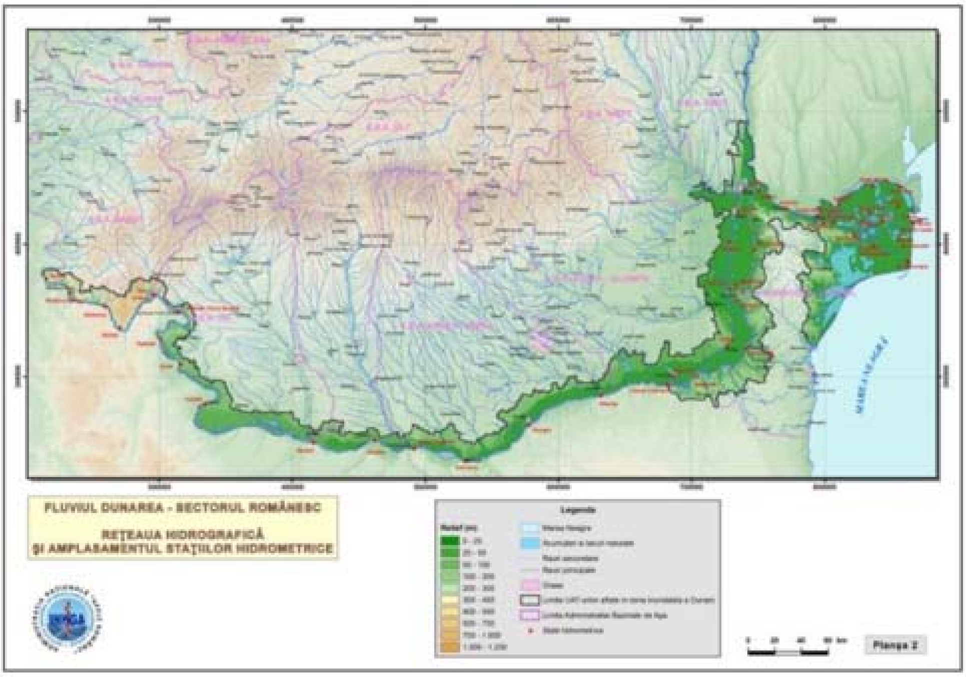

Figure 40. Danube River, Romanian Sector, Hydrographic Map. Source: Danube River, Flood Risk Management Plan, (ANAR), 2021.

Geology

The Lower Danube region is mainly characterized by newer formations, due to the high sediment influx from the Danube River. Most of the formations are young, ranging from the Holocene period (medium and inferior) that lie on the Upper Pleistocene fundament.

Since the construction of Iron Gates dams, the sediment afflux was strongly decreased, but the main source of material is still being transported by the Danube.

5.3. Challenges

Nexus-related challenges

This area has a moderate population level with strongly anthropomorphized areas that fall under different administrations.

The main issues encountered in the pilot are a combination of two major hazards, i.e., floods and riverbank erosion. Some urban areas were developed on the Danube riverbank, very close to the water, and they are very susceptible, where no engineering works to improve riverbank stability have been performed, to floods and riverbank collapse.

Considering REXUS objectives two major challenges are in discussion. The first one is the continuous exploitation of the Danube River resources at the maximum of its potential, including navigation. the second one is to implement a sustainable exploitation that could provides a lower degree of financial benefits but with the advantage of having a smaller impacts on the natural environment.

The most important actors in the region are trying to shift the balance of decision making. The agricultural associations are requesting larger quotas of water needed for irrigation, while affecting the hydropower energy production, navigation, and sediment transport especially during drought periods when the water level is low. When the water level is low also the environmental impacts on the riverbank, i.e., erosion, result evident.

Actions to meet Sustainable Development Goals

SDG targets for the pilot area are SDG number 2, 6, 7, 13, and 15.

Now, all the SDG targets are in progress in conformity with the European directives, but local data are unavailable to the public since these are ongoing projects.

On a nation level, some regulations that can affect these EU directives have been proposed by the Ministry of Environment as a national Water Law.

According to the Water Law, the strategies and national policies concerning water management are under the competence of the Ministry of Environment. The responsible for the application and control of these activities is the “Romanian Waters” National Administration through its water directorates.

The National Plan for Prevention and Flood Protection is part of national policies and constitutes a necessary tool for the national coordination and the basin correlation of investments in water management domain.

The National Strategy for Flood Risk Management adopted in December 2005 takes into consideration the following aspects and priorities:

- Preliminary estimation of the flood risk.
- Critical analysis of the existing flood defenses.
- Set the basic principles for the national strategy for flood risk management on medium and long term.
- Risk reduction in terms of vulnerability and setting the objectives for mitigation.
- Structural and non-structural measure.
- European context: directives, funds.

In the National Strategy for Flood Risk Management all local and regional conditions have been taken into consideration.

The existing legislative framework offer to the central authorities and public local administration the legal support for the prevention, protection, and preparation activities in flood risk management, i.e., the regulations regarding floods adopted in 2005.

Currently, it is necessary a strong coordination among the activities based on flood risk mitigation regulations, strategies, and policies: cost-benefit analysis; economic, social and environment impact assessment; and programs and plans for spatial planning.

5.4. Key stakeholders

The key stakeholders in the pilot area are summarised in Table 42.

Table 43. Key Stakeholders in lower Danube

n°	Institution	Department
1	Ministry of Agriculture	Governmental institution
2	Ministry of Waters and Forests	Governmental institution
3	Ministry of Transport	Governmental institution
4	Ministry of Regional Development and Tourism	Governmental institution
5	ANAR – Romanian Waters National Administration	Governmental institution
6	Lower Danube River Administration	Local administration
7	ANM – National Meteorological Administration	Governmental institution
8	Environmental Guard	Governmental institution
9	National Agency for Environmental Protection	Governmental institution
10	Local Administration	Local administration
11	County council	Local administration
12	WWF Romania	NGO
13	Associations for Fishing and Hunting	NGO

n°	Institution	Department
14	Environment NGO's	NGO
15	Energy authority	National company
16	Citizens	Local citizens
17	Farmers	Local farmers
18	Insurance companies	Private companies

The requirements vary from sector to sector but most of them are focused on improving living conditions for the local population. This includes the health, standard of life, and access to new and better-paid jobs.

5.5. Policy

Relevant policies for all Nexus domains

The principal strategy is the National Strategy for Flood Disaster Prevention and the Flood Management Plan. The short-term strategy for flood protection has the following principles:

- Sustainable development.
- Economic, social, end ecological acceptability.
- Strategic assessment for a long period.
- Simplicity and transparent aspects.
- Basin approach of the flood problem.
- Interdisciplinary approach.
- Solidarity.

The maintenance of an equilibrium among preventive, response, and post-factum measures, using the national territory plans, structural, and non-structural measures, such as intervention plans for emergency situations, is needed.

Application of best practices proposed by EU and UN Economic Commission for Europe regarding flooding preventive measures, protection and effects mitigation are under implementation.

Flood Management Plan for the short-term strategy implementation started in 2005 by integrated actions for 5 years (2010):

development of the hydrological information system and modernization of the early warning system – DESWAT Project

rehabilitation of the old flood defense hydraulic infrastructure and building new ones in areas of high risk,

Flood hazard mapping and flood management plans. The first pilot basin was Siret.

The National Plan have been finalized in the frame of the River Basin Management Plans – Flood management Section first draft, until December 2009 and have been adopted by mid-2010.

In mean time, during 2009 has been finalized mid and long-term National Strategy for Flood Risk management, which considered the need for Flood Directive implementation.

Side effect in policy implementation

The biggest conflict in the region can be observed between the local farmers and the water management entity.

As the need arises, during the drought periods, more irrigation can provide a better crops growth that can be translated in bigger financial gains. Since the Danube irrigation systems and the general framework do not allow for a bigger volume of water to be diverted for any use due to navigation and erosion complications, most of the local farmers must rely on the groundwater. Because of the large exploitation and of climate conditions, in some cases, the water level drops below the safety margin and some local communities are affected by the very low availability of drinkable water.

Some of the projects that affect the local water regime are reservoirs, deviations, and water transfers from neighbouring basin into reservoirs and levees. These types of infrastructures are the most useful instruments for water management, offering possibilities in getting regulation of different volumes during the seasons and sometimes during the year and offering flood protection or dilution in case of accidental pollution. To protect goods and human lives, on the Romanian territory hydraulic structures, composing the National System for Flood Defence, have been realized.

The works done along Danube course and in the Delta have been aimed the following main goals:

- Take off from the floods influence of the areas from the Danube floodable wetlands.
- Capitalization of the hydro-energetic potential of the river.
- Cutting short of the navigable way between the Danube and the Black Sea, through the Dunre-Marea Neagra Canal, including the possibility to catch on the cooling water for Cernavoda Nuclear Power Plant.
- The supply with drinkable and industrial water of the important localities situated on the Danube bank.

5.6. Relevant documents and Governance systems

Planning documents

- The National Strategy for Flood Risk Management on short term (Governmental Decision 1854 from 2005), which establish prevention and protection measures for flood effects mitigation for each of involved structures from central to local level.
- National Plan for Prevention and Flood Protection at Hydrographic Basin level (Governmental Decision 1309 from 2005).
- The Water Law 107 from 1996, modified and completed according to the National Strategy.
- Emergency Orders regarding safety operation of the reservoirs for aquaculture, recreation, or local importance, establishing operating conditions.
- Regulation for management of emergency situations generated by flooding, dangerous meteorological phenomena, and accidents at hydraulic structures adopted in May 2005.

Based on these regulations, considering the 2005 and 2006 floods, new flood protection plans at basin, county and local level have been approved in 2006. These plans comprise maps with level curves that bordered flooded zones by watercourses overflow and versant run-off corresponding to the maximum known discharges. In 2009 all flood protection plans have been updated with limited access. Currently, the Danube River Management Plan is being updated.

Governance systems
After several discussions with the local stakeholders that took place at an earlier date the biggest concerns and bottlenecks are:

- The lack of transparency regarding different authorizations needed for any change in the current situation.
- Very high bureaucracy.
- Lack of means and interest of the local population regarding the in-the-field situation.
- Split decision making – too many entities that have the same juridical coverage and overlapping agendas.

5.7. Basic climate and soil data

Climate: Lower Danube pilot area experiences a temperate climate, with rains along the whole year, with hot and dry summers. Compared to the other areas of the country, this area is characterized by the highest temperatures, both in the summer and in the winter, with an annual average temperature of 11.50 ºC. The pilot area has some climatic particularities due to its location in the South-West of the country being influenced by the Mediterranean climate. Its climate is characterised by droughts periods during summer, with maximum two rain periods. Average annual temperature during the interval 1991 – 2000 was 11.9ºC. The highest annual average temperature (13.20ºC) was registered in 2000, while the lowest annual average temperature (11.0ºC) was recorded in1996. The highest monthly values are recorded in July and the lowest in January. Hence, the highest monthly average value (29.10ºC) within this time interval (1991-2000), was recorded in July 1993, and the lowest monthly average value (27ºC) was recorded in January 1996. These values have been recorded at the meteorological station). Average annual amplitude is about 24.6ºC.

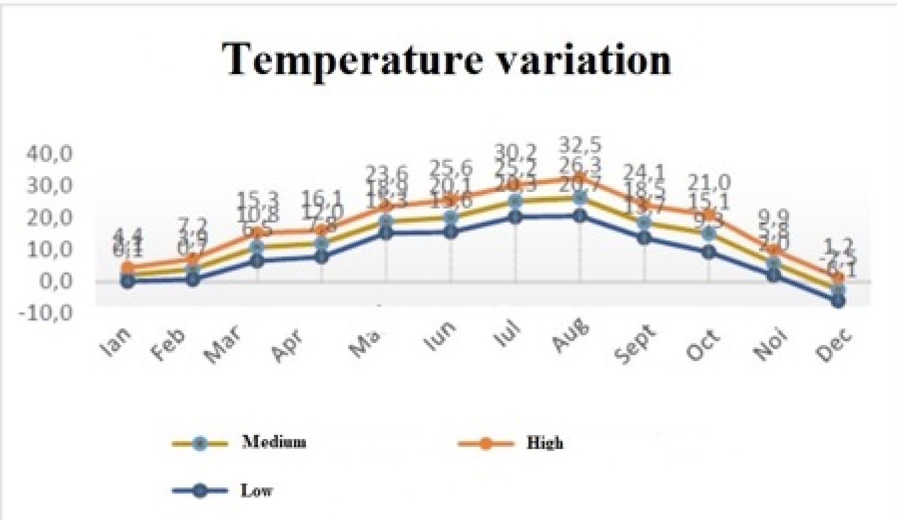

Figure 41. Variation of temperatures (°C) at Calafat meteorological station (year 2002). Source: GeoEcoMar.

The first autumn frost is usually around 7th of November and the last spring frost was at the end of March. In between these dates, there were 221 days without frost and 145 days with frost. In autumn, the frozen process happens starting between the 12th October and the 24th November. In spring the frost end between the 1st of

March and the 20th of April. Therefore, autumn (12th October - 24th November) spring (1st of March -20th of April) are possible intervals of frost. This area has the shortest period of frost in the Southern part of the country.

Considering seasons duration, in accordance with the biological steps of the plants, there is a prevalence of summer days, for more than one third of the year, being the longest summer in the country. If also the number of spring and autumn days when temperature is higher than 5ºC is considered, the result is that for this part of the country the vegetation period is almost 9 months.

Precipitations: Local data regarding the Danube region is inconsistent but we can observe a trend by looking at the general values. Yearly precipitations have an average of 637 mm which decrease in intensity from West to East, from 600 mm to 500 mm in the East Romanian Plain, to about 350 mm by seaside. In the mountainous areas precipitation can reach up to 1000-1500 mm.

5.8. Current and emerging water sources and uses

Since there are no recordings regarding the real time water usage in the target area, a general estimation has been made.

A large part of the surface and ground water in the Danube region is generated in the Upper Danube, especially in the western and southern sub-basins in Germany and Austria (Karabulut et al., 2016). For example, Austria, with 10% of the basin area, has 25% of the water provisioning capacity while, Romania, with 29% of the area, only has 17% of this capacity. Water use, on the other hand, occurs mainly in the valleys and downstream plains, shared between energy production (44%), agriculture and livestock (26%), industry (17%), and domestic water use (13%). Water availability has also important implications for navigation on the Danube River (Scholten and Rothstein, 2016). Data reveal a complex but clear connection between water levels and transport prices, impacting the volume of goods transported and other related aspects (such as the shift from large ships to a larger number of smaller ships when the water levels are low). Every 10 cm of water level decrease, the capacity utilization decrease about 0.6%, corresponding approximately to 1,700 t. This can be limited to some extent by switching to smaller ships, adapting the shape and materials of ships, or engaging in hydraulic engineering works, thereby impacting river hydro morphology.

5.9. Current and emerging land uses, major crops, and farming systems

The land in the Lower Danube Corridor has as main use the agriculture, irrigated and non-irrigated. The forests have a very poor representation in the floodplain due to the climate and of the soil composition. In the years 2006-2007 a national situation plan has been created that recorded the land use distribution, as seen in the table below (Table 44). The main destinations are: 1. Agriculture, 2. Forests, 3. Fishing, 4. Reed exploitation, 5. Energy, 6. Industry, 7. Transport, 8. Construction, 9. Community Services, 10. Residential, 11. Unused, and 12. Unidentified.

Table 44. Land distribution, main destinations. Source: Geoecomar, 2021.

An / Utilizare	2006		2007	
	TOTAL (Ha)	%	TOTAL (Ha)	%
1. Agricultura	442986	70.88	442784	70.85
2. Silvicultura	63024	10.08	64640	10.34
3. Piscicultura	22018	3.52	22018	3.52
4. Exploatare Stuf	2020	0.32	2020	0.32
5. Energergie	808	0.13	808	0.13
6. Ind. si Prelucrare	404	0.06	404	0.06
7. Transport	43834	7.01	42218	6.76
8. Constructii	3232	0.52	3232	0.52
9. Serv. Comunitare	2828	0.45	2828	0.45
10. Rezidential	8484	1.36	9292	1.49
11. Neutilizat	29290	4.69	33532	5.37
12. Neidentificat	6060	0.97	1212	0.19
TOTAL	624988	100	624988	100

Regarding agriculture land use we can observe the different crops share in Figure 42.

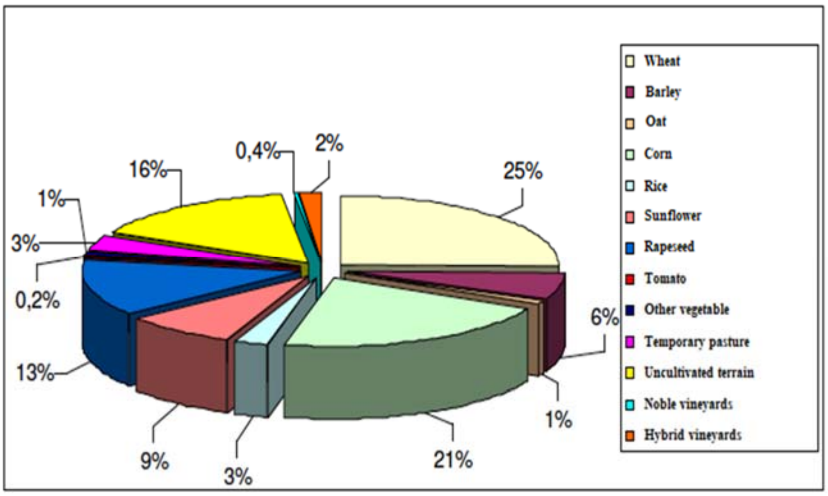

Figure 42. Specific land use. Source: Geoecomar, 2021.

5.10. Energy generating infrastructure

Iron Gate I. Hydroelectric Power Station is the largest dam on the Danube River and one of the largest hydropower plants in Europe. It is located on the Iron Gate gorge, between Romania and Serbia.

The Romanian side of the power station produces approximately 5.24 TWh annually, while the Serbian side of the power station produces 5.65 TWh. The discrepancy in power output between the two halves is due to the generating equipment. While Romania's equipment is newer and thus more efficient (thereby generating more power), it is proving more unreliable, resulting in increased downtime for maintenance/repairs, and consequently lower annual power output overall.

Iron Gate II. It is a large dam on the Danube River, between Romania and Serbia.

The dam is built at the Danube's 853 km (530 mi). The project started in 1977 as a joint venture between the governments of Romania and Yugoslavia for the construction of large dam on the Danube River which would serve both countries. At the time of completion in 1984 the dam had 16 units generating a total of 432 MW, divided equally between the two countries at 216 MW each.

The Romanian part of the power station was modernized, and another 2 units were installed. The nominal capacity of the 10 units was increased from 27 MW to 32 MW thus having an installed capacity of 321 MW. The Romanian side of the power station produces approximately 1.3 TWh per year.

The Serbian part of the power station currently has 10 units with a nominal capacity of 27 MW each and a total power generation capacity of 270 MW. The Serbian side of the power station produces approximately 1.31 TWh per year. At the celebration ceremony for the 27 years since the power station's deployment it was announced that production in 2011 reached 1.46 TWh despite bad weather conditions. Current total power generation capacity of the power station is 591 MW.

In 2011, a border checkpoint between Serbia and Romania for cars and light cargo vehicles was open. As of 2018 the Serbian side of the power plant is in the process of revitalization. When finished, the power of each aggregate will be lifted from 27 to 32 MW. (Wikipedia).

5.11. Demographic data at pilot scale

From an administrative point of view, the Danube riverbank area includes 139 administrative territorial units from the counties of Brăila, Constanţa, Galaţi, Tulcea (belonging to South-East development regions), Călărasi, Giurgiu, Ialomiţa, Teleorman (belonging to South-Muntenia development regions), Dolj, Mehedinti, Olt (belonging to South-West Oltenia development regions), and Caras-Severin (belonging to West development regions).

Whithin the 139 administrative territorial units there are 341 localities, of which 11 are municipalities, 10 are cities (whose composition includes in addition to the localities of residence and a number of 18 villages) and 117 communes (consisting in addition to the localities of residence and 185 villages).

The total population of the 139 territorial administrative units along the Danube River was, according to the 2011 census, 1,292,115 inhabitants (representing 6.4% of the total population of Romania), of which 886,839 inhabitants in urban areas (69%) and 405,276 inhabitants in rural areas (31%).

5.12. Major economic activities / industries, employment

The main economic activity of the Danube River area is represented by agricultural activities, such as land cultivation and animal farming.

Industrial activities are concentrated mainly near urban areas and are represented by chemical industry, metal production and processing, paper and wood processing industry, waste and wastewater management, electricity production, food industry. Trade is another important branch of the basin district, being mainly represented by shops, restaurants, banks, medical laboratories.

Fluvial transport is an important branch being provided by the most important waterway in Romania. The main river ports in Romania, in this sector are: Orsova, Drobeta-Turnu Severin, Calafat, Corabia, Turnu Magurele, Zimnicea, Giurgiu, Oltenita, Calarasi, and Cernavoda. The river-sea ports - Galaţi, Brăila, Tulcea - are inland ports with a long tradition, located at the intersection of the two types of waterways, sea and river. There are two hydrotechnical facilities in operation on the Romanian sector of the Danube: The Iron Gates I and the Iron Gates II, constructed both for the production of hydroelectric energy and for the easing of navigation conditions.

5.13. Organizational infrastructure, Innovation capacities and Data

The existing road and railway infrastructure in the Danube River area occupy approximately the 1% of the total area of the administrative territorial units bordering the Danube River.

Road networks have the largest share (41% of the total length of road infrastructure), followed by communal roads (20% of the total length of road infrastructure), national roads (19% of the total length of road infrastructure), county roads (15% of the total length of road infrastructure), European roads (4% of the total length of road infrastructure), and the A2 Bucharest-Constanţa "Autostrada Soarelui" highway (1% of the total length of road infrastructure). The railway network represents about 12% of the total length of the communication routes and includes portions of the highways 700 Bucharest North – Galaţi, 800 Bucharest North – Mangalia and 900 Jimbolia – Bucharest North.

The region is served by the "Danube Delta" Tulcea airport located 15 km from Tulcea and, in Fetesti, there is 86 Fetesti Air Base with military regime.

The naval transport is made on a length of 1,691 km, of which 1,075 km the international navigable Danube, 524 km the navigable arms of the Danube, and 92 km artificial waterways (Danube - Black Sea and White Gate - Năvodari canals).

Regarding the Danube crossing points on the Romanian sector, they are: Giurgiu - Ruse bridge, Romania - Bulgaria border crossing point (road and railway), Fetesti - Cernavoda bridges (road and railway), Calafat - Vidin bridge (road and railway), the Giurgeni - Vadul Oii bridge (road) and the Iron Gates I dam (road), border crossing point between Romania and Serbia.

Another way of crossing the Danube is by crossing the ferry: in Moldova Veche, Sviniţa, and Orsova; between Romania and the Republic of Serbia, in Calafat, Bechet, Turnu Măgurele, Giurgiu, Olteniţa, and Călărasi; between Romania and the Republic of Bulgaria a: in Brăila, Galaţi, and Tulcea.

5.14. EU &/or national projects where the pilot was an important test case

Danube Sediment project – Danube Transnational Programme, Interreg (2017-2019). The main objectives of the projects were to establish the balance of sediments in the Danube basin, to identify the surplus and deficit sectors, to assess the level of degradation of the riverbed, to face the sediment problems in flood risk management, to improve the drinking water production, hydropower production, navigation, and quality water ecology, as well as improving knowledge for a better understanding of sediment transport and morpho-dynamic processes in the Danube River.

DANUBE FLOODPLAIN project. The main objective was to reduce the risk of flooding through floodplain restoration along the Danube and other rivers in the Danube basin.

The DANICE project focused on ice transport research on the Danube River and flood management caused by ice.

The LAREDAR project focuses on hazard and risk mapping, planning management of risks of lakes and accumulations in the Danube basin.

Coca-Cola - World Wilde Fund "Partnership for a Living Danube". Coca-Cola (TCCC) and the World-Wide Fund for Nature (WWF) work in within a seven-year partnership to restore vital wetlands and floodplains along the Danube River and its tributaries.

5.14.1. References

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