DEPARTMENT OF INTERNATIONAL AND EUROPEAN ECONOMIC STUDIES

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

A System Innovation Approach for Science-Stakeholder Interface: Theory and Application to Water-Land-Food-Energy Nexus

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Working Paper Series

21-08

July 2021

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KEYWORDS: Water-Food-Energy Nexus; Thessaly, Greece; Systems Innovation Approach; scientific and stakeholder collaboration; framework development.

ABSTRACT

The Water-Food-Energy Nexus can support a general model of sustainable development, balancing resources with increasing economic/productive expectations, as e.g. in agriculture. We synthesize lessons from Greece's practical and research experience, identify knowledge and application gaps, and propose a novel conceptual framework to tackle these challenges. Thessaly (Central Greece), the country's driest region and largest agricultural supplier is used as an example. The area faces a number of water quantity and quality issues, ambitious production-economic objectives, continuous (historically) drought and flood events, conflicts, administrative and economic issues, under serious climate change impacts. A detailed assessment of the current situation is carried out, covering all these aspects, for the first time in an integrated way. Collaboration gaps among different stakeholders are identified as the biggest impediment to socially acceptable actions. For the first time, to our knowledge, the Nexus is set as a keystone to develop a novel framework to reverse the situation and achieve sustainable project planning under commonly acceptable long-run visions. The proposed framework is based on Systems' Theory, innovative principles, uses a multi-disciplinary platform to bring together all relevant key stakeholders, provides scientific support and commitment, and makes use of technological advances for the systems' improvement.

1. INTRODUCTION

Water-Food-Energy Nexus is imposing new challenges to research and modelling, as a result of the integration and complexity of these fields, while sharing same concerns and goals. According to the System's Theory, the nexus is defined as a centre point, or a center of various connections, similarly with the way that Water-Food-Energy jointly considered as pillars of environmental security, economic prosperity and social equity (Bazilian et al., 2011). The international experience on this Nexus indicates that research focuses on these pillars mostly independently from different perspectives, because each one of its components is a large and complex field itself (WBCSD, 2018). For example, researchers-stakeholders within the water resources management field see food and energy systems as users of resources, the food perspective sees water and energy as inputs, while the energy perspective sees water as input and food as the output of the procedure. Such approaches divide the system and lead policies to sub-optimal solutions (optimal only for one sub-system). However, analysing the nexus and its components as a single system can lead to globally optimum and highly efficient solutions and policies. The impediment to such approaches is the limited understanding of the nexus concept and the lack of systemic thinking from the public (FAO, 2013). So, training and education of key stakeholders to build on commonly understandable bases is an essential starting point.

Greece has been slow to examine the Nexus based on systems analysis, with the exception of the recent studies of Laspidou et al. In 2018 they enriched the Water-Food-Energy nexus with the land use and climate components, and argued about the interlinkages of these five elements, while a year later they created a scoring system for these interlinkages (Laspidou et al., 2019a). Laspidou et al. (2019b) presented a System Dynamics Model (SDM) to establish and quantify the interlinkages among these five Nexus dimensions for Greece, using thematic models which produced forecasted trends up to 2050 for various climatic scenarios. Nexus studies on Greek agricultural catchments are very limited, given the difficulties in data collection and stakeholder cooperation (Psomas et al., 2018).

In order to achieve the systemic analysis of the Nexus, and provide globally optimum solutions, the international literature increasingly proposes the co-existence of two parallel procedures (Alamanos et al., 2021a; Albrecht et al., 2018; Endo et al., 2020):

- The science; to enhance the understanding of interactions within the nexus, support its systemic approach, and critically form models aiming to globally optimum solutions,
- A proper stakeholder analysis and engagement; to collaborate, co-design future visions and ensure a healthy two-way feedback.

Both procedures must be based on the principles of transparency and openness, fairness, equality and respect, efficiency, collegiality and tolerance, common goal-visions, and commitment, under the purpose of the community’s and individuals’ good (Alamanos et al., 2021a). The analysis of Laspidou et al. (2020) notes that to move from a general nexus thinking to an operational nexus concept, it is important to focus on data availability and scale. Using a regional scale will require such data, while stakeholder analysis is a key to achieve sustainability through the Nexus. However, the international experience has limited, and the Greek literature has no examples, of stakeholder-based approaches, aiming to communicate a systemic Nexus thinking, and using it as a basis for sustainable planning.

The main goal of this study is to address this research question, using the Water District (WD) of Thessaly (regional scale) and its key stakeholders in a series of meetings, by demonstrating a combination of two novel frameworks for their analysis: The Framework for Integrated Land and Landscape Management (FILLM) and the Systems Innovation Approach (SIA). FILLM is used as a conceptual model for understanding the Nexus components as a single system and SIA is used to unite the different interests of the region under a common vision for the future. This effort is part of an ongoing project–experiment designed to address realistic situations, problems, different interests, and policy "on the making", in order to achieve acceptable and immediately applicable solutions for the Nexus' benefit.

2. STUDY AREA

The Nexus in this study is considered according to the approach of Laspidou et al. (2018) namely, Water-Land-Climate-Food-Energy components. The study area is described in the following sections.

Background

The WD of Thessaly covers a total area of 13377 km² in Central Greece. Although the region accounts only for the 5% of the national GDP (7,853 out of 155,780 million€ in 2018), it is the second biggest agricultural producer in the country (935 million€ of Gross-Value-Added from agriculture) (ELSTAT, 2021). Subsequently, it is the largest water consumer of the country and one of its driest areas with an average precipitation of 600-800mm/yr and average annual temperature of 16-17°C. This leads to great losses because of evapotranspiration, almost 60% of the total average annual precipitation (Koutsoyiannis et al., 2008). Figure 1 shows the main land uses.

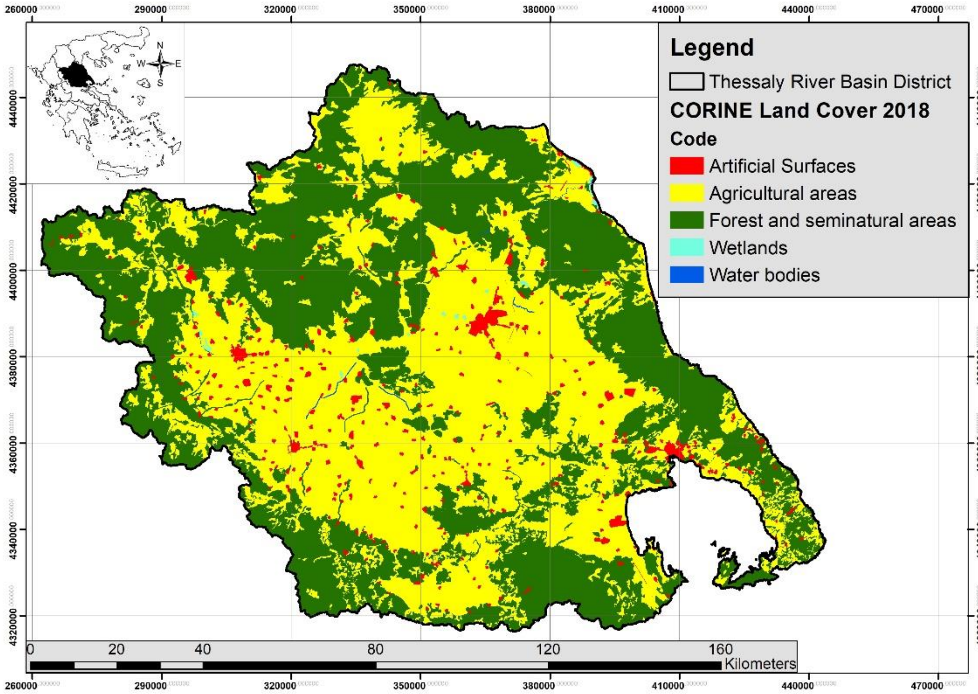

Figure 1. WD of Thessaly, and main land uses.

Agriculture is the biggest pressure on water availability and pollution, while its economic management and regulatory control is challenging. Wheat and other cereals (except maize) are the main crops, followed by cotton, and tree-crops.

Water Deficits

Irrigation uses around 92% of the total water consumption, urban water use 6.63%, livestock 0.91%, and industry 0.62% according to the River Basin Management Plans (RBMPs) of the Greek Ministry of Environment and Climate Change (GMECC, 2017). The annual hydrological balance of the WD is constantly negative, leading to the overexploitation of the non-renewable groundwater stocks (Koutsoyiannis et al., 2008; Alamanos et al., 2019). The highly-demanding irrigation is covered by surface (24%) and by groundwater resources (76%) through legal or illegal and unregistered wells (GMECC, 2017). Urban water demand is covered only from groundwater. Subsidies and product prices have expanded areas of water-consuming crops. Hence the intensified water abstraction from every surface Water Body (WB), while the 33% of the groundwater resources are historically in “bad status” – overexploited.

Qualitative degradation

Livestock units are dominant regarding the point pollution concentrations (74% of the total BOD, 60.4% of Nitrogen, and 62% of Phosphorous), followed by Wastewater-Treatment Plants, discharges of sewerage networks, large hotels, industrial units, and aquaculture. Unorganised pasture and fertilisers and pesticides, are the major non-point pollution sources. All these types of pressures are uniformly distributed in the WD, while farming plays the dominant role. Figure 2 is indicative of the quantitative, qualitative (chemical/ecological) and overall degradation of the WD, according to the RBMPs. The local stakeholders and authorities, as we analyse below, believe that the situation is much worse.

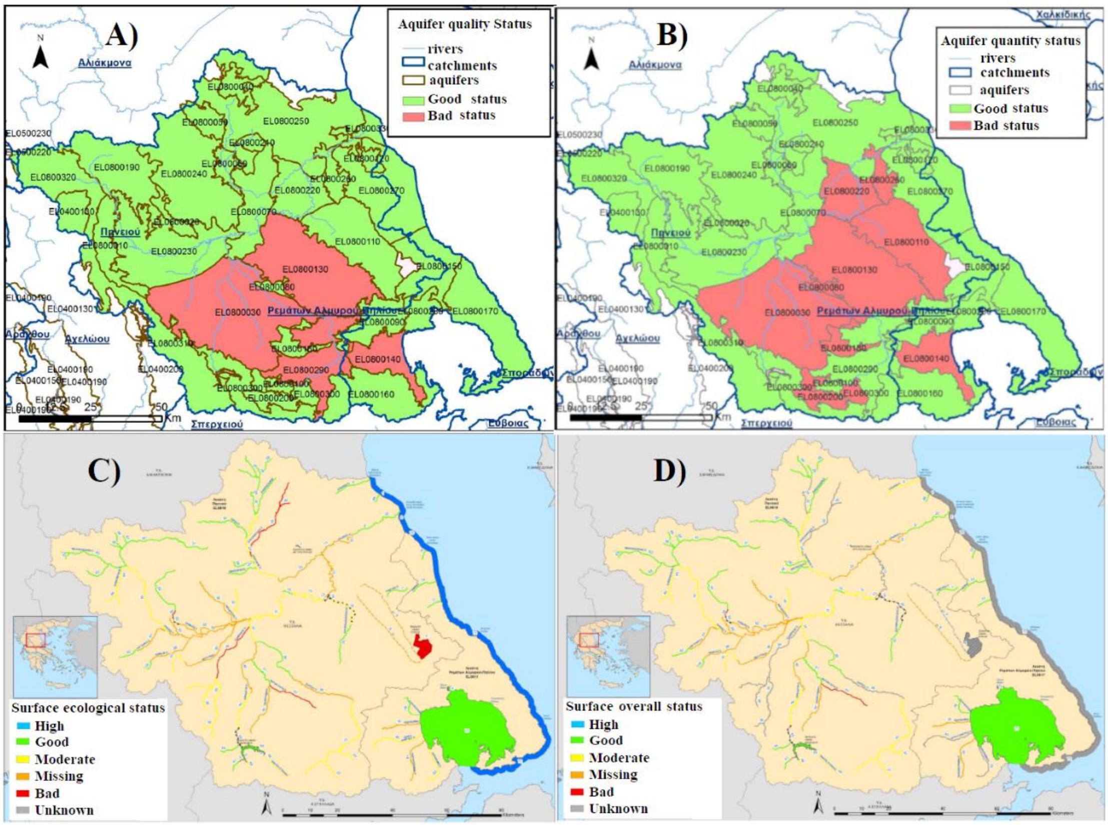

Figure 2. A) qualitative, and B) quantitative status of groundwater WBs. C) ecological and D) overall status of surface WBs (Adapted from GMECC, 2017).

According to the GMECC’s assessment, the WBs status is:

- Ecological status of river WBs: Unknown-1.4%, Missing-16.67%, Bad-4.17%, Medium-22.22%, Good-55.5%
- Chemical status of river WBs: Below good-22.22%, Good-77.78%

- Ecological and chemical status of lake WBs: 3 lakes, one of Good, one of Bad and one of Unknown Status
- Quantitative status of groundwater WBs: Bad-30.3%, Good-69,7%
- Chemical status of groundwater WBs: Bad -12.1%, Good-87,9%

Administrative and Economic challenges

The Greek Committee for Environment coordinates the related policies and the programs of measures in cooperation with the Prefecture of Thessaly. The Agricultural Agency of Land Reclamation (AALR) is responsible for the agricultural water management, the actions in local level are coordinated by the Local Agencies of Land Reclamation (LALR). The other water uses are mainly responsibilities of the Water Utilities. LARLs rely on farmers' payments for irrigation, which are based on the cultivated area (e.g. €/km^2). LARLs are facing high debts, farmers state that they do not even know how much water they consume, but when there is a shortage they consider the other farmers as responsible, and they open private (legal or not) wells (Mylopoulos & Fafoutis, 2014). The situation creates huge welfare losses to the LALRs and also environmental degradation.

The concept of the 'full cost recovery' according to the Water Framework Directive (WFD) is far from achievable, since only a small part of the monetary cost is being recovered, while natural resource and environmental costs are unknown concepts (Alamanos et al., 2020b; 2021b).

Currently, there is no infrastructure or policy actions to change the economic management of agriculture or support monitoring. LARLs lack of basic data (many cases of unknown status), personnel, and complete understanding of their responsibilities, while the water efficiency is low (irrigation with open channels and sprinklers) (Alamanos et al., 2020a). Production expectations are increasing, following the markets' trends and the subsidies, however not all products are exploited by the local communities. There is no integrated or central planning on water-land-food production issues and the inefficient management creates high energy (and production and environmental) costs. Thus, the 'nexus' case of Thessaly is very challenging. Furthermore, the region suffers from continuous extreme phenomena, as the next two sections explain.

Droughts

Several indices have been proposed to describe the drought intensity and duration or spatial distribution, based on historical data (time-series observations) (Tsakiris et al., 2007). The GMECC (2014) followed a modified approach of the Water Exploitation Index (WEI) to express the situation of Thessaly, which indicates a "severe water-stress" status. The WEI of the central part of Thessaly was found 49% (2014), while the region historically suffers from droughts (Kanellou et al., 2008; Loukas & Vasiliades, 2004; Tigkas, 2008). Loukas et al. (2008) proved that drought severity, duration and intensity increased, and spatially extended droughts would be expected in future, indicating the necessity of mitigation and adaptation actions.

Floods

It is known that the plain of Thessaly suffered from floods since antiquity, when several structures had been built to control Pinios river 2500 ago. The WD is continuously affected by flood events and has attracted the interest of many scholars: Psomiadis et al. (2019) applied remote sensing to observe flash floods, define risk zones and estimate damages. (Papaioannou et al., 2018; 2021) combined hydrological and hydraulic methods to guide the implementation of the Flood Directive in Greece, using also case studies from Thessaly. Bathrellos et al. (2018) analysed the spatiotemporal flood event distribution and its severity based on the associated damages. Many areas in Thessaly that are historically affected by floods are still being damaged today. The lack of organised central and local planning, and wildfires have been identified as the major causes (Batelis & Nalbantis, 2014). Thessaly is the most vulnerable WD of Greece, and the flood-risk zones cover the 31.2% of its area (GMECC, 2017).

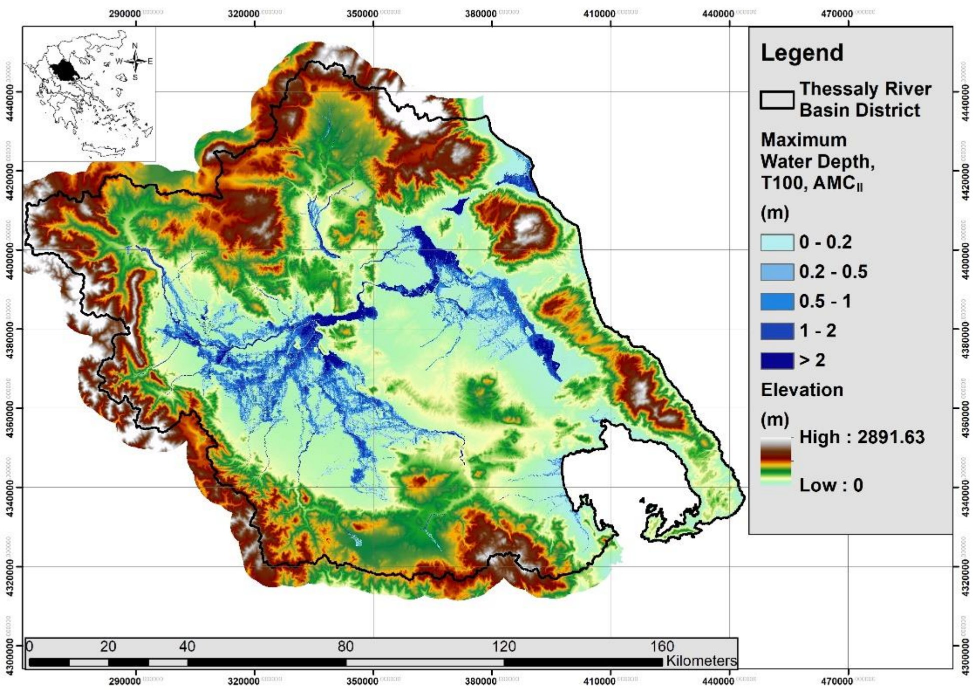

Figure 3. Indicative results of 2-D flood (T=100) simulations for Thessaly (Adapted from: Papaioannou et al., 2021).

<u>Impacts of climate change</u>

Changes of the future climate will affect the parameters of the hydrological cycle and the human activities. Climate projections refer to increased temperatures and reduced rainfalls. This will reduce the available water supply, since the evaporation losses will be higher, while surface runoff and groundwater recharge will be reduced (Mimikou et al., 2000). The water demand will increase (e.g. more irrigation water will be needed to cover driest conditions), hence the annual water balances will become more deficit. The Bank of Greece (2011) studied the climate change’s impacts on the increased energy demand (electricity, cooling and heating), general ecosystems degradation (soil, erosion, biodiversity, built environment, etc.), and related activities (fishing, tourism, leisure), and on transport, health, mining, etc. (describing actually a Nexus problem). Moreover, disasters due to extreme phenomena are expected to occur more frequently (Loukas et al., 2008). Exactly these situations have been noted in Thessaly by the local-scale studies of (Alamanos et al., 2018; 2019; Sidiropoulos et

al., 2019) prove that water quantity-quality degradation are connected for surface and groundwater resources.
International literature highlights the importance of a more efficient water management, especially in agriculture, as the achievement of good-quality food is necessary, and the integration of the socio-economic impacts (production, welfare losses and increased production costs) must be considered (Alcamo et al., 2007; Calzadilla et al., 2014; McDonald & Girvetz, 2013). Several studies in Thessaly show that the situation can still be reversed, and prove that water resources are more affected by human exploitation and management, than by climate change (Loukas et al., 2015; Tzabiras et al., 2016; Mylopoulos et al., 2017).
A take-away message from the above is that a more reasonable management aiming to water-use efficiency can still provide sustainable solutions. However, this will require a cooperative action and initiative.

3. METHODOLOGY: SYSTEMS INNOVATIONS AS A NEXUS APPROACH

Our research team participates in a project for integrated and sustainable planning in Thessaly, through understanding and co-designing solutions with key-stakeholders, providing continuous scientific support and technological solutions. For the first time, to our knowledge, the Nexus is used for the development of a framework to communicate the above challenges as functions of a single system, according to the Systems Theory. The FILLM is used for that purpose, with the simple goal to promote the "thinking out of the borehole" to the locals, enlarging their field of understanding towards cause-effect relations and integrated catchment management. Thus, water-land-food-energy-economy can be coordinated to find globally optimum solutions, avoiding "one-sided" management. Alamanos et al. (2021a) analysed FILLM's structure and toolkits, so in this study we will briefly mention that its central idea is to:

- understand the nexus components (air-atmosphere-land-soil-water-energy-economy) and their interactions or cause-effect relations (*becoming conscious*),
- *model* them with environmental (engineering models) which will provide a detailed catchment and WB characterisation, assess and optimize the different measures, and support the decision-making process,
- scientific and committed *stakeholder analysis* (parallel process) with continuous feedback for the decision-making (co-design common long-run visions) and measures' implementation (see next section), and
- continuous *progress tracking* (inspection and re-feeding the described loop).

This framework was firstly proposed in Ireland in the end of 2020 and this is its first application in Greece, where the stakeholders have well-receipted it so far.

For the stakeholder analysis-engagement, the description of the study area (section 2) is an essential starting point for the living labs that will follow, based on the "Systems Innovation Approach" (SIA). Systems innovation is a conceptual framework for stakeholder analysis, defined as an "interconnected set of innovations, where each influences the other, with innovation both in the parts of the system and in the ways in which they interconnect" (Mulgan & Leadbeater, 2013). SIA reflects a fundamental change in the way that the creation of knowledge is perceived and endorsed. It shifts attention away from technological inventions and research, towards the whole process of innovation, where research is only one component. This framework sets the basis for future developments of Nexus problems, where technological solutions are not sufficient and the collaboration of the key stakeholders is required.

The foundations of SIA are lying on developing the suitable setting for unfolding the stakeholders' perspectives seeking to understand the challenge in a holistic manner. Agreeing on the problems understanding and the Nexus' components interactions, paves the way to create integrated solutions. In this project, we use a series of monthly meetings with 27 key-stakeholders of the WD (representatives from the government, local authorities, experts and experienced professionals, start-ups and technological solutions, agricultural co-operations and local agencies), ensuring scientific support, analysis and democratic feedback for the design of commonly accepted actions for a sustainable future (Table 1).

Table 1. The stages of the SIA process.

Stating the problem and challenges from an academic point of view based on the literature.
The stakeholder management process consists of two steps: stakeholder analysis and engagement. • Stakeholder analysis seeks the identification of the desirable stakeholder groups, their behaviours, initial preferences and needs as well as the characterization of the relationships that govern these groups. Tools used for this phase are the "stakeholder mapping" tool, which helps rating the stakeholders on two or three key attributes and then to see the differences and potential synergies or conflictive relationships; and the "Stakeholder universe" tool, which can expose potential connections and patterns of flows of knowledge and resources which, in return, can be seen as flows of power (De Vicente Lopez & Matti, 2016). • Stakeholder engagement reflects the method we will use to bring the stakeholders together as well as the stage at which all groups will be integrated in the process. Based on the stakeholder analysis results, stakeholders will either be invited to form the core stakeholder group that will participate in the living labs or will be considered at latent based on their preliminary interest, relevance, and expertise in the field.
After gathering representatives from the stakeholder groups as described above, they actively participate in structured workshops, seeking to unravel the local challenges from a number of perspectives (environmental, technological, policy, economic and social). One of the tools used at this stage are the "pentagonal problem", which helps the individuals nail down the problem into the different components. The goal of this stage is to: • unfold hidden reasons and challenges that cannot be found in the literature, • unblock the process of deep listening, i.e. the process of listening to learn. The latter outcome is essential to proceed to the next phases of SIA; the participants need to be able to understand the position of the other parties and work towards a common good.
Next, the Multi-level perspective (MLP) is performed as an analytical approach to outline how innovation is created and how to achieve the transition in socio-technical systems. MLP decomposes the system of interest into three levels: macro (landscape), meso (regimes) and micro (niches of innovation). The landscape indicates exogenous, long-term and independent trends and major crises, e.g. climate change, urbanisation, unexpected events etc. The landscape can create tension affecting significantly the other two levels. Regimes comprise of stakeholders in powerful positions, who seek to maintain the status quo, showing the dimensions around which the system is organised, such as regulations, institutions (political, financial, social...), user behaviours and cultural values. Finally, the niches of innovation can be perceived as the place where radical inventions and ideas are created, such as Universities, R&D departments and the military. An indicative tool used in this phase is the "context map", which helps to comprehend how the system around the problem works and to identify opportunities or significant threats (De Vicente Lopez & Matti, 2016).
The trajectories of change are sought to unravel how the system evolves and where innovation comes from in order to achieve the co-developed vision. This phase gives the opportunity to the stakeholders to co-develop the necessary trade-offs that need to be made. For instance, the "ocean of opportunities" tool helps interpreting the sources of resistance and resilience to changes in the system and the distance

of alternatives that co-evolve simultaneously in different trajectories, while the "future radars" which helps the optimisation of the co-decided actions under the different scenarios using time frames.

Stakeholder co-development of the trajectories of change can offer validity to national and sectoral interpretations and reveal important uncertainties or deficiencies. Pecl et al. (2019) argue that engaging the public on scientific issues may possibly contribute to changes in community knowledge, attitudes, and behaviours. This approach seeks to ensure the commitment of the stakeholders in the co-developed solutions, testing the assumption that the sense of "belonging" and "co-developing" will lead to behavioural change in order to best manage the components of Figure 5: Balancing all the components of supply and demand (systems and sub-systems) will bring sustainability – while the proper response (minimizing failures and recovering timely) will enhance the systems resilience. Strong policy instruments and finance, as well as the necessary educational bases will provide the tools and the achievement towards sustainability and resilience. This is the overall goal of the discussions process, to reach to commonly acceptable and desirable solutions for such a multi-level management.

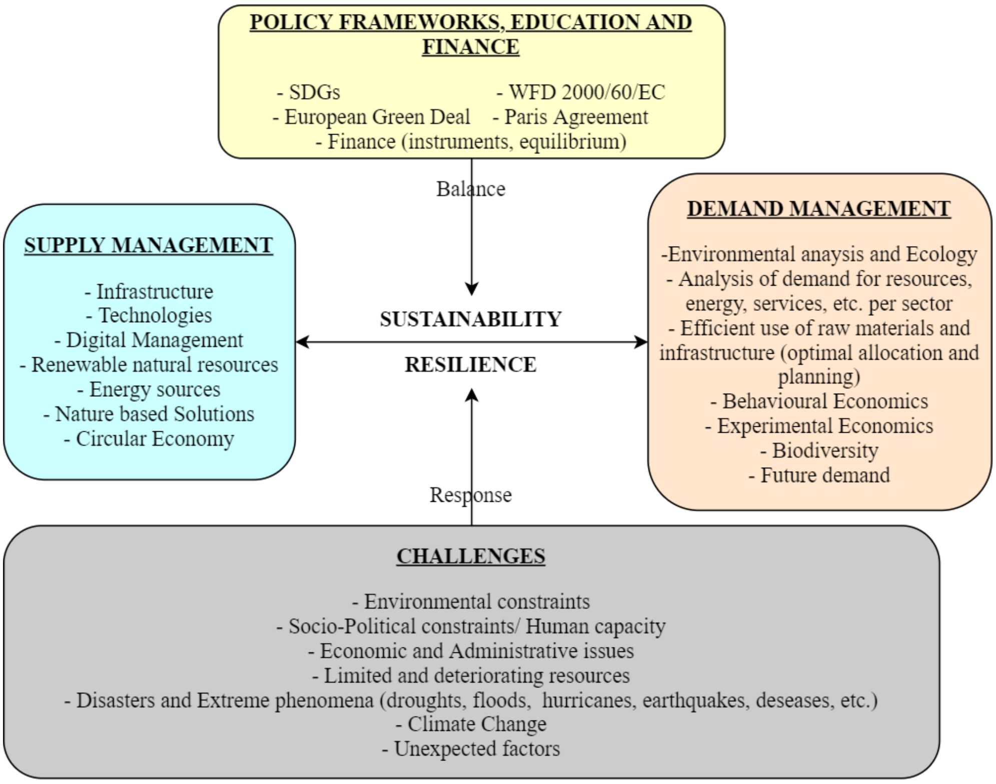

Figure 4. The most common components of the supply and demand sides, which must be balanced to achieve sustainability (environmental, economic, etc.); the challenges that our systems are facing trying to become more resilient. The policy-finance frameworks and education will ensure this managerial approach.

The process of SIA is followed by guiding the discussion during the meetings process, and the tools mentioned can be applied through the use of visual collaboration platforms, such as MIRO[1], that enables the efficient and effective intuitive collaboration of the stakeholders.

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[1] *Miro(2020). Online Whiteboard for Visual Collaboration*.

4. PRIMARY RESULTS AND FUTURE STEPS

Following the process of Table 2 each stage is accomplished through monthly workshops. Due to Covid-19 restrictions the meetings are held on Zoom, and MIRO software is used for the analysis. Each stage is enriched and supported by a variety of tools based on the needs of each workshop and the specificalities of the living lab (what are their interests, needs, conflict points etc).

Table 2. Timeline of the Living Labs.

March 2021	**April 2021**	**May 2021**	**June 2021**
Goals of these living labs and introduction to the challenge	Understanding the challenge of Climate Change in terms of water usage	Understanding various stakeholders' perspectives	Understanding and validating various policy measures-actions
July 2021	**August 2021**	**September 2021**	**October 2021**
Understanding the implemented projects and their results	-	Understanding what went wrong in the past	Macro-level perspective
November 2021	**December 2021**	**January 2022**	**February 2022**
Meso-level perspective	Micro-level perspective	Vision development	Trajectories of change
March 2022	**April 2022**	**May 2022**	**June 2022**
Developing the different scenarios	Ideation of the suggested trajectories opportunities	Guiding solutions step by step from the future	Co-creation of the Socio-technical roadmap

During our first workshop we asked the participants to introduce themselves and their work after presenting them the challenge of water scarcity in the region of Thessaly and the goals and desired outcomes of this project. The first phase of SIA started in our second meeting, when the participants tried to unravel the challenge taking into consideration the policy, environmental, social, economic and technological angles of this challenge, as presented in Figure 5a. This tool enabled us to define the problem getting a common ground for future discussions. In our case, most of the participants seem to understand the gravity and the depth of the challenge and agree in most of the different components and details raised during the workshop. The FILLM concept was used to highlight the importance of a "whole-of-environment" (sub-sustem of Figure 5), hence Nexus approach, outlining the fundamental principles mentioned in the methodology section, and explaining them with examples. This stage sets the bases for approaching complex Nexus problems and thinking thus in a broader systemic way (with all the environmental, social, and economic sub-systems). The participants recognized the beneficial elements of this concept and note that the main impediments in Thessaly are political, regulatory, and education related. More specifically, the opinions converge on the problematic limit-setting of each Body, and the inability to plan for the long-run due to the lack of consistency among different governments. Next, the participants stated the biggest challenges (according to the ‘pentagonal tool’ of Figure 5a). There is an understanding of the magnitude of the problems, perceived solidly as a Nexus problem with intense socio-political aspects. Again, opinions converge and issues of education-information, individual political interests, lack of long-term vision, planning, practical implementation, and lack of commitment were named.

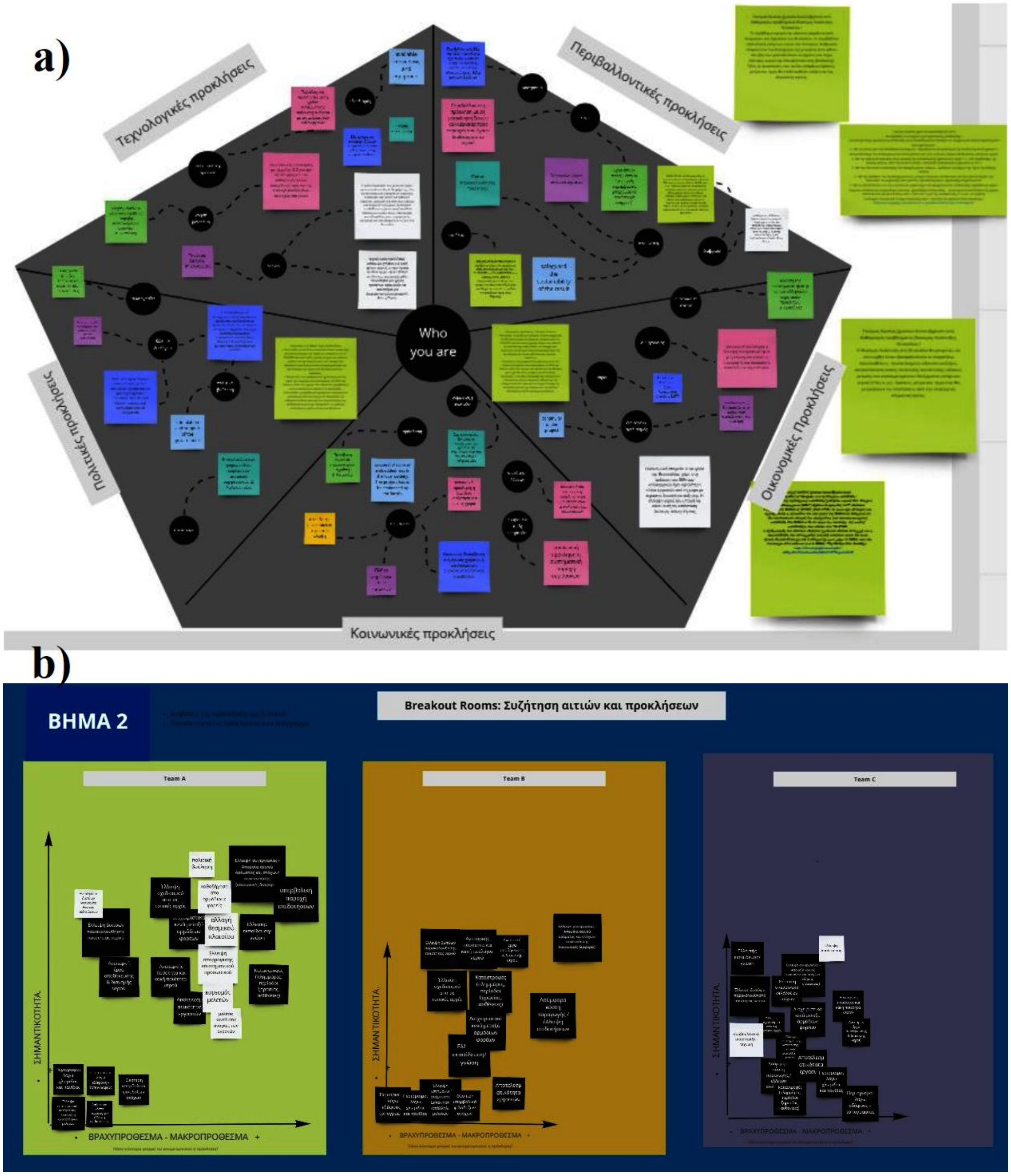

Figure 5. a) The Pentagonal problem. It is indicatively showing how the participants simultaneously described the: Environmental, Technological, Economic, Political and Social challenges they feel to face, by putting a note-description in the respective section of the pentagon. More explanatory notes can be added, as well as certain connections to indicate agreements and links between observations. b) Importance - Timeframe matrix. This is indicatively showing how the participants evaluated the different challenges (black post-its) regarding their severity (y-axis) and the time-frame needed to address them (x-axis). The figures are in Greek, as the exercises were elaborated in Greek, but are indicative to show two examples of the various exercises of parallel actions

carried out in MIRO together with the discussions.

After identifying the key challenges, some of the participants were asked to present the complex situation in Thessaly as well as the implements projects throughout the years aiming to enrich the discussion sharing their experience and insights with the rest of the participants (third meeting). Then, an "importance-timeframe" matrix tool (**Error! Reference source not found.**) was used aiming to help the participants to prioritize these challenges based on their importance (in terms of their impact to the economy, environment and society) and on the time frame (long- and short-term) in which these challenges can efficiently be addresses. To guarantee that multiple perspectives are taken into account, the participants were split in three break-out rooms, and then discussed as a whole the final hierarchy of the challenges to be addressed. It was clear that the main challenge is the water deficit, so reaching to a positive water balance is the common goal. On this basis, several stakeholders directly proposed solutions (fourth meeting). Here the views diverge between: Large-scale long-term solutions referring to supply management (e.g. partial diversion from Acheloos river basin - Tyralis et al., 2017) and smaller scale 'mild' targeted interventions aiming to demand management for a more efficient and reasonable water use (e.g. crop replacement, smart agriculture based on monitoring, more efficient water use, new technologies).

Subsequently, the fifth meeting was an exercise of evaluating the measures of the RBMPs and those planned under the Recovery and Resilience Plan. Around 40 specific measures were evaluated and discussed in order to find out which of them are acceptable or not and why, and why most of them have not been implemented: Basic measures (EU Directives), water demand and supply management, project management, and Acheloos diversion works were the categories evaluated. The major findings were that:

- The majority of the participants are more familiar or have expertise in demand management,
- Their priorities are the completion of uncompleted water supply works, a proper, clear and transparent project management, demand management works, and finally Acheloos diversion.
- The vast majority are experienced and have significant academic and practical contributions on demand management applications in agriculture, including new technologies, however most suggestions are not proceeding due to the weak political will.
- Regarding the evaluation of specific measures, upgrading and modernizing Local Authorities, and forming a National Water Management Body (NWMB) are considered necessary and were set as priorities (more than 85% agreement). Followed by the supply and demand management works (work completion and new initiatives). The desire of a NWMB has been stated even from the first meetings, as it is seen as a way of having a fairer management with greater technical, executable, and regulatory capacity.

The ongoing presentations and discussion already reflect deeper issues of the Greek society, that extent to the perception of water resources and their management. The proposed systematic approach is covering a wide range of topics and seems to adequately contribute to the assessment of technical, economic, social, political-governance challenges (analyzing and understanding their severity, time-horizon for tacking them, and necessary behavioral changes).

The next phase will focus on how innovation is created and how to achieve the transition in socio-technical systems taking into account the exogenous, long-term and independent trends and major crises, the dynamics of the stakeholders and cultural values as well as the process of achieving works to improve the situation. The actions towards a NWMB will be an issue for further examination if it is perceived as a win-win agreement. The upcoming phase encompasses the co-creation of the shared long-term vision, which will comprise the flagship of this project and one of the key milestones of this exercise. The vision is expected to be at a mature stage by February 2022. Finally, we will build different scenarios that will aim at the achievement of this vision and co-develop the steps that need to be taken in each time frame.

5. CONCLUSIONS

In this work, a Nexus complex problem is presented and a methodological framework for its management is described. The situation in the WD of Thessaly, one of the most challenging case-studies in Europe, regarding water scarcity, was analyzed, providing a comprehensive review for each aspect of the problem for the first time so far, to our knowledge. Another novel element is the combination of a “whole-of-systems” approach (SIA) including a “whole-of-environment” sub-systemic approach (FILLM). This is being used successfully so far, for addressing complex problems in terms of systems dynamics and stakeholder behaviour.

SIA with a proper scientific support can be a powerful tool, particularly useful for better understanding and systematically analyzing the interactions between the natural, social, and economic factors, and to move towards a more coordinated management and use of natural resources across sectors and scales (Figure 5). Moreover, it reveals and addresses deeper shortcomings of the institutional framework, the authoritarian behaviour of the State, misleading perceptions about natural resources management, and the weakness of cooperation between stakeholder groups.

One challenging aspect is the self-improvement through education, in the form of a continuous loop of inform and being informed. Aristotle considers that humans are inherently *political beings* –not as parts of political parties, but as components of the society/community – a community that has Good as its end. The co-development of a common vision is a key-driver that builds on common understanding and goals, under a common purpose, higher than the individual interest but without undermining it. As SIA relies on stakeholder engagement, it recognizes the importance of moving from opinion-based to knowledge-driven decision-makers. This assumption is essential in order to avoid blindly-defended positions, and cultivate the need of each individual to find optimal ways, reconsidering and improving him/herself. Again, to quote Aristotle, Good is an outcome of virtue, which is a function of ‘per-head’ effort, defined by right and healthy purposes (Aristotle, *Ethics*). The necessary scientific support in methodological terms (the ‘know-how’ to achieve the end’s application) guided by the necessary experience to avoid strategies that may be based on empathy, must be ensured at every stage of the process.

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