frontiers in Water

ORIGINAL RESEARCH
published: 14 January 2022
doi: 10.3389/frwa.2021.744773

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

Angelos Alamanos[1†], *Phoebe Koundouri*[2,3,4*], *Lydia Papadaki*[2,3,4,5] and *Tatiana Pliakou*[2,3,4]

[1] Centre for Freshwater and Environmental Studies, Dundalk Institute of Technology, Dundalk, Ireland, [2] Department of International & European Economic Studies, School of Economics, Athens University of Economics and Business, Athens, Greece, [3] Sustainable Development Unit, Athena Research Center, Marousi, Greece, [4] United Nations Sustainable Development Solutions Network Greece, Athens, Greece, [5] European Institute of Innovation and Technology Climate-Knowledge and Innovation Community Hub Greece, Athens, Greece

OPEN ACCESS

Edited by:
Bassel Daher,
Texas A&M Energy Institute,
United States

Reviewed by:
Mahdi Asgari,
University of California, Riverside,
United States
Srinivasa Reddy Srigiri,
Deutsches Institut für
Entwicklungspolitik (DIE), Germany
Nicholas Dercas,
Agricultural University of
Athens, Greece

***Correspondence:**
Phoebe Koundouri
pkoundouri@aueb.gr

†ORCID:
Angelos Alamanos
orcid.org/0000-0002-3875-2449

Specialty section:
This article was submitted to
Water and Human Systems,
a section of the journal
Frontiers in Water

Received: 20 July 2021
Accepted: 20 December 2021
Published: 14 January 2022

Citation:
Alamanos A, Koundouri P, Papadaki L and Pliakou T (2022) A System Innovation Approach for Science-Stakeholder Interface: Theory and Application to Water-Land-Food-Energy Nexus. Front. Water 3:744773. doi: 10.3389/frwa.2021.744773

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 synthesise 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 management under socially acceptable long-term visions. The proposed framework is based on Systems' Theory, innovation, uses a multi-disciplinary platform to bring together all relevant stakeholders, provides scientific support and commitment, and makes use of technological advances for the system's improvement.

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

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 centre 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 Leadership Program., 2018). For example, water managers see food and energy systems as users, aiming to minimise their consumption to conserve resources; the food perspective sees water and energy as inputs for exploitation; while the energy perspective sees water as input and food as the output of the procedure. The lack of integration of the analysis (research) and planning (decision-making) of those different sub-systems divides the problem's components and leads to sub-optimal solutions (optimal only for one sub-system). However, analysing the nexus and its components as a single system can lead to overall optimum and highly efficient solutions and policies. Limited understanding of the nexus concept and the lack of systemic thinking can be often impediments to such approaches. So, training and education of key stakeholders to build on commonly understandable bases is an essential starting point, to reach to the convergence of the different ideas under a more holistic thinking.

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 optimum solutions, the literature increasingly proposes the co-existence of two parallel procedures (Albrecht et al., 2018; Yung et al., 2019; Endo et al., 2020; Alamanos et al., 2021):

- The science; to enhance the understanding of interactions within the nexus, support its systemic approach, and critically form models aiming to overall optimum solutions,
- A proper stakeholder analysis and engagement, integrating local knowledge; 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., 2021). 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 cover this gap, analysing the Nexus in the Basin District of Thessaly (regional scale) and its key stakeholders in a series of meetings, by demonstrating a combination of the two parallel procedures mentioned above, introducing two novel frameworks: 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 (An Fóram Uisce, 2021). The paper focuses on the methods of SIA and FILLM, as ways to achieve deep understanding of each stakeholder's view on the presented problems, and reach to common objectives. 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 socially acceptable and tangible solutions.

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, in order to provide a holistic assessment of the study area (described in the following sections) and highlight their interlinkages to the stakeholder group.

Background

The Basin District of Thessaly covers a total area of 13,377 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 600–800 mm/year 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.

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 uses 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 Basin District 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 drills (GMECC, 2017). Urban water demand is covered only from groundwater, with the exception of the town of Karditsa, which uses surface water from the neighbouring lake. 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

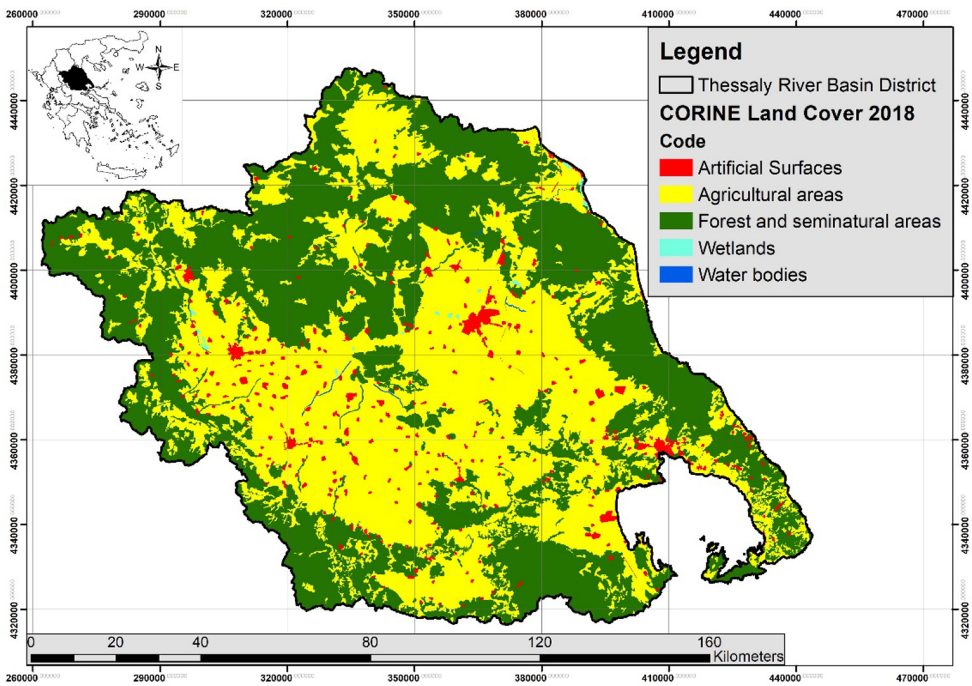

FIGURE 1 | The Basin District of Thessaly, and main land uses.

status"—overexploited. Subsequently, the energy demand and costs are dramatically increasing.

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 Basin District, while farming plays the dominant role (and is also affected because of the quality of water used for irrigation and food production). **Figure 2** is indicative of the quantitative, qualitative (chemical/ecological) and overall degradation of the Basin District, according to the RBMPs. The RBMPs grouped the WBs' status into different classes depending on the pressures levels (concentrations of pollutants).

According to the GMECC's assessment, the ecological status of river WBs is 1.4% unknown, 16.67% missing, 4.17% bad, 22.22% medium, and 55.5% good. 22.22% of rivers have "below good" chemical status. With respect to the three reported lakes, one is of Good, one of Bad and one of Unknown Status. Finally, groundwater bodies have 30.3% bad quantitative and 12.1% have bad chemical status.

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. €/km²). 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) drills (Mylopoulos and Fafoutis, 2014). This situation creates huge revenue 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., 2020a,b).

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,b). 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

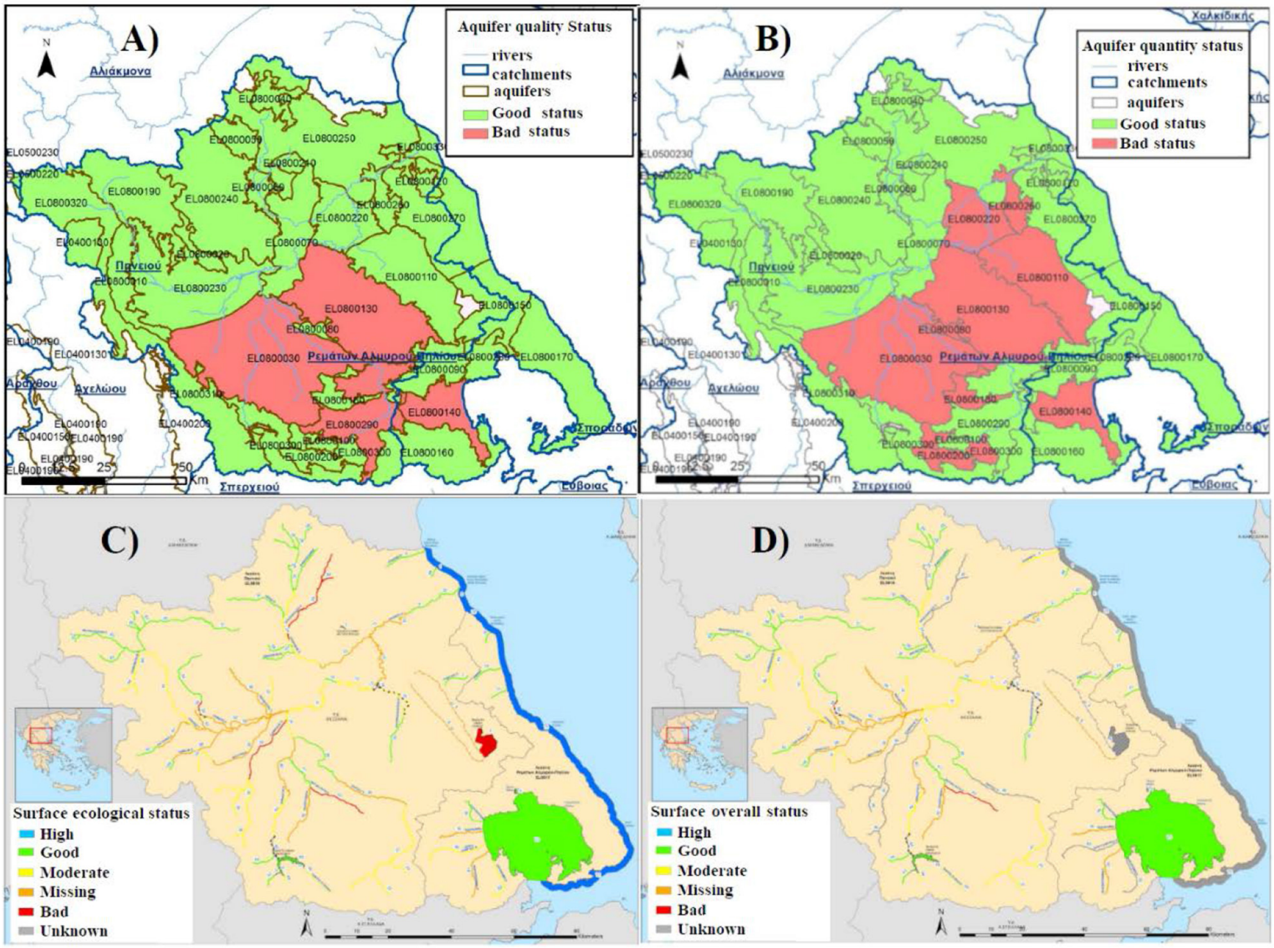

FIGURE 2 | (A) qualitative and **(B)** quantitative status of groundwater WBs. **(C)** ecological and **(D)** overall status of surface WBs (Adapted from GMECC, 2017).

of Thessaly is very challenging. Furthermore, the region suffers from continuous extreme phenomena, as the following 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 (Loukas and Vasiliades, 2004; Kanellou et al., 2008; Tigkas, 2008). Loukas et al. (2008) proved that drought severity, duration and intensity increased (compared to the historic period 1960–1990), and spatially extended droughts would be expected in the future decades (2020 and onwards), 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 2,500 years ago (Mimikou and Koutsoyiannis, 1995). The Basin District 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 (**Figure 3** shows the most flood prone areas and the maximum expected water depths). The lack of organised central and local planning, and wildfires have been identified as the major causes (Batelis and Nalbantis, 2014). Thessaly is the most vulnerable Basin District of Greece, and the flood-risk zones cover the 31.2% of its area (GMECC, 2017).

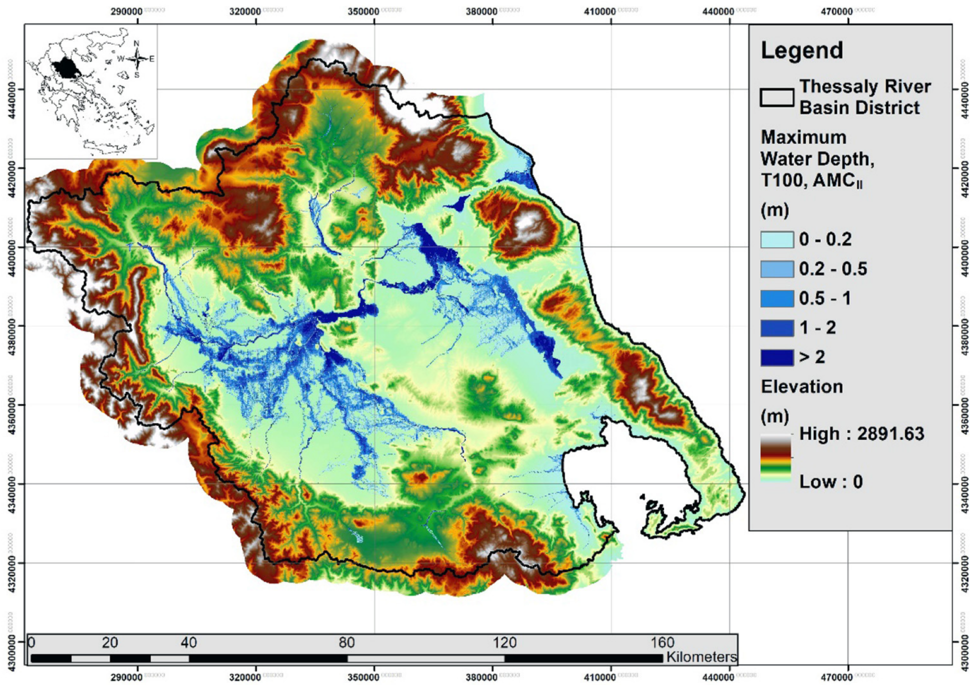

FIGURE 3 | Indicative results of 2-D flood (T = 100) simulations for Thessaly (Adapted from: Papaioannou et al., 2021).

Impacts of Climate Change

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 (food production, 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 and prove that water quantity-quality degradation are connected for surface and groundwater resources.

The 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, revenue losses and increased production costs) must be considered (Alcamo et al., 2007; McDonald and Girvetz, 2013; Calzadilla et al., 2014). 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).

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 overall optimum solutions, avoiding "one-sided" management. Alamanos et al. (2021) 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 optimise 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 Study Area) 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 and 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 Basin District (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**).

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 all components involved in the Nexus. Obviously, this approach requires extensive prior research for the study area and international practises, hence the understanding of the context and efficient workshop coordination are ensured, and necessary information is available to share with stakeholders.

The process of SIA serves as a guide to coordinate the discussion during the meetings process, and the tools mentioned can be applied through the use of visual collaboration platforms, such as Miro (2020), that enables the efficient and effective intuitive collaboration of the stakeholders.

TABLE 1 | The stages of the SIA process (indicative as any problem, stakeholder group, and solutions differ).

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 characterisation 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 and 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 and 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.

WORKSHOPS

Following the process of **Table 1** each stage is accomplished through monthly workshops (**Table 2**). Due to COVID-19 restrictions the meetings are held on Zoom, and MIRO software is often used for the analysis. Each stage is enriched and

TABLE 2 | Timeline of the Living Labs and workshop structure.

March 2021	April 2021	May 2021	June 2021
Goals of these living labs and introductions	Understanding the Nexus challenges and their environmental-socio-economic consequences	Understanding the different stakeholders' perspectives	Understanding and validating various policy measures-actions (existing and proposed ones)
July 2021	**August 2021**	**September 2021**	**October 2021**
Understanding the implemented projects and their results and the literature's points	-	Understanding what went wrong in the past (obstacles for works, policies, initiatives)	Supply and Demand Management
November 2021	**December 2021**	**January 2022**	**February 2022**
Examples of stakeholders' experience, knowledge, applied projects (no. 1)	Examples of stakeholders' experience (no. 2): fields for cooperation	Balancing supply and demand—working towards a unifying framework	Vision development (policy and economic instruments)
March 2022	**April 2022**	**May 2022**	**June 2022**
Ideation of the suggested trajectories opportunities	Criteria for optimum performance of the proposed solution	Co-creation of the Policy-technical-socio-economic bases	Building partnerships—implementation

supported by a variety of tools based on the needs of each workshop and the specificities of the living lab (stakeholders' interests, needs, conflict points etc).

In the first workshop, the goals of the living labs and the expectations from the process were reflected from the team and the participants. Each one introduced him/herself and while they were glad to be part of a transdisciplinary group, they feel pessimistic about the project's outcomes. They feel that the lack of political will and/or capacity to "make works and solutions happen" can hardly change. The first phase of SIA started in our second meeting, when the challenges were presented in detail (as described in the study area section). The participants agreed with the issues presented, then tried to unravel the challenges taking into consideration the policy, environmental, social, economic and technological angles of this challenge. The role of MIRO is to visualise positions and/or priorities set by the stakeholders (**Figure 4**), making it easier to group them and understand their relationships (3rd workshop).

There is an understanding of the magnitude of the problems, perceived as a Nexus problem with intense socio-political aspects. Most stakeholders recognise agricultural pressures; however, the local authorities see agriculture as the only way towards economic (and political) benefits in the region. All stakeholders agree on the severity of the water scarcity issues, and believe that things may be even worse than reported. Stakeholders from LALRs feel that the situation is too bad and almost unreversible in terms of water quantity and quality deterioration. The debts they face make it difficult to operate, have the required staff, and make any investments. The stakeholders also recognise the changing climatic conditions, they have faced extreme phenomena with serious economic losses, and they seek mechanisms that will be able to respond promptly and efficiently are needed. During these stages, the FILLM was used (references and examples—presentations, material, infographics, etc. as in Alamanos et al., 2021) in order to adopt the "nexus thinking," accepting that all disciplines are interconnected. Moreover, the importance of data availability and transparency is highlighted, both in small and large scales. Stakeholders also discussed solutions considering either large-scale long-term solutions referring to supply management (e.g. partial diversion from Acheloos river basin—Tyralis et al., 2017) or 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). Building on this discussion, all the actions proposed from the state (RBMPs' measures, action under the Resilience and Recovery Plan), the academia (literature review presented), private sector and local initiatives (presented from the participants) were evaluated. Moreover, the pros and cons of each approach were discussed. Around 50 specific actions 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, Acheloos diversion works, and non-state initiatives were the categories evaluated. We found that:

- The majority of the participants are more familiar, have expertise and work on projects for demand management. Although they have significant experience, their suggestions have received very limited attention from the local authorities.
- 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 participants identified many common views and rationale in their approaches to solve the problems outlined. This serves

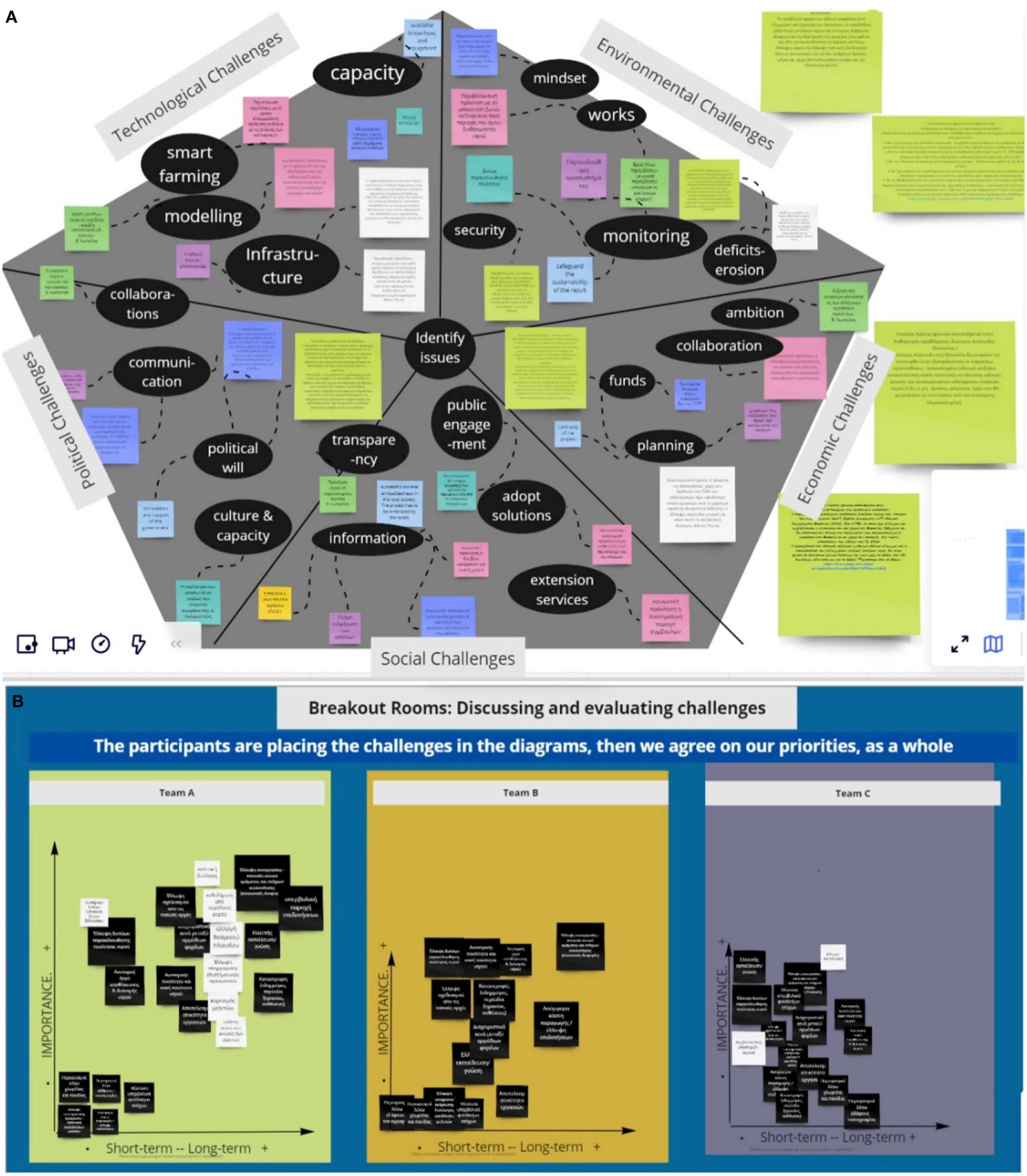

FIGURE 4 | (A) The Pentagonal problem. It is indicatively showing how the participants simultaneously described the: Environmental, Technological, Economic, Political and Social challenges they feel to face, by putting a note-description in the respective section of the pentagon. More explanatory notes can be added (sticky notes), 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). Three break-out rooms were used, hence the three diagrams, and each participant posted a sticky note with a representative phrase indicating how important or not is to address a specific problem in the short or long-term. The stakeholders' comments are in Greek, as the exercises were elaborated in Greek, but are indicative, only to show two examples of the various exercises of parallel actions carried out in MIRO together with the discussions.

as the basis for their co-operation in order to create our common vision (according to SIA's principles).
- Issues of individual political interests, lack of long-term vision and commitment (mainly because of changing governments), planning, practical implementation, and transparency were identified as the main obstacles so far. Most stakeholders see this situation as the root of most problems, and find it difficult to change.

A take-away message from the above is that a more reasonable management aiming to environmental and economic sustainability and resilience is mandatory, as it will benefit all stakeholders, with different ways. Reaching to an agreement on this matter is crucial: In this study we built on the acceptance of the nexus concept (using FILLM), and then, according to SIA, each participant needs to understand the expected benefits, overall and individually (using examples, presentations, or the appropriate arguments within our conversations).

PRIMARY RESULTS AND FUTURE STEPS

During the discussions, and especially during the evaluation of specific measures, on the occasion of highlighting the necessity for upgrading and modernising Local Authorities, the idea of a Water Management Body was suggested by several participants. This idea was again suggested as an option to achieve the common goal of the group, "*a more reasonable management aiming to environmental and economic sustainability and resilience,*" as mentioned. Of course, this goal requires cooperative action and initiative from all stakeholders, in order to provide the means to be successful. Given the absence and/or poor performance of the existing mechanisms to deal with larger scale—than the limits of the Basin District—actions (e.g. finish incomplete water-transfer works), address issues affecting the nexus (water quantity and quality degradation, extreme phenomena, economic and administrative problems, difficulties to produce adequate and high quality food products, increasing energy costs), the inability of the local authorities to undertake and complete the planned works, leading to unexploited EU funds, the formation of a National Water Management Body (NWMB) was considered necessary from the participants. When questioned, the stakeholders set this as a priority—umbrella objective (more than 85% agreement). The desire of a NWMB has been stated even from the first meetings, and it is seen as a way of having a fairer management with greater technical, executable, and regulatory capacity. At this point, we have set two questions to be answered in the future: (a) what should the NWMB do and how to ensure its successful operation? (b) can the state cover these needs from the existing or other mechanisms, and how?

The answer to the first question is actually addressed by the goal of "*achieving sustainability and resilience,*" and develops our "common-vision." An initial effort to shape this is presented in **Figure 5**: Balancing all the components of supply and demand (systems and sub-systems) will bring *sustainability*—while the proper response (minimising 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*. A NWMB will be responsible to provide in a coherent and efficient way the policy basis and instruments to manage these elements for overall benefits, according to the Nexus concept.

Ensuring that all stakeholders and relevant bodies are regularly reminded of this vision and their role in achieving and supporting it, becomes easier and more efficient through a NWMB engaging stakeholders. The provision of a unifying platform within the NWMB for multiple and sometimes competing interests to work together in a collaborative manner, and drawing on each other's expertise and experience, addressing the many challenges to the vision, is also a function to be explored. Other crucial points are the exploitation of EU funds, and the capacity building to manage effectively all components of **Figure 5**. Further questions-details with respect to the role of such a Body, and leadership, technical, financial issues are to be developed in the upcoming workshops, and majorly depend on the answer to the second question. The group prefers to find the answer to a reformulation of the existing State's mechanisms and support their operation, although it is challenging. In any case, the criteria to ensure the successful operation of this Body will have a strong connection with the understanding of the nexus, adopting integrated systemic approaches, and of course having the support of the group's stakeholders. In the following workshops we will engage with the responsible people from the Greek Ministry of Environment in order to assess their structures and potential, and identify areas for cooperation in order to reach this vision.

CONCLUSIONS

In this work, a Nexus complex problem is presented and a methodological framework for its management is described. The situation in the Basin District of Thessaly, one of the most challenging case-studies in Europe, regarding water scarcity, was analysed, 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). In this work, the combination of SIA and FILLM in the context of living labs was presented to address complex nexus problems, and was successful as a means of reaching to common visions, and motivating different stakeholders to cooperate for this vision. The living labs reflect deeper issues of the Greek society, that extent to the perception of the nexus and its management, in a rural and water-scarce Basin District. 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 (analysing and understanding their severity, time-horizon for tacking them, and necessary behavioural changes). Of course, each application is different, however, following these general principles is recommended in similar exercises: SIA (with the proper scientific support) can be a powerful tool, particularly useful for better understanding and systematically analysing the interactions between the nexus' components, and to move

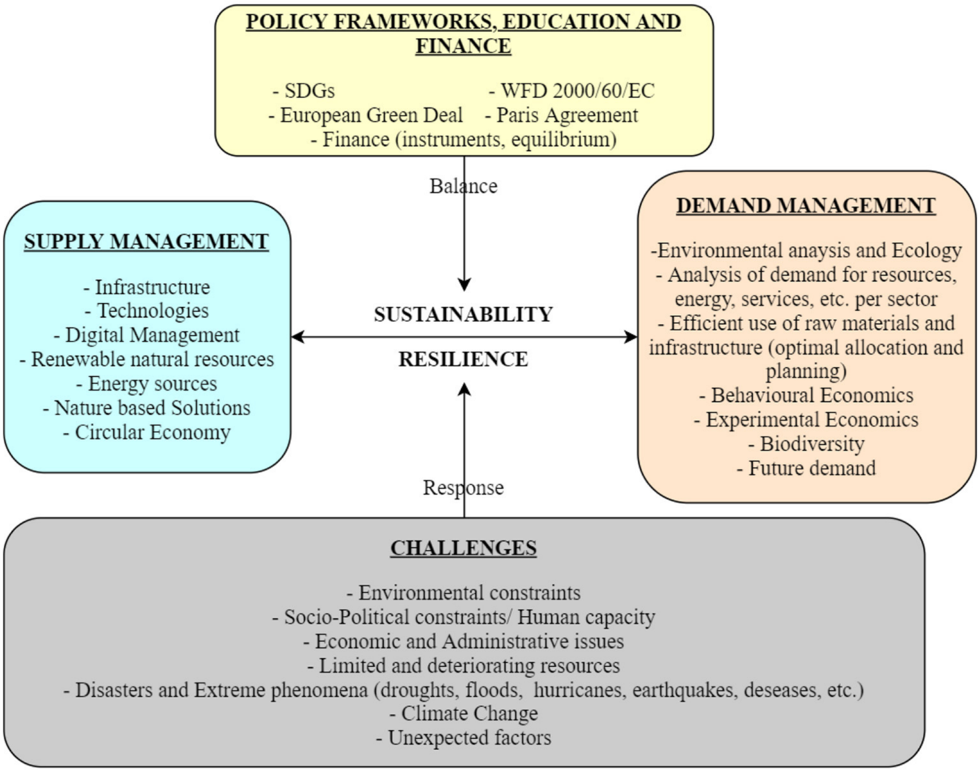

FIGURE 5 | The most common components of the supply and demand sides, which must be balanced to achieve sustainability (environmental, economic, etc.); the challenges that our systems are facing trying to become more resilient. The policy-finance frameworks and education will ensure this managerial approach.

towards a more coordinated management and across sectors and scales (**Figure 5**). Moreover, it reveals and addresses deeper shortcomings of the institutional framework, the behaviour of the State, misleading perceptions, and the obstacles for more efficient cooperation between stakeholder groups.

One challenging aspect through the process is the self-improvement through education, in the form of a continuous loop of inform and being informed (both for the research team and the stakeholders). 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 recognises 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, 2006, *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.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

AA and PK contributed to conception and design of the study. AA wrote the first draft of the manuscript. AA, PK, LP, and TP wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

REFERENCES

Alamanos, A., Latinopoulos, D., Loukas, A., and Mylopoulos, N. (2020b). Comparing two hydro-economic approaches for multi-objective agricultural water resources planning. *Water Resour. Manag.* 34, 4511–4526. doi: 10.1007/s11269-020-02690-6

Alamanos, A., Latinopoulos, D., and Mylopoulos, N. (2020a). A methodological framework for an easy and reliable estimation of the full cost of irrigation water. *Water Environ. J.* 34, 529–539. doi: 10.1111/wej.12556

Alamanos, A., Latinopoulos, D., Xenarios, S., Tziatzios, G., Mylopoulos, N., and Loukas, A. (2019). Combining hydro-economic and water quality modeling for optimal management of a degraded watershed. *J. Hydroinform.* 21, 1118–1129. doi: 10.2166/hydro.2019.079

Alamanos, A., Rolston, A., and Papaioannou, G. (2021). Development of a decision support system for sustainable environmental management and stakeholder engagement. *Hydrology* 8:40. doi: 10.3390/hydrology8010040

Albrecht, T. R., Crootof, A., and Scott, C. A. (2018). The water-energy-food nexus: a systematic review of methods for nexus assessment. *Environ. Res. Lett.* 13:043002. doi: 10.1088/1748-9326/aaa9c6

Alcamo, J., Florke, M., and Marker, M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. *Hydrol. Sci. J.* 52, 247–275. doi: 10.1623/hysj.52.2.247

An Fóram Uisce (2021). *Framework for Integrated Land and Landscape Management (FILLM).* Available online at: https://thewaterforum.ie/infographic-for-the-framework-for-integrated-land-and-landscape-management-fillm/ (accessed April 15, 2021).

Aristotle. (2006). *Ethics Nikomacheian, Book 1 Zitiros*. Available online at: https://www.politeianet.gr/books/9789608437661-aristotelis-zitros-aristotelis-ithika-nikomacheia-protos-tomos-194312 (accessed February 28, 2021).

Bank of Greece (2011). *The environmental, economic and social effects of climate change in Greece.* Athens: Climate Change Impact Study Committee.

Batelis, S.-C., and Nalbantis, I. (2014). Potential effects of forest fires on streamflow in the Enipeas River Basin, Thessaly, Greece. *Environ. Processes* 1, 73–85. doi: 10.1007/s40710-014-0004-z

Bathrellos, G. D., Skilodimou, H. D., Soukis, K., and Koskeridou, E. (2018). Temporal and spatial analysis of flood occurrences in the drainage Basin of Pinios River (Thessaly, Central Greece). *Land* 7:106. doi: 10.3390/land7030106

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., et al. (2011). Considering the energy, water and food nexus: towards an integrated modelling approach. *Energy Policy* 39, 7896–7906. doi: 10.1016/j.enpol.2011.09.039

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J., and Ringler, C. (2014). Climate change and agriculture: impacts and adaptation options in South Africa. *Water Resour. Econ.* 5, 24–48. doi: 10.1016/j.wre.2014.03.001

De Vicente Lopez, J., and Matti, C. (2016). *Visual toolbox for system innovation*. https://cristianmatti.com/2016/07/30/practice-based-knowledge-on-system-innovation-and-sustainability/ (accessed September 23, 2021).

ELSTAT (2021). *Hellenic Statistical Authority*. Available Online at: https://www.statistics.gr/ (accessed September 20, 2021).

Endo, A., Yamada, M., Miyashita, Y., Sugimoto, R., Ishii, A., Nishijima, J., et al. (2020). Dynamics of water–energy–food nexus methodology, methods, and tools. *Curr. Opin. Environ. Sci. Health* 13, 46–60. doi: 10.1016/j.coesh.2019.10.004

GMECC (2014). *Greek Ministry of Environment and Climate Change, 2014. Water Scarcity and Drought Management Plan - Management Plan of the Thessaly Water Basin.* Special Secretariat for Water, Athens.

GMECC (2017). *Greek Ministry of Environment and Climate Change, 2017. Revised River Basin Management Plan of the Thessaly Water Basin (EL08).* Special Secretariat for Water, Athens

Kanellou, E., Domenikiotis, C., Tsiros, E., and Dalezios, N. (2008). Satellite-based drought estimation in Thessaly. *Eur. Water*. 23/24, 111–122.

Koutsoyiannis, D., Andreadakis, A., Mavrodimou, R., Christofides, A., Mamasis, N., Efstratiadis, A, et al. (2008). *National Program of Water Resources Protection and Management*. National Technical University of Athens, Athens, Greece. doi: 10.13140/RG.2.2.25384.62727

Laspidou, C. S., Kofinas, D. T., Mellios, N. K., and Witmer, M. (2018). Modelling the water-energy-food-land use-climate Nexus: the Nexus tree approach. *Proceedings* 2:617. doi: 10.3390/proceedings2110617

Laspidou, C. S., Mellios, N., and Kofinas, D. (2019b). Towards ranking the water–energy–food–land use–climate nexus interlinkages for building a nexus conceptual model with a heuristic algorithm. *Water* 11, 306. doi: 10.3390/w11020306

Laspidou, C. S., Mellios, N. K., Kofinas, D. T., Ioannou, A., Spyropoulou, A. E., Papadopoulou, M. P., et al. (2019a). "*A system dynamics model for the water-energy-food-land use-climate Nexus: the Greek* case study, in *38th IAHR World Congress* (Panama City, FL). 2964–2972. doi: 10.3850/38WC092019-0495

Laspidou, C. S., Mellios, N. K., Spyropoulou, A. E., Kofinas, D., and Papadopoulou, M. P. (2020). Systems thinking on the resource nexus: modeling and visualisation tools to identify critical interlinkages for resilient and sustainable societies and institutions. *Sci. Total Environ.* 717:137264. doi: 10.1016/j.scitotenv.2020.137264

Loukas, A., Sidiropoulos, P., Mylopoulos, N., Vasiliades, L., and Zagoriti, K. (2015). Assessment of the effect of climate variability and change and human intervention in the lake Karla aquifer. *Eur. Water* 49, 19–31.

Loukas, A., and Vasiliades, L. (2004). Probabilistic analysis of drought spatiotemporal characteristics inThessaly region, Greece. *Nat. Hazards Earth Syst. Sci. 4*, 719–731. doi: 10.5194/nhess-4-719-2004

Loukas, A., Vasiliades, L., and Tzabiras, J. (2008). Climate change effects on drought severity. *Adv. Geosci.* 17, 23–29. doi: 10.5194/adgeo-17-23-2008

McDonald, R. I., and Girvetz, E. H. (2013). Two Challenges for U.S. Irrigation due to climate change: increasing irrigated area in wet states and increasing irrigation rates in dry states. *PLoS ONE* 8:e65589. doi: 10.1371/journal.pone.0065589

Mimikou, M., and Koutsoyiannis, D. (1995). *Extreme Floods in Greece: The Case of 1994*. Perugia: U.S. - ITALY Research Workshop on the Hydrometeorology, Impacts, and Management of Extreme Floods.

Mimikou, M. A., Baltas, E., Varanou, E., and Pantazis, K. (2000). Regional impacts of climate change on water resources quantity and quality indicators. *J. Hydrol.* 234, 95–109. doi: 10.1016/S0022-1694(00)00244-4

Miro (2020). *Online Whiteboard for Visual Collaboration*. Available online at: https://miro.com/app/ (accessed June 20, 2021).

Mulgan, G., and Leadbeater, C. (2013). *Systems Innovation.* London: Nesta.

Mylopoulos, N., and Fafoutis, C. (2014). Willingness to pay for more efficient irrigation techniques in the Lake Karla basin, Greece. *Geophys. Res. Abstr*. 16:15055.

Mylopoulos, N., Fafoutis, C., Sfyris, S., and Alamanos, A. (2017). Impact of water pricing policy and climate change on future water demand in Volos, Greece. *Eur. Water* 58, 473–479.

Papaioannou, G., Efstratiadis, A., Vasiliades, L., Loukas, A., Papalexiou, S. M., Koukouvinos, A., et al. (2018). An operational method for flood directive implementation in ungauged urban areas. *Hydrology* 5:24. doi: 10.3390/hydrology5020024

Papaioannou, G., Vasiliades, L., Loukas, A., Alamanos, A., Efstratiadis, A., Koukouvinos, A., et al. (2021). A flood inundation modeling approach for urban and rural areas in lake and large-scale river basins. *Water* 13:1264. doi: 10.3390/w13091264

Pecl, G. T., Stuart-Smith, J., Walsh, P., Bray, D. J., Kusetic, M., Burgess, M., et al. (2019). Redmap Australia: challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change. *Front. Mar. Sci.* 6:349. doi: 10.3389/fmars.2019.00349

Psomas, A., Vryzidis, I., Spyridakos, A., and Mimikou, M. (2018). Towards agricultural water management decisions in the context of WELF nexus. *Proceedings* 2:613. doi: 10.3390/proceedings2110613

Psomiadis, E., Soulis, K. X., Zoka, M., and Dercas, N. (2019). Synergistic approach of remote sensing and GIS techniques for flash-flood monitoring and damage assessment in Thessaly Plain Area, Greece. *Water* 11:448. doi: 10.3390/w11030448

Tigkas, D. (2008). Drought characterisation and monitoring in regions of Greece. *Eur. Water* 23/24, 29–39.

Tsakiris, G., Pangalou, D., and Vangelis, H. (2007). Regional drought assessment based on the Reconnaissance Drought Index (RDI). *Water Resour. Manag.* 21, 821–833. doi: 10.1007/s11269-006-9105-4

Tyralis, H., Aristoteles, T., Delichatsiou, A., Mamassis, N., and Koutsoyiannis, D. (2017). A Perpetually interrupted interbasin water transfer as a modern greek drama: assessing the acheloos to pinios interbasin water transfer in the context of integrated water resources management. *Open Water J.* 4:11.

Tzabiras, J., Vasiliades, L., Sidiropoulos, P., Loukas, A., and Mylopoulos, N. (2016). Evaluation of water resources management strategies to overturn climate change impacts on Lake Karla Watershed. *Water Resour. Manag.* 30, 5819–5844. doi: 10.1007/s11269-016-1536-y

WBCSD Leadership Program. (2018). *Communicating Sustainable Development and Reporting to Stakeholders Group Projects*. Geneva: Class of 2018 World Business Council for Sustainable Development.

Yung, L., Louder, E., Gallagher, L. A., Jones, K., and Wyborn, C. (2019). How methods for navigating uncertainty connect science and policy at the water-energy-food nexus. *Front. Environ. Sci.* 7:37. doi: 10.3389/fenvs.2019.00037

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.