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A methodological framework for assessing the coherence of Water-Energy-Food-Ecosystem nexus policies: Illustration and application at the river basin level

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ABSTRACT

The Water-Energy-Food-Ecosystem (WEFE) nexus emerged as an approach for efficient management of natural resources. WEFE nexus governance aims to ensure exploiting synergies and managing trade-offs arising from the WEFE nexus interlinkages. In this context, policy coherence is not only a critical component, but also an indicator of successful WEFE Nexus governance. Despite its importance to the nexus, there are few policy coherence assessment methods and policy coherence investigations into the WEFE nexus. The existing policy coherence assessment approaches fail to offer an assessment of the coherence in both policy documents and practical implementation of policies. Moreover, to understand policy coherence in practice, insights of local stakeholders are needed, which is often missing in the existing approaches. We propose a comprehensive policy coherence assessment framework (PCAF) that assesses policy coherence in both its formulation and implementation. Specifically, we adapt and combine the methods of Nilsson et al. (2016) and Mooren et al. (2024) and demonstrate its usefulness by applying it to the Nestos river basin in Greece. Our results show that shifting the focus from analyzing the net influence of policies on one another to identifying Nexus hotspots helps to effectively manage policy trade-offs and synergies by: 1) enabling the identification of policies requiring revision or strengthening; 2) providing insights into whether these hotspots have positive or negative cascading effects throughout the nexus; and 3) via stakeholder feedback on the policy coherence analysis, offering insights on policy implementation in practice.

1. Introduction

The Water-Energy-Food-Ecosystem (WEFE) nexus gained attention in science, policy and practice as an approach for efficient management of natural resources in the face of growing population, increasingly scarce resources and climate change (Canessa et al., 2022; Mpandeli et al., 2020). Evidence that water, energy, food, and ecosystem resources are interlinked has led scholars to increasingly advocate for integrated approaches to manage trade-offs and exploit potential synergies stemming from such interlinkages to improve resource efficiency (Simpson and Jewitt, 2019; Sušnik and Staddon, 2021).

Nexus studies have fast developed over the past decade with a body of literature exploring the bio-physical interlinkages within the WEFE nexus (e.g. van den Heuvel et al., 2020 Purwanto et al., 2019 Sušnik et al., 2021). These studies often focus on the optimization of nexus resources e.g., (Ahani et al., 2024). However, adopting nexus thinking involves managing trade-offs and exploiting synergies to enable the efficient use of nexus resources and achieving multiple, interconnected goals. As such, nexus thinking is essentially about finding a balance between competing resource uses (EL-Gafy et al., 2025; see Lucca et al., 2025 for further conceptualization of the WEFE nexus). A less developed strain of governance literature focuses on governance frameworks and policy design approaches to effectively manage trade-offs and synergies (Urbinatti et al., 2020). This literature points to policy coherence as a

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critical component of the governance of the water, energy, food and ecosystem policy domains (Giest and Mukherjee, 2022; Roidt and Avellán, 2019). Sectoral policies, typically developed in silos, tend to pursue sector's goals and pay little attention to aligning policy goals and related instruments across sectors and scales, ultimately resulting in resource management inefficiencies (Lewison et al., 2019; Papadopoulou et al., 2020).

Policy coherence has a long scholarship tradition in the notions of policy integration (Briassoulis, 2004), policy coordination (Meijers and Stead, 2004; Metcalfe, 1994) and policy coherence for development (Nilsson et al., 2012) along with varying conceptualizations and methodologies for assessment (Nilsson et al., 2017; Weitz et al., 2017; Strambo et al., 2015). However, despite the increased attention for policy coherence in both science and policy, with the exception of a few examples (Blicharska et al., 2023; Papadopoulou et al., 2020), there is scarce literature specifically addressing policy coherence assessments within the context of the WEFE nexus (Beretić et al., 2024). Furthermore, existing policy coherence assessment methods do not offer a comprehensive assessment of coherence within policy documents and in policy implementation. Stakeholder insights are essential for understanding policy coherence in practice (Fopa Tchinda and Talbot, 2024), and should therefore be integrated into assessment approaches.

We argue that effective governance of the WEFE nexus requires novel, more comprehensive approaches to assess and enhance policy coherence in both policy formulation and implementation. This is particularly important because, despite a large body of literature advocating for embedding policy integration mechanisms within governance structures to manage sectoral interdependencies in policy design, the inclusion of nexus thinking in decision-making remains limited, (D'Souza, 2020; Zhu et al., 2024).

Based on a literature review of policy coherence assessment methods and the authors practical experience, the proposed methodological framework integrates the policy coherence assessment approach of Mooren et al. (2024) with that of Nilsson et al. (2016). These methods were chosen because they are complementary, together providing a comprehensive assessment of coherence in policy documents and implementation. On the one hand, Nilsson et al.(2016)'s approach assesses the coherence between pairs of policy goals across sectors as defined in policy documents and can be applied to policy instruments in a similar fashion (Nilsson et al., 2016). On the other hand, Mooren et al. (2024)'s approach first maps the existence and stringency of provisions for managing cross-sectoral trade-offs and synergies within policy documents and then reflects with stakeholders on their implementation or lack thereof in practice. Moreover, we adapted the Nilsson et al. (2016) approach scoring method by placing emphasis on the intensity of the policy interactions rather than their net effect (see Section 3 for details). By integrating these methodologies, our approach provides a more comprehensive and nuanced assessment of the coherence between sectoral policies. This, in turn, contributes to advancing policy coherence assessment methodologies and facilitates informed decision-making for improved WEFE nexus governance.

The scope of this paper is methodological: it introduces a novel methodology, explains how it should be applied, and demonstrates its practical use in a case study. To this purpose, the paper starts with an overview of the literature that informed the design of the framework (Section 2). Section 3 presents the proposed methodological framework in a step-by-step manner, including details on data collection and analysis. The application of the framework to the Nestos case study, from data collection to analysis and interpretation was conducted in the context of anonymous project and is demonstrated in Section 4. The paper ends with a discussion and conclusion in Section 5.

2. Framing policy coherence and policy coherence assessment

A WEFE nexus approach aims to ensure energy, food and water security while keeping healthy ecosystems by leveraging synergies and managing trade-offs between the WEFE policy domains (Benson et al., 2015; Chenoweth and Al-Masri, 2021; Hoff, 2011; Mooren et al., 2024). To achieve such a goal, governance arrangements need to foster the design of integrated policies across the WEFE nexus domains, thus ensuring their coherence (Blicharska et al., 2023). This is a necessary yet not sufficient condition for coherence in practice. Promoting such integrated policy design, however, poses a number of governance-related challenges, which Mooren et al. (2025) categorized into five types. First, goal-related challenges referring to the need to manage conflicting sectoral policy goals. Second, actor-related challenges referring to the existence of conflicting perspectives and values between actors across different policy domains concerning priorities and solutions. Third, scale-related challenges as nexus problems involve multiple spatial scales but are often not addressed at the appropriate administrative level. Fourth, institutional-related challenges referring to misalignment of sectoral regulatory models, jurisdictional fragmentation, and ability of sectoral institutions to collaborate. Fifth, resource-related challenges such as insufficient financial and human resources for cross-sectoral collaboration. Most governance challenges underpin issues related to coordination, collaboration and integration of policies across sectors. Accordingly, policy coherence is a key component of successful WEFE nexus governance (Roidt and Avellán, 2019).

In the literature the terms policy coordination, policy coherence and policy integration are often used interchangeably to refer to ways to overcome the limitations of sectoral policies. Despite some common features such as reducing contradictions and fostering synergies among different policy sectors, these terms are different (Hüesker et al., 2022). According to Meijers and Stead (2004), policy coordination strives for aligning policies to prevent conflicting objectives. This coincides with Metcalfe (1994) notion of policy coordination that the policy system works in a way that different parts of the system do not counteract each other. Policy integration involves the coordination of sectoral policies (Briassoulis, 2004), in which two or more policy domains collaboratively design a joint policy document covering their respective domains (Meijers and Stead, 2004) (e.g. the water and agriculture domain design a policy together). Hence, policy coordination can be seen as the process of creating synergies and managing trade-offs within and between policy domains via policy integration practices, ultimately achieving policy coherence (Hüesker et al., 2022; Meijers and Stead, 2004). E.g. The water and energy sectors collaborate to identify trade-offs and synergies, and to propose coordinated actions through an inter-ministerial working group focused on integrated planning. Policy coherence is, therefore, the outcome of such processes consisting of shared policy goals and instruments across multiple domains, limiting potential drawbacks in other policy domains and leveraging synergies (Giest and Mukherjee, 2022; Nilsson et al., 2012; OECD, 2016). Thus, policy coherence is an indicator of successful nexus governance (Mooren et al., 2024) and can exist both between different policy scales (vertical coherence) and levels (horizontal coherence) (Nilsson et al., 2016).

The focus of this research is on a methodology for assessing policy coherence across WEFE domains in both its formulation and practice. An assessment of policy coherence could shed light on opportunities for improving nexus governance thereby enhancing policy coherence (Blicharska et al., 2023). Several policy coherence assessment methods have been developed over the years to address policy coherence at different scales. Nilsson et al. (2016) and Weitz et al. (2018) for instance investigated the coherence between Sustainable Development Goals (SDGs) and their targets. Nilsson et al. (2016) propose a methodology for analyzing the interactions between SDG goals, while Weitz et al. (2018) investigate the interactions between SDG targets highlighting how this exercise might help prioritizing SDG goals in Sweden. Examples of policy coherence assessments at the European scale are Nilsson et al. (2012) and Strambo et al. (2015). Strambo et al. (2015) classified the interactions between the European energy security policies and the climate mitigation policies, identifying several interactions requiring attention. Moreover they stressed that future policy coherence depends on external factors such as the gas market and policies managing trade-offs. Nilsson et al. (2012) mapped the interactions between European policy goals, instruments and related implementation looking into the interaction between renewable energy and cohesion policies on biodiversity, habitats, water and resource efficiency, finding coherence among the policy goals, but not as much at the policy instrument level. Giest and Mukherjee (2022) investigated how organizational tools, such as multi-ministerial committees, foster policy coherence in the Mediterranean region. They found that while these tools foster coordination among stakeholders, they cannot achieve effective integration. Papadopoulou et al. (2020) applied the Nilsson et al. (2016) approach at the national scale (Greece) on the Water-Energy-Food-Climate-Land (WEFCL) nexus. Blicharska et al. (2023) followed a similar approach investigating the WEFCL nexus in Sweden. Both studies highlight the need to involve stakeholders in coherence assessments. Mooren et al. (2024) adapted the approach of Munaretto and Witmer (2017) to assess policy coherence of the WEFE nexus in transboundary contexts by adding a stakeholder reflection component to the analysis to understand how the (in)coherent policies play out in practice.

The policy coherence assessment approach proposed by Nilsson et al. (2016) and that proposed by Mooren et al. (2024) proved suitable for application in the nexus context Their application, as demonstrated by Papadopoulou et al. (2020), Blicharska et al. (2023), and Mooren et al. (2024), yielded insightful results on cross-sectoral trade-offs and synergies. Moreover, together they fill the gap regarding the limited investigation of policy coherence within the nexus, and that of lack of insights on how policy interactions play out in practice. The approach of Nilsson et al. (2016) focusses on assessing policy coherence between policy goals and between goals and policy instruments by having experts of different sectors assessing the potential interactions between pairs of policy goals and between goals and instruments. However, how these interactions play out when policies are implemented is not investigated with this method. In contrast, in an attempt to fill this gap, Mooren et al. (2024) approach first maps the presence and stringency of measures for managing trade-offs and synergies within sectoral policy documents, and then via policy implementation expert's focus groups assesses how these measures play out in practice. In so doing, this approach provides insights on policy coherence in practices, but lacks depth on the policy goals and instruments interactions that Nilsson et al. (2016) provides. To build a comprehensive understanding of policy coherence in the nexus, we propose combining Nilsson et al. (2016) and Mooren et al. (2024) approaches into an integrated framework, which, following Blicharska et al. (2023) suggestion, is strongly rooted in stakeholder consultation.

3. The policy coherence assessment framework (PCAF): components, data collection and analysis

Fig. 1 illustrates the PCAF and in this section we present its structure, components, data collection approach and data analysis and interpretation.

Similar to Mooren et al. (2024) and Hüesker et al. (2022) our approach starts with the design of a policy inventory. This inventory consists of a database (e.g. Excel database) to store relevant data of selected policies: policy area, type of policy document, title, year of release, time horizon of the policy, status of policy (in force, under revision, etc.), degree of legal forcibility, geographical scale, policy goals, and policy instruments (see supplementary material; a less detailed version of the policy inventory can be found in Annex 1). The problem under investigation is what guides the identification of the relevant nexus sectors (e.g. water-energy-food-ecosystem, water-food--land, or Water-Food-Land-Climate) and related policies and is informed by stakeholders and experts' consultation.

Following the approach of Nilsson et al. (2012); (2017) a coherence assessment between policy goals and between goals and instruments is conducted. Two impact matrices are designed: the "Goals vs. Goals" impact matrix and the "Instruments vs. Goals" impact matrix. The "Goals vs. Goals" matrix includes, in both rows and columns, policy goals. The "Instruments vs. Goals" matrix includes policy instruments in its rows and policy goals in its columns.

The assessment consists of pairwise comparisons between all pairs of goals (Goals vs. Goals matrix) and between pairs of instruments-goals (Instruments vs. Goals matrix). The comparison is made by using a qualitative color coding scale (Table 1) to define seven types of possible interactions between pairs of goals and pairs of instruments-goals. The comparison goes beyond simply identifying synergies or conflicts. Each point of this scale in fact indicates if the interaction between two goals or between a goal and an instrument is positive or negative as well as the degree of a positive/negative interaction (Papadopoulou et al., 2020). Differently from Nilsson et al. (2016), Weitz et al. (2018) and Papadopoulou et al. (2020) we choose to use a colour scheme instead of a numerical score as the former better reflects the qualitative nature of the assessment. In the original scoring system, the net-influence of a policy goal or instrument is calculated by summing all interactions a policy goal or instrument has. The original scoring system of Weitz et al. (2018) is as follows: cancelling:-3; counteracting: -2; constraining: -1; consistent:0; enabling:$+$ 1; reinforcing:$+$ 2; Indivisible:$+$ 3. However, Weitz et al. (2018) already noted that the net-influence sum loses the nuances of the goal or instrument influence because it does not account for the strength of the positive or negative interactions, resulting in missing influential goals or instruments. For instance, interactions with several indivisible ($+$3) and cancelling (-3) scores cancel each other out, resulting in a medium net-influence sum, despite being very influential. To provide more information that allows for priority-setting, and not overlooking potentially influential policy goals and instruments, we therefore opted for a colour-scheme thus eliminating summing the scores. Instead, we propose to identify "hotspots" based on the frequency and intensity of the interactions. Hotspots are: 1) the goal(s) or instrument(s) with the highest number of positive interactions; 2) the goal(s) or instrument(s) with the highest number of negative interactions; 3) the goal(s) or instrument(s) with the highest number of interactions at the most intense negative level within the investigated context; 4) the goal(s) or instrument(s) with the highest number of

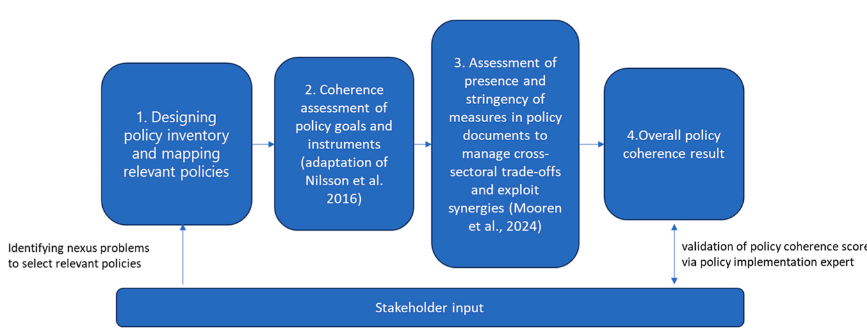

Fig. 1. Visual overview of the policy coherence assessment framework.

Table 1
Color coding scheme for assessing cross-sectoral policy goals and instruments interactions (Nilsson et al., 2016; Weitz et al., 2018).

Colour label	Qualitative score	Description
(dark red)	Cancelling	Prevents the achievement of an objective
(red)	Counteracting	Conflicts with an objective
(light red)	Constraining	Limits the options of an objective
(white)	Consistent	Neither a positive nor negative interaction
(very light green)	Enabling	Creates circumstances to advance an objective
(light green)	Reinforcing	Facilitates the achievement of an objective
(dark green)	Indivisible	Supports strongly the achievement of an objective

interactions at the most intense positive level within the investigated context.

The assessment is conducted by experts of the investigated nexus domains in a workshop setting or via multiple iteration of groups of experts until agreement is reached on coherence results. The guiding question for the assessment is: *How does the implementation of policy instrument X (or the pursuing of policy goal X) affect the achievement of policy goal Y*. Based on expert judgment a coherence result color code is assigned (Table 1). Justification of each result should be provided. After completing the assessment for all pairs of goals and goals/instruments, hotspots are identified using the four criteria above.

Taking the analysis a step further, we propose to investigate what measures the same initially identified WEFE policy documents envisage, if any, to manage and reduce the identified negative interactions and exploit the potential synergies. Such investigation is done by using the approach proposed by Hüesker et al. (2022) and Mooren et al. (2024) and operationalized by La Jeunesse et al. (2023). Following this approach, a sector-by-sector matrix is designed. In its rows the title of the policy documents and related WEFE sector goals are listed. In its columns the WEFE nexus sectors are displayed. Per each policy document, the extent to which sectoral policies account for cross-sectoral interactions is assessed using a qualitative coding system (Table 2). The assessment is conducted by experts of the investigated nexus domains in a workshop setting or via multiple iteration of small groups of nexus experts until agreement is reached. Justifications of results are provided. The outcomes are subsequently validated by stakeholders having experience on policy implementation. The stakeholders' group validating the coherence results should include at least one representative per each of the investigated nexus domains representing the scale (s) at which policy implementation takes place. In a facilitated focus group setting, stakeholders are asked whether they agree with the coherence results based on their daily policy implementation practice,

Table 2
Color coding scale for the assessment of presence and stringency of measures for managing cross-sectoral trade-offs and exploiting synergies (Mooren et al., 2024 adapted from Munaretto and Witmer, 2017).

Not applicable	No coherence	Weak coherence	Strong coherence
The policy document **is not expected to refer** to other nexus sectors or sectors' policies.	The policy document **does not refer** to other nexus sectors or sectors' policies although impacts and/or potential synergies exist.	The policy document **only mentions/ acknowledges** possible impacts/ synergies with other nexus sectors or sectors' policies but there are no mandatory measures.	The policy document **prescribes specific measures** to ensure that impacts on other nexus sectors are managed and/or synergies exploited.

especially on the practical implications of implementation or lack thereof of measures to manage trade-offs and synergies. The assessment results can be adjusted based on stakeholders' input and justification is provided.

4. Applying the policy coherence assessment framework in the Nestos river basin (Greece)

4.1. Case study description

The PCAF was applied in Nestos (Greece), the downstream branch of the transboundary Nestos-Mesta river basin shared between Greece and Bulgaria (See Fig. 2) (Boskidis et al., 2018; Kamidis and Sylaios, 2017; Proutsos et al., 2022). About 40 % of its total catchment area belongs to the Greek territory, and the Nestos Delta is a Natura 2000 protected area, also protected by the RAMSAR Convention (Boskidis et al., 2018; Kamidis and Sylaios, 2017; Proutsos et al., 2022;La Jeunesse et al., 2023). Aside from its ecological value, the basin is important for the food, energy, and tourism sectors (La Jeunesse et al., 2023). Its waters are used for irrigation of water intensive crops, whose production constitutes one of the main economic activities in the region. Moreover, the river is used for hydropower production, contributing to a substantial fraction of the national energy balance (Boskidis et al., 2018). There are three dams in the Greek part of the basin: two hydroelectric power dams and one for irrigation (Andredaki et al., 2014; Boskidis et al., 2018). The basin faces recurrent floods, to which solid waste pollution contributes, affecting ecosystems and consequently all sectors relying on it; decreasing water quality stemming from intensive agriculture; increasing water demand for multiple uses that places at risk ecological flow and habitats; and land-use conflicts especially between the food and energy sectors related to the increasing use of agricultural land for renewable energy production (Mooren et al., 2024). These cross-sectoral issues emphasize the need for improving coordination of resources management among the WEFE domains and greater policy coherence.

4.2. Data collection and analysis

The data was collected by a team of researchers including policy, governance and bio-physical nexus experts and local and regional practitioners with expertise on Greek context in general and on the Nestos in particular. The whole investigation took place over a period of 2 years between June 2022 and June 2024.

As a first step, a policy inventory was constructed by the research team. At the same time, a stakeholders' workshop was organized by the research team in order for local stakeholders to identify WEFE nexus problems and pressures existing in the greater Nestos region. This process guided the selection of 16 relevant policy documents whose goals and instruments were recorded in the policy inventory (Annex 1).

The second step was the construction of the "Goals vs. Goals" impact matrix (Table 3) and the "Instruments vs. Goals" impact matrix (Table 4) including goals and instruments extracted from the policy documents. 14 policy goals and 43 policy instruments were selected and the interactions assessed by the research team using the coding system illustrated in Table 1.

To assess the presence and stringency of measures managing WEFE interactions in sectoral policies, an in-depth analysis of the policy documents was conducted. The research team scored the level of coherence using the scoring system illustrated in Table 5. Justification of results was provided. The research team discussed the results and adjusted them as needed when in disagreement, providing justification (see La Jeunesse et al., 2023; Mooren et al., 2024).

As a final step, the results were validated via a focus group with a group of 4 local experts from the water, food and ecosystem sectors with experience on policy implementation. The stakeholders received the policy coherence result matrix a week before the focus group. During the focus group they were asked to reflect on each policy and its interactions with the other sectors. Specifically, the stakeholders were asked: 1) *What was your first impression of the policy coherence result matrix?*; 2) *Do you agree that the coherence results represent the policy documents? If not, how and why?*; 3) *Do you agree that the coherence result represents what is happening in practice? If not, how and why?*; 4) *Is there a policy document*

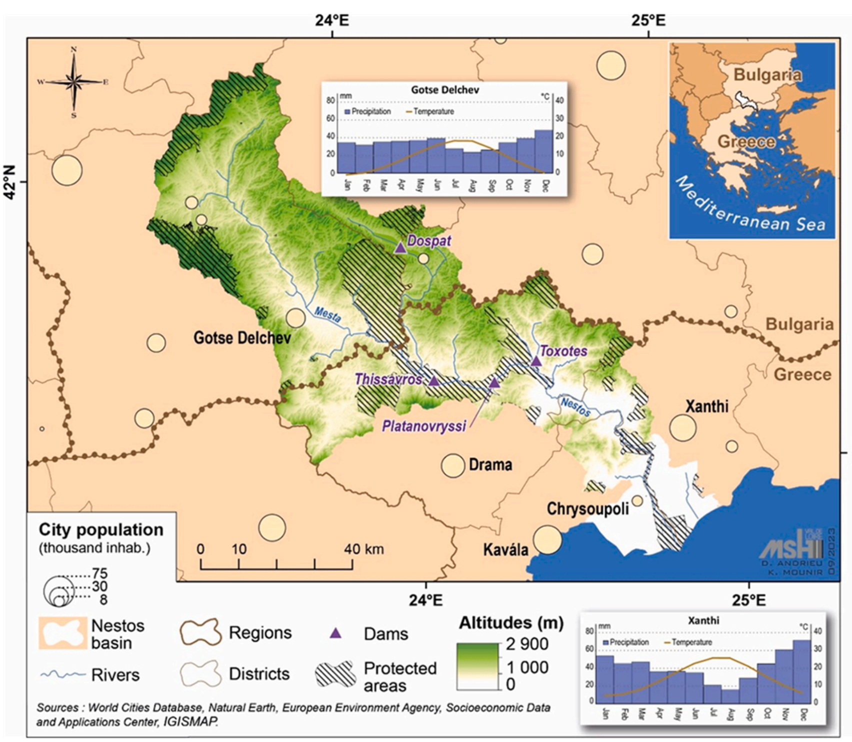

Fig. 2. The Mesta-Nestos river basin (Mooren et al., 2024).

Table 3
Goals vs. Goals impact matrix. Legenda: W= Water policy goals, EN= Energy policy goals, F= Food/ agricultural policy goals, EC= Ecosystem/biodiversity policy goals. Scoring scale is illustrated in Table 2. - – see annex 1 for explanation of the policy goals.

Influencing policy goals	Influenced policy goals: W1	W2	W3	EN1	EN2	EN3	F1	F2	F3	EC1	EC2	EC3	EC4	EC5	Count of "+"	Count of "-"	Critical interactions
W1															10	1	
W2															8	0	
W3															4	0	
EN1															9	0	
EN2															3	5	
EN3															8	0	
F1															9	0	
F2															5	2	
F3															4	0	
EC1															10	0	
EC2															8	2	
EC3															10	2	
EC4															10	2	
EC5															12	0	
Count of "+"	10	6	3	5	6	7	8	6	6	11	9	10	9	12			
Count of "-"	1	0	0	4	3	0	0	0	0	1	1	2	2	0			
Critical interactions																	

missing that is important for your case study? Because only stakeholders from the water, food and ecosystem sector were represented in the focus group, the results were also discussed at a stakeholders workshop organized by the research team attended by local governmental authorities, farmer associations, water management authorities, environmental organizations, private sector representatives, and research and academic institutions. Results did not change, thus validating the research team's assessment.

4.3. Results

4.3.1. Interactions between WEFE policy goals

Table 3 shows the interactions between the WEFE policy goals. The policy inventory including the policy document title, policy goals, policy instruments and their corresponding labels can be found in Annex 1. For conciseness we mainly refer to the policy goals and instruments label in the text. Policy goals are listed in the first row and column of the table. The influence of policy goals listed in rows over policy goals listed in columns is assessed. For example, W1 in the first row has a negative effect on EN1. The guiding question for the assessment is: How does policy goal W1 affect policy goal EN1? The "count" columns and rows report the total number of positive and negative interactions and allow to identify the hotspots (marked in yellow).

Overall, there are more positive than negative interactions among WEFE sectors (see Table 3, 110 positive interactions vs 14 negative interactions), 27 with the highest positive intensity (indivisible), and none with high negative intensity (cancelling or counteracting). As expected, the strongest positive interactions are observed between the policy goals within a single policy domain, the strongest positive interactions being present within the ecosystem policy domain (21 indivisible interactions). Conflicting interactions are observed between the ecosystem and energy policy domain (10 constraining interactions), the ecosystem and food policy domain, (2 constraining interactions) and the water and energy policy domain (1 constraining interaction). The interactions between the food and energy domains are mostly neutral or slightly positive. Also, the interactions between the water and ecosystem policy domain are mostly positive or neutral (8 consistent and 1 enabling interaction).

Eight hotspots with either positive or negative cascading effects throughout the nexus are identified in Table 3. The four policies having the strongest influence on other policies are EN2 (highest number of negative interactions (5), which is also the one with the highest number of most intense negative interactions, being them constraining interactions), EC5 (highest number of positive interactions (12)), and F1 and EC2 (highest number (5) of indivisible interactions). The most influenced policy goals are EN1 (highest number of negative interactions (4)), EC5 (highest number of positive interactions (12)) and EC4 (highest number of indivisible interactions (5)).

EN2 "Promotion of electricity production from RES and cogeneration of high-performance electricity and heat in the internal market" (see annex 1) is also a hotspot, having the highest number of negative interactions (5). More specifically, this policy goal limits the achievement of five other policy goals (W1, EC1, EC2, EC3, EC4). If this policy is implemented as intended, trade-offs can be expected between this policy and policies from both the water (water quantity) and ecosystem sector (sustainable land management, ecosystem and natural capital preservation). This policy goal does, however, create conditions for the achievement of two other energy goals related to renewable energy production and circular economy (EN1 and EN3) and one water goal related to water pricing (W3).

EC5 “Assessment of ecosystem services and promotion of Greek biodiversity” has the highest number of interactions with other policy goals and has therefore the strongest impact on the other policy goals (12). All interactions are positive except for one neutral interaction (F1). Given the high number of positive interactions, it is expected that pursuing this policy goal will have a positive cascading effect across the nexus by creating synergies between the different WEFE nexus sectors, if actions are implemented as intended. Moreover, this result shows the decisive role that ecosystems and their services play to the sustainable development of the region and the efficient use of resources as ecosystems occupy a considerable area of the basin.

“F1: Measures and provisions for the rational use of pesticides” and EC2 “Sustainable management and effective preservation of biodiversity / Monitoring mechanisms”, while having a relatively low number of interactions (9 and 10 respectively, see Table 3), they are the policy goals with the highest number of interactions with high intensity (5 indivisible interactions). Specifically, the achievement of goal F1 is necessary to achieve two other food goals (F2, F3) and three ecosystem goals (EC1, EC3, EC4). The achievement of W1, EN3, EC2 and EC5 is also facilitated by F1. The positive influence of F1 can be expected as the use of pesticides has a strong effect on ground and surface water quality, sustainable agricultural practices and ecosystem health. Moreover, both EC5 and F1 reflect specific priorities of the Nestos region such as the protection of water quality and the reduction of pollution emanating from agricultural waste, the need to safeguard ecosystems and biodiversity as well as the emphasis on preserving ecosystem services and their contribution to environmental protection, social welfare and economic prosperity. As for EC2, this goal positively affects eight other goals and negatively affects two goals. EC2 creates the circumstances to achieve the three policy goals for the food sector aiming at fostering more sustainable agriculture (F1, F2, F3). Moreover, the achievement of EC2 is necessary to achieve W1, EC1, EC3, EC4 and EC5. It is not surprising that policy goals from the same policy domain promote synergies within the sector. As for W1, this water goal is closely related to the overall ecosystem health as it aims to protect surface and groundwater resources, which is arguably part of the ecosystem domain (Mooren et al., 2025).

Aside from having the highest number of interactions with other policy goals, EC5 “Assessment of ecosystem services and promotion of Greek biodiversity” is also the most positively influenced goal, with 12 interactions in total, all positive, and is therefore a hotspot among the affected goals. More specifically, the achievement of 5 policy goals (W1, W2, EC2, EC3, EC4) likely results in the achievement of also EC5. W3, EN1, F2, F3, EC1 create the circumstances for EC5 to be achieved and EN3 and F1 facilitate the achievement of EC5.

EC4 “Management/Protection of biodiversity under climate change conditions” is also strongly influenced by 11 policy goals, with 5 indivisible interactions with W2, F1, EC2, EC3, EC5 (the highest number of all goals, hence it is a hotspot, see Table 3). EC4 is mostly positively influenced by the other goals (9 out of 11 interactions), with only two negative interactions with EN2 “Promotion of electricity production from RES and cogeneration of high-performance electricity and heat in the internal market” and F2 “Sustainable development of aquaculture”, which limits the options of achieving EC4.

EN1 “Identification of rules and criteria for the sustainable management and installation of RES” is the most negatively impacted policy goal, with 4 goals (W1, EC2, EC3, EC4) affecting it, despite EN1 aiming to eliminate land use conflicts among sectors so that agriculture and ecosystems are protected from the expansion and allocation of RES infrastructures. The reason for such an impact is that W1, EC2, EC3, EC4 have likely set stricter biodiversity and water protection goals than what is feasible for the sustainable management and installation of RES (EN1).

4.3.2. Interactions between policy instruments and goals

The “Instruments vs. Goals” impact matrix (Table 4) presents the results of the analysis of the interactions between policy instruments and policy goals. Specifically, it shows the influence of each policy instrument (in rows) on the achievement of each goal (in columns). Table 4 should be read as follows: the capital letters W, EN, F, EC indicate which sector the policy goal or instrument stems from (water, energy, food, ecosystem respectively). The numerical value after the letters indicates the policy goal. If this is followed by a non-capital letter, it means that it is a policy instrument. For example: W1 corresponds to water policy goal 1 in Table 3. W1a corresponds to the first policy instrument contributing to achieving water policy goal 1 .

The policy inventory in Annex 1 shows which policy instruments are designed to address which policy goal. Table 4 shows that policy instruments designed to reach their corresponding policy goal have an indivisible interaction with them, as is to be expected (for instance see instruments W1a-W1e and goal W1). Moreover, the majority of policy instruments have a positive effect on policy goals within their respective sector, even though they are not specifically designed to reach those goals (for instance instrument EC3g-EC5i and goals EC1-EC5). Overall, this indicates a relatively high level of coherence between instruments and goals within each policy domain. Similarly to the interactions between policy goals, positive interactions can be observed between water policy instruments and ecosystem goals and vice versa (65 and 16). Most negative interactions can be found between ecosystem policy instruments and energy goals (11), and energy policy instruments and ecosystem goals (13). A similar pattern can be observed between the food instrument F2d and the ecosystem goals EC2 and EC3, and the water instruments W1d and W1e and food goal F2. Interestingly, the energy policy instruments have either positive or neutral effect on the water goals (5 positive, 31 neutral), but two of the water policy instruments do have a negative effect on EN1 and EN2 (4 negative interactions). Similarly to the interactions between policy goals, the interactions between energy policy instruments and food sector goals are mostly neutral (31) or slightly positive (5).

Several hotpots can be identified in Table 4. Instrument EN1d “Definition of criteria for the installation of geothermal plants (geothermal potential / geothermal fields)” has the highest number of negative interactions with other policy goals (4), especially with EC1, EC2, EC3, EC4. This can be expected as EC1–4 focuses on environmental conservation while EN1d promotes the installation of new geothermal plants, which could conflict with ecosystem preservation, depending on the location.

EC2b and EC4j show the most intense conflict with the energy sector (both 1 counteracting interaction). EC2b “Characterization of areas as: strict nature reserves, nature reserves (protected areas)” has a counteractive interaction with EN1 “Identification of rules and criteria for the sustainable management and installation of RES”, and EC4j “Protection and management of agricultural and landscape biodiversity” has a counteractive interaction with EN2 “Promotion of electricity production from RES and cogeneration of high performance electricity and heat in the internal market”. These two interactions highlight a clear trade-off between land use for energy installations and biodiversity protection.

The policy instruments with the highest number of positive interactions with policy goals are W1a “River Basin Management Plans”, and EC5I “Definition of specific indicators monitoring the impacts of tourism on natural resources and infrastructures, biodiversity indicators per productive sector, indicators related to RES” (both 13 positive interactions). The instruments with the highest number of indivisible interactions (5) with policy goals are EC3g “Land use management in order to protect biodiversity from urban, industrial and touristic development/expansion” and W1d “Specific measures against pollution

Table 4
Instruments vs. Goals impact matrix – see annex 1 for explanation of the policy goals and instrument labels.

		Policy goals														Count of "+"	Count of "-"
		W1	W2	W3	EN1	EN2	EN3	F1	F2	F3	EC1	EC2	EC3	EC4	EC5		
Policy instruments influencing the policy goals	W1a															13	0
	W1b															12	0
	W1c															10	0
	W1d															10	3
	W1e															8	3
	W2f															3	0
	W2g															9	0
	W2h															9	0
	W2i															8	0
	W3j															9	0
	W3k															7	0
	W3l															8	0
	W3m															7	0
	EN1a															7	0
	EN1b															7	0
	EN1c															4	0
	EN1d															4	4
	EN1e															7	3
	EN2f															5	0
	EN2g															4	0
	EN2h															3	3
	EN3i															3	0
	EN3j															9	0
	EN3k															5	3
	EN3l															11	0
	F1a															10	0
	F1b															10	0
	F2c															8	0
	F2d															4	3
	F3e															4	0
	F3f															4	0
	EC1a															9	1
	EC2b															8	3
	EC2c															9	3
	EC2d															7	3
	EC3e															8	0
	EC3f															7	0
	EC3g															7	0
	EC4h															11	1
	EC4i															10	1
	EC4j															10	2
	EC4k															11	2
	EC5l															13	0
Count of "+"		28	20	9	23	13	21	22	17	20	34	30	34	33	35		
Count of "-"		1	0	0	5	10	0	0	7	0	2	4	5	4	0		

(e.g. penalties, quality standards, maximum accepted values, pollution indicators)". These outcomes are expected as these instruments are designed to have a broad spectrum of impacts beyond just the ecosystem.

The policy goals with the most synergistic interactions with the policy instruments is EC5 "Assessment of ecosystem services and promotion of Greek biodiversity" (35 positive interactions). EC3 "Preservation of natural capital is the policy goal" with the most indivisible interactions (11). Such an outcome is more than expected as ecosystems' health and viability of biodiversity are strongly affected by water availability and water quality, sustainable and environmentally friendly agricultural practices as well as by energy production activities and land use.

As expected, the policy goals generating the most trade-offs are EN2 "Promotion of electricity production from RES and cogeneration of high-performance electricity and heat in the internal market" (highest number of negative interactions (10) and of counteracting interactions (1)) and EN1 "Identification of rules and criteria for the sustainable management and installation of RES" (highest number of counteracting interactions (1)). Trade-offs are expected with both the ecosystem and water sectors as renewable energy infrastructure competes with land for ecosystem preservation and aquaculture has a direct negative effect on water quality.

4.3.3. *Presence and stringency of measures in policy documents addressing cross-sectoral interactions*

The results presented in Table 5 show an overall low level of cross-sectoral policy coherence in policy documents (14 weak integration, 19 no integration, 15 strong integration), indicating potential for conflicts where trade-offs exist and missed opportunities to exploit synergies. The ecosystem domain is the one least addressed in sectoral policy documents. Only one energy and two water policies include mandatory measures addressing negative interactions with the ecosystem domain. Most other policies who have interactions with the ecosystem do not even mention it (see Table 5, 9 out of 14 interactions scores no integration). Concerning ecosystem-energy interactions, only one ecosystem policy (PCEC1) prescribes mandatory measures to account for the interactions with the energy sector. However, two water policies (PDW1, PDW2), one ecosystem (PDEC1) and one food policy (PDF3), do mention their impact on the energy domain. Five policies provide specific measures that take the food domain into account and another five policies acknowledge the food domain in their text. The sector which is the subject of most prescriptive measures from other sectors is the water sector. Only one policy from the energy sector (PDEN4) and one policy from the food sector (PDF3) do not take the water sector into account at all in spite of the existing interactions.

Looking at the individual policies in Table 5, the ones that show the highest level of integration with other sectors are the energy sector, policy "Special legislative framework of spatial planning and sustainable development for the renewable energy sector and the respective strategic environmental impact assessment" corresponding to policy goal EN1 and the ecosystem policy "National Strategy for biodiversity between 2014 and 2029 and 5-years action plan" corresponding to goals EC3, EC4 and EC5. The policies with no prescriptive measures for the other domains are the water policy "Assessment and management of flood risk in compliance with the provisions of the European Directive 2007/60/EC" corresponding to goal W2 and the energy policy "Operation of electricity markets and natural gas markets - Research, production and transmission networks for hydrocarbons" corresponding to goal EN2. These policies are designed on specific topics within their respective sectors and do not acknowledge their own impact on the other nexus sectors. The remaining policies mention in their text the interactions with at least one other sector.

The Goals vs Goals matrix (Table 3) shows that policy goals F1, EC2 and EC5 have the highest potential for synergies across the nexus. However, the policy document which corresponds to policy goal F1 (PDF1) includes prescriptive measures only for the water sector, while the ecosystem is only acknowledged, and the energy sector is not mentioned at all. This means that while there is potential for a cascade of positive cross-sectoral effect when pursuing these goals, in practice synergies are unlikely to manifest as the potential is not harnessed through mandatory measures. The policy document corresponding with EC2 (PDEC1) does not account for the food sector and does not have mandatory measures for the energy sector. This most likely will result in not managing the trade-offs between this policy and the energy sector, and not realizing the potential synergies between this policy and the food sector. The ecosystem goal EC5 is set in policy "National Strategy for biodiversity between 2014 and 2029 and 5-years action plan" (Ministerial Decision No. 40332/2014 - in Greek), which does include mandatory measures to address interactions with the other nexus sectors. Therefore, synergies are likely to manifest in practice, if measures are implemented properly.

The energy goal EN2 shows the highest potential for trade-offs, especially with the ecosystem and water sectors (Table 3). Policy goal EN2 is found in several energy policy documents, namely: PDEN 2-PDEN6 (see Table 3) None of these policies however have mandatory measures in place that take the ecosystem sector into account. The trade-offs identified in the Goals vs. Goals impact matrix are therefore not managed, leading to no policy coherence.

The ecosystem goal EC2 is set in the "Preservation of Biodiversity" policy. The Goals vs. Goals impact matrix shows the potential for trade-offs between goals EN1 and EN2 and synergies of these goals with F1, F2, F3 and W1. The policy document does exploit the synergies with the water sector through mandatory measures, but not those with the food sector, which are not even mentioned. The policy document, however, does make a first attempt to mitigate the trade-offs with the energy sector by mentioning potential impact. Unfortunately, this is unlikely to translate into practice as there are not mandatory measures .

4.3.4. *Summary of Nestos coherence assessment results and stakeholder feedback*

The overall policy coherence assessment for the WEFE nexus domains in Nestos shows a generally good level of coherence between nexus goals and between goals and instruments (Tables 3 and 4), with most positive interactions manifesting within the same nexus domain. Particularly high level of coherence exists among ecosystems policy goals, where most interactions are either reinforcing or indivisible. Furthermore, coherence between instruments and goals within the same sector is generally strong. This is unsurprising, as instruments are designed to achieve corresponding goals. As for cross-sectoral interactions, the strongest positive ones (indivisible and reinforcing) are observed between the water and ecosystem goals and the food and ecosystem goals and instruments. However, this level of goals and goals/instruments consistency is not adequately reflected in the policy documents as shown in Table 5, as only 2 out of 5 water policy documents have mandatory measures for the ecosystem domain. This was confirmed by stakeholders when asked about implementation practices during the focus group. For instance, food policies (PDF1–3) do not have mandatory measures to harness the synergies between the food and ecosystem goals and instruments. As for negative cross-sectoral interactions, the fact that there are no 'cancelling' pairs of policy goals is positive. However, there are inconsistencies among policies, manifesting as constraining and counteractive interactions between goals and between goals and instruments (See Tables 3 and 4). These concern the water and energy sectors, mainly due to competitive uses, and the energy and ecosystems sectors, mainly due to land use conflicts. While 2 policies (PDEN1 & PDEC2) have mandatory measures in place to mitigate the effects of the negative interactions, most (8) policies (PDEN 2–6, PDEC1, PDF2) do not and therefore policy revisions are necessary.

The analysis of the focus group and stakeholder workshop data shows that stakeholders who participated in the workshops and focus groups confirmed the need to address the identified policy conflicts and

Table 5
Presence and stringency of measures in policy documents addressing cross-sectoral interactions - – see annex 1 for explanation of the policy goals.

			WEFE sectors			
	Policy document (PD)	**Policy goal**	Water	Energy	Food	Ecosystem
Policies influencing the WEFE domains	PDW1: Law 3199/2003 on the protection and management of water resources - Reconciliation with the WFD 2000/60/EC	W1				
	PDW2: Legislative Decree 51/2007 on the determination of measures and procedures for the integrated protection and management of water resources in compliance with the WFD 2000/60/EC	W1				
	PDW3: Measures for the protection of groundwater from pollution and deterioration in compliance with the European Directive 2006/118/EC	W1				
	PDW4: Assessment and management of flood risk in compliance with the provisions of the European Directive 2007/60/EC	W2				
	PDW5:General rules regulating the costs and pricing system of water services. Method and processes for recovery of costs for water services and relevant water uses	W3				
	PDEN1:Special legislative framework of spatial planning and sustainable development for the renewable energy sector and the respective strategic environmental impact assessment	EN1				
	PDEN2: Electricity production from RES and cogeneration of high-performance electricity and heat	EN2				
	PDEN3: Promotion of cogeneration from two or more types of energy - Issues concerning Mesochora hydroelectric power project	EN2				
	PDEN4: Operation of electricity markets and natural gas markets - Research, production and transmission networks for hydrocarbons	EN2				
	PDEN5: Support electricity production from RES and high-performance electricity and heat production from cogeneration - Legal and operational separation of natural gas supply and distribution	EN2				
	PDEN6:Ratification of the National Energy Plan for Energy and Climate	EN2, EN3				
	PDF1:Pesticides market in Greece - Rational use of pesticides	F1				
	PDF2: Development of the aquaculture sector	F2				
	PDF3Administrative measures, processes and penalties for the implementation of EU and National legislation in the sectors of food, feed, health and protection of animals	F3				
	PDEC1:Preservation of Biodiversity	EC1, EC2				
	PDEC2: National Strategy for biodiversity between 2014-2029 and 5-years action plan	EC3, EC4, EC5				

revise the corresponding policies to enhance policy coherence in practice. In particular, during the discussions in the focus group, they emphasized the importance of regional authorities prioritizing water use conflict resolutions and land use policy revisions to ensure the long-term sustainability of the entire Nestos basin and its resources. Additionally, stakeholders are local experts and therefore understand how national policies affect nexus issues at the local and regional scale. Based on their experience, stakeholders identified the supralocal as the most appropriate level for adapting national policies to local needs (vertical policy coherence) and for strengthening coherence across WEFE nexus policy domains (horizontal policy coherence). During the focus group discussion, stakeholders mentioned that prioritizing less costly solutions can sometimes lead to trade-offs with other sectors, highlighting this as a barrier for policy coherence in practice. As a result, they stressed the importance of integrating scientific knowledge early in the policy implementation process to bridge the gap between coherence "on paper" and in practice.

5. Discussion and conclusion

This research set out to develop and test the Policy Coherence Assessment Framework (PCAF), to assess coherence in policy formulation and implementation, and demonstrated its application in the Nestos river basin (Greece). The framework integrates Nilsson et al. (2016) and Mooren et al. (2024) approaches and includes a stakeholder engagement component. Stakeholder input is collected from the start of the coherence assessment to identify the nexus problem in the investigated area, to identify stakeholder priorities, to select the policies to analyze, to validate the results and provide input on policy implementation in practice. Through adapting and combining the Nilsson et al. (2016) and Mooren et al. (2024) approaches, we filled the knowledge gap in existing policy coherence assessment approaches assessing by evaluating coherence in policy documents and practices through a strong stakeholder engagement component. By identifying nexus hotspots and policy documents requiring revisions, sectoral interdependencies are highlighted and could potentially help integrate WEFE nexus thinking in decision-making. Something that is currently lacking according to D'Souza (2020) and Zhu et al.(2024), and not sufficiently addressed in the existing approaches reviewed in Section 2. Moreover, by identifying policy documents requiring revision and creating understanding of policy interdependencies, our method could help manage conflicting cross-sectoral policy goals, thus addressing goal-related WEFE nexus governance challenge; and misalignment of sectoral regulatory frameworks, thus addressing institution-related WEFE nexus governance challenge (Mooren et al., 2025).

Our approach has several benefits compared to applying the Nilsson et al. (2016) and Mooren et al. (2024) approaches separately. First, we adapted the Nilsson et al. (2016) scoring system by replacing numerical score with a color scheme and focusing on identifying hotspots rather than calculating the net influence of goals. This way we addressed the limitation highlighted by Weitz et al. (2018), who argued that the net influence method fails to capture the meaningful impact of one instrument or goal on another goal, potentially overlooking influential policy instruments or goals. By identifying hotspots, we can clearly highlight the most influential policy instruments and goals, providing a clear first indication of which policies require revision. For instance, if the net influence method was applied, the policy instruments W1a, EC2b, EC3g, EC4j, and EC51 would not have been identified as influential as they have counterbalancing scores, lowering their net influence following the Nilsson et al. (2016) scoring method (see also Annex 2 for the goals vs goal matrix following the Nilsson et al., 2016 scoring system).

Second, by combining the two approaches and identifying hotspots we gain insight into cascading effects throughout the nexus. For instance, hotspots with a high number of positive, intense goals interactions have the potential to bring about positive cascading effects across the nexus (e.g. Goals EC2, EC5, EC4, F1 see Table 3). But if the corresponding policy documents do not prescribe measures to take the other sectors into account, a policy is unlikely to harness such positive cascading effects, and therefore requires revision. This is the case of, for example, goal F1 where a high number of positive interactions (9) across the nexus are not exploited with mandatory measures in the relevant policy documents as can be seen in Table 5. Similarly, if policy goals or instruments are incoherent EC3 & EC4 with EN1 and EN2, but measures mandated in policy documents manage such trade-offs effectively as is the case in PDEC2, policy revisions are likely not needed. This suggests that our approach could help policymakers prioritize which policies should be revised.

Third, engaging stakeholders in policy coherence assessment studies has several benefits. While coherent policies are essential, their effectiveness is limited if they do not adequately address the natural resource management issue at hand (Yunita et al., 2022). The Nestos case study demonstrated that stakeholder engagement in the coherence assessment process can provide valuable insights into regional and local implementation challenges and opportunities of national policies. Integrating these insights into national policy design could enhance vertical policy coherence, as well as the credibility and legitimacy of national policies (Uittenbroek et al., 2019). This, in turn, would promote successful implementation, as regional and local stakeholders are likely to accept and support policy measures and interventions they contribute to shape (Beretić et al., 2024). Moreover, by creating the space for stakeholders to reflect on the impact of sectoral policies across multiple sectors, a policy coherence assessment study has the potential to enhance stakeholders' understanding of cross-sectoral interdependencies, as it happened in the Nestos case. This, ultimately, can encourage greater collaboration among different sectors (Driessen et al., 2001), thereby addressing the goal-related challenges as identified by Mooren et al. (2025). Another benefit of involving stakeholders is ensuring relevance and robustness of the assessment findings. The selected policies, goals and instruments are those most relevant to the specific needs and challenges of the context, while stakeholder validation allows for triangulation of data from document analysis and expert judgment.

Practical challenges in the application of the PCAF method exist. In particular, the application is both time and resource consuming. Policy analysts and domain experts across science, policy and practice at different scales are needed to perform the analysis. This expertise is not always available, and it is costly. Furthermore, identifying and engaging with relevant stakeholders is a time-consuming and complex process, as observed in other nexus projects (Kliskey et al., 2023). Engagement is particularly challenging in contexts such as the Nestos, where stakeholders are not accustomed to participating in such assessments. Furthermore, should the method be applied at transboundary scale, it would require even more investment of time, resources and expertise. In the Nestos we applied the method only to the Greek side of the basin. However, the basin is also influenced by upstream policies in Bulgaria as well as European policies affecting both countries. To investigate the interactions between the Greek and Bulgarian sectoral policies, and as well as between European and national sectoral policies, the method should be tested and potentially revised in future research.

Finally, in this study we applied the PCAF on the WEFE nexus. However, its application can be extended to any Nexus e.g. WEF, WEF-Land-Climate, or WEF-Waste nexus. (Albrecht et al., 2018); (Papadopoulou et al., 2022); (Garcia et al., 2019) to understand the degree to which any set of sectoral policies are coherent. The problems present in the case studies are what should guide the selection of the nexus sectors to investigate. Moreover, the method can be applied by anyone, not just scientists, who wants to identify policies in need of revision. The PCAF could especially be useful in cases with clashing views in which (national) sectoral policies are pursued and could benefit from policy coherence. For instance, transboundary case studies or cases in which there are strong sectorial visions. In these instances the PCAF could be used by inter-ministerial committees at various scales as a starting point for cross-sectoral dialogue and action towards more coherent and sustainable policies. Moreover, the results could be used as a diagnostic tool for institutional fragmentation in future applications, thus addressing the institutional challenges of nexus governance identified by Mooren et al. (2025). The nexus hotspots guide not only which policies should be revised, but also where more institutional coordination is needed.

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CRediT authorship contribution statement

Caro E. Mooren: Writing – original draft, Writing – review & editing, Validation, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Chrysaida-Aliki Papadopoulou:** Writing – original draft, Writing – review & editing, Validation, Investigation, Formal analysis, Conceptualization. **Stefania Munaretto:** Writing – original draft, Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Katerina Levedi:** Investigation, Formal analysis. **Maria P. Papadopoulou:** Writing – original draft, Writing – review & editing, Funding acquisition, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT to improve readability and English language **of a few sentences** in the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Declaration of Competing Interest

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Annex 1. : Policy inventory

a/a	Nexus sector	Policy Goals	Policy Instruments
1	Water	W1: Protection and management of surface water and groundwater resources	– Wa: River Basin Management Plans[a] – Wb: National monitoring network (quality and quantity of water) – Wc: Upgrading and restoration of surface/artificial/particularly modified water systems[b] – Wd: Specific measures against pollution (e.g. penalties, quality standards, maximum accepted values, pollution indicators) – We: General rules regulating water use (water supply, irrigation, industrial use, energy production, recreation)
		W2: Assessment and management of flood risks/Limitation of flood impacts	– Wf: Proactive assessment of flood risk for each river basin – Wg: Assessment of potential future effects of floods on human health, natural environment, cultural heritage and economic activities – Wh: Determination of special zones with high flood risk – Wi: Increasing public awareness with respect to flood risk
		W3: Establishment of a national water pricing system	– Wj: Stimuli for water users aiming at the effective use of water resources. – Wk: Establishment of a general framework regulating agricultural use of water. – Wl: Establishment of general rules regulating agricultural water pricing in case of organized collective agricultural networks (volumetric charge per cubic meter) – Wm: Establishment of general rules regulating agricultural water pricing in case of not organized collective agricultural networks
2	Energy/Climate	EN1: Identification of rules and criteria for the sustainable management and installation of RES	– ENa: Identification of suitable areas for the installation of wind parks and wind turbines (spatial and environmental criteria) – ENb: Definition of criteria for the installation of photovoltaics (barren or low-productivity land, invisible areas, connection capabilities) – ENc: Definition of criteria for the installation of biomass/biofuels processing units (next to agricultural areas, large farms, landfills, etc.) – ENd: Definition of criteria for the installation of geothermal plants (geothermal potential / geothermal fields) – ENe: Definition of criteria for the assessment of hydropower receptors' carrying capacity (satisfaction of water supply, irrigation and ecological needs, etc.)
		EN2: Promotion of electricity production from RES and cogeneration of high-performance electricity and heat in the internal market	– ENf: Adoption of cogeneration technologies – Eng: Increase sharing of RES and cogeneration power plants to the energy market – ENh: Operational incentives (compensation-economic incentives) of RES and cogeneration power plant owners
		EN3: Waste management and recovery on the basis of circular economy	– ENi: Development of infrastructures supporting energy storage. – ENj: Development of new financial instruments / Green financing – ENk: Promotion of energy crops – Enl: Adoption of new technologies supporting circular economy and waste management

(*continued on next page*)

(*continued*)

a/a	Nexus sector	Policy Goals	Policy Instruments
3	Agriculture/ Food	F1: Measures and provisions for the rational use of pesticides	– Fa: Organisation of training programmes for the sustainable use of pesticides – Fb: Monitoring rational use of pesticides / Reduction of pesticide use in specific areas (e.g. protected areas)
		F2: Sustainable development of aquaculture (spatial criteria – sea and lakes, permissions, type of aquaculture activities, etc.)	– Fc: Land use (water areas) regulations – Fd: Expansion and relocation of waterborne aquaculture units
		F3: Definition of administrative measures, processes and penalties for the implementation of EU and National legislation in the food sector, fodder sector and the sector of animals protection and health	– Fe: Monitoring / Destruction of non-secure food or feed – Ff: Controls in food and feed industry and imposition of penalties in case of offenses
4	Ecosystems/ Biodiversity	EC1: Sustainable management of the LULUCF sector	– ECa: Protection of forest land, grassland, wetlands and crops
		EC2: Sustainable management and effective preservation of biodiversity / Monitoring mechanisms	– ECb: Characterization of areas as: strict nature reserves, nature reserves (protected areas), natural parks (national/regional), protected habitats (special preservation zones, areas of special protection, habitats of wildlife or combination of all the above), protected landscapes – ECc: Measures for the protection of endemic biodiversity – ECd: Register of small-scale wetlands
		EC3: Preservation of natural capital	– ECe: Protection of biodiversity from intensive agriculture – ECf: Preservation of agricultural genetic diversity – ECg: Land use management in order to protect biodiversity from urban, industrial and touristic development/expansion
		EC4: Management/Protection of biodiversity under climate change conditions	– ECh: Inventory of biodiversity threats/pressures[c] – ECi: Inventory of primary factors for biodiversity loss[d] – ECj: Protection and management of agricultural and landscape biodiversity – ECk: Economic stimuli for biodiversity protection
		EC5: Assessment of ecosystem services and promotion of Greek biodiversity	– ECl: Definition of specific indicators monitoring the impacts of tourism on natural resources and infrastructures, biodiversity indicators per productive sector, indicators related to RES

[1]River basin characteristics, effects of human activities on surface water and groundwater, economic analysis of water uses

[2]Water quality, chemical status, ecological potential

[3]Urban, industrial and touristic expansion, intensive agriculture, expansion of agricultural land-aquaculture-intensive livestock, mining, energy production from RES (hydroelectric power plants are excluded), transportation-communication-energy networks, exploitation of biological resources (wood, poisoned baits, etc.), human disturbance (hunting, logging, etc.), amendment of natural systems (forest fires, dams, land use changes), invasive species, pollution (urban-industrial-agricultural-solid waste, air pollution), climate change (extreme weather conditions, drought, etc.).

[4]Lack of adequate scientific data, time lags concerning promotion-integration-implementation of urban and spatial planning in order to preserve biodiversity, problems concerning the implementation of the respective legislative framework, lack of environmental awareness, funding gaps, sustainable development priorities have not been fully adopted by the several productive sectors.

Annex 2. : Example of the policy coherence scores following Nilsson et al. (2016); (Weitz et al., 2018 scoring system

	W1	W2	W3	EN1	EN2	EN3	F1	F2	F3	EC1	EC2	EC3	EC4	EC5	SUM
W1		3	2	-1	1	0	1	1	0	2	2	1	1	3	16
W2	3		0	1	0	0	0	1	0	2	1	2	3	3	16
W3	2	0		0	1	0	0	0	0	0	0	1	0	1	5
EN1	2	1	0		3	1	0	0	0	1	1	2	2	1	14
EN2	-1	0	1	1		1	0	0	0	-1	-1	-1	-1	0	-2
EN3	0	0	0	2	2		1	0	0	1	1	1	1	2	11
F1	2	0	0	0	0	1		3	3	3	2	3	3	2	22
F2	2	0	0	0	0	0	1		2	1	0	-1	-1	1	5
F3	0	0	0	0	0	0	3	2		1	0	0	0	1	7
EC1	2	2	0	2	2	1	2	0	0		2	2	2	1	18
EC2	3	0	0	-1	-1	0	1	1	1	3		3	3	3	16
EC3	1	1	0	-1	-1	1	2	1	2	3	3		3	3	18
EC4	1	2	0	-1	-1	1	2	1	1	3	3	3		3	18
EC5	2	2	1	1	1	1	0	2	1	2	3	3	3		22
SUM	19	11	4	3	7	7	13	12	10	21	17	19	19	24	

Data availability

No data was used for the research described in the article.

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