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# Towards transboundary Water-Energy-Food-Ecosystem Nexus governance: a comparative governance assessment of the Lielupe and Mesta-Nestos river basins

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## ABSTRACT

In recent years, the conceptualization and application of the WEF and later WEFE nexus in science, policy and practice has progressed significantly. Despite the transboundary nature of sustainability and WEFE nexus issues, research on WEFE nexus governance in a transboundary context is less developed. WEFE nexus governance refers to societal decision-making to address challenges related to goals, actors and actor networks, scales, institutions and resources. In this paper, we explore the governance challenges encountered when implementing WEFE nexus governance in a transboundary setting. To identify these challenges in practice, we conducted a WEFE nexus governance and policy coherence assessment in two transboundary case studies: the Lielupe river basin and Mesta-Nestos river basin. Our analysis shows that in both cases the governance arrangements are restrictive towards WEFE nexus governance. Based on the factors contributing to the degree of restrictiveness, we identify four key conditions to overcome the transboundary governance challenges: (1) awareness of WEFE nexus interlinkages at all governmental levels; (2) local cross-border and sectoral communication and trust; (3) addressing issues at the appropriate level; and (4) adequate resources and natural resource monitoring across sectors. These conditions lead to recommendations to proceed towards more integrated approaches to transboundary WEFE nexus governance.

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## KEYWORDS

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WEFE nexus policy;  
governance assessment;  
cross-sectoral collaboration

## 1. Introduction

Water-Energy-Food (WEF) nexus thinking gained attention in recent years as a response to increasing depletion of natural resources due to excessive demand (Allouche et al., 2015; Benson et al., 2015; White et al., 2017). Simultaneously, evidence shows that interlinkages between WEF nexus domains (i.e. connections through which the nexus domains influence each other) are strong and activities in one domain can create negative spillover effects in another domain (De Strasser et al., 2016; Mooren et al., *Under review*). More recently, authors have added the Ecosystem domain, resulting in the WEFE nexus (e.g. De Strasser et al. (2016), Bidoglio et al. (2019), and Malagó et al. (2021)). Within this framework, cross-domain knowledge co-production and governance are based on the assumption that all nexus domains are equal and interdependent. It aims to manage natural resources in a coherent and sustainable

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manner by leveraging synergies and managing trade-offs between domains on a regional scale (Avellán et al., 2017; Benson et al., 2015; Chenoweth & Al-Masri, 2021; Hoff, 2011; van den Heuvel et al., 2020). The scientific debate on WEF nexus governance has progressed significantly in the past decade (e.g. González-Rosell et al., 2023; Kurian et al., 2018; Lebel et al., 2020), with the development of several methods to analyze and implement the nexus approach in policy practice (Daher & Mohtar, 2015; Halbe et al., 2015; Harwood, 2018; Hoff et al., 2019; Pereira Ramos et al., 2022).

However, the role and integration of the ecosystem in the nexus remains debated and requires further attention (Sušnik & Staddon, 2021). Lucca et al. (under review) highlight the discussion on the role of the ecosystem in the conceptualization of the WEF nexus and the different terminology used such as nature, biodiversity, natural environment, and natural resources. Moreover, adding the ecosystem component adds challenges to nexus governance. Many sustainability and WEF issues are transboundary by nature as the biophysical properties of the ecosystem and the WEF nexus interlinkages that derive from it do not always follow administrative boundaries. A well-known example is that of rivers, which cross multiple countries (Armitage et al., 2015). As a result, water pollution is not contained in the upstream country, but affects the down-stream country as well. Upstream placed irrigation dams directly affecting down stream water quantity for irrigation purposes are another example.

The transboundary aspect of the nexus amplifies the complexity of nexus governance. Transboundary governance itself is complicated by an increased number of stakeholders, power imbalances, cultural differences, conflicting perspectives and values, socio-economic differences between countries, and the need to integrate different types of knowledge (Armitage et al., 2015; Dore et al., 2012; Finger et al., 2006; Gerlak, 2015; Mylopoulos et al., 2008). Additional complication stems from the complex set of biophysical interlinkages leading to cross-sectoral trade-offs whose management requires coherent WEF policies (Hoff, 2011). Several authors have reflected on governance aspects of importance to the nexus (de Andrade Guerra et al., 2021; Jones & White, 2021; Pahl-Wostl et al., 2021; Roidt & Avellán, 2019; Scott et al., 2018). In particular, Mooren et al. (under review) identified five types of governance challenges (see section 2) for the WEF nexus, highlighting its complexity: goal-related, actor-related, scale-related, institutional-related, and resource-related governance challenges. Based on these challenges, Mooren et al. (under review) observe that striving for policy coherence, which can be defined as having aligned policy goals and instruments between policy domains fostering synergies between those domains and reducing trade-offs (Giest & Mukherjee, 2022; Nilsson et al., 2012), is a difficult endeavor. However, it is also an indicator for successful WEF nexus governance, requiring negotiated policy goals based on shared perspectives, consistent coordination between WEF institutions and actors, a match between the biophysical scale of the problems and the governance structures addressing them, and consistent allocation of sufficient human and financial resources to ensure sustainable management of WEF resources. Therefore, it is important to assess governance systems' current orientation, and their capacity to support or restrict the transition towards transboundary WEF nexus governance. This could help to identify entry points for change.

Despite these challenges, insights about transboundary WEF nexus governance approaches are limited in the literature. While there is a growing body of literature on the nexus in a transboundary context, most approaches are technical, focusing on bio-physical modeling (Chenoweth & Al-Masri, 2021). When studies focus on nexus governance issues, they often exclude the ecosystem with the exception of De Strasser et al. (2016) and Dondeynaz et al. (2018). Nevertheless, Dondeynaz et al. (2018) maintain a rather technical focus in its attempt to define a nexus governance framework and De Strasser et al. (2016) lack clear nexus governance instruments. Moreover, the systematic literature review of Urbinatti et al. (2020) shows that research on the nexus should include different knowledge types across different stakeholders. This is especially important in a transboundary context as local scale problems and related impacts are often neglected when addressing nexus issues (Scott et al., 2011). Local stakeholder engagement is usually limited due to centralized national governmental processes for transboundary issues (Jager et al., 2016; Nielsen et al., 2013).

This paper therefore aims to contribute to the transboundary WEF nexus governance literature by providing insights into conditions enabling WEF nexus governance in transboundary river basins by analyzing

two cases, the Lielupe (Latvia-Lithuania) and the Mesta-Nestos (Bulgaria-Greece) transboundary river basins. More specifically, this research sets out to answer three research questions:

- To what extent are the current governance arrangements in the two case studies supportive or restrictive towards WEFE nexus governance?
- What factors contribute to the restrictiveness or supportiveness?
- Based on lessons learned across the two cases, what recommendations can be formulated for transboundary WEFE nexus governance?

To answer these research questions, the paper starts with presenting the research approach and analytical framework (section 2), followed by the methodology (section 3). After illustrating the case studies' WEFE nexus issues (section 4.1), section 4.2 presents the governance and policy coherence assessment results. Section 4.3 illustrates the factors explaining the assessment results in a comparative fashion. The paper ends with a discussion, recommendations (section 5) and a conclusion (section 6).

This research is conducted within the European funded research project NEXOGENESIS.

## 2. Research approach and analytical framework

Our research approach consists of three steps (Figure 1). First (step 1), a WEFE nexus governance assessment is conducted using the Nexus Governance Assessment Tool (NXGAT) (La Jeunesse et al., 2023; La Jeunesse et al., forthcoming) integrated with a policy coherence assessment as suggested by Mooren et al. (under review). The overall assessment identifies elements contributing to restrictiveness and supportiveness of the governance arrangements towards WEFE nexus governance. These elements, analyzed in light of the nexus governance challenges suggested by Mooren et al. (under review) and related explanatory factors (step 2), permit to identify suitable governance arrangements and related enabling conditions for transboundary WEFE nexus governance (step 3).

### 2.1. Governance and policy coherence assessment

The analytical framework underpinning the WEFE nexus governance and policy assessment is reported in details in La Jeunesse et al. (forthcoming), Mooren et al. (Under review), and Hüesker et al. (2022). Here we briefly summarize it.

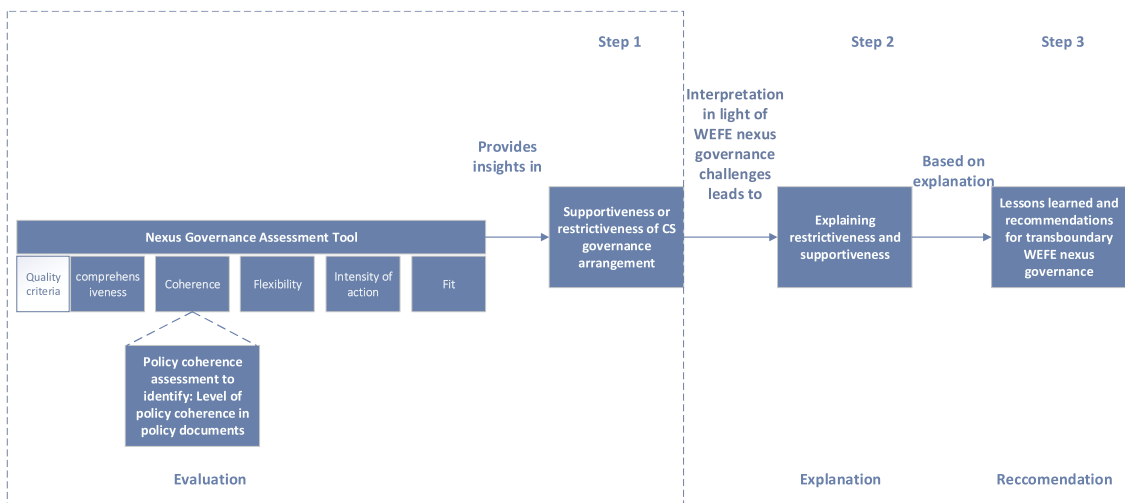


Figure 1. Research approach.

The NXGAT (ibid) assesses the degree of restrictiveness or supportiveness of governance arrangements towards WEFÉ nexus governance by providing an understanding of how governance arrangements perform in relation to key nexus governance challenges, and consequently, which barriers, opportunities and entry points for change exist. Supportiveness is defined as the degree to which a governance system enables WEFÉ nexus governance. Restrictiveness is defined as the degree to which the governance arrangement hinders WEFÉ nexus governance (La Jeunesse et al., [Forthcoming](#)). To identify key factors contributing to the degree of supportiveness or restrictiveness, the NXGAT assesses five governance dimensions (levels and scales, actors and networks, problem perspectives and goal ambitions, strategies and instruments, and resources and responsibilities) against five governance quality criteria (comprehensiveness, coherence, flexibility, intensity of action, and fit). Both the governance dimensions and criteria are developed based on key nexus governance characteristics and challenges identified by an extensive literature review (Mooren et al. [under review](#)). The quality criteria in the NXGAT are scored on a four-point scale (very low – low – high – very high) per governance dimension. The overall evaluation of the governance orientation towards WEFÉ nexus governance of a specific case study (CS) is based on the overall scores of the quality criteria. If three out of five is very low/low, the governance arrangement is restrictive. If three out of five is high/very high, the governance arrangement is supportive towards WEFÉ nexus governance. The assessment is based on interviews with relevant stakeholders across the WEFÉ domains and literature review. The evaluation questions and qualitative scoring system per each pair of criteria/quality dimension can be found in the supplementary material – Annex 2.

Furthermore, for the NXGAT governance dimension ‘strategies and instruments’ an in-depth investigation of the quality criteria ‘Coherence’ is conducted using a dedicated policy coherence assessment method. This additional investigation gains specific insights on how WEFÉ policies account for nexus trade-offs and synergies. Because policy coherence is a key aspect and an indicator of successful nexus governance (Mooren et al., [under review](#)), such analysis validates the quality criteria coherence of the NXGAT and strengthens the overall nexus governance assessment evaluation. The coherence investigation consists of assessing the presence and stringency within WEFÉ policy documents of measures to reduce trade-offs and exploit synergies that exist across WEFÉ policy domains. The presence and stringency of prescriptions is assessed through a four-point scoring system: not applicable, no-coherence, weak coherence, strong coherence (see Hüesker et al. (2022) for more details on the method and supplementary material-Annex 2). The assessment is based on an in-depth analysis of policy documents through expert judgement and a validation with a group of key stakeholder representing the WEFÉ nexus policy domains.

## **2.2. Explanatory framework for successful transboundary WEFÉ nexus governance and policy**

To explain the level of restrictiveness or supportiveness of governance arrangements towards transboundary WEFÉ nexus governance found in the case studies, we operationalized the nexus governance challenges identified by Mooren et al. ([under review](#)) into a number of explanatory factors ([Table 1](#)). A high degree/level of each factor is indication of support for transboundary WEFÉ nexus governance, whereas a low degree/level is indication of the factor being restrictive.

## **3. Methodology**

This study uses a comparative case study design to find similarities and differences in the elements supporting or restricting transboundary WEFÉ nexus governance in two cases: the Mesta-Nestos river basin and Lielupe river basin (Verschuren et al., 2010). This helps to interpret factors contributing to either supporting or restricting transboundary WEFÉ nexus governance and to formulate recommendations accordingly.

The two cases were selected among the case studies of the NEXOGENESIS project based on three criteria. The case studies should:

- Have a comparable legislative system. Both cases are European Union (EU) Member States and therefore have to comply with EU regulations.

**Table 1.** Key explanatory factors for the level of restrictiveness or supportiveness towards transboundary WEFE nexus governance.

Type of governance challenge	Explanatory factor for the level of restrictiveness or supportiveness towards transboundary WEFE nexus governance	References
<p><b>Goal and problems –</b>  <i>Conflicting policy goals between the WEFE nexus domains and complexity associated to ensuring a certain degree of policy integration across the WEFE policy domains</i></p>	1. Degree to which efforts are taken towards integration and coherence of different WEFE nexus policy domains in policy and legislative documents and in practice	1. Scott et al. (2018); De Grenade et al. (2016)
<p><b>Actor and networks-</b>  <i>Conflicting perspectives and values and power imbalances between the actors of the different WEFE domains</i></p>	2. Degree of willingness to collaborate and compromise between different WEFE domains and nations 3. Degree of willingness to incorporate local views and perspectives in transboundary actions 4. Level of agreement and trust between countries	2. Salmoral et al. (2019) 3. Purwanto et al. (2019) 4. Link et al. (2016)
<p><b>Scale –</b> <i>A lack of fit between nexus issues and the administrative scale dealing with these issues</i></p>	5. The degree to which administrative levels of the governance arrangement that deal with the WEFE domains match the bio-geophysical scale at which the domains operate	5. Mooren et al. (under review); Pahl-Wostl et al. (2021)
<p><b>Institutional-</b>  <i>The mismatch between sectoral regulatory models, the jurisdictional overlap between policy domains creating unclear responsibilities, and the impact of the interaction between institutions addressing WEFE issues on their effectiveness, a phenomenon known as institutional interplay (Cash et al., 2006; Pahl-Wostl et al., 2021; Young et al., 1999)</i></p>	6. The degree of willingness of national institutions to intervene at different scales (related to scalar strategies challenge) 7. The level of sectoral and transboundary institutional collaboration (related to institutional interplay) 8. The extent to which legislation is unambiguous and comprehensive 9. The degree of coordination between domains and countries 10. The extent to which a match between sectoral and national regulatory models is present	6. Pahl-Wostl et al. (2021). 7. Pahl-Wostl et al. (2021) 8. Olawuyi (2020) 9. Carlisle and Gruby (2019) 10. Scott et al. (2018); Olawuyi (2020)
<p><b>Resource –</b> <i>A lack of nexus specific knowledge, nexus-dedicated human and financial resources, and political will to address problems with a WEFE cross-domain perspective.</i></p>	11. The extent to which knowledge, human and financial capital for addressing transboundary nexus issues are available 12. The extent to which resources are clearly assigned for intersectoral transboundary resource management	11. (Salmoral et al., 2020); Scott et al. (2018) 12. Olawuyi (2020)

- Have similarities in the types of river basins; both river basins are transboundary equally shared by two countries.
- Share similar types of problems; in both river basins, WEFE nexus issues are present.

The WEFE nexus governance and policy assessment were conducted using a mix of qualitative methods. The nexus governance assessment was carried out via in-depth semi-structured interviews with relevant WEFE stakeholders to assess the governance arrangement as a whole using the NXGAT. Each interview lasted 1.5–2 hours and was conducted by a multidisciplinary research team including the first and fifth author of this paper during 1–2 weeks field visits. 37 stakeholders were interviewed for the Lielupe case study and 27 for the Mesta-Nestos case study. Respondents were selected based on purpose- and snowball sampling (Bernard, 2017). Respondents included WEFE resource managers, resource users, NGOs and public authorities across different administrative levels and scales. Most interviews were conducted in English, when impossible, a translator was present on site. All interviews were recorded, and the research team kept a record of notes. Additional notes were gathered through transboundary stakeholder workshops to which the first and fifth author participated. Two transboundary workshops were held in the Lielupe river basin, one in September 2022 with local and regional stakeholders and one in June 2023 with local, regional and national stakeholders. The transboundary workshop in the Mesta-Nestos river basin was held in March 2023 with local and regional stakeholders. The workshops were organized as part of the NEXOGENESIS project activities. These workshop discussions allowed to gather additional insights on the stakeholders perceptions of problems and solutions and their understanding of WEFE nexus and WEFE nexus governance in their region.

The research team coded the data answering the NXGAT questions to score the quality criteria for each governance dimension, and came to the final overall evaluation of the level of supportiveness or restrictiveness of the governance arrangements via in-depth discussions among the research team members that lasted up to eight hours per case study. The quality criteria were scored following the NXGAT methodological table (supplementary material – annex 2). The scores and final evaluation were validated with the local case study partners and discussed with the interviewees and additional stakeholders during a post-assessment workshop.

This exercise was complemented by the policy coherence assessment that started with a document analysis of the coherence of relevant policies in the case studies. The analysis was conducted per country of each river basin and included transboundary policies when existing. First, local NEXOGENESIS case study partners made an initial selection of the policies based on the WEFÉ nexus problems present in the case studies. The local partners stored these policies in an Excel database indicating the name of the policy, its policy domain, its goals, targets and policy instruments. As second step, the local partners conducted an in-depth reading of the policy documents and scored the coherence of each policy document with the other WEFÉ domains, including a justification. Subsequently, the first author of this paper reviewed the scores based on the evidence listed by the local partner. The local partners and first author discussed the scores for which there was disagreement until they reached consensus. To complete the triangulation of the results, the policy coherence scores were discussed and validated with local stakeholders during an online focus group. One stakeholder from each WEFÉ policy domain familiar with implementation of identified policies was invited. Although representatives from most nexus domains were present in the focus groups, the energy sector was not represented in Lithuania and in Greece. However, all WEFÉ nexus domains were represented in a workshop where we discussed the policy coherence results.

## 4. Results

### 4.1. Case study description

The **Mesta-Nestos river basin** is a transboundary river basin located in upstream Bulgaria (Mesta) and downstream Greece (Nestos) (Figure 2) (Boskidis et al., 2018; Kamidis & Sylaios, 2017; Proutsois et al., 2022). Water quantity and quality are the main transboundary challenges in the river basin. The ecological water quality is deteriorating due to the use of agricultural fertilizers both up – and downstream and solid waste pollution upstream affects downstream water quality. As for water quantity, an often insufficient minimum ecological flow leads to habitat degradation downstream as a result of water abstractions for agricultural purposes upstream, and the presence of three hydropower dams, i.e. the Dospat (Bulgaria), the Thissavros and the Platanovryssi (Greece) and one irrigation dam, the Toxotes (Greece) putting pressure on the riparian ecosystem in both countries. Moreover, these dams block fish migration routes, harming not only natural fish populations, but also impacting the fishery industry in Greece. At the same time, there are tensions between the agricultural and energy sector in Greece over land-use for the installation of solar power plants on agricultural land. Lastly, a large part of the river basin is located within a European Natura 2000 protected area in both countries, creating tensions between the ecosystem preservation organizations and the other WEFÉ nexus domains, nationally and cross-border.

The **Lielupe river basin** (Figure 3) is located in upstream Lithuania and downstream Latvia (Koltsova & Belakova, 2009). The main transboundary issues are related to water quality. Agricultural and transit pollution have increased eutrophication, which resulted in deterioration of the ecological water quality stemming (Česonienė et al., 2021; Jekabsons et al., 2022). While affecting in the entire river basin, water pollution is a major issue downstream, in Latvia. Moreover, hydro-morphological alterations of the river due to channeling for agricultural land drainage and small hydropower plants are increasingly problematic for the ecological quality of the river in Latvia. The energy sector is searching for alternative energy resources in both countries, therefore looking to the other domains to, for example, use agricultural land or the sea for wind parks. This creates tensions with the ecosystem preservation organizations and

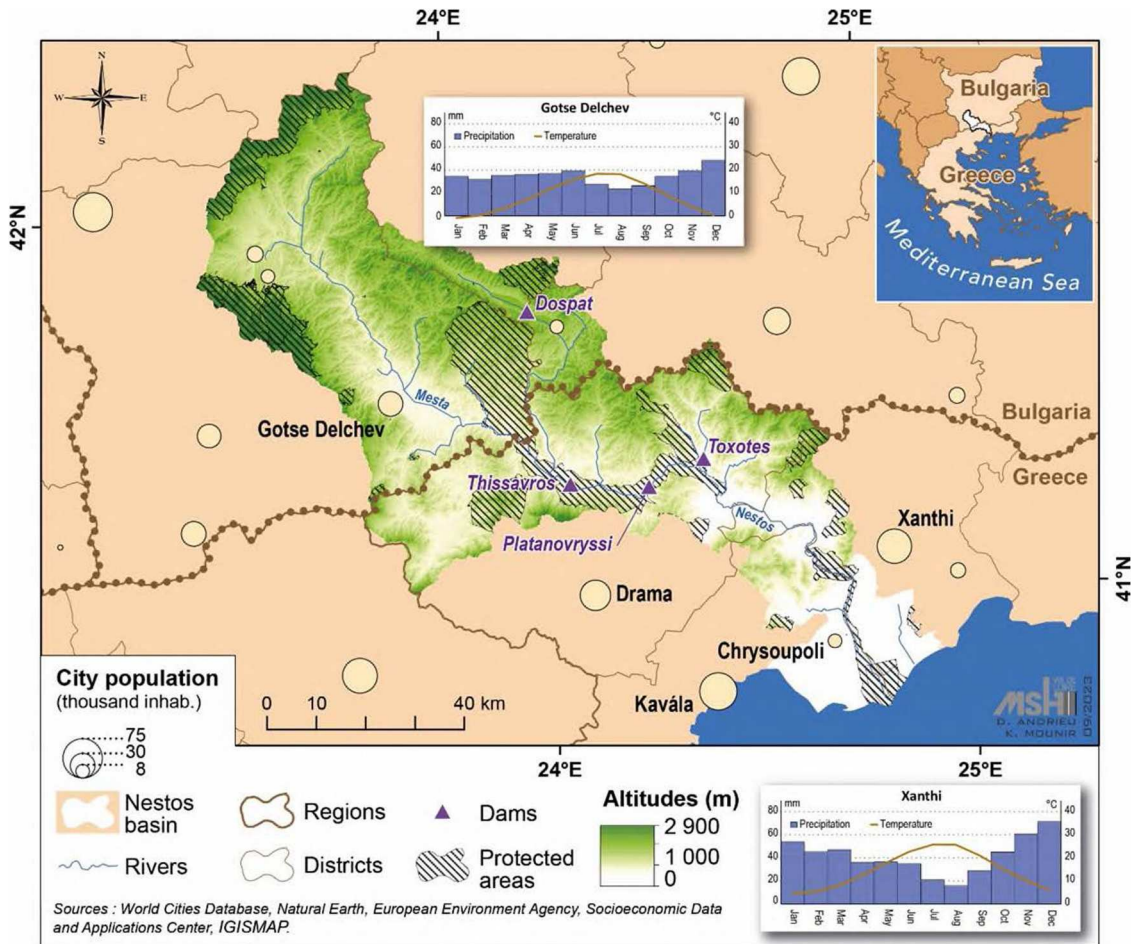


Figure 2. Mesta-Nestos River basin.

the agricultural sectors. At the same time, water quantity issues (excessive water) are a problem in Latvia where floods during spring time damage agricultural crops, thus exacerbating ecosystem-agriculture tensions (Merkuryeva et al., 2015). A more detailed illustration of the key characteristics of the river basins can be found in the supplementary material-Annex 1.

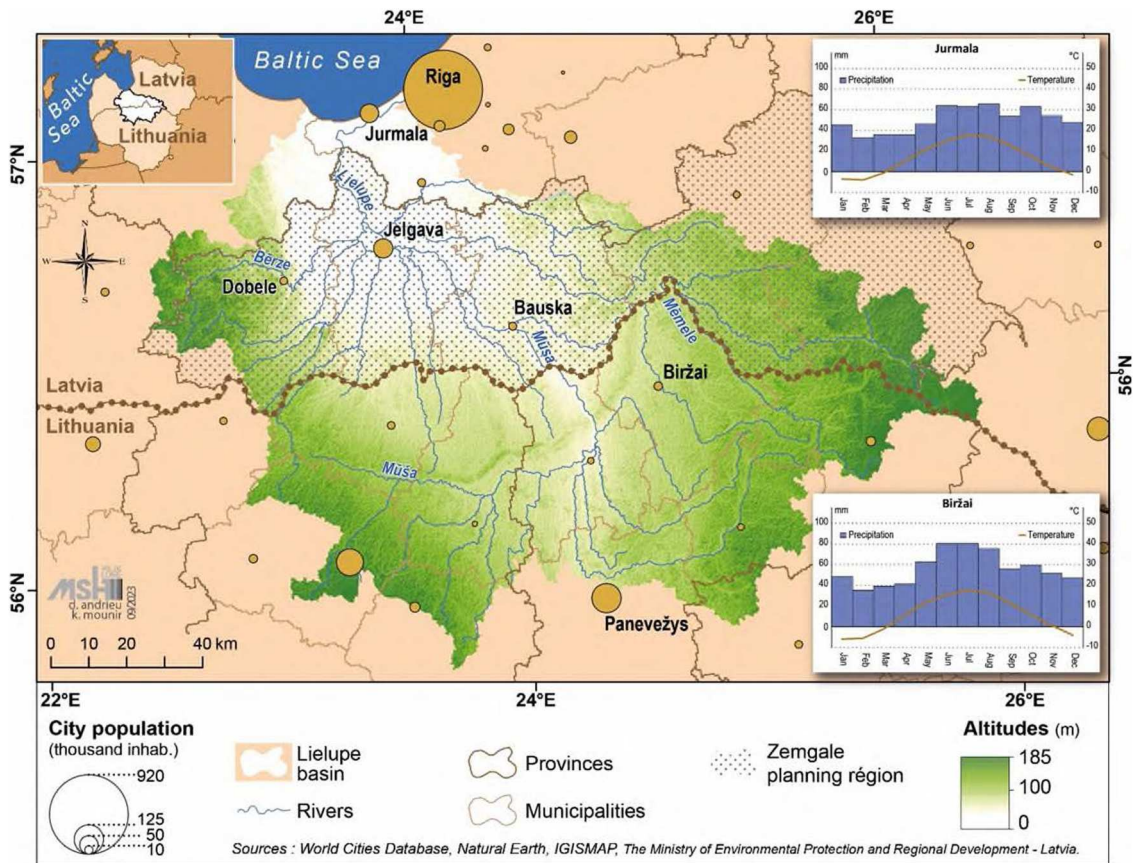
#### 4.2. WEFE nexus governance in the two river basins

This chapter answers the first research question: to what extent are the governance arrangements in the case studies restrictive or supportive towards WEFE nexus governance?

##### 4.2.1. Mesta-Nestos

The governance of the Mesta-Nestos river basin is **restrictive** towards transboundary WEFE nexus governance. Insights from the interviews and process observations show that the strict top-down governance arrangements combined with a strong hierarchical institutional structure, lack of trust between the administrative levels, and high level of bureaucracy makes it difficult to involve the regional and local levels in transboundary cross-sectoral governance discussions. All transboundary contacts take place at the national level.





**Figure 3.** Lielupe River basin.

Moreover, the national level did not engage in the research interviews, focus groups, or workshops, indicating little interest in including more local perspectives in transboundary discussions. Specifically, the strong sectoral vision of the national governments is a restrictive element for WEF nexus-oriented measures at the river basin level. There is no local transboundary contact between the border municipalities resulting in a lack of trust between the two countries at the local level. Local transboundary collaboration is further complicated by a language barrier and high levels of bureaucracy, specifically concerning water quality and quantity data sharing. Moreover, there is a lack of trust between the actors of the different WEF domains in both countries. More specifically, there are tensions within the Greek agriculture sector between two agricultural districts making use of the same water source for irrigation, the Nestos. While both countries share similar views on most issues in the river basin, they have different perspectives on the causes of these issues due to limited understanding of the hydraulic system's complexity. For example, according to the Bulgarian stakeholders, the Dospat dam, a hydropower dam in a tributary of the Mesta river (Dospat river), does not influence Mesta's water levels as it is not located in the Mesta (See Figure 2). However, this tributary flows into the Nestos and therefore influences the water levels of the Nestos river. While a bilateral river basin agreement has been in place since 1995, stating that 29% of the water originating from Bulgaria should flow to Greece (Karasani et al., 2022), Bulgarian stakeholders indicate that there is a need to renegotiate this agreement in light of climate change. According to stakeholders, there have not yet been negotiations, while the meteorological conditions have changed since 1995, indicating that this agreement is rather inflexible. The agreement was intended to ensure sufficient water quantity for both countries, and as such having a positive effect on the WEF nexus by ensuring sufficient water for all uses. However, due to different climatic conditions, currently

the agreement may have a negative impact on water uses across WEFE domains on both sides of the basins, which may exacerbate in the future. Lastly, limited funds and human resources make it difficult to undertake cross-sectoral initiatives for which often no budget is allocated.

There are a few positive signs for more transboundary WEFE nexus governance. Recently, the responsibility for the design of the river basin management plan (RBMP) has been shifted from the national to the regional level in both countries, thus increasing the fit between the scale of the problem and the policy solutions. Moreover, several stakeholders in both countries indicated that indeed a regional river basin authority could foster local transboundary WEFE nexus governance. Furthermore, both the Mesta and Nestos are within Natura 2000 protected areas. In addition, EU projects, such as the NEXOGENESIS project, proved a useful platform for local and regional stakeholders from the different WEFE nexus domains to meet and discuss transboundary WEFE nexus issues and potential solutions. Lastly, the current energy crisis pushes the energy sector to look for alternative energy resources such as solar power. This requires cross-sectoral collaboration. For instance, the energy sector needs to collaborate with the food sector to install solar power panels on agricultural plots. The last positive element is the opportunity for increased recognition of cross-sectoral interdependences offered by reframing sectoral problems in the broader WEFE nexus picture. These elements are merely preliminary steps and examples. They do not offer structural solutions yet to overcome the restrictive elements.

#### 4.2.2. Lielupe

The governance of the Lielupe river basin is *restrictive* towards transboundary WEFE nexus governance. The strict top-down governance arrangements lead to a lack of involvement of local/regional actors in transboundary governance, while some issues, such as riverbed clean-ups are more efficiently addressed at the local level. The countries agree on water quality and flood risk problems in the river basin, but have different nitrogen pollution thresholds, with Lithuania (upstream) using higher thresholds than Latvia (downstream). If the two governments cannot agree on the problem, involving different domains in the two countries in a discussion becomes more difficult. Moreover, the lack of human capital, environmental expertise and funding hinders the implementation of, and compliance with cross-sectoral measures such as the enforcement of buffer strips in the river bed. These are strips of land next to the river where agriculture is forbidden to prevent runoff of fertilizers and pesticides into the river. A lack of human and financial capital makes it difficult to monitor compliance, and therefore these strips are often still cultivated. The last restrictive element towards transboundary WEFE nexus governance is the sectoral vision at the national level, resulting in sectoral-oriented policies and strategies to address transboundary river basin issues.

We found few elements that could support the transition towards transboundary WEFE nexus governance. Both countries started an inter-ministerial board and working groups aiming to foster more policy coherence within the respective countries. This is a result of pressure from the European level for more policy coherence and transboundary river management and the energy crisis, which urges both countries to search for alternative energy resources, requiring more cross-sectoral collaboration. Most stakeholders across levels and scales, while not always agreeing on the solutions, tend to agree on the most important issues. Despite the top-down governance arrangement, the national-level interviewees expressed interest and willingness to include the local and regional levels more in transboundary governance. Not only were catchment officers proposed by the stakeholders as a solution to link the different countries, sectors and levels of governance, but the national level was also actively contributing to the interviews, focus groups and workshops organized for this research. Moreover, local transboundary communication occurs. Such communication is facilitated by the existence of common language, Russian, as results of their shared history. Despite the current geopolitical tensions with Russia, Russian was used during the stakeholder workshops. The Stakeholders took on a pragmatic approach to enable high level discussions. However, communication, collaboration and ideas are not sustained with consistent funding. Local transboundary collaboration mostly takes places in the context of European funded projects, which have a short time frame to build and support long lasting collaborations. From 1993 to 1997 a transboundary agreement on environmental management of the Lielupe river basin was in place. It contained several proposed actions such as monitoring and a joint commission (World Bank,

1995). To our knowledge and based on stakeholder interviews no further action is partaken to follow-up on this agreement. Instead, the Lithuanian-Latvian Intergovernmental Commission (IGC) for cross-border cooperation exists. While during the most recent meeting (April 2024) Lielupe river basin management and eutrophication reduction was discussed, there is no evidence that transboundary river basin management is a regular topic at the IGC meetings. While there are some supportive elements present, they are in preliminary stages and not yet structurally implemented to overcome the restrictive elements.

### 4.3. Understanding WEFE nexus governance in light of WEFE nexus governance challenges

We use the factors in Table 1 to explain the restrictiveness of the governance arrangements in the case studies and to identify the opportunities for change through the supportive elements. In so doing, we answer the second research question: what factors contribute to the restrictiveness or supportiveness? Figures 4 and 5 show the degree to which the explanatory factors are present in case studies, thus explaining the restrictiveness

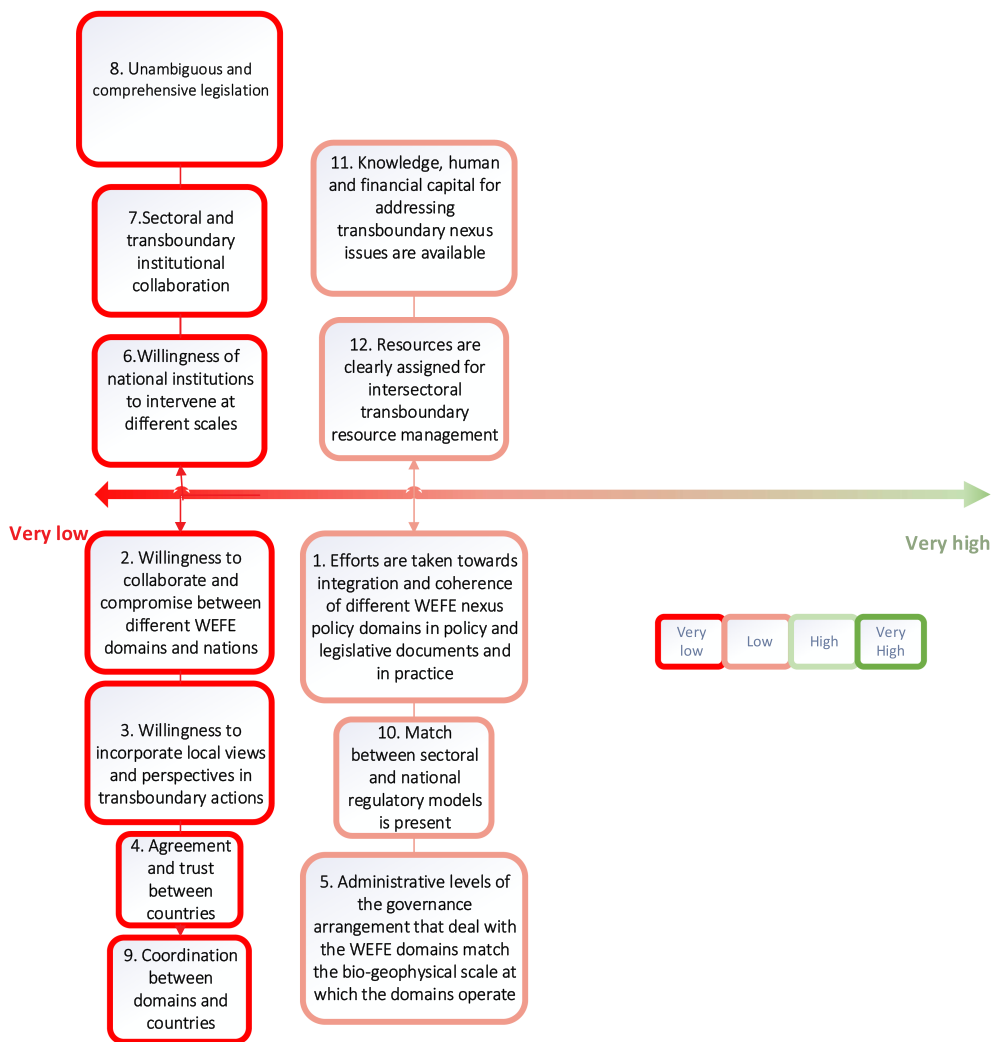
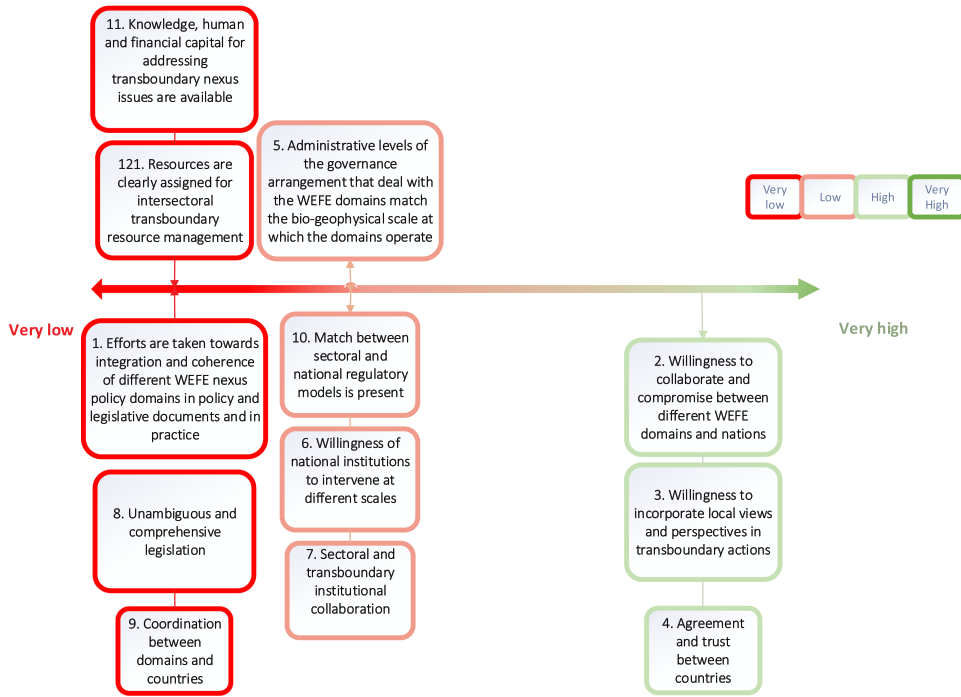


Figure 4. Overview of the degree to which the explanatory factors are present in Mesta-Nestos river basin. The intensity of the colors reflects the degree to which these factors are present.



**Figure 5.** Overview of the degree to which the explanatory factors are present in Lielupe river basin. The intensity of the colors reflects the degree to which these factors are present.

of their governance arrangements. The intensity of the color and the position in the line reflect the degree to which the factors are present in the case studies (see legenda in figures).

**4.3.1 Goal and problem-related factors**

The first category of factors is concerned with the *degree to which efforts are taken towards integration and coherence of different WEFE nexus policy domains in policy and legislative documents and in practice* (table 1, #1). We conclude that this has taken place to a very low to low degree. In both cases, the WEFE nexus domains and national governments have a strong *sectoral* vision. This makes discussion and agreement on *cross-sectoral* issues difficult, despite the existence of inter-ministerial committees and working groups. Intra-sectoral conflicts, like disagreement over water usage in the agricultural sector in the Greek part of the basin, further challenge achieving cross-sectoral consensus, given the difficulty of agreeing on a common view even within a single sector. In the Lielupe, efforts for transboundary cross-sectoral collaboration are complicated by the use of different thresholds for nitrogen concentration in the water in the two countries, an indication of disagreement on the water quality problem.

Notwithstanding, there are opportunities to enhance this factor. The energy crisis provides momentum for fostering cross-sectoral collaboration, particularly in the context of renewable energies. However, in the Mesta-Nestos case, the fact that solar panels cannot be installed next to irrigated land shows the importance of good cross-sectoral coordination to safely exploit the cross-sectoral synergies offered by the energy transition. Another opportunity for more cross-sectoral transboundary collaboration is framing sectoral issues in an integrated perspective. For example, in the Greek part of the Mesta-Nestos river basin, the fisheries governor reframed the issue of obstruction of fish movement in the river caused by hydropower dams. This reframing positioned the problem as a shared concern of both the food and the ecosystem domains, resulting in fishermen and ecosystem representatives lobbying together for fish passages in hydropower and irrigation

dams. Lastly having the same perspective on transboundary issues, as in the Lielupe case, is an important starting point to design coherent solutions to address these issues.

#### 4.3.2 Actor and network-related factors

The degree of *willingness to collaborate and compromise between different WEFE domains and nations* (Table 1, #2) is higher in the Lielupe case than in the Mesta-Nestos case. In the latter case, we found a lack of interaction and distrust between transboundary municipalities and across the nexus domains. The local stakeholders consistently mentioned a lack of communication between the Greek and Bulgarian municipalities in the river basin due to a language barrier. In contrast, in Lielupe, while there are sometimes different problem perspectives, local actors across the border of the two countries communicate on occasion, facilitated by the fact that they speak a common language, and this interaction has facilitated trust building. Moreover, in Latvia the regional level is highly motivated to facilitate integration between levels and domains, which could support the willingness of the domains and administrative levels to collaborate.

Similarly, in the Lielupe case, there was more *willingness to incorporate local views and perspectives in transboundary actions* (Table 1, #3). In the former case, representatives from the national level participated in the interviews and workshops and expressed interest in increasing local participation in transboundary management of the river basin. In the Mesta-Nestos case it proved difficult to engage with the national level in both the interviews and workshops. This difference might be explained by the different types of interaction between the administrative levels in the case studies. The interaction between the different levels in the Lielupe case is *consistent and based on trust*, while the relationship between the different administrative levels in Mesta-Nestos is characterized by *distrust* (Table 1, #4). One reason for this difference might be the different size of the countries. In the Lielupe case, stakeholders often mentioned that both countries are small and actors from different administrative levels know each other and interact on a regular basis. Greece and Bulgaria are both bigger countries and the river basin is located far away from the capital, creating more distance between the administrative levels. Less opportunities for in person exchange makes it difficult to build relationships and trust and therefore less attention for including local perspectives in transboundary decision-making. Despite there being more willingness to collaborate, including different perspectives and a higher level of transboundary trust in Lielupe than in Mesta-Nestos, both case studies are restrictive towards WEFE nexus governance. The willingness to collaborate and include different perspectives is hindered by a lack of resources and a lack of capacity to act on this willingness.

#### 4.3.3 Scale-related factors

In both cases, administrative levels of the governance arrangement that deal with the WEFE domains *match the bio-physical scale of river basin issues to a low degree* (Table 1, #5). Both cases have a strict-top-down governance arrangement where most policies are designed at the national level, often leading to incongruence with local and regional realities. A result of this top-down governance system is the absence of transboundary river basin organizations. The RBMP in Lielupe, for example, is designed at the national level, which constitutes a restrictive factor for local transboundary WEFE nexus governance. All these aspects contribute to a low match between the bio geographical scale and the administrative scale at which the problem is addressed.

However, in both cases the local and regional levels expressed interest in more local and regional transboundary governance in the form of catchment officers or river basin authorities, potentially leading to better management at the river basin scale. In the Mesta-Nestos case, the RBMP is designed by the regional level on both sides of the border. Regionally designed and managed RBMPs combined with the recent creation of local offices of the national NECCA in Greece offer opportunities to integrate local and ecosystem considerations in transboundary governance. This could contribute to a higher match between the biogeographical scale and the administrative scale at which the problem is addressed.

#### 4.3.4 Institutional related factors

*The degree of willingness (or ability) of national institutions to intervene at different scales* (Table 1, #6) is very low in Mesta-Nestos and higher in Lielupe. However, despite this indicated willingness in the Lielupe case, the

top-down governance style in both cases makes intervention at different scales difficult in practice. For example, municipalities in Greece are not allowed to intervene in the riverbed unless mandated by the national level or during emergencies. On top of that, in the Mesta-Nestos, *the level of sectoral and transboundary institutional collaboration* (Table 1, #7) is very low. Unclear, at times overlapping, responsibilities and bureaucracy along with poor cross-sectoral and cross-country communication hinder the presence of good coordination between sectors and countries. Poor communication between administrative levels contributes to low trust and poor awareness of local and regional issues at the national level. Trust in the capacity of the lower administrative levels and awareness of local issues is needed before the national level would consider decentralizing power. Moreover, there is a very low *degree of coordination between domains and countries* (Table 1, #8) in Mesta. The high level of bureaucracy further complicates activities dealing with different sectoral regulatory models. For example, certain activities such as acquiring irrigation permits require permits from multiple institutions, but because their timelines do not align, the permit processes often end in standstills. This affects trust and collaboration among different institutes, who may blame each other for the slow processes.

The results of the policy coherence assessment show a low *match between sectoral regulatory models* (Table 1, #10) in both the Lielupe and Mesta-Nestos river basin. The different nitrogen thresholds in Lielupe illustrate this on a transboundary scale. On the Bulgarian side of the Mesta-Nestos river basin there are high levels of policy coherence reported due to their relatively recent (and incomplete harmonization process with EU law). This leads to ambiguity and non-comprehensive legislation resulting in legislative gaps (Table 1, #8). The legislative gap is used by organizations representing the ecosystem domain as an opportunity to block developments in the energy sector (wind/hydropower energy). While this is positive for ecological conservation, it hinders collaboration between WEFE domains.

However, the relatively high level of policy coherence of Bulgaria has the potential to foster *alignment between different sectoral regulatory models* (Table 1, #10). The lower levels of governance have to align their local policies with national policies, which show a relatively high level of policy coherence that could trickle down to the regional and local policies. Moreover, the minor decentralization of the RBMP design in Mesta-Nestos could lead to include interventions from local administrative levels. Lastly, in Lielupe, there is a growing trend towards more *intersectoral coordination* (Table 1, #9) at the national level, as evidenced by the creation of inter-ministerial committees and working groups that aim to foster more policy coherence in general. By regularly interacting within these groups and committees, sectoral actors would be able to exchange, learn about sectoral needs, perspectives and interdependences and slowly build trust, which in turn could support cross-sectoral collaboration and coordination of cross-sectoral initiatives.

#### 4.3.5 Resource-related factors

In both case studies, *knowledge, and financial and human resources for environmental management* (Table 1, #11) are only available for a low to very low extent. This makes it difficult to establish environmental monitoring and to enforce adequate penalties in the river basins, with consequent increase of water pollution especially in the downstream countries. For example, infrequent monitoring in combination with low fines for violations of the rules on buffer zones along the riverbanks make environmental friendly agricultural policies ineffective. Furthermore, the limited available funds are often assigned to domain-specific activities, resulting in *insufficient and discontinued budget for cross-sectoral and local transboundary activities* (Table 1, #12). Many local transboundary projects depend on EU (typically Interreg) funds, which are time bounded, contributing to the financial discontinuity. Finally, in both cases, institutional capacity to attract personnel with the right expertise to work in public organizations is limited, due to non-competitive salaries compared to the private sector.

On the positive side, in both cases, the countries have many policy instruments at their disposal that could be used to foster transboundary WEFE nexus governance. Specifically, the European Natura 2000 regulation on nature and biodiversity conservation via protected areas seems promising. This regulation requires any WEF sectoral development within these areas to take the ecosystem into account, thus supporting a dialogue

among stakeholders from the different domains. This could help increase the environmental awareness of stakeholders. Interviewees found the European Union (EU) funded projects useful platforms to engage in local/regional transboundary governance. Stakeholders also appreciated the NEXOGENESIS project for bringing stakeholders from different WEFÉ nexus domains and countries together to jointly reflect on the nexus issues in the river basin. These projects not only provide temporary funding for transboundary resource management, but also improve institutional capacity through knowledge exchange and stakeholder awareness of the WEFÉ nexus interdependencies. The main challenge with these projects is to create the conditions for continuity beyond the project.

## 5. Discussion: lessons learned and recommendations for transboundary WEFÉ nexus governance

Based on the insights in chapter 4 we answer the second research question in this section; What recommendations can be formulated based on the lessons learned across the two case studies for transboundary WEFÉ nexus governance?

In section 4.3 under *the goal and problem related factors*, we saw that stakeholders' silo approach to inter-related issues in the river basins affects the efforts taken towards *policy integration*. In both case studies, the national government is a powerful actor controlling sectoral policies. Our analysis shows a limited degree of *policy coherence* across sectoral policies. Moreover, the cases highlighted that stakeholders across all levels of governance and sectors have limited *awareness* of the WEFÉ nexus interlinkages, making it difficult to overcome sectoral-oriented policy-making. Hence, there is a need to increase knowledge on the WEFÉ interdependencies. This is in line with existing literature as Armitage et al. (2015) see science used for policy-making as one of the key conditions for effective transboundary governance. Science for policy-making requires effective science communication targeted towards the relevant policy makers (Armitage et al., 2015). While scientific knowledge is important, local non-scientific knowledge should also be considered. Hence, different knowledge types should be integrated and platforms to bring different stakeholders together are important to this purpose (Fulgenzi et al., 2020). This relates to the *actor-related factors*, such as willingness to incorporate local views. Our research showed that the majority of the stakeholders were *unaware* of the WEFÉ nexus interlinkages characterizing the problems existing in the river basin. Consequently, collaborating across WEFÉ sectors is not perceived as very important, coinciding with *actor and network related factors*. The interview questions of the governance assessment helped stakeholders reflect on the interconnected nature of the issues in the river basin as the researchers contextualized the problems in the bigger picture. This understanding supported the discussion among stakeholders across WEFÉ nexus domains and governance levels in the NEXOGENESIS workshops. Moreover, stakeholders indicated that the project workshops allowed to meet representatives from other countries and WEFÉ nexus sectors for the first time. The process also paved the way to discuss potential actions to be taken at the local/regional level to initiate transboundary WEFÉ nexus activities relevant for the local level. This initial discussion led to identify some small-scale, local transboundary activities that, if implemented, could lead to small wins encouraging more of these actions. Therefore, our first recommendation is to increase *awareness* through **more nexus research projects** employing strategies taking the problems as understood by the stakeholders as a foundation and **contextualize them in the broader nexus context** as shown by the Mesta-Nestos case.

Under the *actors and networks related factors* in section 4.3 we noticed that a lack of local cross border and cross-sectoral communication and trust restricts the ability and willingness to *collaborate* and *coordinate*. The language barrier was mentioned as the main cause of distrust. Therefore, we recommend civil servants working at border municipalities to speak a **common language** between neighboring countries.

Both the *scale and institutional related factors* in section 4.3 provided insights that could further explain the lack of local cross border and sectoral communication and interaction in the case studies. Because of the strict top-down governance arrangement and the transboundary status of the river basin, the responsibility of the river basin falls under the national level. Transboundary governance almost always takes place at the national level as a result of centralized national governmental processes (Jager et al., 2016; Nielsen et al., 2013). Our

results show, in line with other authors, that including local perspectives in transboundary governance is necessary for legitimacy and local acceptance of solutions (Armitage et al., 2015; Green et al., 2013). Moreover, the low coherence and lack of trust between the different administrative levels limits the willingness to intervene at different and often more appropriate scales. One possible explanation could be the distance between the administrative levels, especially in the Mesta-Nestos case study. Proximity fosters knowledge exchange between actors (Biggiro & Sammarra, 2010). The cases show that some issues are very local and require solutions based on local knowledge, and are often more adequately tackled from the local/regional level than from the national level. To address issues at the appropriate level we recommend that allocating a **bigger role for the regional level** could reduce the distance between the national and local level leading to more *integration* and *coordination*. More specifically, **catchment officers could bridge the different administrative levels, countries, and WEF nexus sectors**. They could act as boundary organizations or workers. Boundary organizations and boundary workers are mentioned in the literature as one of the key conditions for transboundary governance (Armitage et al., 2015). Boundary organizations are formal institutions at the intersection between governmental and non-governmental organizations aiming to bring social actors and their views together. Catchment officers, can be seen as boundary workers. Such agents have successfully been used in Denmark to foster communication and trust building between different types of stakeholders (e.g. public administrations, scientist, private actors), while at the same time supporting the implementation of nutrient mitigation measures (Hoffmann et al., 2020). Another successful example is the Dutch Delta program, a national program responsible for advising the Dutch government on flood protection and fresh water supply (Restemeyer et al., 2017). To be effective, impartial and avoid institutional crowdedness, these organizations should have the clear aim and mandate to mediate between different WEF domains and governmental scales, rather than adding their own agenda to existing ones (Biesbroek et al., 2011; Smith & Porter, 2010). These organizations or individuals should function as true boundary organizations/workers, responsible for facilitating inclusive communication, creating common ground and mutual understanding between the stakeholders, making space for all perspectives to be heard, and laying down the rules for decision-making (Van Enst et al., 2017). This could enable different national and sectoral institutions to *collaborate* and *coordinate*. Hoffmann et al. (2022) reflect on the roles and expertise that individuals bridging multiple disciplines and, science and practice should have. They often take on roles such as bridge builders, translating different perspectives, fostering synergies between different perspectives, mediating between different groups, but also facilitating and evaluating the process. These roles require specific skills and expertise which the catchment officers should have. They should be creative, patient, and reflexive. Moreover, these individuals should be integrative thinkers, have interactional and referred expertise (Hoffmann et al., 2022). The former refers to the ability to understand and communicate with disciplines other than your own discipline, and the latter the ability to use expertise from one discipline in another (Collins, 2004; Collins & Sanders, 2007; Hoffmann et al., 2022) Catchment officers should either be selected based on this expertise or supported to develop it.

Our findings regarding the *resource related factors* show that both case lack knowledge, human and financial resources hindering monitoring of natural resource. A lack of monitoring of water quality and quantity, in turn, complicates transboundary negotiations over natural resource allocation or pollution. Our findings confirm existing literature identifying lack of monitoring, non-transparent data and having different indicators and/or targets as a challenge to transboundary governance (Green et al., 2013; Voss et al., 2013). For instance, disagreement on hydraulic models or pollutants thresholds complicates the process to reach an agreement on transboundary resource quality and use (Krengel et al., 2018; Voss et al., 2013). Green et al. (2013) suggest that joint monitoring of natural resources can be a first step in transboundary collaboration and data sharing because reliable, credible data can foster collaboration (Namany et al., 2023). Monitoring is not only important as a precondition for collaboration, but also to evaluate the effectiveness of measures taken, and so their enforcement (Jiménez et al., 2020). Unfortunately, as seen in the cases, insufficient funding in the public sector or insufficient fines do not stimulate behavioral change. The literature points to potential solutions. Benefit-sharing schemes, for instance, are a way to foster self-enforcement and serve as an incentive for transboundary cooperation (Green et al., 2013; Namany et al., 2023). Other options would be to set up cost-sharing schemes between transboundary countries by



broadening the valuation of ecosystem services beyond only conservation or making use of public-private-partnerships (PPP) (Mirumachi & Hurlbert, 2022). However, mitigating the risks of PPPs and making it successful requires well-functioning laws, regulations, and adequate resources (Mirumachi & Hurlbert, 2022). Based on experiences in our research, we noticed that EU-projects are often used to instigate local transboundary actions. Therefore, we recommend using **EU-projects as temporary funds** to finance projects and meetings and are therefore not a permanent solution. However, they are useful platforms to initiate local transboundary dialogue between different administrative organizations, and between representatives from different WEFÉ nexus domains. This could be combined with **well-coordinated private investments in cross-sectoral initiatives** as a long-term solution.

The recommendations above are formulated based on the interview results and our observations and experiences in the NEXOGENESIS project. The project is transdisciplinary and researchers from various disciplines frequently interact with stakeholders to produce results. These interactions might contribute to high stakeholder interest and cross-sectoral learning, despite some stakeholder fatigue. It should be noted that the stakeholders explicitly mentioned the usefulness of these transdisciplinary projects and activities.

## 6. Conclusion

This paper set out to fill a knowledge gap on practical transboundary WEFÉ nexus governance approaches and tools by means of two transboundary cases, the Lielupe and the Mesta-Nestos river basins. We addressed three research questions: (1) to what extent are the current governance arrangements in the Lielupe and Mesta-Nestos river basin supportive or restrictive towards WEFÉ nexus governance? (2) what factors contribute to supportiveness and restrictiveness? (3) what recommendations can be formulated based on the lessons learned across the two case studies for transboundary WEFÉ nexus governance?

Our analysis shows that the governance arrangements in both cases are *restrictive* towards transboundary WEFÉ nexus governance. It also revealed a number of elements contributing to the level of restrictiveness, which interpreted in light of 5 types of governance challenges and related explanatory factors, allowed to formulate four recommendations to organize transboundary WEFÉ nexus governance in a more optimal way.

This research compared two transboundary river basins in Europe. The WEFÉ nexus governance assessment methodology proved useful to provide case-relevant insights and recommendations. However, the findings are difficult to generalize since the methodology has been applied only to two transboundary cases so far. Further testing and application in other transboundary contexts and also across different nexus issues is necessary to consolidate it. Moreover, the practical feasibility of the recommendations should be further investigated. A final suggestion is to have the national level reflect on these results, especially on the current relevance of the formal transboundary agreements and the need to revise or to establish new ones.

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## References

- Allouche, J., Middleton, C., & Gyawali, D. (2015). Technical veil, hidden politics: Interrogating the power linkages behind the nexus. *Water Alternatives*, 8(1), 610–626.
- Armitage, D., De Loë, R. C., Morris, M., Edwards, T. W., Gerlak, A. K., Hall, R. I., Huitema, D., Ison, R., Livingstone, D., MacDonald, G., Mirumachi, N., Plummer, R., & Wolfe, B. B. (2015). Science–policy processes for transboundary water governance. *Ambio*, 44(5), 353–366. <https://doi.org/10.1007/s13280-015-0644-x>
- Avellán, T., Roidt, M., Emmer, A., Von Koerber, J., Schneider, P., & Raber, W. (2017). Making the water–soil–waste nexus work: Framing the boundaries of resource flows. *Sustainability*, 9(10), 1881. <https://doi.org/10.3390/su9101881>
- Benson, D., Gain, A. K., & Rouillard, J. J. (2015). Water governance in a comparative perspective: From IWRM to a ‘nexus’ approach? *Water Alternatives*, 8(1), 756–773.
- Bernard, H. R. (2017). *Research methods in anthropology: Qualitative and quantitative approaches*. Rowman & Littlefield.
- Bidoglio, G., Vanham, D., Bouraoui, F., & Barchiesi, S. (2019). The water–energy–food–ecosystems (WEFE) nexus. *Encyclopedia of Ecology*, 459–466. 2nd ed.; Fath, B., Ed. <https://doi.org/10.1016/B978-0-12-409548-9.11036-X>
- Biesbroek, R., Klostermann, J., Termeer, C., & Kabat, P. (2011). Barriers to climate change adaptation in the Netherlands. *Climate Law*, 2(2), 181–199. <https://doi.org/10.1163/CL-2011-033>
- Biggiro, L., & Sammarra, A. (2010). Does geographical proximity enhance knowledge exchange? The case of the aerospace industrial cluster of Centre Italy. *International Journal of Technology Transfer and Commercialisation*, 9(4), 283–305. <https://doi.org/10.1504/IJTTC.2010.035397>
- Boskidis, I., Kokkos, N., Sapounidis, A., Triantafillidis, S., Kamidis, N., Koutrakis, E., & Sylaios, G. K. (2018). Ecohydraulic modelling of Nestos River Delta under low flow regimes. *Ecohydrology & Hydrobiology*, 18(4), 391–400. <https://doi.org/10.1016/j.ecohyd.2018.06.004>
- Carlisle, K., & Gruby, R. L. (2019). Polycentric systems of governance: A theoretical model for the commons. *Policy Studies Journal*, 47(4), 927–952. <https://doi.org/10.1111/psj.12212>
- Cash, D. W., Adger, W. N., Berkes, F., Garden, P., Lebel, L., Olsson, P., Lowell, P., & Young, O. (2006). Scale and cross-scale dynamics: Governance and information in a multilevel world. *Ecology and Society*, 11(2).
- Česonienė, L., Šileikienė, D., & Dapkienė, M. (2021). Influence of anthropogenic load in river basins on river water status: A case study in Lithuania. *Land*, 10(12), 1312. <https://doi.org/10.3390/land10121312>
- Chenoweth, J., & Al-Masri, R. A. (2021). The impact of adopting a water–energy nexus approach in Jordan on transboundary management. *Environmental Science & Policy*, 118, 49–55. <https://doi.org/10.1016/j.envsci.2021.01.006>
- Collins, H. (2004). Interactional expertise as a third kind of knowledge. *Phenomenology and the Cognitive Sciences*, 3(2), 125–143. <https://doi.org/10.1023/B:PHEN.0000040824.89221.1a>
- Collins, H., & Sanders, G. (2007). They give you the keys and say ‘drive it!’ Managers, referred expertise, and other expertises. *Studies in History and Philosophy of Science Part A*, 38(4), 621–641. <https://doi.org/10.1016/j.shpsa.2007.09.002>
- Daher, B. T., & Mohtar, R. H. (2015). Water–energy–food (WEF) Nexus Tool 2.0: Guiding integrative resource planning and decision-making. *Water International*, 40(5–6), 748–771. <https://doi.org/10.1080/02508060.2015.1074148>
- de Andrade Guerra, J. B. S. O., Berchin, I. I., Garcia, J., da Silva Neiva, S., Jonck, A. V., Faraco, R. A., Silva de Amorim, W., & Ribeiro, J. M. P. (2021). A literature-based study on the water–energy–food nexus for sustainable development. *Stochastic Environmental Research and Risk Assessment*, 35(1), 95–116. <https://doi.org/10.1007/s00477-020-01772-6>
- De Grenade, R., House-Peters, L., Scott, C., Thapa, B., Mills-Novoa, M., Gerlak, A., & Verbist, K. (2016). The nexus: Reconsidering environmental security and adaptive capacity. *Current Opinion in Environmental Sustainability*, 21, 15–21. <https://doi.org/10.1016/j.cosust.2016.10.009>
- De Strasser, L., Lipponen, A., Howells, M., Stec, S., & Bréthaut, C. (2016). A methodology to assess the water energy food ecosystems nexus in transboundary river basins. *Water*, 8(2), 59. <https://doi.org/10.3390/w8020059>
- Dondeynaz, C., Pastori, M., Amettoy, I., & Carmona-Moreno, C. (2018). Assessing the WEFE Nexus and finding optimal solutions in the Mékrou transboundary river basin. *Water-Energy-Food-Ecosystems (WEFE) Nexus and Sustainable Development Goals (SDGs)*, 101, 101–109.
- Dore, J., Lebel, L., & Molle, F. (2012). A framework for analysing transboundary water governance complexes, illustrated in the Mekong Region. *Journal of Hydrology*, 466–467(466), 23–36. <https://doi.org/10.1016/j.jhydrol.2012.07.023>
- Finger, M., Tamiotti, L., & Allouche, J. (2006). Multi-governance, and transboundary river basin management. *The Multi-Governance of Water: Four Case Studies*, 173.

- Fulgenzi, A., Brouwer, S., Baker, K., & Frijns, J. (2020). Communities of practice at the center of circular water solutions. *Wiley Interdisciplinary Reviews: Water*, 7(4), e1450.
- Gerlak, A. K. (2015). Resistance and reform: Transboundary water governance in the Colorado River Delta. *Review of Policy Research*, 32(1), 100–123. <https://doi.org/10.1111/ropr.12114>
- Giest, S., & Mukherjee, I. (2022). Evidence integration for coherent nexus policy design: A Mediterranean perspective on managing water-energy interactions. *Journal of Environmental Policy & Planning*, 24(5), 553–567.
- González-Rosell, A., Arfa, I., & Blanco, M. (2023). Introducing GoNEXUS SEF: A solutions evaluation framework for the joint governance of water, energy, and food resources. *Sustainability Science*, 18, 1683–1703.
- Green, O. O., Cosens, B. A., & Garmestani, A. S. (2013). Resilience in transboundary water governance: The Okavango River Basin. *Ecology and Society*, 18(2).
- Halbe, J., Pahl-Wostl, C., Lange, M., & Velonis, C. (2015). Governance of transitions towards sustainable development—the water-energy-food nexus in Cyprus. *Water International*, 40(5-6), 877–894. <https://doi.org/10.1080/02508060.2015.1070328>
- Harwood, S. A. (2018). In search of a (WEF) nexus approach. *Environmental Science & Policy*, 89, 79–85. <https://doi.org/10.1016/j.envsci.2018.01.020>
- Hoff, H. (2011). *Understanding the nexus: Background paper for the Bonn 2011 Nexus Conference*. SEI.
- Hoff, H., Alrahaife, S. A., El Hajj, R., Lohr, K., Mengoub, F. E., Farajalla, N., Fritzsche, K., Jobbins, G., Özerol, G., Schultz, R., & Ulrich, A. (2019). A nexus approach for the MENA region—from concept to knowledge to action. *Frontiers in Environmental Science*, 7, 48. <https://doi.org/10.3389/fenvs.2019.00048>
- Hoffmann, S., Deutsch, L., Klein, J. T., & O'Rourke, M. (2022). Integrate the integrators! A call for establishing academic careers for integration experts. *Humanities and Social Sciences Communications*, 9(1), 1–10. <https://doi.org/10.1057/s41599-021-01017-z>
- Hoffmann, C. C., Zak, D., Kronvang, B., Kjaergaard, C., Carstensen, M. V., & Audet, J. (2020). An overview of nutrient transport mitigation measures for improvement of water quality in Denmark. *Ecological Engineering*, 155, 105863. <https://doi.org/10.1016/j.ecoleng.2020.105863>
- Hüesker, F., Sievers, E., Mooren, C. E., Munaretto, S., Canovas, I., La Jeunesse, I., Cirelli, C., Mounir, K., Madrigal, J., Schmeier, S., Müller, A., & Avellan, T. (2022). *Stakeholders' co-creation approach for WEF nexus Governance*. Retrieved from Leipzig, Germany.
- Jager, N. W., Challies, E., Kochskämper, E., Newig, J., Benson, D., Blackstock, K., Collins, K., Ernst, A., Evers, M., Feichtinger, J., Fritsch, O., Gooch, G., Grund, W., Hedelin, B., Hernández-Mora, N., Hüesker, F., Huitema, D., Irvine, K., Klinke, A., Lange, L., Loupsans, D., Lubell, M., Maganda, C., Matczak, P., Parés, M., Saarikoski, H., Slavikova, L., Van der Arend, S., & Von Korff, Y. (2016). Transforming European water governance? Participation and river basin management under the EU Water Framework Directive in 13 member states. *Water*, 8(4), 156. <https://doi.org/10.3390/w8040156>
- Jekabsons, J., Abersons, K., Kolcova, T., & Tirums, M. (2022). First steps in the ecological flow determining for Latvian rivers. *Hydrology Research*, 53(8), 1063–1074. <https://doi.org/10.2166/nh.2022.019>
- Jiménez, A., Saikia, P., Giné, R., Avello, P., Leten, J., Liss Lymer, B., Schneider, K., & Ward, R. (2020). Unpacking water governance: A framework for practitioners. *Water*, 12(3), 827. <https://doi.org/10.3390/w12030827>
- Jones, J. L., & White, D. D. (2021). A social network analysis of collaborative governance for the food-energy-water nexus in Phoenix, AZ, USA. *Journal of Environmental Studies and Sciences*, 1–11.
- Kamidis, N., & Sylaios, G. (2017). Impact of river damming on sediment texture and trace metals distribution along the watershed and the coastal zone of Nestos River (NE Greece). *Environmental Earth Sciences*, 76(10), 373. <https://doi.org/10.1007/s12665-017-6707-5>
- Karasani, M., Dionissis, L., Susanne, S., & Ifigenia, K. (2022). Identifying water governance priorities and gaps in transboundary basins through SWOT: The case study of Mesta/Nestos River Basin. *Environmental Sciences Proceedings*, 21(1).
- Koltsova, T., & Belakova, J. (2009). *Storm surges on the southern coast of Gulf of Riga: Case study of the Lielupe River*. Paper presented at the Threats to global water security.
- Krengel, F., Bernhofer, C., Chalov, S., Efimov, V., Efimova, L., Gorbachova, L., & Nabyvanets, Y. (2018). Challenges for transboundary river management in Eastern Europe—three case studies.
- Kurian, M., Portney, K. E., Rappold, G., Hannibal, B., & Gebrechorkos, S. H. (2018). Governance of water-energy-food nexus: a social network analysis approach to understanding agency behaviour. *Managing Water, Soil and Waste Resources to Achieve Sustainable Development Goals: Monitoring and Implementation of Integrated Resources Management*, 125–147.
- La Jeunesse, I., Cirelli, C., Canovas, I., Mooren, C. E., Sievers, E., Munaretto, S., & Mounir, K. (2023). *D1.2 governance and policy assessment in case studies*. [Unpublished manuscript] University of Tours
- La Jeunesse, I., Mooren, C. E., Munaretto, S., Cirelli, C., Canovas, I., Hueesker, F., & Sievers, E. (Forthcoming). *Water-energy-food-ecosystem nexus governance: Methodological aspects of the assessment of supportive and restrictive contexts*. [Unpublished manuscript] University of Tours.
- Lebel, L., Haefner, A., Pahl-Wostl, C., & Baduri, A. (2020). Governance of the water-energy-food nexus: Insights from four infrastructure projects in the Lower Mekong Basin. *Sustainability Science*, 1–16.
- Link, P. M., Scheffran, J., & Ide, T. (2016). Conflict and cooperation in the water-security nexus: A global comparative analysis of river basins under climate change. *WIREs Water*, 3(4), 495–515. <https://doi.org/10.1002/wat2.1151>

- Lucca, E., Kofinas, D. T., Avallan, T., Kleeman, J., Mooren, C. E., Blicharska, M., & Laspidou, C. (under review). Integrating “Nature” in the Water-Energy-Food Nexus: Current perspectives and future directions.
- Malagó, A., Comero, S., Bourraoui, F., Kazezyilmaz-Alhan, C. M., Gawlik, B. M., Easton, P., & Laspidou, C. (2021). An analytical framework to assess SDG targets within the context of WEFE nexus in the Mediterranean region. *Resources, Conservation and Recycling*, 164, 105205. <https://doi.org/10.1016/j.resconrec.2020.105205>
- Merkuryeva, G., Merkuruyev, Y., Sokolov, B. V., Potryasaev, S., Zelentsov, V. A., & Lektauers, A. (2015). Advanced river flood monitoring, modelling and forecasting. *Journal of Computational Science*, 10, 77–85. <https://doi.org/10.1016/j.jocs.2014.10.004>
- Mirumachi, N., & Hurlbert, M. (2022). Reflecting on twenty years of international agreements concerning water governance: Insights and key learning. *International Environmental Agreements: Politics, Law and Economics*, 22(2), 317–332. <https://doi.org/10.1007/s10784-022-09564-9>
- Mooren, C. E., Munaretto, S., La Jeunesse, I., Sievers, E., Hegger, D., Driessen, P. P., & Mounir, K. (Under review). *Water-Energy-Food-Ecosystem Nexus: How to frame and how to govern?* [Unpublished manuscript] KWR Water Research Institute.
- Mylopoulos, Y., Kolokytha, E., Kampragou, E., & Vagiona, D. (2008). A combined methodology for transboundary river basin management in Europe. Application in the Nestos–Mesta catchment area. *Water Resources Management*, 22(8), 1101–1112. <https://doi.org/10.1007/s11269-007-9214-8>
- Namany, S., Govindan, R., & Al-Ansari, T. (2023). Operationalising transboundary cooperation through game theory: An energy water food nexus approach for the Middle East and North Africa. *Futures*, 152, 103198.
- Nielsen, HØ, Frederiksen, P., Saarikoski, H., Rytkönen, A.-M., & Pedersen, A. B. (2013). How different institutional arrangements promote integrated river basin management. *Evidence from the Baltic Sea Region. Land use policy*, 30(1), 437–445. <https://doi.org/10.1016/j.landusepol.2012.04.011>
- Nilsson, M., Zamparutti, T., Petersen, J. E., Nykvist, B., Rudberg, P., & McGuinn, J. (2012). Understanding policy coherence: Analytical framework and examples of sector–environment policy interactions in the EU. *Environmental Policy and Governance*, 22(6), 395–423. <https://doi.org/10.1002/eet.1589>
- Olawuyi, D. (2020). Sustainable development and the water-energy-food nexus: Legal challenges and emerging solutions. *Environmental Science & Policy*, 103, 1–9. <https://doi.org/10.1016/j.envsci.2019.10.009>
- Pahl-Wostl, C., Gorris, P., Jager, N., Koch, L., Lebel, L., Stein, C., Venghaus, S., & Withanachchi, S. (2021). Scale-related governance challenges in the water–energy–food nexus: Toward a diagnostic approach. *Sustainability Science*, 16(2), 615–629. <https://doi.org/10.1007/s11625-020-00888-6>
- Pereira Ramos, E., Kofinas, D., Sundin, C., Brouwer, F., & Laspidou, C. (2022). Operationalizing the Nexus approach: Insights from the SIM4NEXUS project.
- Proutsos, N. D., Solomou, A. D., Koulelis, P. P., Bourletsikas, A., Chatzipavlis, N. E., & Tigkas, D. (2022). *Detecting changes in annual precipitation trends during the last two climatic periods (1955–1984 and 1985–2018) in Nestos River basin, N Greece.* Paper presented at the Proceedings of the 10th International Conference on Information and Communication Technologies in Agriculture, Food and Environment, HAICTA.
- Purwanto, A., Sušnik, J., Suryadi, F., & de Fraiture, C. (2019). Using group model building to develop a causal loop mapping of the water-energy-food security nexus in Karawang Regency, Indonesia. *Journal of Cleaner Production*, 240, 118170. <https://doi.org/10.1016/j.jclepro.2019.118170>
- Restemeyer, B., van den Brink, M., & Woltjer, J. (2017). Between adaptability and the urge to control: Making long-term water policies in the Netherlands. *Journal of Environmental Planning and Management*, 60(5), 920–940. <https://doi.org/10.1080/09640568.2016.1189403>
- Roidt, M., & Avellán, T. (2019). Learning from integrated management approaches to implement the Nexus. *Journal of Environmental Management*, 237, 609–616. <https://doi.org/10.1016/j.jenvman.2019.02.106>
- Salmoral, G., Schaap, N. C., Walschbauer, J., & Alhajaj, A. (2019). Water diplomacy and nexus governance in a transboundary context: In the search for complementarities. *Science of the Total Environment*, 690, 85–96. <https://doi.org/10.1016/j.scitotenv.2019.06.513>
- Salmoral, G., Zegarra, E., Vázquez-Rowe, I., González, F., Del Castillo, L., Saravia, G. R., Graves, A., Rey, D., & Knox, J. W. (2020). Water-related challenges in nexus governance for sustainable development: Insights from the city of Arequipa, Peru. *Science of the Total Environment*, 747, 141114. <https://doi.org/10.1016/j.scitotenv.2020.141114>
- Scott, C. A., Albrecht, T. R., De Grenade, R., Zuniga-Teran, A., Varady, R. G., & Thapa, B. (2018). Water security and the pursuit of food, energy, and earth systems resilience. *Water International*, 43(8), 1055–1074. <https://doi.org/10.1080/02508060.2018.1534564>
- Scott, C. A., Pierce, S. A., Pasqualetti, M. J., Jones, A. L., Montz, B. E., & Hoover, J. H. (2011). Policy and institutional dimensions of the water–energy nexus. *Energy Policy*, 39(10), 6622–6630. <https://doi.org/10.1016/j.enpol.2011.08.013>
- Smith, L. E., & Porter, K. S. (2010). Management of catchments for the protection of water resources: Drawing on the New York City watershed experience. *Regional Environmental Change*, 10(4), 311–326. <https://doi.org/10.1007/s10113-009-0102-z>
- Sušnik, J., & Staddon, C. (2021). Evaluation of Water-Energy-Food (WEF) Nexus Research: Perspectives, challenges, and directions for future research. *JAWRA Journal of the American Water Resources Association*, 58(6), 1189–1198.
- Urbinnati, A. M., Benites-Lazaro, L. L., Carvalho, C. M. d., & Giatti, L. L. (2020). The conceptual basis of water-energy-food nexus governance: Systematic literature review using network and discourse analysis. *Journal of Integrative Environmental Sciences*, 17(2), 21–43. <https://doi.org/10.1080/1943815X.2020.1749086>

- van den Heuvel, L., Blicharska, M., Masia, S., Sušnik, J., & Teutschbein, C. (2020). Ecosystem services in the Swedish water-energy-food-land-climate nexus: Anthropogenic pressures and physical interactions. *Ecosystem Services*, 44, 101141. <https://doi.org/10.1016/j.ecoser.2020.101141>
- Van Enst, W. I., Driessen, P. P., & Runhaar, H. A. (2017). Working at the boundary: An empirical study into the goals and strategies of knowledge brokers in the field of environmental governance in the Netherlands. *Sustainability*, 9(11), 1962. <https://doi.org/10.3390/su9111962>
- Verschuren, P., Doorewaard, H., & Mellion, M. (2010). *Designing a research project* (Vol. 2). Eleven International Publishing The Hague.
- Voss, K. A., Famiglietti, J. S., Lo, M., De Linage, C., Rodell, M., & Swenson, S. C. (2013). Groundwater depletion in the Middle East from GRACE with implications for transboundary water management in the Tigris-Euphrates-Western Iran region. *Water Resources Research*, 49(2), 904–914. <https://doi.org/10.1002/wrcr.20078>
- White, D. D., Jones, J. L., Maciejewski, R., Aggarwal, R., & Mascaro, G. (2017). Stakeholder analysis for the food-energy-water nexus in Phoenix, Arizona: Implications for nexus governance. *Sustainability*, 9(12), 2204. <https://doi.org/10.3390/su9122204>
- World Bank, T. W. (1995). *Staff appraisal report Republic of Latvia Siauliai environment project*.
- Young, O. R., Agrawal, A., King, L. A., Sand, P. H., Underdal, A., & Wasson, M. (1999). Institutional dimensions of global environmental change. *Public Administration and Public Policy*, 2(1999), 100.