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Assessing to act: A water-energy-food-ecosystem (WEFE) nexus governance assessment for the Inkomati-Usuthu river basin in South Africa

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ABSTRACT

Water, energy, food, and ecosystems (WEFE) are inherently interlinked, forming a complex system (nexus) that is shaped by natural and anthropogenic factors. The nexus concept was introduced as a holistic approach to resource governance. Yet, many studies remain rather technical and governance and policy-related questions often unanswered. This paper presents a WEFE nexus governance assessment for the Inkomati-Usuthu river basin in South Africa. The assessment is based on interviews and workshops with stakeholders from the four WEFE sectors and local, regional and national levels. Using the WEFE nexus governance assessment tool NXGAT, we evaluated the current governance system along five governance dimensions (*actors and networks, levels and scales, problem perspectives and goal ambitions, strategies and instruments, and responsibilities and resources*) and five governance quality criteria (*comprehensiveness, coherence, flexibility, intensity of action, and fit*). Our results show that the current governance system of the Inkomati-Usuthu river basin is *moderately restrictive* towards WEFE nexus governance, in particular due to the poor performance of the governance quality criteria *comprehensiveness, coherence, and intensity of action*. We give practical recommendations for nexus-oriented actions that can be implemented as key steps towards WEFE nexus governance. Subsequently, we reflect on our methods and discuss limitations of our study. We conclude that a WEFE nexus governance assessment based on stakeholder experiences and knowledge provides valuable insights and contributes to broader efforts to enable more contextualised assessments.

1. Introduction

Water, energy, food, and ecosystems (WEFE) are inherently interlinked, forming a complex system (nexus) that is shaped by natural and anthropogenic factors. For example, food production requires water and energy (e.g., irrigation, fertiliser use, food processing), water management requires energy (e.g., drinking water provision, wastewater treatment), and energy provision requires water (e.g., hydropower production, cooling water for power plants, biofuel production), while all three affect ecosystems (e.g., mining may lead to pollution and ecosystem fragmentation, agricultural practices may lead to ecosystem degradation and land conversion, and water provisioning may lead to overextraction of groundwater sources) (UNECE, 2020). Yet, WEFE

policies are often developed ‘sectorally’, not fully considering nexus interlinkages (Pahl-Wostl, 2019).

The nexus concept was introduced as a holistic approach to resource governance aiming to advance understanding of WEFE nexus interlinkages, reduce cross-sectoral trade-offs, and leverage potential synergies (Al-Saidi and Elagib, 2017, Carmona-Moreno et al., 2019). While earlier nexus research centred around WEF nexus conceptualisations (e.g., Hoff, 2011), more recent studies expand the nexus to other resources, such as the water-energy-food-land-materials (WEFLM) nexus (e.g., Bleischwitz et al. 2018), water-energy-food-land (WEFL) nexus (e.g., Lazaro et al., 2021), or water-energy-food-land-climate (WEFLC) nexus (e.g., Sušnik et al., 2021). To acknowledge and emphasise the vital role of ecosystems in the nexus, WEFE nexus conceptualisations are

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becoming increasingly relevant in nexus literature (e.g., [Carmona-Moreno et al., 2021](#), [Malagó et al. 2021](#), [Mooren et al. \(under review\)](#)).

However, many publications on the resource nexus have a strong technical, analytical, or conceptual focus ([Wiegleb and Bruns, 2018](#)). Although there is a general trend to also tackle questions related to nexus governance, policy and implementation, these topics are still underrepresented or insufficiently addressed ([Allouche et al., 2015](#), [Weitz et al., 2017](#), [Urbinnati et al., 2020](#)). Main governance challenges reported in nexus literature are siloed management approaches and institutional frameworks, policy incoherence, and issues of scale. Moreover, complexity resulting from nexus governance poses a major challenge, as many diverging interests and objectives are involved, potentially leading to conflict ([Al-Saidi and Elagib, 2017](#), [Weitz et al., 2017](#), [Pahl-Wostl et al., 2021](#)). As a result, potential synergies between sectors are not fully exploited and persistent trade-offs lead to ineffective implementation outcomes. Lastly, fostering policy coherence and implementation is an inherently political process requiring dialogue and negotiation among stakeholders of different levels and sectors ([Allouche et al., 2015](#), [Scott, 2017](#)). Yet, stakeholder engagement in nexus governance and research remains limited. Consequently, a divide between science (e.g., academia), policy (e.g., decision-makers) and practitioners (e.g., resource managers) has emerged and nexus assessments often lack contextuality ([Al-Saidi and Elagib, 2017](#), [Hoolohan et al., 2018](#), [John et al., 2023](#)).

Starting from the above-mentioned challenges, this paper presents a WEFE nexus governance assessment for the Inkomati-Usuthu river basin in South Africa. The assessment is based on interviews with stakeholders from local, regional and national levels and the four WEFE sectors. To ensure the assessment is relevant to the local context and takes into account stakeholder needs, it is embedded in a series of stakeholder workshops (two pre-assessment and one post-assessment). The workshops were organised by different work packages of the European Union's Horizon2020 programme funded project NEXOGENESIS of which our research is part of. To evaluate the level of supportiveness or restrictiveness of the current governance system towards WEFE nexus governance, we used the WEFE nexus governance assessment tool NXGAT of [La Jeunesse et al., \(forthcoming\)](#), which was developed as part of the project ([La Jeunesse et al., \(forthcoming\)](#), [Hüesker et al., 2022](#)). Using NXGAT, we aim to unravel synergies and trade-offs between WEFE sectors and identify barriers and levers towards WEFE nexus governance in the Inkomati-Usuthu river basin.

2. The Inkomati-Usuthu river basin

The Inkomati-Usuthu is a transboundary river basin shared between Eswatini, South Africa, and Mozambique. It covers a total area of approximately 46.800 km², of which 2600 km² (6 %) are located in Eswatini, 28700 km² (61 %) in South Africa, and 15500 km² (33 %) in Mozambique (upstream to downstream) ([Slinger et al., 2010](#)).

The Inkomati-Usuthu Water Management Area (IUWMA) is one of nine Water Management Areas in South Africa. It is located in Mpumalanga Province extending over four main river catchments, namely Sabie-Sand, Crocodile, Komati and Usuthu ([Fig. 1](#)). The river catchments drain in easterly direction and flow together in Mozambique, where they form the Inkomati river and discharge into the Indian Ocean. IUWMA covers three district municipalities, namely Ehlanzeni, Gert Sibande and Nkangala and ten local municipalities with Mbombela, Bushbuckridge and Nkomazi being the largest ([IUCMA, 2023](#)). Alongside municipal and provincial governments, traditional leadership structures, particularly in areas of former bantustans, play a significant role in governing land allocation and local resource use ([Peters and Woodhouse, 2019](#)).

The IUWMA is divided by the Great Escarpment into the Highveld, a western high-plateau area (1500–2100 m) characterised by temperate climate and annual precipitation of up to 1200 mm, and the eastern Lowveld (150–600 m) with sub-tropical climate and precipitation of only 400 mm per year. Average cumulative rainfall trends of the past

decades show a decline in overall rainfall and an increase in frequency, duration, and intensity of extreme weather events such as droughts and floods. The patterns clearly show the impacts of climate change and highlight the importance to account for them, as matters will most likely escalate in the future ([IUCMA, 2023](#)).

2.1. WEFE nexus challenges

The Inkomati-Usuthu river basin is vital to South Africa's water, energy, and food security and covers substantial high-priority biodiversity conservation areas. Hence, WEFE nexus challenges of the river basin are manifold. Generally, water demand is higher than water availability leading to severe water stress and allocation conflicts in some areas. Predominant water use types are irrigated agriculture by both emerging and commercial farmers, extensive afforestation, and strategic water use for cooling purposes ([Du Plessis, 2019](#)). Cooling water is mainly used for electricity generation by Eskom and cooling of power plants of the Sasol Secunda Complex, a synthetic fuel plant in Mpumalanga. Moreover, South Africa has international water obligations to Mozambique, as IUWMA is part of the transboundary Inkomati-Maputo river basin ([IUCMA, 2023](#)). Approximately 37 % of the Kruger National Park is located in IUWMA with Sabie River flowing through Kruger National Park and Crocodile River forming the southern border of the park, making ecological water requirements particularly relevant. Eco-tourism is a central income source next to other key economic activities such as agriculture, forestry, and mining ([IUCMA, 2018](#)). Extensive coal mining and unauthorised river sand mining pose a major threat to water quality and quantity in the Upper Komati sub-catchment ([IUCMA, 2023](#)). Urbanisation and insufficient wastewater treatment are further challenges for water quality in the river basin.

Finally, IUWMA is characterised by large social disparities and inequitable access to resources, especially in areas of the former 'homelands' Lebowa, Gazankulu, and KaNgwane, urban townships, and informal settlements ([Peters and Woodhouse, 2019](#), [van Koppen et al., 2024](#)). 'Homelands', also known as bantustans,¹ were created under the Apartheid government as part of the 'separate development' policy, which sought to force black South Africans into set aside scattered parcels of uneconomic land, according to their ethnic identity ([Walker, 2014](#), [Méndez-Barrientos et al., 2018](#)). Today, historical imbalances in the IUWMA continue to grow, as resource access and availability for the rural and peri-urban population of the congested and scattered settlements of the former bantustans is very limited. Most citizens depend on informal self-supply of water for domestic uses, livestock watering, and farmer-led irrigation, largely outside state control and public services ([van Koppen et al., 2024](#)).

3. Methods

The methodological approach adopted for this study consists of three key steps ([Fig. 2](#)). First, we operationalised the WEFE nexus governance assessment tool NXGAT of [La Jeunesse et al., \(forthcoming\)](#) to assess the WEFE nexus governance orientation in the Inkomati-Usuthu river basin. Next, we organised a series of stakeholder workshops in preparation of the assessment and field visit to the case study area and to subsequently present our results, aiming to obtain stakeholder validation. Finally, we conducted on-site stakeholder interviews and began analysing and synthesising the data for the final governance assessment.

¹ The term 'bantustan' is favoured by many scholars because it indicates their illegitimacy as apartheid-era constructions, a convention we adhere to in this paper.



Fig. 1. The Inkomati-Usuthu Water Management Area indicating the four main catchments Sabie-Sand (blue), Crocodile (green), Komati (red) and Usuthu (yellow) (IUCMA, 2021).



Fig. 2. Illustration of the methodological approach consisting of three key steps.

3.1. Operationalisation of NXGAT for the Inkomati-Usuthu river basin

The WEF nexus governance assessment tool NXGAT of La Jeunesse et al. (forthcoming) assesses the level of supportiveness or

restrictiveness of the current governance system towards WEF nexus governance. NXGAT is structured along five governance dimensions and five governance quality criteria (Table 1). Using the tool of La Jeunesse et al. (forthcoming), we aim to unravel synergies and trade-offs between

Table 1

Definitions of the governance dimensions and governance quality criteria of NXGAT provided by La Jeunesse et al. (forthcoming).

Governance dimensions
<ul style="list-style-type: none"> • <i>Actors and networks</i> refers to the involved actors and networks in the WEFE nexus governance system, their roles, potential conflicts and power relations. • <i>Levels and scales</i> describes the administrative levels and the biophysical scales involved in the WEFE nexus sectors and their interdependencies. In this study, we refer to <i>levels</i> as distinct units of governance (local, regional, national), whereas <i>scales</i> pertains to the spatial dimensions of the biogeophysical processes in water, energy, food, and ecosystems. • <i>Problem perspectives and goal ambitions</i> concerns the various perspectives, ambitions and levels of awareness of WEFE nexus stakeholders about nexus issues. • <i>Strategies and instruments</i> refers to the policy instruments and strategies available to address WEFE nexus issues. • <i>Responsibilities and resources</i> describes the available resources and responsibilities and their distribution to address WEFE nexus issues.
<p>Governance quality criteria</p> <ul style="list-style-type: none"> • <i>Comprehensiveness</i> assesses the degree to which the current governance system includes relevant WEFE nexus elements. • <i>Coherence</i> assesses the degree to which the elements of the governance system are strengthening rather weakening each other. • <i>Flexibility</i> assesses the capacity of the current governance system to provide different pathways towards WEFE nexus governance. • <i>Intensity of action</i> assesses the capacity of the current governance system to urge for WEFE nexus-oriented actions. • <i>Fit</i> assesses the degree to which the current governance system corresponds to ecosystem properties and functions.

WEFE sectors and identify barriers and levers towards WEFE nexus governance in the Inkomati-Usuthu river basin.

To operationalise NXGAT for the assessment in the Inkomati-Usuthu river basin, we developed an interview guide structured along the five governance dimensions and quality criteria with questions that are suitable for semi-structured stakeholder interviews (Appendix, Table 3). Finally, we applied the scoring system of La Jeunesse et al. (forthcoming) to assess the level of supportiveness or restrictiveness of the governance system towards WEFE nexus governance (Appendix, Table 4). Overall assessment scores are assigned per governance quality criterion (along columns), as the study aims to evaluate the overall capacity of the current governance system (i.e. across all governance dimensions) for WEFE nexus orientation. Fig. 3 provides an overview of the key elements of NXGAT and indicates how the governance assessment is carried out.

3.2. Series of stakeholder workshops

As part of the stakeholder engagement strategy of NEXOGENESIS, a total of six stakeholder workshops were planned for the Inkomati-Usuthu river basin by the local case study leads of which three are relevant to the WEFE nexus governance assessment presented in this paper. Prior to the initiation of the workshops, a stakeholder register was compiled consisting of individuals representing WEFE sectors that may work in or have an impact on the IUWMA, from local to national level. The stakeholder register is kept updated throughout the NEXOGENESIS project, and used to guide the case study on participants to invite to the workshops. The first workshop took place in May 2022 and aimed to initiate the stakeholder engagement process, build trust among participants, discuss project expectations, identify potential interview partners, and collect initial data on WEFE nexus interlinkages. All stakeholders listed on the stakeholder database were invited to the workshop. The workshop was hosted online and a total of 29 stakeholders from all WEFE sectors and local to national levels joined. Workshop 2 was organised as an in-person workshop in October 2022. Again, all stakeholders listed in the database were invited in an attempt to boost participation in the workshop. 12 stakeholders from the water, food, and ecosystem sectors participated, while the energy sector was not represented. Stakeholders were mostly from regional and local levels, as the workshop took place in the river basin area, in Mbombela, which is over 300 kilometres from Pretoria, where most national stakeholders are located. It was devoted to an in-depth mapping of WEFE nexus interlinkages in the Inkomati-Usuthu river basin and a discussion on resulting governance challenges, policy gaps and stakeholder policy preferences. The interlinkage maps created during the workshop were digitised and served as preparation for the upcoming WEFE nexus governance assessment and related field trip to the river basin. The third workshop was hosted online again and took place in June 2023. All stakeholders listed in the database were once again invited to the workshop. However, closer to the workshop date, a drive

to contact stakeholders that had shown increased interest in the project, had attended previous workshops, and who play a critical role in WEFE nexus governance within the catchment was undertaken. A total amount of 38 stakeholders from the water, food, and ecosystem sectors and local to national levels joined. The energy sector was not represented. Taking place post assessment, workshop 3 provided a platform to present the assessment results to the stakeholders with the aim of obtaining stakeholder validation. Additionally, key recommendations resulting from the findings were discussed in break-out rooms. It is important to note that stakeholder attendance varied, however, a core group of stakeholders was present in all workshops.

3.3. Stakeholder interviews and data analysis

The interviewer team consisted of a lead interviewer, co-interviewer, and note-taker, as well as a local case study lead who functioned as a knowledge broker when necessary. The team was composed of an interdisciplinary group of researchers with expertise in water policy, hydrology, integrated resource management, sustainability governance and environmental authorisations and licensing. Given our research backgrounds, we recognise a bias towards water and ecosystems and a less comprehensive representation of food and energy.

The stakeholder interviews were carried out in course of a two-week field trip to the Inkomati-Usuthu river basin in February 2023. We conducted 13 interviews with 23 stakeholders from the four WEFE sectors and local, regional, and national levels (Appendix, Table 5). Of the 13 interviews, 12 were face-to-face interviews, one was online, six were individual interviews, and seven were group interviews with 2–3 interviewees of the same organisation. The local case study lead was requested to assist with selection of interviewees with the aim of one interviewee per sector-level combination (e.g., water-local, -regional, national, energy-local, -regional, -national etc.) at a minimum. The stakeholder register was used to identify stakeholders that fell within the requested criteria. Where stakeholders were not identified using the register, the case study lead requested assistance from existing stakeholders and conducted an internet search on potential organisations and stakeholders to contact. Following identification of the interviewees, the case study lead contacted the stakeholders and informed them of the interviews, accompanied with a request for their participation. The selection of interviewees according to the criteria was successful for all sector-level combinations except for energy-local (Fig. 4).

Interviews were semi-structured, conducted in English, and typically lasted between 60 and 120 minutes. To maintain consistency across interviews, we used an interview guide consisting of 25 questions structured along the governance quality criteria and dimensions of NXGAT (Appendix, Table 3).

By the end of each interview day, we began analysing and synthesising the data in debriefing meetings with the interviewer team, which typically lasted between 1 and 3 hours. During the debriefing meetings, the interview data was coded and assigned to one of the 25 governance

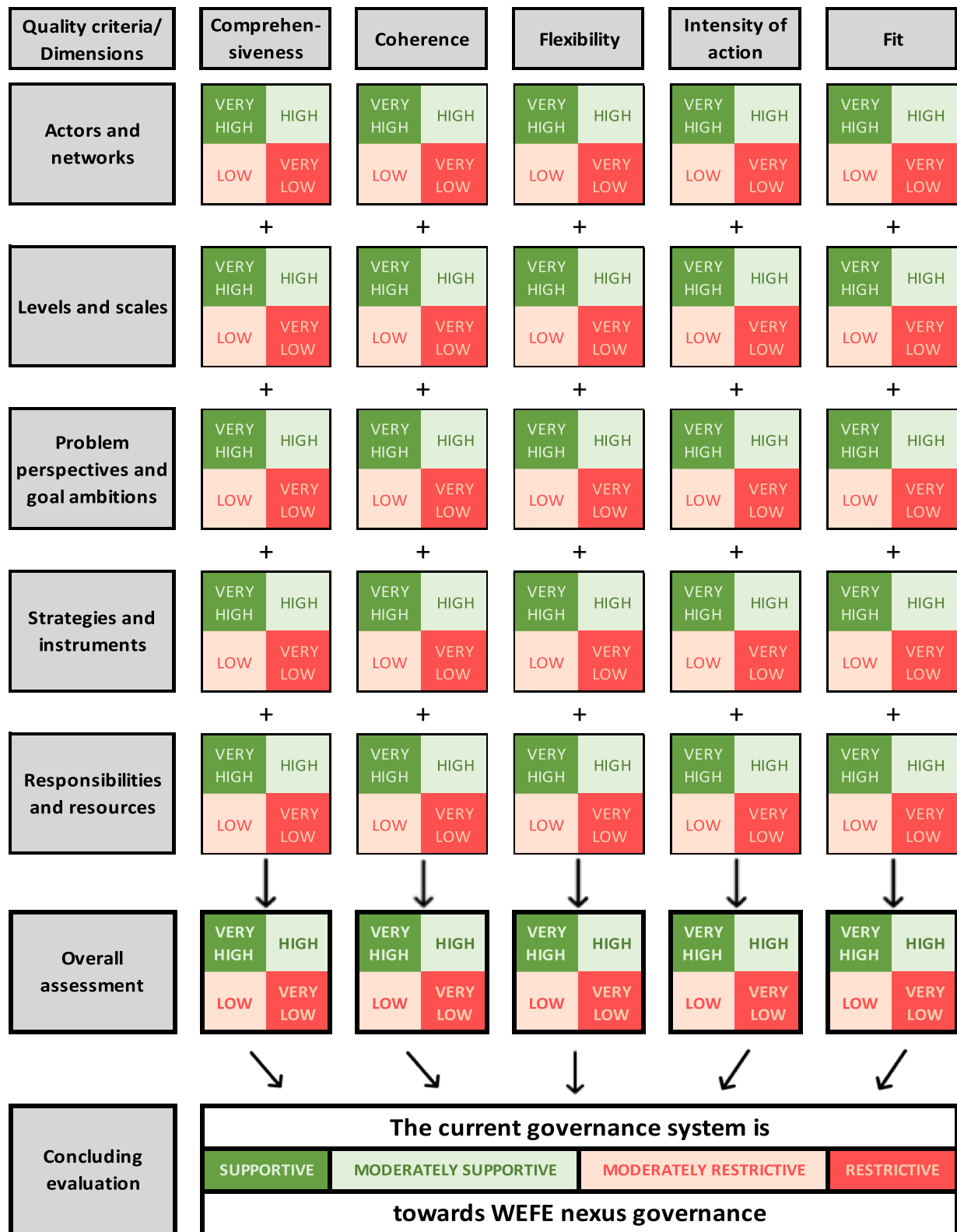


Fig. 3. WEFE nexus governance assessment tool NXGAT structured along five governance dimensions (rows) and five quality criteria (columns). One of four scores (very high, high, low, very low) is assigned to each cross-tabulated governance dimension and quality criterion, resulting in an overall assessment score per column. The concluding evaluation is based on the five overall assessment scores (adapted from La Jeunesse et al. (forthcoming)).

dimension-quality criterion combinations of NXGAT (Fig. 3). This allowed us to avoid overlaps and ensure no information was lost while analysing the data. The purpose of the daily interview debriefs was to reduce bias from subsequent interviews and preserve the original

stakeholder’s perspective as much as possible. Finally, points that required further clarification were labelled with notes for desk research following the field trip. This included, for example, retrieving policy documents and instruments such as guidelines, agreements, strategies,

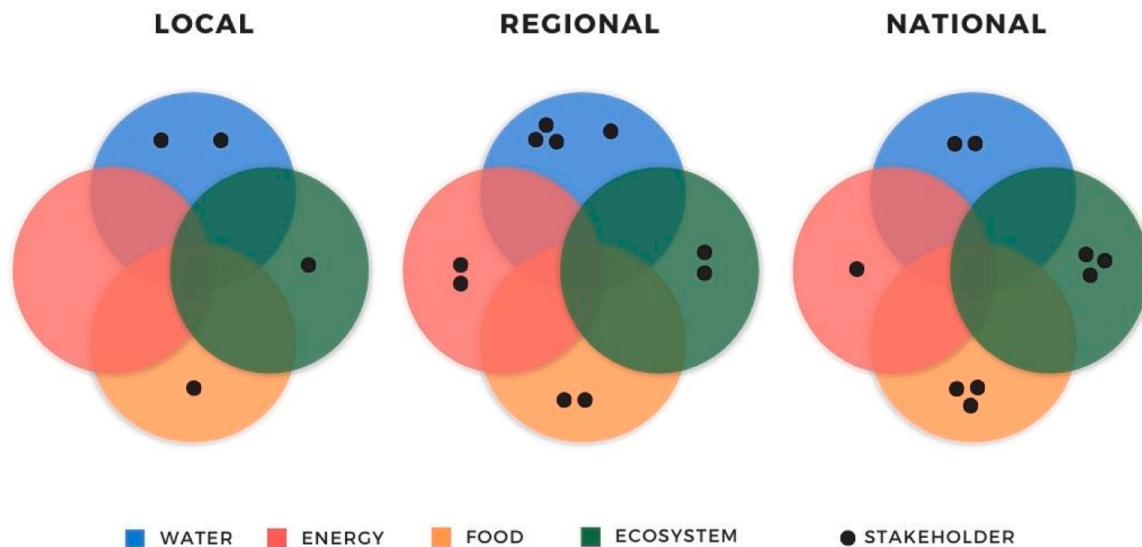


Fig. 4. 13 interviews with 23 stakeholders divided by WEFE sector and level associated with the stakeholder. The number of black dots indicate whether individual (1 participant) or group (2–3 participants) interviews were conducted.

and plans mentioned by interviewees to examine the WEFE nexus orientation as part of the governance dimension *strategies and instruments*. We exclusively looked at the documents mentioned, which represents a selective approach rather than a systematic analysis. Therefore, we not only searched for nexus terminology, but also for the mention and non-mention of other sectors and the quality of interaction that can be deduced from the text.

After the field trip, we further distilled the interview data, starting from a NXGAT matrix with original quotes of the interviewees (filled in interview guide), through to a matrix with summarised statements per stakeholder (synthesis 1), to the final NXGAT matrix summarising the statements of all stakeholders in one sentence per matrix cell (synthesis 2). The two synthesis rounds allowed us to identify main contradictions and points of agreement between the interviewees, giving us a comprehensive and nuanced overview of all nexus perspectives before assigning scores. Finally, we scored the quality criteria based on our expert judgement, drawing on the two synthesis rounds, our in-depth knowledge of nexus interlinkages in the river basin, and extensive discussions among the interviewer team.

In addition to the stakeholder workshops and interviews, the lead interviewer conducted four background interviews with South African WEF(E) nexus researchers between April and November 2023. The aim was to gain a more nuanced understanding of the history and complex social dynamics of South Africa and to assess how more overarching political, economic, and societal factors play out in WEFE nexus governance issues, eventually putting our results into more perspective.

4. Results

The results are presented along the five governance quality criteria, aiming to assess the overall capacity of the current governance system for WEFE nexus orientation. Therefore, we first provide a table summarising the assigned scores and providing a brief explanation (Table 2). In the following, we will take a closer look at constraining and enabling factors for each governance quality criterion and provide more in-depth information.

4.1. Comprehensiveness

The scores of comprehensiveness show a very mixed picture (Table 2). The majority of *actors and networks* of WEFE sectors is involved in nexus governance, albeit to varying degrees. For example,

the mining sector and majority of municipalities in the river basin only attend committees or consultative boards when required for own (sectoral) licensing processes, showing more passive involvement. Currently, all relevant *levels and scales* are represented in WEFE nexus governance for the Inkomati-Usuthu river basin, including transboundary (i.e. riparian neighbours Eswatini and Mozambique), national, regional or provincial, catchment, and local levels. In addition, two interviewees (ID 3: regional - water, ID 4: regional - ecosystem) mentioned the role of the community level in managing protected areas. However, while the municipal level, through the integrated development plans, is intended to be a key institutional level for enabling cross-sectoral collaboration, its crucial role is not fully exploited in practice.

Main factors constraining comprehensiveness relate to *problem perspectives and goal ambitions, responsibilities and resources*, and especially *strategies and instruments*. The most frequently mentioned *problem perspective* is load shedding followed by unauthorised mining activities, untreated sewage, and solid waste disposal. Most frequently mentioned *goal ambitions* relate to energy and food security and (economic) development of the region. as One interviewee adds: ‘Poverty is a key barrier to more nexus orientation’ (ID 11: national - water). *Responsibilities* are mostly clearly assigned; however, insufficient *resources* are a major issue, especially in municipalities and communities at the local level: ‘There are no skills, finance, or manpower. We are really hamstrung by this’ (ID 1: national - energy). Moreover, lacking *resources* show in insufficient law enforcement and implementation. In addition, the immense power of the energy sector in South Africa, combined with and resulting in lacking (political) willingness to prioritise WEFE nexus orientation over energy goals, leads to issues of accountability and irresponsible behaviour. In terms of *strategies and instruments*, only few policies are inherently and purposely nexus oriented. Hence, in practice, nexus-oriented actions are also rare, as most policies fail to lay the foundation for integrated and nexus-oriented governance. Generally, there is a discrepancy between relevance and level of integration of policies. The more relevant policies are, the less integrated they seem to be and vice versa. Some documents, such as the Mpumalanga Biodiversity Sector Plan,² and the Mpumalanga Spatial Development

² Mpumalanga Tourism and Parks Agency. 2014. Mpumalanga Biodiversity Sector Plan.

Table 2

Results of the WEFE nexus governance assessment for the Inkomati-Usuthu river basin. The matrix shows the scores assigned for each cross-tabulated governance dimension and quality criterion and provides a brief explanation. The overall assessment of the governance quality criteria comprehensiveness, coherence, and intensity of action is low, while flexibility and fit score high. The resulting concluding evaluation is that the current governance system is moderately restrictive towards WEFE nexus governance.

Quality criteria/ Dimensions	Comprehensiveness	Coherence	Flexibility	Intensity of action	Fit
Actors and networks	HIGH The majority of relevant <i>actors and networks</i> affected by or affecting WEFE sectors is involved in WEFE nexus governance.	VERY LOW Most interactions of relevant <i>actors and networks</i> across WEFE sectors are neither cooperative nor solid or based on trust.	HIGH The governance system allows to include new <i>actors and networks</i> or shift the lead if necessary.	VERY HIGH There is strong pressure from a relevant <i>actor or network</i> across WEFE sectors urging for more WEFE nexus-oriented governance.	HIGH Most of the relevant <i>actors and networks</i> across WEFE sectors are appropriate to deal with and manage the interacting biogeophysical processes in water, energy, food, and ecosystems.
Levels and scales	VERY HIGH All relevant <i>levels and scales</i> across WEFE sectors are involved in WEFE nexus governance.	LOW Relevant <i>levels and scales</i> across WEFE sectors rarely work together or acknowledge interdependencies and have little trust on each other.	HIGH Most of the time, the governance system allows to change <i>levels and scales</i> at which WEFE nexus issues are addressed.	LOW There is some pressure from relevant <i>levels and scales</i> across the WEFE sectors pushing for more WEFE nexus-oriented governance.	HIGH Relevant <i>levels and scales</i> of the governance system mostly match the characteristics of the interacting biogeophysical systems.
Problem perspectives and goal ambitions	LOW A limited number of <i>problem perspectives</i> across WEFE sectors are taken into account in WEFE nexus governance and only a few are translated into WEFE nexus <i>goal ambitions</i> .	LOW <i>Problem perspectives and goal ambitions</i> across WEFE sectors rarely mutually reinforce each other.	HIGH The governance system allows to re-assess and combine <i>goal ambitions</i> across WEFE sectors and shift priorities if circumstances require.	LOW <i>Problem perspectives and goal ambitions</i> across WEFE sectors weakly urge WEFE nexus orientation.	LOW <i>Problem perspectives and goal ambitions</i> across WEFE sectors rarely take into account biogeophysical conditions.
Strategies and instruments	VERY LOW Relevant strategies and instruments are not WEFE nexus-oriented.	LOW Relevant <i>strategies and instruments</i> across WEFE sectors rarely reinforce each other.	HIGH The governance system mostly allows to combine or use different <i>strategies</i> and types of <i>instruments</i> across WEFE sectors.	VERY LOW Relevant <i>strategies and instruments</i> across WEFE sectors do not push for WEFE nexus-oriented governance.	HIGH Relevant <i>strategies and instruments</i> across WEFE sectors most of the time account for the interacting biogeophysical systems.
Responsibilities and resources	LOW Most responsibilities are clearly assigned but only limited resources are allocated across WEFE sectors to support WEFE nexus governance.	VERY LOW Most <i>responsibilities</i> assigned, and <i>resources</i> allocated across WEFE sectors do not lead to cooperation among them but rather create competition and conflict.	VERY LOW The governance system allows to pool assigned <i>responsibilities</i> and allocated <i>resources</i> across WEFE sectors but not without compromising accountability and transparency.	VERY LOW <i>Responsibilities and resources</i> across WEFE sectors do not urge implementation of WEFE nexus-oriented actions.	LOW <i>Responsibilities and resources</i> across WEFE sectors are rarely appropriate to deal with the interacting biogeophysical systems.
Overall assessment	LOW	LOW	HIGH	LOW	HIGH
Concluding evaluation	The current governance system is moderately restrictive towards WEFE nexus governance				

Framework³ include reference to different WEFE sectors but are not necessarily affiliated with a specific one. The Catchment Management Strategy,⁴ as part of the National Water Act⁵, and the National Environmental Management Act⁶ could be exceptions, as they seem both relevant and integrated to some extent. However, it is worth noting that Catchment Management Strategies have generally had very limited success across the country, so the example of the Inkomati-Usuthu Catchment Management Agency (IUCMA) should be considered a positive outlier rather than the norm (Munnik, 2020).

4.2. Coherence

Coherence is the quality criterion that scores lowest of all (Table 2); thus, it represents the main barrier to WEFE nexus-oriented governance. Incoherence is strongly related to assigned *responsibilities*, as mandates are predominantly ‘sectorally’ oriented resulting in lacking communication and cooperation among *actors* and a tendency to push own mandates. Moreover, bureaucrats of different government departments work in a competitive environment, for example, in terms of obtaining funding and political agenda setting, which inhibits nexus-oriented thinking and action. This creates tensions resulting in some severe conflicts, for example, between the Department of Agriculture, Land Reform and Rural Development (DALRRD) and the Department of Mineral Resources and Energy (DMRE), which are at odds over land use and water allocation priorities: ‘The departments are so stuck in their own television; they just look at themselves, but each sector has a hell of influence on the next one. But they don’t worry about interlinkages, instead they fight wars between one another’ (ID 8: local - food). Coherence is highest between the water and ecosystem sector, as main *strategies and instruments*, such as National Water Act and National Environmental Management Act, are mutually reinforcing. There is some perceived incoherence within the water sector, between water resources management (National Water Act) and water services (Water Services Act⁷) and within the energy sector, between policies of the mining sector and the electricity public utility ESKOM.

At river basin level, the role and *responsibilities* of the IUCMA were frequently mentioned as promoting cooperation between WEFE sectors, some interviewees, however, also noticed overlap with the Komati Basin Water Authority (KOBWA). In addition to lacking horizontal coherence, interviewees also mentioned lacking vertical coherence resulting in a disconnect and co-existence of different governance levels: ‘After making the policies, the national level cannot interfere or prescribe anything to the other levels anymore, they can just recommend. This disconnect inhibits implementation’ (ID 1: national - energy). Furthermore, incoherence between national and regional levels was mentioned, as mining permits are issued by DMRE at national level, but water uses are authorised by IUCMA at regional level. Incoherence of *problem perspectives and goal ambitions* is perceived to be most damaging at national level, as local and regional levels share a common interest in regional development. We could identify coherence of *problem perspectives and goal ambitions* regarding issues related to equity and justice, which were consistently viewed as fundamental across all WEFE sectors and governance levels. Ensuring fair access to WEFE resources is broadly accepted as a key goal. However, energy security at national level has

priority, which can be in conflict with all other WEFE sectors.

4.3. Flexibility

Scores of flexibility are the highest overall but toned down by one outlier, *responsibilities and resources* (Table 2). Flexibility is high, as new levels (e.g., sub-catchment level, metropolitan area level, transfrontier landscape level) can emerge if circumstances require. At the same time, the governance system is very fragmented and rigid inhibiting law enforcement and implementation at different levels, which eventually constrains flexibility: ‘Areas related to rules and regulations, bureaucracy in general, seem quite rigid. For example, legislation and guidelines are under review for ages meaning that we are forced to work with draft bills and face huge implementation delays’ (ID 11: national - water). Generally, interviewees agreed that flexibility is higher at local and regional level than at national level, not only in terms of *actors and strategies*, but also in terms of shifting priorities and *goal ambitions* and finding innovative solutions. Especially in the context of crisis or emergency, new *actors and networks* can be swiftly engaged, and extraordinary bodies established. For example, during droughts or floods, new working groups (e.g., Crocodile River or Olifant River Working Groups or drought committees) can be established to quickly re-allocate water uses and secure environmental flows. The same applies to *strategies and instruments*: ‘In case of emergency, there are legal ways to bypass the latency of national policy and catalyse immediate, on-the-ground action, for example, by using Emergency Protocols that are part of General Authorisations’ (ID 5: local - ecosystem).

At the same time, flexibility is impaired by the lengthiness, rigidity or even dysfunctionality of bureaucratic and legal processes of the ordinary governance system. This also explains the outlier position of *responsibilities and resources*, because although they can be swiftly adapted when required, the repeated circumvention of ordinary *responsibilities* and the recurring use of extraordinary bodies and institutions is a threat to inclusiveness, transparency, and thus accountability. Hence, despite the effectiveness of short-term flexibility, it is always linked to an impairment of procedural justice. For example, in case of water scarcity, the mission of extraordinary task forces is to agree on adjusted water allocations quickly. Due to prevailing inequity, there is a risk of favouring or excluding certain voices from the decision-making process, undermining inclusiveness in short-term measures given the current power dynamics. At the same time, there is a lack of clarity and openness about what decisions are being made and by who, diminishing transparency and making it difficult to hold individuals responsible for their actions (ID 11: national - water; ID 10: national - food; ID 12: national - ecosystems).

4.4. Intensity of action

Scores for intensity of action show a mixed picture, with scores ranging from very low to very high values (Table 2). Regarding *actors and networks*, IUCMA was mentioned frequently as pushing most strongly for more cross-sectoral governance, particularly through organising river forums (IUCMA forum and 6 sub-catchment forums): ‘IUCMA has the right institutional dynamics to push for more cross-sectoral orientation, but also individuals within the agency are champions for integrating different sectors’ (ID 5: local - ecosystem). However, some interviewees also mentioned that the efforts of IUCMA are not sufficient and some sub-catchment forums show no or very limited impact across sectors, which is a common phenomenon (Munnik, 2020). In terms of equitable resource access, the Department of Water and Sanitation (DWS) was mentioned to push for water reallocations (ID 1: national - energy). Moreover, the Department of Cooperative Governance and Traditional Affairs (COGTA) supports local and district municipalities in enabling cross-sectoral integration.

It stands out that pushing for more nexus-oriented governance largely depends on individual champions or institutions but is not an

³ Department of Cooperative Governance and Traditional Affairs. 2019. Mpumalanga Spatial Development Framework.

⁴ Inkomati-Usuthu Catchment Management Strategy. 2023. Catchment Management Strategy 2023–2028.

⁵ Department of Water and Sanitation. 1998. National Water Act [No. 36 of 1998].

⁶ Department of Fisheries, Forestry and the Environment. 1998. National Environmental Management Act [No. 107 of 1998].

⁷ Department of Water and Sanitation. 1997. Water Services Act [No. 108 of 1997].

established *problem perspective* or *goal ambition* yet. This becomes even clearer when looking at more system-related governance dimensions. For example, there are rarely any *strategies and instruments* that urge more nexus orientation, especially at national level where sectoral thinking and action are still most prevalent: ‘Although there are some *strategies and instruments* that look cross-sectoral on paper, for example, the Presidential Climate Commission, the Inter-Ministerial Task Team or the Just Energy Transition,⁸ the intensity of action undertaken in practice is low’ (ID 9: regional - food). The Inkomati-Usuthu Catchment Management Strategy, the Spatial Planning and Land Use Management Act⁹ or the National Wetland Management Framework¹⁰ could be seen as first efforts, but overall, the intensity of action remains very low. Efforts of national spatial planning departments to transform inequitable infrastructures, especially in areas of former bantustans, were recognised as an attempt to implement more nexus-oriented solutions on the ground (ID 10: national - food). There are some examples of assigned *responsibilities* (IUCMA, spatial planning unit of DALRRD) and allocated *resources* (World Bank funds, transfrontier landscape resources, IUCMA budget) that push for more cross-sectoral orientation. However, looking at the actual impact, particularly compared to the large body of siloed *responsibilities and resources*, the overall intensity of action remains very low.

4.5. Fit

The overall assessment of fit is high, as the structural levels of governance generally align with the interacting biogeophysical processes in water, energy, food, and ecosystems (Table 2). Fit is created for the water, ecosystem, and agriculture sector, as their *actors and networks* are quite decentralised (‘trickle-down representation’). However, the energy sector is poorly represented on the ground, thus lacking effective mechanisms to adapt planning and operation procedures to biogeophysical systems. Also regarding *levels and scales*, fit occurs for the water and ecosystem sector, to some extent also for the agriculture sector but not for the energy sector. Scalar configurations of key institutions of the energy sector are very top-down and centralised in policy and planning at national level. Thus, the sector is lacking effective representation at regional and local levels to account for the biogeophysical conditions. This bears the risk of misfit with local needs and biophysical realities, reinforcing existing inequalities, for example in rural and marginalised communities that not only struggle with accessing resources but are also in competition with national interests. In contrast, the ecosystem sector creates good fit, as the *scale* of interacting biogeophysical systems often determines the governance level they are dealt with, rather than administrative boundaries: ‘We introduced the transboundary level for river basins and the transfrontier landscape level for terrestrial ecosystems to ensure the requirements of natural systems are the focus of discussion. These levels are a sweet spot for fit, because they allow us, for example, to collaborate with the Mozambique Regional Administration of Waters in the South (ARA-Sul) and establish partnerships between the Kruger National Park in South Africa, Limpopo National Park in Mozambique, and Gonarezhou National Park in Zimbabwe’ (ID 5: local - ecosystem). For *strategies and instruments*, the results look quite similar to those of *levels and scales*. Fit is created for the water and ecosystem sector, to a limited extent also for agriculture, and for energy only if external *instruments* such as permitting and licensing are included. Generally, *goal ambitions* are still very much defined in a siloed way, giving ‘sector goals’ priority. One

interviewee explains that creating fit is not a priority for all sectors: ‘Some sectors have an interest in preserving resources, for example, the ecosystem sector is responsible for biodiversity, the water sector wants to preserve water resources and agriculture needs clean water and land as well, so they share a particular interest. The energy sector uses water and land, they don’t conserve them, so also good fit is not their priority’ (ID 12: national – ecosystem). Shared *problem perspectives* among actors, for example on persistent ‘lock-ins’, can however create awareness for cross-sectoral impacts and spill-over effects. Yet, they rarely result in joint cross-sectoral action. In addition, some *responsibilities*, for example of the environmental planning unit of DALRRD and the Department of Forestry, Fisheries and the Environment (DFFE) and DWS are overlapping. In terms of *resources*, there are overlaps between KOBWA and IUCMA. Although redundancy resulting from these overlaps could have a positive effect on cross-sectoral governance, it mostly leads to ineffectiveness due to lacking coordination in reality. Finally, the good overall scalar fit of governance structures and biogeophysical systems can be a lever for WEF nexus governance. A basic degree of alignment between key institutions and the complexity of interacting biogeophysical systems ensures appropriateness and effectiveness of the governance system, which is a crucial requirement to foster WEF nexus governance. Currently, this process is still constrained by misfit challenges in *problem perspectives and goal ambitions* and *responsibilities and resources*.

In conclusion, our results show that the current governance system of the Inkomati-Usuthu river basin is *moderately restrictive* towards WEF nexus governance (Table 2). This is mainly due to the *very low* and *low* scores of the governance quality criteria *comprehensiveness*, *coherence*, and *intensity of action*.

5. Discussion

Our study presents the current state of WEF nexus governance in the Inkomati-Usuthu river basin. In the following, we give practical recommendations for nexus-oriented actions that can be key steps towards WEF nexus governance and implemented by decision-makers and other stakeholders from WEF sectors. Subsequently, we reflect on our methods and discuss limitations of our study.

5.1. Recommendations

Our first recommendation refers to **wastewater treatment** as a key driver to enhance *coherence* of WEF nexus-oriented goal ambitions. Improved wastewater treatment works exploit various synergies of WEF sectors, such as improved water and food security, increased water quality, and higher water use efficiency. The responsibility for the operation and maintenance of wastewater treatment works lies at a municipal level. Many interviewees (local, regional, national – water and local, regional - food) acknowledged that municipalities often face challenges due to a lack of financial and skilled resources, which hinder the effective management of the wastewater treatment works within some municipalities. A partnership between the IUCMA and municipalities to transfer the necessary skills and knowledge for the operation and maintenance of the wastewater treatment works should be considered for municipalities to perform their mandate.

Moreover, introducing an integrated and nexus-oriented common digital information system could be a powerful instrument to increase *coherence* between extracting sectors without compromising ecosystem functioning and significantly reduce bureaucratic costs, which was flagged as an institutional hurdle by many interviewees across all levels and sectors. Currently, licensing processes, for example for mining operations, are very fragmented and siloed, resulting in water and land use conflicts, ecosystem degradation, insufficient monitoring and thus non-compliance. In some cases, mining permits are issued by DMRE at national level without taking into consideration water use authorisation, which is the responsibility of the IUCMA at catchment level and DWS. A

⁸ Presidential Climate Commission. 2022. South Africa’s Just Energy Transition Investment Plan (JET-IP).

⁹ Department of Agriculture, Land Reform and Rural Development. 2013. Spatial Planning and Land Use Management Act [No. 16 of 2013].

¹⁰ Department of Fisheries, Forestry and the Environment. Prepared 2021, forthcoming. National Wetland Management Framework.

common digital information system could provide a reliable and integrated database of all active authorisation and licence applications (granted or in progress) and provide oversight of current operations. By incorporating data from all WEFE sectors, it would significantly contribute to enhancing *comprehensiveness*, help identify 'hotspot' areas and major trade-offs, and create transparency of decisions. The Department of Trade, Industry and Competition (DTIC) is currently developing a system of this sort and therefore could be the custodian of the common digital information system, as it is an entity with no bias towards one particular sector.

To enhance *intensity of action* towards WEFE nexus governance, actions should focus on building institutional capacity and establishing cross-sectoral collaboration as a routine practice. Therefore, it is crucial to build on existing institutional champions, such as the IUCMA, and strengthen their cross-sectoral leadership efforts. In case of the Inkomati-Usuthu river basin, it may be useful to expand the role of river forums and put WEFE nexus thinking within the scope of the river basin at centre. This way, the river forums could provide a permanent platform to establish cross-sectoral exchange and collaboration. To ensure all key stakeholders are present, it could be useful to create formal mandates that require representation of all relevant WEFE sectors, especially the energy sector, which holds immense power in South Africa. The provision of legal, technical and financial support, including access to resources, expertise, and data, is necessary to enable and sustain such an initiative over time. To enhance *comprehensiveness* and achieve lasting, system-wide changes towards WEFE nexus orientation, efforts should also be directed at sub-catchment forums, which are currently often underfunded and receive insufficient support. To not only promote bottom-up nexus thinking, but also enhance nexus-oriented policymaking, the establishment of a 'nexus task team' at national level would be promising (Scott, 2017). Such a task team would comprise senior experts from all ministries responsible for the WEFE sectors (i.e. DWS, DMRE, DALRRD, and DFFE at a minimum) and be a first step towards institutionalised nexus governance at national level.

5.2. Reflection and limitations of the study

Our results and recommendations show that it is impossible to study WEFE nexus interlinkages without taking into account the complex relationships of actors and society to these very resources. Therefore, the governance assessment of our study is embedded in three stakeholder workshops and based on interviews with stakeholders from all four WEFE sectors and local to national levels, aiming to learn from the practical experiences and hands-on knowledge of practitioners.

This way, we provided a platform for dialogue, especially for stakeholders from different levels and WEFE sectors and stakeholders with no history of collaboration. The workshops brought different perspectives on WEFE nexus issues to the table, created space for deliberation and out-of-the box thinking and the joint development of boundary objects. Organising both online and in-person workshops ensured equal participation opportunities and a level playing field for local and national stakeholders. Finally, the workshops allowed us to gain a more comprehensive understanding of WEFE nexus governance in the Inkomati-Usuthu river basin and give actors that are currently represented and part of the governance system a prominent role in our

assessment.

However, by focussing on the current system and 'who and what is there', our assessment only marginally covers issues related to power and somewhat overlooks the question of 'who and what is not there'. In our study, we consider three levels of formal governance structures: national, regional, and local. We do not account for traditional leadership structures or informal governance systems. The example of water allocation makes particularly clear why this is a drawback. Due to the design of NXGAT, we focus on formal water economies only, including stakeholders and governance structures of, for example, public water facilities, management agencies, and high-impact corporate sector water users, such as large-scale farmers, mining companies or the tourism industry. On the contrary, the majority of residents in rural and peri-urban regions of the Inkomati-Usuthu river basin rely on informal self-supply largely beyond the scope of governmental oversight (van Koppen et al., 2024). Although self-supply keeps expanding, not only in the realm of water, and high population densities and rapid growth create an enormous demand for water, energy, food, and ecosystem services (Schwabe, 2020, Marutlulle, 2021), informal governance structures are not part of our assessment, and nor are communities and land that fall under traditional leadership according to customary law. This poses the risk that major challenges in terms of legal rights and physical access to resources and disparities in resource usage remain invisible in our study. Although equity considerations emerged from almost every stakeholder interview, operationalising NXGAT did not allow us to formally integrate them in our assessment. We aimed to mitigate this by analysing the equity considerations from the interview data and incorporating them in our results. However, the lack of a formal integration in our assessment remains a major limitation of our study, constraining the significance of our findings.

Whereas our assessment succeeded in identifying barriers and levers towards WEFE nexus governance, the operationalisation of NXGAT specifically for the Inkomati-Usuthu river basin also revealed some conceptual ambiguity of the tool. For instance, the definition of *flexibility* (Table 1) and corresponding interview questions (Table 3) predominantly focus on short-term flexibility (e.g., institutional provisions for emergency measures). This is not necessarily in line with strategic adaptive resource management and social and institutional learning, allowing for long-term flexibility. Another conceptual inaccuracy emerged in relation to *intensity of action*. The definition (Table 1) places the capacity to urge for more nexus-oriented actions at the centre. In practice, however, also other aspects related to *intensity of action* such as quality, vigour, and frequency of actions play a role. We acknowledge these limitations and hope that future research building on our findings can critically reflect on and account for them, for example, by adding more nuances to NXGAT and introducing an informal level to the assessment.

Operationalising the five governance dimensions and quality criteria of NXGAT, the assessment reveals a complex landscape of synergies and trade-offs between water, energy, food, and ecosystem sectors and local, regional, and national levels. Our results show that nexus thinking is championed by individual actors and organisations but not yet established as a systematic and sustained part of water, energy, food, and ecosystem sector decision-making. In particular, this relates to siloed policy documents and instruments, sectoral responsibilities and

Table 4

The scoring system used to assess the level of supportiveness or restrictiveness of the governance system towards WEFE nexus governance based on La Jeunesse et al. (forthcoming). According to the scores per governance quality criterion, an overall assessment score was assigned per column (very high – very low). The sum of all overall assessments leads to the concluding evaluation (supportive – restrictive)

Overall assessment	Concluding evaluation
VERY HIGH	SUPPORTIVE
HIGH	MODERATELY SUPPORTIVE
LOW	MODERATELY RESTRICTIVE
VERY LOW	RESTRICTIVE

mandates, as well as sector-specific resources that pursue sectoral goal ambitions. Our study on the Inkomati-Usuthu river basin contributes to the promotion of nuanced and contextualised WEFE nexus governance assessments towards more sustainable futures. The operationalisation of NXGAT demonstrates the value of a strong participatory research process and collaborative analysis for more comprehensive and representative nexus governance assessments. Insights of this paper can inform similar efforts in diverse global contexts and provide lessons learnt.

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CRedit authorship contribution statement

Eva Sievers: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ingrid Canovas:** Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Appendix

Interview guide

Table 3

Operationalised interview questions for the Inkomati-Usuthu river basin sorted along five governance dimensions and quality criteria based on La Jeunesse et al. (forthcoming)

Quality criteria / dimensions	Comprehensiveness	Coherence	Flexibility	Intensity of action	Fit
Actors and networks	Are all key actors taken into account (which one is missing)?	What type of relationship do actors have? Cooperation? Synergies? Rivalry, conflict?	Is it possible to involve new actors? If yes, which ones? If not, why?	Is there an organization that strongly supports change towards more cooperation between the four WEFE domains?	Are the actors appropriate to deal with ecosystem properties and dynamics? Appropriate to steer processes in WEFE sectors? Or mismatches between scales actors work on and processes take place?
Levels and scales	What are different levels and scales that are currently involved in natural resource	Are interdependencies and influences between different levels and scales	Is it possible to change level or scale depending on the issue?	Is there a particular level or scale that is currently pushing for more cross-sectoral management?	Are current levels and scales appropriate to deal with ecosystem properties and dynamics? Appropriate to

(continued on next page)

Table 3 (continued)

Quality criteria / dimensions	Comprehensiveness	Coherence	Flexibility	Intensity of action	Fit
	management in the river basin? Any missing?	taken into account? Is there coherence or conflict?			steer processes in WEFE sectors? Or mismatches between levels and scales of management and ecosystems?
Problem perspectives and goal ambitions	What are the most important issues of natural resource management in the river basin? What are the most important problems and goals?	To what degree are different perspectives and goals coherent? Mutually supportive? Conflicting? Trade-offs?	What are priorities and is it possible to reassess these priorities?	Is there an ambition to shift towards more cross-sectoral management? Actions to combine management of WEFE sectors?	When problems are identified or goals set, do they take into account ecosystem properties and dynamics? Are interlinkages between WEFE sectors taken into consideration?
Strategies and instruments	What are the most important strategies and instruments to manage natural resources in the river basin? Do they take into account other WEFE sectors?	Are instruments from different sectors mutually reinforcing? Supportive? Conflicting? Trade-offs?	Is there flexibility to propose new (or combine) strategies and instruments to reduce trade-offs/improve management?	To what degree do existing strategies and instruments push for more cross-sectoral management?	To what degree are strategies and instruments appropriate to take into account ecosystem properties and dynamics?
Responsibilities and resources	Are responsibilities clearly assigned and sufficiently supported with resources?	To what degree do assigned responsibilities promote cooperation or create conflict between WEFE sectors?	Is there flexibility to re-assign responsibilities and re-allocate resources, if necessary (e.g., if context changes)?	Do responsibilities and resources currently push for change towards more cross-sectoral management?	Do assigned responsibilities and allocated resources take into account ecosystem properties and dynamics?

Scoring system

List of interviewees

Table 5

List of interview partners labelled with ID 1 – 13, giving information on governance levels and WEFE sector represented and the number of interviewees present (1 = individual interview, 2–3 = group interview setting)

ID	Governance level and WEFE sector represented by interviewee	Number of interviewees
ID 1	National – energy	1
ID 2	Regional – energy	2
ID 3	Regional – water	1
ID 4	Regional – ecosystem	2
ID 5	Local – ecosystem	1
ID 6	Local – water	1
ID 7	Regional – water	3
ID 8	Local – food	1
ID 9	Regional – food	2
ID 10	National – food	3
ID 11	National – water	2
ID 12	National – ecosystem	3
ID 13	Local – water	1

Data availability

The data that has been used is confidential.

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