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Abstract: The "nexus" is a potentially very appropriate approach to enhance resource efficiency and good governance in transboundary basins. Until now, however, evidence has been confined to isolated case studies and the nexus approach remains largely undefined. The methodology presented in this paper, developed for preparing a series of nexus assessments of selected river basins under the Water Convention of the United Nations Economic Commission for Europe (UNECE), is a timely contribution to this ongoing debate. The nexus assessment of a transboundary basin has the objective of identifying trade-offs and impacts across sectors and countries and to propose possible policy measures and technical actions at national and transboundary levels to reduce intersectoral tensions. This is done jointly with policy makers and local experts. Compared to an Integrated Water Resource Management approach, the water energy food ecosystems nexus approach concurrently considers multiple sectors and their evolution. This offers the opportunity to better involve key economic sectors—energy and agriculture in particular—in the dialogue over transboundary water resource uses, protection and management.

Keywords: nexus; transboundary; methodology; participatory; water; energy; food; land; ecosystems

1. Introduction

The concept of regional, national and local integrated resource assessment and the links between resources and service supply chains have grown in understanding [1]. The term nexus has been used in a variety of contexts with the aim of advancing an understanding of how sectors are linked, and in turn to inform cross-sectoral governance coherence. On one hand, resources become scarcer as demand for them increases. Multiple uses of resources are increasingly at risk of becoming conflictual, undermining energy, water, food and environmental security [2–6]. On the other hand, the established "silos" approach to policy making (developing and implementing sectoral plans independently, without accounting for trade-offs and impacts across sectors) becomes more and more risky because spillover effects across sectoral policies become more expensive and unsustainable. In other words, the interlinkage (or "nexus") between sectors becomes stronger. This calls for coherent, responsible and consultative planning [7,8].

Despite its increasing popularity, there is no universal set of sectors to be analysed when the nexus is being studied. Depending on the context, the nexus framework has been used to include two or more sectors among energy, water, food, land, climate, environment, and ecosystems [9]. This lack of a clear definitions makes it difficult to establish what constitutes a good nexus analysis [10]. However, there is one characteristic that strongly defines it and makes it innovative, which is the shift from a sector- or resource-centric perspective to a multi-centric one [11]. At its simplest, the nexus is the complex of connections and interactions among water, food, energy, ecosystems and other related systems (or sectors) and the "nexus approach" to natural resource management takes into account these complex interactions, as such resembling the "multi-use sustained-yield" analytical framework applied to resources such as forests in the 1950s and 1960s.

In this paper, applying a "nexus approach" means taking into account the links and dynamics between resource systems to harmonize their outlook and management. The added value of a nexus approach compared to others (in particular, when it comes to water management, to the well-established Integrated Water Resource Management (IWRM), defined by the Global Water Partnership (GWP) as 'a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' [12]) has been questioned [10,13]. However, traditional "integrated" approaches typically have limited analytical scope and often do not consider re-enforcing stresses or indirect links (such as, for example, climate change affecting water demand and in turn energy production) [14]. Therefore, a holistic approach that extends beyond IWRM can be recommended, for example, when assessing large infrastructure interventions where social, economic and environmental factors are of major importance [15].

A major criticism of the nexus approach is that the nexus concept itself is rooted in global considerations, such as increasing demands for water, energy and food, climate change and increased pressure on the environment (directly descending from the Gaia Hypothesis and "The Limits to Growth" [16] of the 1970s). Yet, little has been done to scale this understanding to a pragmatic local, national and regional planning approach [10].

The potential of using integrated assessments for the purpose of improving resource planning and management is becoming clearer, but more still needs to be done to make them respond to the actual needs of policy making [7]. Also, it has been observed that important aspects such as social factors can be overlooked in such assessments [17]. Indeed, an analyst aiming at understanding dynamics involving multiple sectors and resources should have the correct skill set to look beyond a purely physical systems analysis. At a governance level this can be essential: there may be overlaps in institutional mandates, lack of compatibility of geographical and political scales, differences in policy or enforcement culture, lack of consistency in regulations, or even power imbalances. Physical trade-offs, however, are a measurable result of sub-optimal management and provide evidence that intersectoral coordination is needed to improve policy coherence and resource efficiency [11].

From the perspective of the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention), which provides an overarching legal and institutional framework for transboundary water cooperation in the pan-European region, a multi-sector nexus approach might help improve transboundary cooperation on water resources. Not only does it explicitly involve key water users beyond drinking water supply, namely agriculture and energy production, as well as environment protection authorities, but by extending beyond the water management domain, it can encourage dialogue about broad benefits across sectors, potentially shifting focus from water allocation only. For instance, in the energy sector an understanding of water resource dynamics may be limited, hence energy planning could be improved with better consideration of water supply risks.

1.1. Intersectoral Policy Coherence in Transboundary Settings

Transboundary river or lake basins are extensive and affect many peoples' lives. In the world there are 263 such basins, covering almost half of the Earth's land surface, and some 40 per cent of the world's population lives within them [18]. Many transboundary issues that create friction between countries sharing the same water resources are intersectoral by nature. A typical example is given by the often conflicting water needs for hydropower production and irrigation purposes, both pulled by strong drivers such as employment, economic growth, energy and food security.

Recent work at country level, for example, in Mauritius [14] and California [19], indicates that intersectoral linkages (or nexi) are of material importance. Interestingly, sectoral policies can impose unintended consequences on other sectors even if there is no explicit competition for a single resource, because sectors are interlinked in a network [14]. Where feedbacks are better understood, sectoral policies can positively influence one another, reducing negative impacts or even generating co-benefits [20].

In transboundary settings, matters become even more complex [21]. The physical linkage of water makes riparian countries deeply interdependent, calling for policy coherence not only between sectors, but also across boundaries. For instance, if oil becomes too expensive in an upstream country, exporting/importing food may become unaffordable. This can cause an increase in subsistence agriculture and a less controlled water use, with potentially negative effects downstream. Such interdependency is accentuated when riparian countries are part of power pools where electricity is shared, or common markets for agricultural products.

1.2. The Nexus Work Under the UNECE Water Convention

Because of its potential in advancing transboundary cooperation, the "water-energy-food-ecosystems nexus" was selected as one of the thematic areas of work under the UNECE Water Convention for the 2013–2015 program of work [22]. A Transboundary River Basin Nexus Approach (TRBNA) methodology has been developed to support this work, which in practical terms involves carrying out a nexus assessment of selected basins. Results of this work have been published by the UNECE [23]. Up to now, the river basins assessed using this methodology are the following:

- The Alazani/Ganykh shared by Azerbaijan and Georgia [24];
- The Sava, shared by Bosnia and Herzegovina, Croatia, Montenegro, Serbia and Slovenia [25];
- The Syr Darya, shared by Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan [26];
- The Isonzo/Soča, shared by Italy and Slovenia (not completed).

The nexus assessment of a basin aims at informing, supporting and promoting transboundary cooperation and assisting countries by:

- Identifying interlinkages (trade-offs and impacts) across sectors and countries and incoherencies in governance;
- Proposing actions to reduce negative impacts, minimise trade-offs and possibly take advantage of existing complementarities and win-win opportunities;
- Providing evidence of benefits from improved cooperation at national and transboundary levels.

1.3. Scope of the Paper

The scope of this paper is to describe the TRBNA methodology and present findings from its application in three river basins: the Alazani/Ganykh, the Sava and the Syr Darya. The novelty of the presented methodology lies in the very fact that it aims at applying a pragmatic "nexus approach". It attempts to deal with the strong complexity linked with intersectoral analysis. Especially challenging is the case of transboundary settings, characterized by a diversity of stakeholders, the multiplicity of institutional settings and a variety of priority water needs.

By sharing key lessons learned from the UNECE nexus project, this paper aims at contributing to the current discussion on the nexus in general, and the practical value of applying a nexus approach in transboundary contexts in particular. After a step-by-step description of the methodology (Section 3) and the illustration of key lessons learned from the case studies (Section 4), the discussion part (Section 5) consists of a dissertation around the following questions:

- How did using a nexus approach contribute to advancing the work of the UNECE?
- What are the strengths and main limitations of this methodology to be taken into account for future applications?

2. Study Context

2.1. Cooperation and Benefits

Cooperation becomes crucial when resources become scarcer, costs are shifted across boundaries, or livelihoods and security of resources are threatened. It is therefore important to ensure that the management of shared water resources is both sustainable and coordinated across riparian countries, respecting international law. A case study on the Rhone demonstrated that increasing cooperation and involving a variety of actors in transboundary dialogue—principles of IWRM—do not guarantee, alone, a more coherent management of the river [27]. However, cooperation is also a necessary (although not sufficient) condition to maintain international relations, in turn necessary to establish agreements and share benefits "beyond the river" [28]. Good governance, including intersectoral coordination, participation of different stakeholders and the availability of transboundary legal frameworks, are important elements in putting the nexus approach into practice in transboundary basins [29].

Improved cooperation generates benefits that propagate across sectors at both national and transboundary level. Sharing water resources sometimes constrains the achievement of these objectives; their uncoordinated management can create tensions and undermine trust between countries, reducing opportunities for regional cooperation [28]. As a result, improved transboundary cooperation can greatly benefit riparian countries in many ways, also (but not only) in economic terms.

By broadening the perspective beyond water allocation, a nexus approach adds value to the IWRM approach in discussing the benefits of cooperation. It was observed that in transboundary contexts a dialogue focused on the value of water, the role of ecosystems and benefits of cooperation is less likely to get stuck on disputes over water resource allocation [30]. Moreover, increasing intersectoral coordination within and between riparian countries (including water management, energy and agriculture) opens opportunities for generating benefits, and also synergies, above the basin scale [15]. The nexus approach allows for a multi-sectoral dialogue that is in principle broader than the dialogue promoted with IWRM and that aims at discussing synergies out of the water management domain and beyond the basin scale.

2.2. Developing the TRBNA Methodology

The objectives of the Water Convention—namely promoting cooperation in the management of transboundary waters—influenced the development of the TRBNA methodology in many ways. First of all, despite the multi-centric nature of the nexus and the fact that it can be applied at different scales, water holds in this context an undeniable importance over the other resources, being the natural vector of transboundary impacts and the subject of transboundary cooperation. This results in the methodology having a certain emphasis on water as the entry point to the nexus (see Sections 3.1.5 and 5.2) and focusing on the basin scale like IWRM (even though specific components of the nexus are analysed at a different scales—notably the energy system, analysed at regional and national level). Nevertheless, since the nexus emerged as a concept rooted in the concepts of water, energy and food security, by nature it goes a step further to IWRM to improve multi-sectoral coordination and integration [31].

A high level of engagement with national administrations in the assessment resulted from the fact that countries are the constituency of the Water Convention (as Parties) and the UNECE (as Member States). The UNECE has engaged officially with the countries sharing the basins, while through the Water Convention's governing bodies the countries have contributed to shaping the assessment process. Stakeholder participation was therefore a pillar for the development of the methodology, being not only a useful tool to better analyse the nexus, but also a necessary step to officially validate results and ensure the policy relevance of the assessments.

In designing the participatory process of the TRBNA, high importance was given to the joint identifyication of the benefits of cooperation. This aims at ensuring that the assessment is relevant for the countries, in the sense that it takes into account national interests. Despite their differences, all countries aim at achieving or improving security in the supply of resources (social stability and equity) and economic stability or growth. Nevertheless, the pursuit of national interests should not prevent the use of shared watercourses from remaining equitable as well as reasonable, and a country's development should not cause significant harm to co-riparian countries, in line with the key obligations of the Water Convention, which are also the main principles of international water law [32].

By design, the nexus assessment goes only as far as to propose beneficial interventions and illustrate how they might improve inter-sectoral transboundary management Other activities can support it or complement it: risk assessments, cost and benefit analyses and integrated modeling efforts can build on its outcomes.

In its final form the methodology synthesizes elements from different approaches, notably the basin approach (inherent to the IWRM) [12]; the Climate, Land use, Energy and Water strategies (CLEWs) framework [33]; the nexus approach developed in the Food and Agriculture Organization of the United Nations [34] and a proposed approach to assess the governance aspects of the nexus [35]. The latter builds on the analytical framework proposed for the project "GOUVRHONE, Governance of the Rhône River from Lake Léman to Lyon", led at the University of Geneva [27], which has been inspired by the Institutional Resource Regime framework [36,37] developed for an analysis of regulatory frameworks through public policies, property rights and the interlinkages between these two legal corpus.

Attention was paid to the challenges of putting the nexus into practice at basin level and finding a balance between the technical and social approaches to the nexus. Consequently, key drivers to the development of the TRBNA were (1) the need to work on two parallel and coordinated lines of analysis: governance- and resource-based; and (2) the aim of pragmatically diagnose inconsistencies and suggest beneficial actions for consideration by the countries concerned, both in terms of administrational and infrastructural interventions.

3. Methodology. The Nexus Assessment of a Transboundary Basin

In order to systematically carry out nexus assessments, an ad-hoc terminology was developed to define nexus related concepts. This was particularly important to clarify differences with other approaches such as IWRM (to which most stakeholders involved in the participatory process are more familiar with) but also to be able to maintain a margin of comparability between the assessments to facilitate sharing of experiences.

As an example, "nexus issues" and "nexus solutions" were defined, respectively, as a problematic situation that affects more than one sector and an intervention that would benefit more than one sector (including interventions that reduce the pressure on ecosystems and the environment at large). Because of the transboundary focus of the assessments, both should have a transboundary dimension, involving or impacting more than one country. It should be noted that a "nexus solution" that affects two sectors may create a new "nexus issue" affecting a third sector. Nexus solutions can take various forms but in general terms they should contribute to improving overall resource use efficiency, improving resilience of socio-economic activities to external shocks (including climate change) and strengthening policy

coherence (thereby minimizing negative externalities). A complete glossary can be found in the final publication of the project [23].

3.1. A Six Steps Process

The TRBNA methodology consists of six steps and this sequence is illustrated in Figure 1. In steps 1–3 the analysts prepare a desk study of the basin, which will be used as basis for steps 4–6, where stakeholders are actively involved and a more in-depth analysis of nexus interlinkages is made. The key instruments utilized at various steps of the process are described below.

The diversity of the basins to be assessed requires the methodology to be flexible enough to allow the analysts to consider a wide range of interlinkages and conditions, applying at the same time a simple and consistent framework. To allow for this flexibility, the assessment process has been designed to zoom-in from a broad socioeconomic diagnosis of the basin to its specific intersectoral issues and existing opportunities to mitigate them.

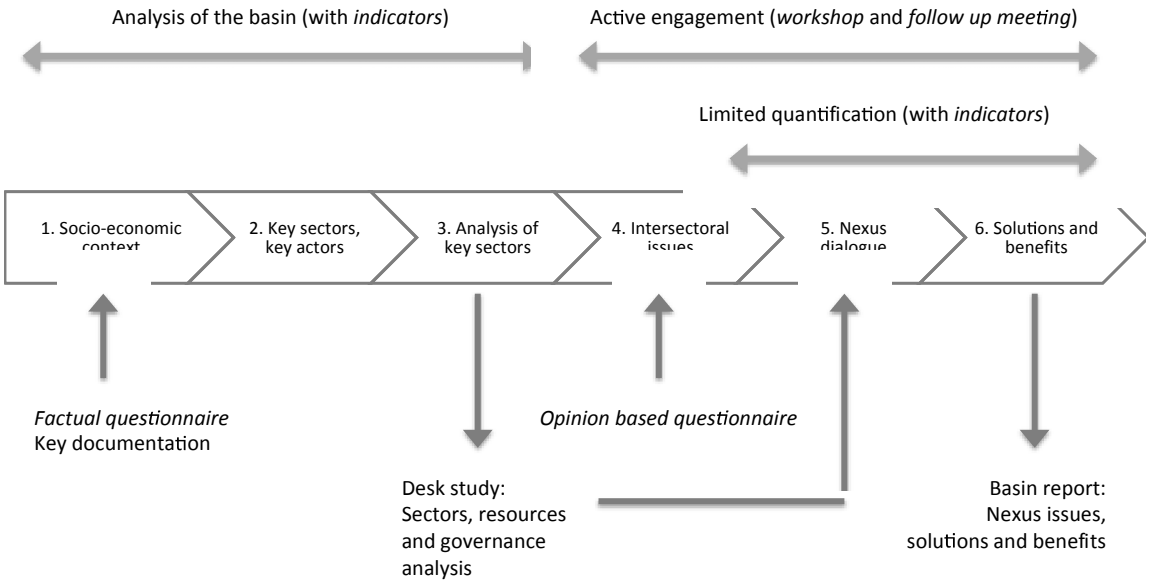

Figure 1. Schematic of the six steps with inputs and outputs.

- Indicators—Steps 1,3,4,6 (see Appendix 1):

Three groups of indicators are used at different stages to substantiate the analysis of the basin:

(1) statistical and spatial screening indicators at country and basin levels;
(2) perspective indicators from the different sectors and countries (see "Opinion based questionnaire");
(3) basin-specific indicators of various kinds, to support the study of interlinkages.

- Factual questionnaire—Step 1

Distributed to the participants to the workshop and local experts to collect basic information on the state and uses of resources as well as issues in the areas of water, energy, food/land and ecosystems.

- Workshop—Steps 4,5,6 (see Appendix 2)

It includes several sessions where participants engage in the nexus assessment process directly, by discussing intersectoral and transboundary issues. On top of providing input to the assessment, this gives them ownership of the process and allows for direct confrontation of various sectors. Ad hoc material, reported in Appendix 3, was prepared to facilitate the discussion in working groups

during the workshops. Sector-centric diagrams were used to facilitate discussion in sectoral groups (as part of Step 4); nexus diagrams were used to facilitate cross-sectoral dialogue (as part of Step 5) (see Figures A1 and A2).

- Opinion based questionnaire—Step 4

Distributed, filled in and collected at the beginning of the participatory workshop to gather the opinions of stakeholders involved in the process and compare the different perspectives between sectors—water, energy, food/land and ecosystems—and countries on various issues. Issues that everyone agrees on and differences in perception are important nexus indicators.

- Follow-up meeting—Step 6

Discussion with authorities on how the findings and solutions included in the assessment relate to policies or programs in the countries, and what could be done to address the identified intersectoral issues. It is a mean of verifying the real relevance of the assessment for policy development.

3.1.1. Step 1—Socio-Economic and Geographical Context

Step 1 aims at characterizing the basin conditions and its economic context and determining the level of dependency of riparian countries on the basin's resources.

(a) *State of energy, food, water and environmental security in the basin.* Emphasis is given to the needs of local populations living in the basin and in its riparian countries. The levels of poverty are established, important livelihoods and social issues understood. Access to and affordability of resources are the primary information to be collected, together with information on environmental issues in the basin. It should be noted that establishing a precise definition of "security" in each nexus areas (water, energy, food/land and environment/ecosystems) was not the focus of this project.

(b) *The relations that exist within the region, the basin and its riparian countries*. The basin is first of all understood in terms of its geographical and geopolitical aspects. The basin is most probably linked to national development plans in a way that affects the use of its resources. The basin may be valuable for specific economic activities taking place in its area, it may be an important transit route, its natural resources may be exploited for the benefit of external actors (e.g., transfer of water, mineral mining, *etc.*). This connection may be understood, at least in the cases of energy and agricultural production, in terms of dependency. For example, it may be interesting to determine how much each riparian country relies on energy produced using water from the basin.

(c) *Main strategic goals, development policies and challenges*. These exist at different scales: basin, country and region. A key strategy for promoting new technologies in irrigation, for example, will translate into changing water use, as will the goal of providing every household with safe drinking water. Strategic goals of riparian countries may affect the resources and population living in the basin also indirectly. For instance, a country can be investing less and less in agriculture and a basin with a high share of population employed in agriculture may experience migration or social change.

The necessary information may be derived from:

- The factual questionnaire compiled by focal points from each riparian country
- Key documentation on the basin and region such as socio-economic reports and environmental reviews. In this process, a basic set of reports was used, such as reports by various UN organizations (e.g., UNECE, FAO) and other international organizations (e.g., World Bank, Global Water Partnership) were typically included in this list, together with River Basin Management Plans)
- Screening indicators at national and basin level. In this process, indicators from World Bank and FAO—Aquastat databases were widely used, however no fixed set of screening indicators was defined (see Appendix 1 and Section 5.2).

3.1.2. Step 2—Identification of Key Sectors and Key Actors

This step aims at identifying the key sectors to be included in the nexus assessment and the key actors to be involved in the assessment process (*i.e.*, workshop and further consultation).

(a) *Identifying the key sectors.* These are determined on the basis of the findings of Step 1 as the ones that play a major role in the basin's socio-economy and environmental protection. In general terms, sectors are resource users. They can be productive (e.g., industry) or just consumptive (e.g., households) (see Section 3.1.4. for a clarification on how the concepts of "sectors" and "resources" were interpreted). The water supply, energy production, agriculture and environmental protection sectors can be considered as a core set of key sectors, however some sub-sectors will be more relevant than others. For example, hydropower as a subsector of energy production, crop production (or even the production of a specific crop) as a subsector of agriculture and so on.

(b) *Identifying key organizations and other actors.* By taking active part in the workshops and in the consultation process, these stakeholders will not only share their knowledge but also offer an opportunity to include the findings from the assessment into actual plans and programs, playing a key role in the nexus assessment. Their identification should be informed or validated by the mapping of actors. It should be noted that in our terminology 'organizations' indicates formal actors such as River Basin Organizations and ministries; 'other actors' could include even individuals who have knowledge on and/or influence over the nexus and the study context.

3.1.3. Step 3—Analysis of Key Sectors

Understanding how the sectors use resources, their socio-economic value and what are the rules, plans and regulations associated with them is the objective of this step. The sectors considered are the ones defined in Step 2. The outcomes of Steps 1–3 constitute the core of the desk study, which informs the discussion on interlinkages and feeds into Steps 4–6.

(a) Sectors and resource flows analysis

Sectors need inputs in certain amounts and quality. For example, water is required in good quality for direct uses but also energy needs to be safe, available in sufficient quantity and clean. Similarly, different land types can be available for different uses. This drives various demands of resources that is satisfied by extracting and processing them. Mapping these resource flows is the start of an integrated system analysis, which could entail the use of sectoral models of the basin and countries. The level of detail that can be reached in this analysis depends on many factors, among which the most constraining are: data and time availability, number and complexity of sectors to include in the system, size of the basin. The minimum output would be a sketched schematic of resource needs by the different sectors, their outputs and impacts, at least semi-quantitatively or with indicative orders of magnitude.

(b) Governance Analysis

We define "governance" as "a system of responsibility and accountability involving formal and informal institutions that builds trust and capacity to cooperate in policymaking, decision-making and implementation of measures".

Conducting a governance analysis helps to gain a better understanding of the context in which the different sectors of activity operate. This multi-level context is composed by different elements. It includes formal rules that depend on public and private law; it entails varying consideration regarding the structure and mandates of public administration (such as varying degrees of centralized or self-organized configurations) and different combinations of actors and interlinkages that rely on formal and informal agreements. A governance analysis helps to generate a better understanding of the extent to which conditions are being met in order to achieve coherent (and sustainable) integration of different sectors (consumers) of resources and to identify its regulatory capacities at different levels.

In line with the objectives of the assessment, the governance analysis includes key sectors and it considers different scales: regional, national and local. Focuses of the governance analysis are the following aspects [23]:

1. Policy framework—strategies and other policy documents, instruments, *etc.*;
2. Legal and regulatory framework—rules and regulations;
3. Organizations and actors—mandates, responsibilities, administration.

While the basin is the appropriate level for consideration of traditional water resources management issues, other geographical scales are appropriate in relation to other sectors. For example, energy security is usually determined according to strict political boundaries. Moreover, cultures of decision-making and administration, and relationships among stakeholders may also be quite different from sector to sector, making comparisons difficult.

These (a) and (b) lines of work are complementary. On one hand, the resource analysis establishes availability and quality of the resources available, as well as the mechanisms (demands, supply, trade, *etc.*) that link them to their uses. On the other, the governance analysis understands how actors and rules determine the management of those resources.

Ad-hoc material to facilitate the discussion at the workshop is prepared as part of the desk study (see Appendix 3). The spatial dimension is important for assessing whether and where resource uses are less compatible. Hence, it may be useful to prepare, additionally to this material, basin maps of the basin displaying key aspects that will be discussed by the sectoral groups (see Step 4) such as protected areas, infrastructure, water bodies, *etc.* At this stage it is also possible to define a set of important drivers, such as policy directions, socio-economic trends and climatic trends. It will be useful to advance a preliminary list of these before the workshop, to inspire and facilitate dialogue.

3.1.4. Step 4—Intersectoral Issues

Step 4 takes place in the participatory workshop, which structure is synthesized in Appendix 2. This step is key in the participatory process because it defines how each sector will interface the others in the nexus dialogue. Here, intersectoral issues are explored from sectoral perspectives (before being jointly discussed and prioritized in Step 5). Participants are divided into thematic groups—water, energy, food/land and ecosystems—according to their expertise or area of interest. They are asked to discuss interlinkages from a sectoral perspective in a sort of brainstorming exercise, using sector-centered nexus diagrams and thematic maps of the basin (see Appendix 3). Information from the desk study is used to inform and facilitate the discussion (see Step 3). Key policies, sectoral plans and data sources are presented and validated by local actors, who also provide expert judgment for prioritization of issues.

An opinion based questionnaire is used to collect the different perceptions of sectors and countries. This contains statements that participants have to rank in terms of importance and personal perception. The questionnaire is anonymous but respondents have to specify their country and area of expertise (water, energy, food/land or ecosystems) so that comparisons between groups can be made. For example, one country could perceive energy security as a top concern while another not at all, or water resources could be described as "scarce" in one country but not in another. Answers can be grouped by country and by sector and compared to measure to what extent the groups agree or disagree.

In this work, the decision of maintaining an ambiguous definition of "sectors" was deliberate. The diagrams used to support intersectoral dialogue do not display key sectors, that we have seen can be various and depend on the basin. They display the four "components" of the nexus: "water", "energy", "food/land" and "ecosystems", which can be interpreted either as resources or sectors depending on the context of discussion. A limitation of using this diagram to illustrate intersectoral issues is that it emphasizes the physical aspect of resource flows across sectors over other important aspects (e.g., economic, legislative, *etc.*). Moreover, sectors consuming the different resources are not spelled out. At the same time, using a simple and intuitive diagram (that workshop participants are invited

to modify if needed) allows for a less constrained dialogue. For the purpose of the assessment, it is important that all pressing intersectoral issues are reflected but there are no "wrong" arrows. For instance, industry could be part of "energy" (*i.e.*, as an extension of the energy industry) or "land" (*i.e.*, as a type of land use), depending on which option participants feel more comfortable with and by the type of industry discussed.

3.1.5. Step 5—Nexus Dialogue

Step 5 can be considered the core of the nexus assessment because it is the moment where intersectoral issues are discussed having all concerned sectors around the table. A shared understanding of the nexus is built on the basis of (1) an agreed picture of the basin conditions, national priorities (in terms of sectors or economic development) and environmental concerns and (2) sectoral perspectives on pressing intersectoral issues.

The interlinkages identified in Step 4 are jointly prioritized and combined into thematic "nexus storylines". Depending on the time available and the number of participants, this can be done in mixed groups or in an interactive plenary session. Typically, the storylines will evolve around the topics of water availability and water quality—in line with the fact that, in transboundary contexts, water is the natural entry point to the nexus dialogue.

Interlinkages (such as multiple uses of resources, negative impacts, trade-offs and dependencies between sectors) are discussed together with the existing obstacles to overcome them, to establish a shared understanding of intersectoral challenges—e.g., diverging objectives and priorities for development, gaps/overlaps of responsibilities and mandates, *etc.* Next, the relevant future tendencies (climate change, socio-economic trends) are identified jointly with participants and the effects that these will have on intersectoral issues are discussed.

3.1.6. Step 6—Solutions and Benefits

Following the discussion on intersectoral issues, possible solutions are discussed. A definition was made to limit candidate solutions, namely that they have to benefit at least two sectors and have a clear transboundary dimension. They can be of two kinds:

(a) Synergetic: when two or more sectors actually cooperate on actions and projects that create multiple benefits.

(b) Sectoral: when the action of one sector has side benefits on other sectors or at least minimizes the negative impact on other sectors.

Technical solutions as well as policy interventions are considered. To the first group belong infrastructural and operational interventions, technological innovation, *etc.* To the second, a broad range of potential interventions, from cooperation agreements to communications, implementation of economic instruments, change to existing policies or development of new ones, institutional arrangements, change in regulation, *etc.*

After the workshop, the analysts will set time to quantify, to the extent possible, the identified interlinkages and benefits associated with the discussed solutions. Quantification is made mainly to illustrate the importance of some of the identified priority issues and give an idea of what a possible fully integrated resource assessment of the basin could look at. The use of integrated modelling can help at this stage, for instance to estimate future water needs coming from the development of new hydropower, the impact of energy efficiency measures on water use and availability for ecosystems, the impact of food trade on domestic water consumption, and so on. However, the extent of the analysis basically depends on the availability of resources and the interest of involved policy makers.

The nexus assessments concludes with "potential beneficial actions", rather than "recommendations", due to the fact that no proper evaluation of the actions is made at this stage. Depending on the type of storylines and proposals emerging from the nexus assessment, follow-up analytical exercises could be set up to study the applicability of solutions, which can include risk

assessments, cost and benefit analyses, integrated modelling of (climatic, socio-economic) scenarios, action planning, policies and plans for stakeholder engagement and other governance aspects.

A follow-up meeting with key stakeholders is needed to make sure that solutions are translated into feasible actions, ideally linked to actual policies or projects on the agenda of national governments or basin organizations. In the course of this meeting the results of the nexus assessment are presented and discussed. These results should point clearly at beneficial actions and benefits that have been identified.

4. Results

For the purpose of this paper some examples have been extracted from the basin assessments, both to illustrate the practical application of each step of the methodology and to provide a point of reference for the key lessons learned.

Examples from the application of Steps 1 and 2 are illustrated respectively in Appendix 4: "Highlights from the socio-economic analysis" and in Appendix 5: "Map of key organizations and actors". They contain comparable information from the three basin: Alazani/Ganykh, Sava and Syr Darya. Step 3 is illustrated with the "Analysis of the energy sector in the Sava basin" (Appendix 6). Examples relative to Step 4 and 5 can be found respectively in Appendix 7: "Intersectoral issues in the Syr Darya River Basin" and Appendix 8: "Nexus dialogue in the Alazani/Ganykh basin". Finally, Step 6 is illustrated in Appendix 9 with an example of "Solution and benefits from the Sava River Basin".

Lessons learned include a variety of considerations on the implementational aspects of the methodology. They are presented following the same step-by-step structure.

4.1. Analysis of the Basin—Steps 1 to 3

Step 1 helps to roughly establish key issues and concerns to be kept in mind during the whole assessment process (see Appendix 4). Resource security issues, strategies, policies and interests on the basin's resource base will either be the core of discussion in the participatory phase or hidden elements that will influence it. As an example, energy security issues and electricity capacity expansion are recurring elements, but they can play different roles in the nexus. In the Syr Darya energy insecurity is a clear driver to hydropower use and expansion (affecting directly seasonal water availability for irrigation); in the Sava, hydropower expansion is strategically relevant because it contributes to reach targets for reducing emissions and incrementing the share of renewables but creates environmental concerns in some areas. In the Alazani/Ganykh, despite strong national interest in expanding hydropower capacity, the particular geo-morphology of the river limits its development there. Energy insecurity in this case manifests itself indirectly, with the reliance of rural communities on fuel wood, contributing to deforestation and loss of forest related ecosystem services.

It is challenging to determine which sectors should be part of the nexus assessment at the early stage of Step 2. However, some initial boundaries need to be set up, not only to move on with the sectoral analysis but also to be able to communicate clearly to the stakeholders involved which sectors are considered as being "inside" the basin-specific, local nexus. These boundaries may be eventually revised and adjusted, after the workshop. In the UNECE nexus assessments, at least water, energy, ecosystems and agriculture were always considered as key sectors. Agriculture was often limited to food production (crops, livestock and fishing), while trade was taken into account only if important interlinkages would arise (Syr Darya). Other aspects of land use such as flood control (associated with the component "food/land" of the nexus) were also considered when relevant (Alazani/Ganykh, Sava).

It is also easily the case that too many actors are identified as relevant for the assessment. It is not always feasible to involve all of them in the process, and at the same time this would not necessarily guarantee a better outcome. In this case, priority should be given to ensure diversity and balance across sectors and countries. It is assumed that the set of stakeholders involved in the participatory process is sufficiently representative of all relevant sectors and interests. However, in practice, the choice of

stakeholders can be influenced by many factors. In this project, the group of stakeholders involved in the process emphasized public administration and was complemented by a limited involvement of operators/state companies, civil society and academia (see Appendix 5). In terms of expertise, water was heavily represented. This should not be interpreted to infer inadequacy of the nexus approach to broaden stakeholder involvement, but rather as a feature of this application of the methodology in this particular framework. In fact, stakeholders should ideally be selected after having rigorously identified key actors (Step 2) but commonly the mapping of actors was completed after the workshop and time constraints in the process resulted in over-reliance on established networks. The application of the methodology revealed also that further refinements are necessary in order to be able to more fully assess the range of characteristics of stakeholder engagement, including the level of self-organization of stakeholder communities, their legitimacy and representativeness, the degree of cooperation, number and quality of opportunities for engagement, and access to review procedures, to name just a few.

The analysis of sectors and resource flows of Step 3 required to go beyond the mere account of resources availability, production and demands. For example, while the waters of the Syr Darya aliment extensive irrigation schemes in semi-arid areas, irrigation in the Sava is very limited, constituting less than the 1% of total water use in the basin. This does not mean, however, that the agricultural sector in the Sava is less relevant from a nexus perspective. Employing 5% to 10% of the population in the region (*i.e.*, all countries), the agro-industry is an important economic sector. Considering the low irrigation capacity and predictions showing a trend towards longer and hotter summers, the resilience of the agricultural sector to climate change and the future development of water demands for agriculture become important areas of investigation.

The experience from the governance analysis of the basins shows that comparisons across basins or countries need to be made with caution. Formal cooperation frameworks between the countries may vary, as well as their coverage in terms of sectors and issues. However, their presence does not necessarily translate into closer cooperation: despite the existence of various inter-state institutions in Central Asia, cooperation in natural resources management and trade remains difficult. Moreover, there are national but also subnational differences: for example, Slovenia does not have regional administration, while Bosnia-Herzegovina, mostly for historical reasons, has a special entity level with its own authorities that enjoys a high degree of autonomy.

It should be kept in mind that governance with respect to the nexus is not the same as governance in a sectoral context. In general, and sector-specific terms, governance has been studied extensively and standards for improving governance have advanced steadily in various fields, even if at different speeds. But governance requires a specific context, whether it be processes of policymaking and decision-making, or implementation and financing. Complex, multi-sectoral, multi-use frameworks are relatively undeveloped, amorphous and ad-hoc. Decision-making involving trade-offs between sectors are usually at a high political level. Consequently, the kinds of platforms, institutional arrangements, and development of practice over time that are characteristic of sectoral processes are largely absent in a nexus context. The most that can be done is to assess parallel governance contexts sector by sector (as can be seen in Appendix 6) and to propose governance principles in connection with nexus analysis as it evolves.

Lastly, an important aspect of a governance assessment is to understand whether there are important "undercurrents" with respect to specific sectors and uses. A well-functioning governance system will ensure transparency and help to resolve conflicts within a sector. If there is an imbalance in governance across sectors, the full range of interests and values will be represented to a different extent, and interactions through a nexus process might reveal weaknesses in the perceived consensus in a sector with relatively poor governance. Governance in the "weaker" sector may be improved thereby, but it should also be recognized that existing power structures may not welcome such changes.

4.2. Active Engagement—Steps 4 to 6

Approaching intersectoral issues starting from sectoral perspectives, as part of Step 4, ensures that all components of the nexus manage to contribute to the subsequent nexus dialogue (see Appendix 7). In particular, a challenge is to go beyond the "security nexus" of energy, food and water and put the fourth dimension of "ecosystems" on the same level. When discussing development objectives, it is sometimes difficult to keep environmental priorities in the discussion. This is because environmental needs are commonly seen as a constraint to the expansion of "productive" sectors. Discussing ecosystem services proved to be quite successful to shift this view: interlinkages with other sectors not only include resource needs and the negative impact of other sectors on the environment, but also the positive contribution of ecosystem services. So, for example, in the Alazani/Ganykh, the water retention and land stabilizing service provided by the forest is considered, in the final nexus dialogue, as a key interlinkage that bridges energy, land and water policies (see Appendix 8).

The nexus dialogue of Step 5 gave very different results from case to case. In the case of the Alazani/Ganykh intersectoral linkages combined clearly in a storyline with clear causality links (see Figure A4). Although non-comprehensive of all relevant intersectoral elements (for example, renewable energy installations in the agricultural sector or water transfer to Baku), this collectively developed picture includes important indirect linkages that provided new important insights. In the Sava and Syr Darya, the nexus dialogue did not produce equally articulated storylines, but it served the purpose of prioritizing the most pressing intersectoral issues.

The search for "nexus solutions" in Step 6 varied according to the fact that riparian countries in each basin are at different stages of transboundary cooperation with each other. In the Alazani/Ganykh, Georgia and Azerbaijan are in the process of negotiating a bilateral agreement on the Kura/Ara(k)s river—of which the Alazani/Ganykh is a tributary [38] and are both developing new legislation on water management. In the workshop, participants were highly engaged in the discussion on nexus solutions to put forward ideas for further work that would contribute to these efforts.

In the Sava basin, the countries were already engaged in transboundary cooperation on a variety of topics within the working program and mandate of the International Sava River Basin Commission (ISRBC). Further integration of water policy with other policies, as well as further dialogue with key sectoral stakeholders, have been set in the Strategy on Implementation of the Framework Agreement of the Sava River Basin as specific objectives in the field of river basin management [39].The nexus assessment was motivated by this wish to broaden the existing engagement of stakeholders, in particular by better involving the agricultural and energy sectors in the dialogue over water management at basin level.

In the Syr Darya, where improving cooperation requires first its restoration, it was necessary to identify solutions that could be taken at national level first. National level benefits were clearly spelled out together with transboundary ones and emphasis was put on national goals that could be pursued without compromising transboundary relations, or even helping its recovery [23].

Follow-up meetings, not foreseen in the initial stages of the methodology development, proved to be a highly valuable addition. The one for the Sava assessment was organized at basin level in May 2015. This meeting allowed discussing the findings across sectors at transboundary basin level. Moreover, modelling efforts initiated during the assessment (the results of which can be found in the final publication of the project [23]) were presented to the countries to discuss opportunities to use them in follow-up actions. In the case of Alazani/Ganykh and Syr Darya, results were presented for discussion to stakeholders in country level meetings in the context of European Union (EU) Water Initiative's National Policy Dialogues. Despite the use of some modeling tools, integrated modeling is not a necessary step of the TRBNA but it is valuable in these meetings to illustrate the potential of taking action in a coordinated manner (see, for example, the case of Sava in Appendix 9). In order to validate results, it was particularly important to prioritize the use of official data and validate all assumptions with local experts.

The nexus assessment of a basin will inevitably reflect the issues and opportunities identified during the course of the participatory process, potentially overlooking or paying only cursorily attention to other important aspects. The role of facilitators at the workshop can be key in ensuring that no major intersectoral issues are neglected; however, the choice of focus of the assessment will ultimately be made by the stakeholders involved, potentially reflecting a deliberate intention to "not discuss" a certain topic or lack of expertise in a certain area within the group.

Finally, it should be noted that sectoral and national interests remain strong even when intersectoral and transboundary understanding is improved. Application of the nexus approach highlights the differences in governance across sectors. The quality of governance can therefore be compared, particularly at the points where various decision-making processes interact. Taking into account such differences in a transparent manner with stakeholder involvement could lead to policy responses to achieve greater balancing of interests in complex decision-making. This may require additional steps in the process, but they should be carefully designed and tested.

5. Discussion

5.1. Value of a Nexus Approach for Advancing Transboundary Cooperation in the Framework of the Water Convention

The development of this methodology and its various applications have involved a number of stakeholders with different views and expectations on what a nexus assessment should focus on and include as well how it should support policy making and improve coherence between sectoral policies. However, this methodology has been developed for the Water Convention, and the nexus assessments were carried out to support transboundary, intersectoral dialogue and to inform policy-making. Considering the actual contribution to the UNECE's work is therefore appropriate, even though the final beneficiaries are the countries.

The nexus assessments build on previous work under the Water Convention, namely the Second Assessment of Transboundary River, Lakes and Groundwaters [40]. This was a comprehensive description of transboundary water bodies and major transboundary issues in the European and Asian parts of the UNECE region. The nexus work is a step forward to discussing transboundary issues and opportunities of cooperation. The effort was parallel to another work item under the Water Convention: "Quantifying the benefits of cooperation" [22,41]. These two mutually benefited each other: on one hand, many benefits of cooperation can be found by applying a nexus approach; on the other, recognizing benefits of cooperation is valuable to motivate engaging into a nexus dialogue.

The response of the countries involved in the assessments was positive. They reviewed favorably the nexus assessment work: the methodology as well as the general conclusions and recommendations were endorsed by the seventh session of the Meeting of the Parties to the Water Convention (Budapest, Hungary, 17–19 November 2015). The Parties also decided that the nexus assessment will be continued as a part of the work programme 2016–2018 under the Water Convention [42]. Although the development of an assessment framework was among the most relevant achievements of the project, the assessments provided for a joint identification and analysis of the main intersectoral issues with the sector authorities of all riparian countries, and for a structured dialogue on them, leading towards discussion about possible improvements to the current resource management and transboundary cooperation. This process could contribute to setting common objectives, reviewing and possibly expanding scope of cooperation or institutional mandates, provide evidence of need for further cooperation, *etc.*

Ultimately, the TRBNA was useful to advance cooperation because it offered the opportunity to identify issues and opportunities jointly with national key actors across sectors and international partners. Even though many solutions are not new, the multiple sectors' participation allows for potentially new input, and the nexus perspective allows for a broader scope of considering and analysing negative and positive impacts as well as measures that could be taken.

In the TRBNA, the implementational aspects of nexus solutions was quite limited and only introduced at the end of the process (Step 6) and suggested as follow-up work. If possible, the thinking and dialogue should be prolonged to explore who (which sector, organization, *etc.*) is in a position to address the potential solutions identified and what concrete actions could be undertaken by which actor. Actions could be incorporated into ongoing or planned initiatives to support policy processes in the countries. For instance, in some basins the riparian countries are part of the European Union (EU) Water Initiative's National Policy Dialogues or there are regional organizations such as basin organizations or other joint bodies, possibly with multiple-sector representation that could provide a framework for identification of beneficial future activities. However, further developing the methodology in this direction will be essential to improve the applicability of results.

5.2. Strengths and Limitations of the TRBNA Methodology

Findings from three nexus assessments highlight several strengths and limitations of the TRBNA methodology identified against the aim of advancing transboundary cooperation. These can help assessing its suitability to further applications.

Strengths:

- Using a highly participatory approach. This allows to focus on actual issues and priorities as well as to validate results from the sectoral and intersectoral analyses.
- Searching for opportunities of cooperation beyond the water domain. This helps discussing the direct and indirect beneficial effects brought by cooperating in other areas (e.g., trading or establishing common objectives at regional level) to potentially broaden consideration and involvement of different sectors and interests in the current water cooperation frameworks.
- Being flexible and adaptable. Focusing more on the "local nexus" by, for instance, avoiding a prescriptive use of indicators, it allows for the consideration of diverse intersectoral issues and cooperative options.
- Substituting direct transboundary confrontation with intersectoral (nexus) dialogue. In contexts where transboundary dialogue is politically sensitive, this may be very useful if not necessary.
- Using a resource-flow approach and a governance analyses in parallel. These two reinforce each other, respectively by providing evidence of physical trade-offs arising from the multiple use of finite resources and by identifying incoherences in the definition of policies or gaps in the institutional and legal frameworks.

Limitations:

- Using sometimes ambiguous definitions and inconsistent indicators. While useful to adapt to different understandings and circumstances, this can create confusion when it comes to comparing results across basins.
- The assessment approach as defined does not address a number of aspects that can be important, for example, financial constraints related to the applicability of solutions, administrative cultures and power imbalances. While already the scoping nature of the assessments and the resources available limited what could be covered, also the institutional set-up and priorities affected what was considered appropriate and relevant to include. Being outlined at a fairly general level, some solutions may be perceived as incomplete or even unclear by sectoral experts involved in the process.
- Over-emphasizing and over-representing water over the other sectors and resources. This causes some important interlinkages to be discussed less, namely food/land-energy, energy-ecosystems and food/land-ecosystems.

Some aspects of the methodology could be improved by amending the existing structure with feedbacks from future case studies or by adapting it to the needs of the basin to be assessed. For instance, with regard to the above limitations:

- Establishing a glossary of terms and a minimum set of screening indicators on the basis of further consultation with experts in intersectoral issues.
- Extending Step 6 to include a better description of what a future analysis of each solution would entail.
- The imbalance of water could be improved by relying less on established networks and carefully selecting key actors (*i.e.*, applying more rigorously Step 2) or at least by better involving those actors in the review of the assessments. Also, more robust methodologies for the governance aspects of the assessment could be developed to better take into account differences among sectors.

Finally, it should be noted that maintaining a critical approach to its application, the TRBNA methodology can be used for any transboundary basin and aquifer. However, its applicability to other scales, for example, national or city level has not yet been tested. Intersectoral issues and solutions have been considered across scales while the focus has remained on the transboundary dimension, reflecting the fact that the methodology was developed specifically to facilitate dialogue at this level.

6. Conclusions

The TRBNA methodology is a proposal to put the nexus into practice at transboundary level in a consistent manner. This is the first general approach of its kind that aims to cast its net (and impact) wider than traditional integrated water, energy, land or environmental assessments. It is formal, while at the same time flexible. It provides a useful entry point to motivate why we should look at international cooperation across sectors to make better use of our limited resources.

Compared to IWRM, the TRBNA considers sectors more broadly, with the intention of explicitly including sectoral perspectives and considering a wider range of opportunities for cooperation. Analyzing sectoral goals and priorities beyond the use of the water resource in question differs from the IWRM approach, which considers sectors precisely in function of their water use.

The methodology development was not a purely academic effort and was strongly influenced by the time constraints of the intergovernmental process and by the need to carry out assessments in politically sensitive contexts. It can be concluded that both the methodology and the assessments concretely contributed to pursue the objectives of the UNECE Water Convention, in particular joint assessment in a participatory manner and by exploring benefits of cooperation.

The understanding, interpretation and codification of various nexus concepts for which there are currently no widely accepted definitions was influenced by the scope of the project. A glossary developed ad hoc for this project was crucial to communicate new nexus concepts to stakeholders. Yet this was not validated by a wider academic community, which would be highly valuable not only for future applications of the TRBNA but also to advance with the much needed definition of nexus related concepts.

Refined and improved after its application to different basins, this methodology is applicable to a variety of geographical, socio-economic and political settings. However, future assessments will likely benefit from a critical approach to its application. In this paper, we highlight only a few general, possible improvements because specific ones will depend on the basin and context of application.

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Author Contributions: Lucia de Strasser, who refined the methodology and consolidated the various basin assessments, is the lead author of this article and integrated the inputs from all the authors. Substantive input was provided by Annukka Lipponen who contributed to shaping the methodology and the nexus assessments as the

process and content coordinator. Together with Mark Howells, they have developed the methodology and carried out the assessments. Christian Bréthaut developed the initial approach to the governance methodology, further developed and integrated into the final methodology by Stephen Stec.

Conflicts of Interest: The authors worked for UNECE on the nexus assessment under the Water Convention either as staff (Annukka Lipponen) or as consultants (Christian Bréthaut, Lucia de Strasser, Mark Howells, Stephen Stec).

APPENDIX 1. Indicators

Table A1. Indicators.

Group	Relation to the Methodology Process	Type	Sources
Screening indicators (basin and national level)	Steps 1 and 3	Statistics Geo-spatial (GIS)	National and international statistics; relevant documents such as river basin management plans.
Perspective Indicators	Step 4	Qualitative/Rankin	Opinion based questionnaire.
Assessment-specific indicators	Step 6	Data	Previous studies, experts, authorities, models and estimations.

Notes: Screening Indicators are often available in the same form for each country and less often for each basin: *i.e.*, large basins such as the Syr Darya feature in the FAO database, but small ones such as the Alazani/Ganykh do not.) For this reason, it is not always possible to keep the analysis consistent across different case studies and most of comparable information can be collected only at country level (e.g., energy produced by source, water resources, *etc*.) In Step 1, it is possible to combine basin and country level Screening Indicators to investigate the relation between the basin and its riparian countries—for example, in terms of energy or crops produced in the basin area (as percentages of total produced in each riparian). A non-prescriptive list of sources for international statistics is given in the final publication of the project [23]. In order to obtain Perspective Indicators, each issue listed in the questionnaire is ranked from not relevant to very relevant and each participant states its country of origin and its area of expertise/work (energy, water, food/land, ecosystems). This allows for a comparison of perspectives from different countries and sectors on a same topic. The choice of assessment-specific indicators depends on the choice of interlinkages to be considered (for example, the change in forest area in the basin is an indicator of deforestation).

APPENDIX 2. Structure of the Workshop

1. Introduction of the nexus and relevant explicatory examples (by the analysts).
2. Distribution of the opinion based questionnaire.
3. Introduction to the key sectors, their main characteristics and issues (by selected speakers).
4. Presentation of national sectoral policies, as well as relevant national strategies and targets that may affect the basin (by relevant authorities).
5. Focus on the basin. Discussion on possible future development of the basin (river basin or aquifer management plan, infrastructure plans, sectoral targets, policy priorities, *etc*.).
6. Illustration of possible interlinkages and nexus conditions. Explanation of the working group sessions.
7. First working group session on intersectoral mapping. Stakeholders are divided according to their area of expertise or work (food/land, water, energy, ecosystems). Each group identifies the most important interlinkages (impacts and trade-offs) associated with its component. (For the material used, see Appendix 3).
8. Joint prioritization of the key interlinkages to be considered in the assessment. (For the material used, see Appendix 3).
9. Presentation of official data on climate change and, if available, the predicted impact on the basin.
10. Second working group session on future dimensions. Participants are divided into mixed groups to define a few relevant scenarios and discuss how the key interlinkages will change under those scenarios (see note below).

11. Discussion on synergetic actions for the identified nexus conditions, by means of measures, policies, coordination arrangements and techno-economic solutions. Reflection on the transboundary dimension. Discussion on the benefits and limitations. Identification of who/which actors could advance the actions.
12. Discussion on indicators and sources available.
13. Presentation (by the analysts) of some key findings and preliminary results from the workshop and desk study, in the form of nexus graphs and storylines that will be analysed further and included in the basin assessment.
14. Presentation of next steps in the assessment.

Note: In the early stages of applying the methodology, the joint discussion on trends was not well structured, so that future challenges remained mostly unexplored. This session was then specifically dedicated to discussing future trends in groups. The short time reserved for this exercise (3 hours) however, did not allow for a satisfying outcome.

APPENDIX 3. Material to Facilitate Intersectoral Dialogue

Intersectoral diagrams have been designed specifically to introduce the nexus dialogue and their features deserve some explanation. The idea behind their design is to support the dialogue by moving from the consideration of interlinkages from a sectoral perspective (which is where, for example, IWRM and integrated energy planning (IEP) stop) to their examination in a roundtable where all perspectives are equally represented: a nexus approach. Participants draw arrows between sectors to indicate dependencies and impacts (unidirectional) and trade-offs (bidirectional).

To represent the nexus, we used a triangular scheme where "energy", "water" and "food/land" are located at the apexes and "ecosystem services" is at the center. This was developed for supporting the nexus dialogue in Step 5. For the sectoral groups (Step 4), we rearranged the same scheme by putting at the center the sector that each group is considering. The others are located at its left and right to stimulate the consideration of interlinkages as inputs (needs) and outputs (impacts). (During this working group session we used "ecosystem services" rather than "ecosystems" to explicitly invite participants to think about the interactions of human activities with the environment rather than only their impact on it.).

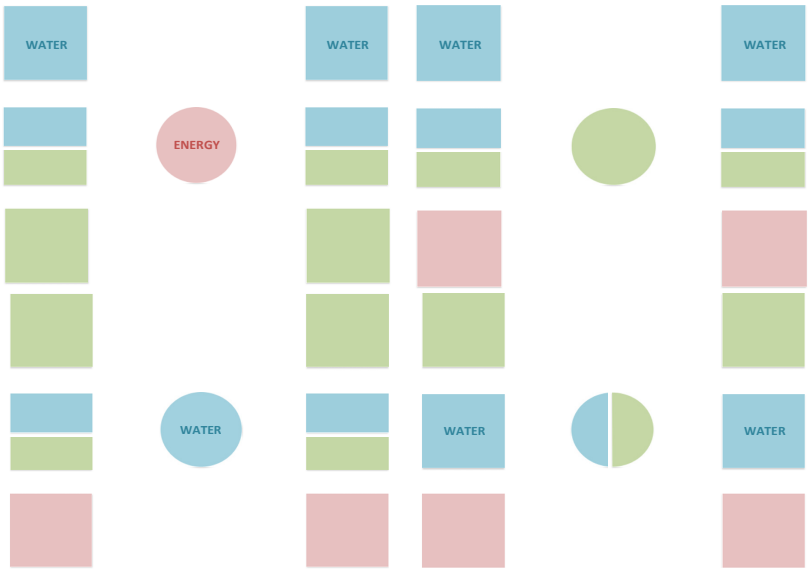

Figure A1. Sector-centered graphs used to facilitate discussion at the workshop [23].

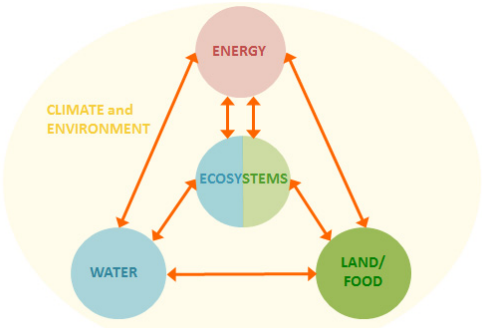

Figure A2. Intersectoral (nexus) graphs used to facilitate discussion at the workshop. Note: Initially—in the first workshop—"ecosystems" constituted a fourth corner in the nexus diagram (Figure A2). This caused confusion because "ecosystems" often logically overlaps with land and water resources (for example, when discussing an impact on water quality participants were unsure if to consider water or ecosystems). The diagram was reviewed accordingly, and "ecosystems" was colored half in blue and half in green to show this overlap [23].

APPENDIX 4. Highlights from the Socio-Economic Analysis (Illustrative of Step 1).

Alazani/Ganykh

(a) State of energy, food, water and environmental security in the basin

In the Georgian side of the basin, population lacks access to affordable energy in rural areas and some heavily rely on fuel wood for household heating and cooking. Water infrastructure, especially irrigation systems, is in poor conditions and lacks maintenance. Frequent flash floods have a devastating effect on local economy, affecting both countries.

(b) Relations within the region, the basin and its riparian countries

The region of Kakheti (practically coinciding with the Georgian part of the basin) is famous for wine production as well as for hosting important biodiversity sites. Water-scarce Azerbaijan recently built a pipeline to transfer groundwater from the basin to its capital, Baku, to supply it with drinking water. Azerbaijan is an important exporter of fossil fuels, and Georgia is a key corridor for natural gas transfer from the Caspian region to Europe. Cooperation between riparian countries is increasing in terms of regional trade agreements and coordinated environmental protection of shared river basins is being built.

(c) Main strategic goals, development policies and challenges

At basin level: interest in advancing cooperation at the Alazani/Ganykh basin level as part of wider international dialogue on the Kura/Ara(k)s basin. At country level: Georgia aims at developing the largely untapped potential of hydropower. Azerbaijan aims at diversifying economy and energy production to reduce dependency from fossil fuels.

Sava

(a) State of energy, food, water and environmental security in the basin

The basin is prone to flood episodes, which can be devastating and—among others—affect energy production and mining sector. Only small areas are irrigated and in times of droughts, large amounts of crops can be lost.

(b) Relations within the region, the basin and its riparian countries

The Sava is an important transportation route. The river and its tributaries are vital for the energy security of riparians as most of their electricity production depends on its water (for hydro and thermal power). Employment in the agro-industry in the basin area is economically relevant for all countries.

(c) Main strategic goals, development policies and challenges

At basin level: Developing and strengthening the mandate of the basin commission (International Sava River Basin Commission), for example, by finalizing a flood control scheme at basin level. At regional level: Strong relation with the European Union (to which some countries are member States). Regional commitments (e.g. EU directives) and development strategies fostering economic cooperation. Targets for increasing the share of renewables (including hydropower), improving energy efficiency and reducing emissions.

Syr Darya

(a) State of energy, food, water and environmental security in the basin

Energy insecurity is an issue in the upstream countries; especially in winter (e.g., winter 2008–2009) households can face severe power shortcuts. This can combine with food insecurity (e.g., high food prices, inadequate transport routes) creating a compound crisis. Seasonally but also due to the high levels of water use, water scarcity affects downstream agricultural production and communities. An aging and inefficient irrigation system is the primary cause of environmental degradation, heavily contributing to seasonal water stress and salinization of agricultural land.

(b) Relations within the region, the basin and its riparian countries

Hydropower production in the basin is the main energy source for Kyrgyzstan. All riparian countries, to a different extent, rely heavily on crop production (and agriculture more broadly)in the basin. The basin area is strategic because of its position in Central Asia, in particular for energy routes (oil and gas pipelines, power transmission lines).

(c) Main strategic goals, development policies and challenges

At basin level: impasse in cooperation over water resources in the Syr Darya basin and in the broader Aral Sea basin. At regional level (Central Asia): Further develop energy production for export and energy transit to neighboring regions (i.e., China, South-Asia, Russia). Challenges exist in all countries to improve livelihoods and resource security in the basin. At country level: Kazakhstan aims at promoting sustainable growth, in particular investing in water and energy saving technologies. Kyrgyzstan and Tajikistan plan to keep on developing hydropower, potentially abundant in both countries. Uzbekistan wants to secure availability of water for irrigated agriculture and modernize related infrastructure.

APPENDIX 5. Map ok Key Organizations and Actors (Illustrative of Step 2)

Table A2. Map ok Key Organizations and Actors.

Basin	Alazani/Ganykh	Sava	Syr Darya
Identification of key actors	Building on earlier intersectoral projects' stakeholder mapping.	Based on a stakeholder analysis for the Sava River Basin Management Plan, seeking to expand the involvement of notably energy and agriculture, which due to the mandate of the International Sava River Basin Commission were less engaged in the basin's management.	The Ministries of Foreign Affairs coordinated the nominations for their country, influencing somewhat the representation of sectors.
Regional and sub-regional level	Intergovernmental Commission for Economic Cooperation	European Union (riparian States have a different status), Energy Community, International Commission for the Protection of the Danube River, Danube (Navigation) Commission.	Commonwealth of Independent States, Eurasian Economic Community; International Fund for Saving the Aral Sea, Interstate Coordination Water Commission (ICWC), Interstate Commission for Sustainable Development, Central Asian Power Council, Central Asian Power System, Coordination dispatching Centre "Energy".
(Transboundary) Basin level	-	International Sava River Basin Commission.	Basin Water Organization Syr Darya (under ICWC).
Central Government	Ministries of energy, agriculture, environment and natural resources, economy (and sustainable development/industry); development and infrastructure; emergency situations, health.	Ministries of trade, economy, energy, agriculture, environment, infrastructure/construction, transport.	Ministries of foreign affairs, economy and trade, energy, agriculture, investment and development, emergency situations, industry, healthcare (and social development or protection)
Entity level	-	Entity level ministries in Federation of Bosnia and Herzegovina and Republika Srpska and District Brcko: energy and industry; agriculture, water management and forestry; physical planning; environment.	-
Government agencies, state committees	National Energy and Water Supply Regulatory Commission; State Committee on Property Issues.	Energy agencies, environmental agencies, national water councils.	State agencies or committees of environmental protection, land management, forestry, geology and mineral resources; Committee for Water Resources (Kazakhstan); Water and Energy Coordination Council (Tajikistan); committee/agency for communal services; state agency, authority or center of hydrometeorology.

Table A2. *Cont.*

Basin	Alazani/Ganykh	Sava	Syr Darya
Companies and utilities (state and private)	Companies on water supply; land reclamation and water resources, renewable energies.	Energy producers	Public utilities for water supply and sanitation; joint stock companies for energy production, transmission or distribution.
Sub-national/provincial level	Regions and districts	Regional or provincial government—absent in Slovenia); (see above regarding entity level in Bosnia and Herzegovina).	Basin inspections, basin water economy administrations, basin councils, basin organizations, basin irrigation authorities.
Local level	Local self-governance institutions, user associations.	Local governments, water supply and sewage companies.	Subsidiary companies of public utilities for water supply and sanitation; local branches of electricity distribution (and transmission); local administrations (city, region and district), water user associations.

APPENDIX 6. Analysis of the Energy Sector in the Sava River Basin (Illustrative of Step 3)

This example illustrates key findings from the analysis of the energy sector (as part of Step 3, which included the other key sectors as well) in the case of the Sava River Basin (SRB) [25]. Such findings informed the dialogue during the participatory workshop, in particular the working group focusing on the energy sector (Step 4).

(a) Key findings from the sector and resource flow analysis:

- The electricity generation in the Sava countries depends heavily on water from the basin (see Figure A3), as the basin hosts high shares of the total thermal and hydropower capacity installed in the region (i.e., all countries) with some countries more dependent on the Sava than others: e.g., the ratio hydropower capacity in the basin/total national hydropower capacity is 5% in Croatia and 45% in Montenegro.
- Energy is used for powering the water sector, which includes water pumping, irrigation and treatment.
- Storage reservoirs help both to balance power demand and supply fluctuations (*i.e.*, providing energy supply to compensate shortfalls from other energy sources) and, together with other water buffer zones such as flood-planes, wetlands and forests, to enhance flood control.
- Extreme flood events can cause damage to coal mines, affecting security of fuel supply. Recent floods have affected cooling systems and a coal mine.

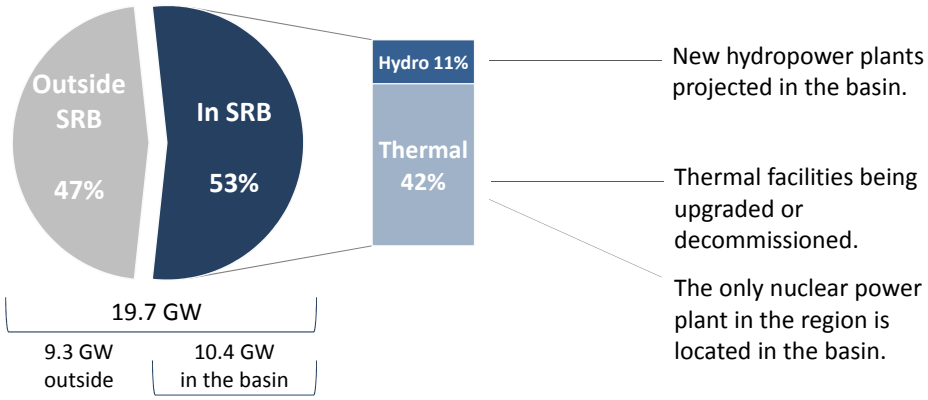

Figure A3. Installed capacity in the region in 2012.

(b) Key findings from the governance analysis:

Targets for renewables and climate mitigation push the countries to develop more hydropower while there are environmental concerns regarding the construction of new dams in environmentally sensitive areas.

Potential conflicts can occur both between upstream and downstream countries based on uses (e.g., hydropower, agriculture) and between local and national authorities within a country (development of energy infrastructure *versus* environmental protection or tourism).

There is a need to improve coordination with the energy sector to achieve representation of the relevant sectors in the work of the International Sava River Basin Commission (ISRBC), and vice versa.

Some of the riparian States do not have well-developed systems for Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). EIAs and SEAs are effective tools to assess the impact of energy projects on ecosystems and to synchronize competing objectives, as well as to ensure proper public participation.

The geographical and political focus for energy security and related governance is generally at the national level, with only secondary regard for ecosystem boundaries or river basins. Resolution of conflicting water uses related to energy has to take into account such differences in scale and in institutional frameworks as compared to other water uses.

Regional energy frameworks are increasingly influencing energy trade and pricing: The Energy Community Treaty (entered into force in 2006) provides for the creation of an integrated energy market (including electricity and gas) among the European Union (EU) member States and other contracting parties. All the Sava River Basin countries belong to the Energy Community either as EU member States or as parties to the treaty.

The European Union's 2030 Framework for Climate and Energy Policies includes, e.g., reducing greenhouse gas emissions by at least 40% from 1990 levels, increasing the share of renewable energy to at least 27%, increasing energy efficiency by the same amount, and, most importantly perhaps for the SRB countries, proposing a new governance framework based on national plans for competitive, secure and sustainable energy including a set of indicators. Developments in this area are rapidly unfolding and could have serious implications for nexus issues in the SRB.

APPENDIX 7. Intersectoral Issues in the Syr Darya River Basin (Illustrative of Step 4)

As the outcome of sectoral work, each of the four groups (energy, water, food/land, ecosystems) came up with a list of important interlinkages from its perspective. This example includes a compilation of interlinkages between the component "agriculture" of the nexus and the other three components of the nexus, in the case of the Syr Darya River Basin [26]. This list, initially compiled after the workshop as a result of Step 4, has been revised and elaborated on taking into account later analysis. It should be noted that in the case of Syr Darya "agriculture" was prioritized over other land use types.

Table A3. Intersectoral Issues in the Syr Darya River Basin.

Interlinkage	Issue
Water-Agriculture	High water requirements for irrigation (thirsty crops and high losses in irrigation schemes);
	Discharges from agriculture cause diffuse pollution of water, limiting other uses and affecting ecosystems downstream;
	High levels of land degradation and salinization, caused mainly by poor drainage and causing loss of fertile soil.
Energy-Agriculture	River flow regulation optimized for energy generation affecting water availability for agriculture;
	Problem of affordability of energy and food upstream, sometimes combined causing situations of energy and food emergency for rural population;
Ecosystems-Agriculture	Prioritization of productive sectors (namely energy and agriculture) over ecosystems, leaving insufficient water for environmental needs;
	High impact of water scarcity on fish catches and aquaculture, the latter being an important livelihood for local settlements in the middle and low course of the river.

APPENDIX 8. Nexus Dialogue in the Alazani/Ganykh River Basin (Illustrative of Step 5)

This example illustrates a possible outcome of applying Step 5 of the methodology. It comes from the assessment of the Alazani/Ganykh River Basin. During the participatory workshop, a clear nexus "storyline" emerged from the intersectoral dialogue of Step 5, including elements that arose separately in the sectoral group discussions of Step 4 [24].

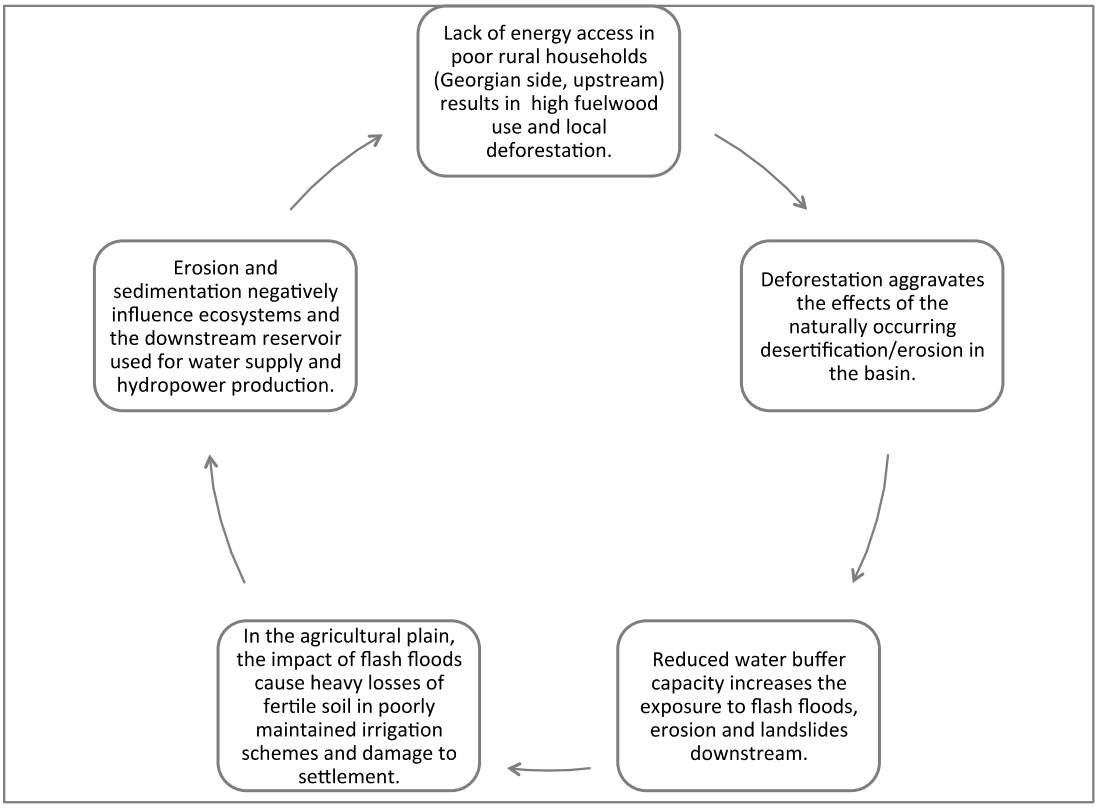

Figure A4. Nexus storyline for the Alazani/Ganykh River Basin.

APPENDIX 9. Solution and Benefits from the Sava River Basin (Illustrative of Step 6)

This example illustrates one specific solution identified in the assessment of the Sava River Basin [25] and the associated table of benefits.

It should be recalled that solutions were not were presented to the countries as "recommendations" but as "potential beneficial actions", the applicability of which was not investigated in detail in the study described in this paper. The emphasis was placed instead on the benefits that the identified nexus solutions would bring across countries. Energy-water modeling results allowed to illustrate the actual benefit of water cooperation at basin level from the perspective of the energy sector.

Selected solution: Coordinate energy and water planning by better involving the energy sector in the Sava consultation process.

Energy planning and climate policies usually take a multi-decadal perspective. However, water planning (driven by the implementation schedule of the EU Water Framework Directive) mostly follows a six-year cycle. Currently, (1) long-term energy planning does not necessarily take into account water constraints, potentially putting long-term investments and policy targets at risk and (2) water management planning marginally reflects important developments on the hydropower sector. While preparation of river basin management plans supports valuable engagement with a broad range of stakeholders at the transboundary level, improving involvement of the energy sector not currently engaged in work of ISRBC at both national and transboundary levels would be beneficial. Furthermore, a consultation process on national and sectoral development strategies, including energy, through the ISRBC, taking into account basin-level impacts, would improve coordination.

A multi-country water-energy model was built to study the electricity system of all riparian countries, in particular hydropower development, allowing to quantify the effects of its deployment on, for example, greenhouse gas emissions and energy imports. One of the findings of this analysis

was that hydropower in the Sava Basin is critical for meeting regional targets for renewable energy sources. Coordination is therefore key to balancing between different objectives and constraints, including energy security and de-carbonization of the energy systems of riparian countries as well as maintaining a good status of shared waters. Moreover, cooperation at the basin level would be beneficial to optimize the use of infrastructure, ensuring also robustness in the face of low flows or floods. (For a better description of the model use, see [25]).

○ Example of solution proposed

Coordinate energy and water planning by better involving the energy sector in the Sava consultation process.

○ Benefits

1. At basin/transboundary level: (1) Reduced frictions between sectoral developments of different countries; (2) Improved efficiency of water resource use in the basin; (3) Decreased risk of water-related disasters if the variability of flow is well taken into account.
2. At national level: (1) Higher efficacy of efforts targeting energy security and low-carbon growth (using hydropower); (2) Reduced exposure of energy sector's operations to water scarcity or water related disasters (floods and droughts).

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