Keskinen, Marko; Guillaume, Joseph H A; Kattelus, Mirja; Porkka, Miina; Räsänen, Timo A.; Varis, Olli

The water-energy-food nexus and the transboundary context

Published in:
Water

DOI:
10.3390/w8050193

Published: 01/01/2016

Document Version
Publisher's PDF, also known as Version of record

water

MDPI

Article

The Water-Energy-Food Nexus and the Transboundary Context: Insights from Large Asian Rivers

Marko Keskinen *, Joseph H. A. Guillaume, Mirja Kattelus, Miina Porkka, Timo A. Räsänen and Olli Varis

Water & Development Research Group, Aalto University, PO Box 15200, 00076 Aalto, Finland; joseph.guillaume@aalto.fi (J.H.A.G.); mirja.kattelus@aalto.fi (M.K.); miina.porkka@aalto.fi (M.P.); timo.rasanen@aalto.fi (T.A.R.); olli.varis@aalto.fi (O.V.)

* Correspondence: marko.keskinen@aalto.fi; Tel.: +358-50-3824626

Academic Editor: Davide Viaggi

Received: 31 January 2016; Accepted: 26 April 2016; Published: 10 May 2016

Abstract: The water-energy-food nexus is a topical subject for research and practice, reflecting the importance of these sectors for humankind and the complexity and magnitude of the challenges they are facing. While the nexus as a concept is not yet mature or fully tested in practice, it has already encouraged a range of approaches in a variety of contexts. This article provides a set of definitions recognizing three perspectives that see the nexus as an analytical tool, governance framework and as an emerging discourse. It discusses the implications that an international transboundary context brings to the nexus and *vice versa*. Based on a comparative analysis of three Asian regions—Central Asia, South Asia and the Mekong Region—and their related transboundary river basins, we propose that the transboundary context has three major implications: diversity of scales and perspectives, importance of state actors and importance of politics. Similarly, introducing the nexus as an approach in a transboundary context has a potential to provide new resources and approaches, alter existing actor dynamics and portray a richer picture of relationships. Overall, the significance of water-energy-food linkages and their direct impacts on water allocation mean that the nexus has the potential to complement existing approaches also in the transboundary river basins.

Keywords: transboundary water-energy-food nexus; transboundary rivers; water resources management; water security; energy security; food security; Central Asia; South Asia; Southeast Asia; Mekong

1. Introduction

Nexus-nexus everywhere—the water-energy-food nexus ("the nexus") has been recognized, promoted and also criticized by a variety of actors (e.g., [1–12]) during the past 5 years. As a result, the number of nexus studies, articles and even special issues is rapidly increasing. And for good reason, given how critical the three 'nexus sectors' of water, energy and food are for the very existence of humankind.

Yet, no commonly agreed definition or conceptual framework for the nexus has emerged and therefore different organisations and authors—intentionally or not—interpret its essence quite differently. Even the very name of the approach is not consistent, with the three nexus sectors written in differing order and the term "security" both included and excluded from the term. The actual number of nexus sectors also differs, focusing sometimes only on two sectors (e.g., [13,14]) or extended to additional sectors such as climate change [15,16], ecosystems [17] and livelihoods [18]. The terms change too, for example, food is sometimes replaced by land [19]. The actual context where nexus is applied varies greatly as well, ranging from cities [2,20,21] to transboundary river basins crossing international borders [17,22–25]. Despite all these publications, the actual added value provided by the nexus approach in different contexts remains partly unclear and also contested.

This article—published as part of the Water journal's "Water-Energy-Food Nexus in Large Asian River Basins" special issue—aims to provide some clarity and structure for the current nexus discussion in the specific context of transboundary river basins. This also means that we focus on the nexus from a water management point of view. We start by synthesizing definitions for the nexus concept based on interpretation of its historical emergence and reflections on its popularity, building on analysis of relevant nexus literature. This provides a foundation for an illustrative comparative nexus analysis for three regions centred around selected transboundary Asian river basins. Based on this analysis as well as the relevant findings from the other articles published in this Special Issue [17,21,26–33], we then discuss what the nexus means in the specific context of transboundary river basins, noting the implications that transboundary context bring to nexus approaches, and *vice versa*.

2. Water-Energy-Food Nexus: Defining the "Nexus Approach"

2.1. The Emergence of Water-Energy-Food Nexus

Water, energy and food are the key prerequisites for our existence, there is no life without them. They are also closely linked with water acting commonly as an enabler and in the areas of water scarcity, limiter for food and energy production [34–36]. Globally, food production comprises the great majority of consumptive water use [37,38], while the most important renewable energy production types in particular, including hydropower, bioenergy and waste, are dependent on water [39]. Hence, the idea of looking at these three aspects and their connections together is in no way new (e.g., [40–42]). In fact, it can be argued that scientists, public officials and other practitioners have been well aware of such interactions for many decades; it has just not happened under the specific term "nexus".

What then, has led to the rapid increase in nexus-related literature since 2011 (a search in Google Scholar for "water energy food nexus" generates just 7 results for year 2011 but 254 results for year 2015)? We argue that the reason is two-fold. The first is increased awareness about the economic risks included in the nexus. The second is the drive to promote the nexus as a new framework for global policy debate about the linkages between resource use and development and ultimately, about the means to facilitate sustainable development.

For the former, the key publication is the World Economic Forum's Global Risks 2011 report [4], which concluded that water, food and energy security are chronic impediments to economic growth and social stability, emphasised their interrelatedness and noted the importance of addressing the nexus trade-offs. For the latter, the discussion emerged first and foremost thanks to the Bonn2011 Conference on water, energy and food security nexus [1,2]. While the conference failed in its aim to include the nexus into the outcome document of 2012 United Nations Conference on Sustainable Development, it was successful in entering the nexus into global policy discussion more broadly. The conference linked the nexus strongly to hunger, poverty reduction and a human rights and recognised two major aspects for the nexus: one related to poverty reduction and the other to sustainable development and growth [1]. The methodological emphasis is similar to that of World Economic Forum, with a focus on trade-offs and synergies.

Other relevant publications and processes have pushed the nexus agenda further as well. In addition to the publications referred to in Introduction for example, the 2011/2012 European Report on Development [43] looked at linkages between water, energy and land, the annual World Water Week in Stockholm has discussed the nexus in many of its sessions in recent years and the UNECE has established a water-food-energy-ecosystems nexus task force that looks at the nexus in selected transboundary river basins [17]. Yet, even with all these publications and processes, there is no general agreement on what the nexus is and what a "nexus approach" actually means and requires. Actual empirical evidence on the benefits and caveats of applying a nexus approach is also relatively thin, although rapidly increasing [17,19,21,30,44].

2.2. Three Perspectives and Definitions for the Nexus

We argue that there are three interlinked perspectives and related definitions for the water-energy-food nexus, stemming from differing interpretations and expectations. First of all, many (see e.g., [2,3,45]) consider the nexus predominantly as an analytical approach or tool, intended to look at the three nexus sectors and their interconnections, often mainly quantitatively based on existing data and related models. This could include consideration of other sectors that have a major influence on one or more of water, energy and food.

The nexus also emerges as a governance framework, intended to facilitate cross-sectoral collaboration and enhance policy coherence across planning and management of the nexus sectors (see e.g., [1,43,46]). The third perspective can be seen to provide a foundation for the others, where the nexus emerges as a boundary concept [47,48] that is used to form a new discourse related to the use and management of water, energy and food [8,49–51]. The nexus is used as a means of establishing a new way of framing problems [52] related to water-energy-food linkages, complementing dominant, often more water-centred and technical (e.g., [22,53]) discourses, for example surrounding Integrated Water Resources Management (IWRM) [54].

Based on the discussion above, we can now provide our definitions on what a "nexus approach" is according to each perspective:

- **A nexus-based analysis** is a systematic process that explicitly includes consideration of water, energy, food and other linked sectors in either quantitative or qualitative terms with a view to better understanding their relationships and hence providing more integrated information for planning and decision making in these sectors.
- **A nexus approach to governance** is one that explicitly focuses on linkages between water, energy, food and linked sectors as well as their related actors in order to enhance cross-sectoral collaboration and policy coherence and ultimately promote sustainability, win-win solutions and resource use efficiency.
- **The nexus is an emerging discourse** that emphasizes the trade-offs and synergies across water-energy-food connections and encourages actors to cross their sectoral and disciplinary boundaries (*i.e.*, acting as a boundary concept).

Each of these broad definitions can and has been followed independently and can be expressed in more precise terms in many different ways, which explains the broad range of nexus approaches and definitions that have been observed to date. Without denying the legitimacy of other interpretations, we argue that an ideal nexus approach would integrate these three definitions and hence draws on disciplines across four levels: value, normative, pragmatic and empirical [55]. The value level corresponds to disciplines interested in values and ethics; the normative level to laws, politics and planning; the pragmatic to management and technological disciplines; and empirical to understanding of the biophysical and social world (Figure 1). The different perspectives of the nexus together span these levels, but in the ideal nexus approach the individual perspectives are transcended and integrated to form a broader view. For the complex problems related to water, energy and food security, it is as important to understand cross-level linkages between disciplines and between nexus perspectives as it is to understand cross-sectoral linkages themselves.

An ideal *nexus approach therefore consists of a systematic process for both analysis and policy-making that focuses on the linkages between water, energy, food and other linked sectors to promote sustainability, synergies and resource use efficiency.* Quantitative analysis helps to understand interconnections, particularly focusing on critical dependencies and means of reducing trade-offs. Analysis of the governance context identifies key actors, policies and legislative frameworks relevant to these connections. It should pay particular attention to politics as the lack of cross-sectoral collaboration is usually not merely due to lack of appropriate mechanisms and approaches, but relates first and foremost to the fight over influence and power between different sectors and actors [8,51].

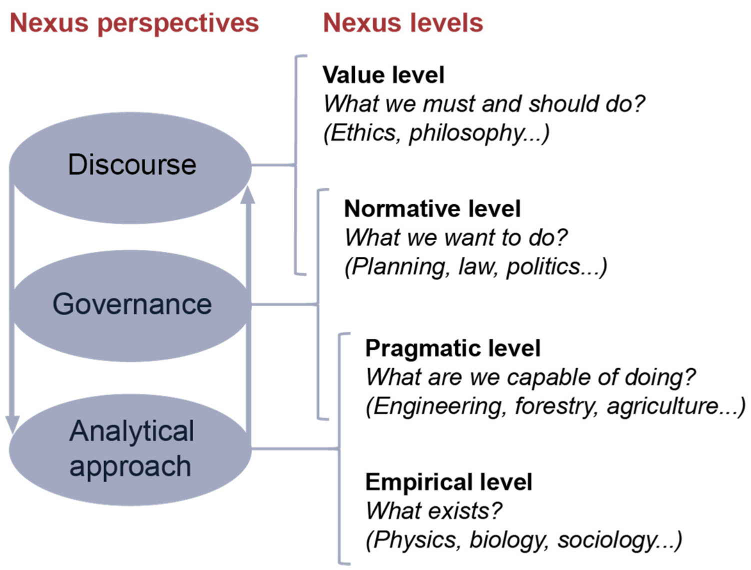

Figure 1. Nexus perspectives and their relation to disciplines of different levels (levels adapted from [55]). In an ideal nexus approach the individual perspectives are integrated to form a broader view, necessary to tackle the complex problems related to the water, energy and food nexus. In addition to cross-sectoral linkages, cross-level linkages between disciplines and between nexus perspectives should be understood.

Analyses should also remain open to changes in scope, recognizing that the nexus is also a dynamic boundary concept that encourages interaction on these key issues. For example, it should, where relevant, include related issues such as non-food, non-energy commodity agriculture that does not strictly fit within water-energy-food linkages. Together, these analyses inform efforts of the actors involved to manage interactions between sectors, facilitating policy coherence and cross-sectoral collaboration and potentially creating new ways to look at water-energy-food linkages.

Taken together, the different perspectives and levels of the nexus emphasise the need to have an integrated view on the nexus. Yet, very few nexus analyses have to our knowledge considered all these different perspectives, with one of the exceptions being the UNECE's Task Force on the Water-Food-Energy-Ecosystems Nexus. As described by another article in this special issue [17], the work of the task force builds on a coherent analytical approach that also addresses the governance context and aims ultimately to revise the way the UNECE views and assesses its transboundary waters. While recognising that it is difficult to achieve this level of integration under any single process or project, we see this as an ideal worth striving for—while leaving room for "better" visions and definitions of the nexus as they emerge.

In relation to transboundary contexts specifically, the linkages in question may occur across boundaries and on large scales. Thus, information must typically be integrated from disparate sources, collaboration must occur between politically independent entities and perspectives on the nexus are likely to differ markedly. The comparative analysis in the next section and the subsequent discussion aim to further highlight these issues.

3. Comparative Nexus Analysis in Three Asian Regions with Large Transboundary River Basins

This section presents a comparative nexus analysis for three regions, namely Central Asia, South Asia and the Mekong Region in Southeast Asia and their related transboundary river basins (Appendix A). The discussion section draws on this comparative analysis to identify key implications of the transboundary river basin context for the nexus and vice versa. Consistent with our approach to look at the nexus from a transboundary water management perspective, transboundary river basins are used as focal points. However, broader regions are used for this comparative analysis, recognising that energy and food interconnections are not limited by river basin boundaries (Appendix B).

The analysis builds on the concept of a "nexus triangle" (Figure 2), which summarizes key nexus interconnections and the relevance of each nexus sector in each region. As the name suggests, the purpose of the comparative analysis is to provide a general comparison of how the nexus manifests itself in different transboundary regions with large river basins. It builds on our previous research in these regions (e.g., [27,30,56–66]) as well as key literature referred to in the text. Comparative analysis is not intended to provide an in-depth analysis of a nexus situation in any particular region or river basin.

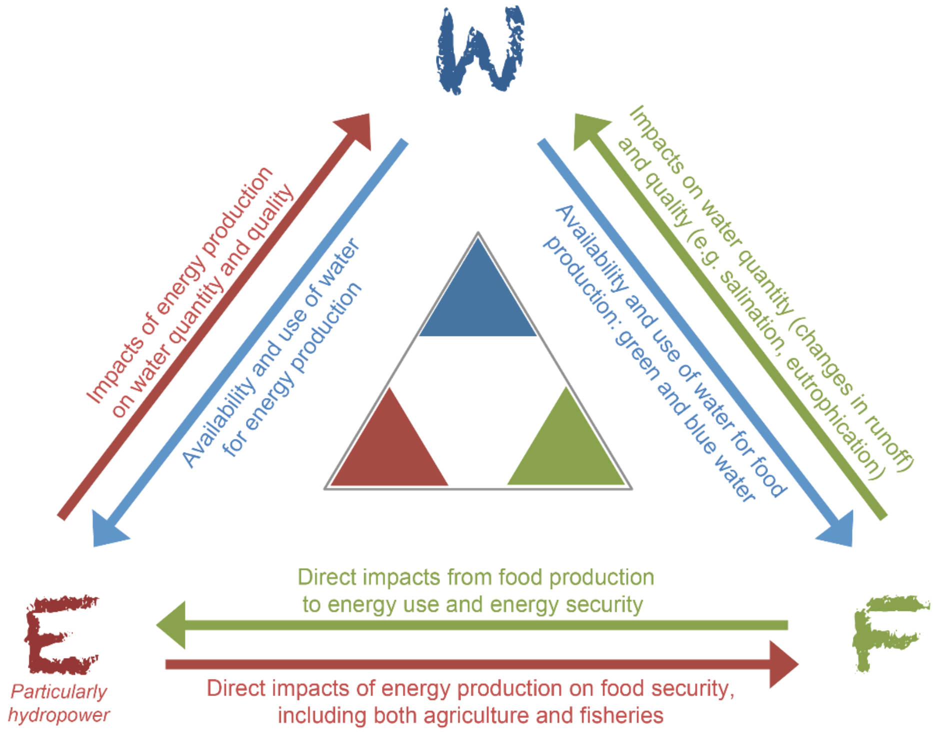

Figure 2. The logic of our "nexus triangle", indicating how we have defined the key interconnections and impacts between the three nexus sectors of water (W), energy (E) and food (F). In the region-specific nexus triangles, we used three different thicknesses for the arrow, corresponding with our subjective judgment of the significance of the connection/impact comparatively within and between regions: the thicker the arrow, the more significant the connection or impact to be. The "status triangle" in the middle similarly indicates the current levels of water security (blue), energy security (red) and food security (green) comparatively for the three regions using three different sizes for the area: the larger the coloured area, the higher level that type of security in the region is seen to be.

3.1. Central Asia

Central Asia here refers to Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, who notably share the Aral Sea basin. Key aspects of the history of the nexus in Central Asia are the need for irrigation in arid areas, winter heating in mountainous areas and environmental impacts from water abstraction and hydropower. Oil and gas production have an important role in Kazakhstan, Turkmenistan and Uzbekistan for national and regional energy security.

During the Soviet era, the water, energy and food sectors were developed in a closely connected manner. Downstream riparian states focused on developing agricultural production (particularly cotton) and provided fossil fuel for heating, while upstream states stored water to facilitate agricultural production downstream as well as to produce hydropower energy [26,67]. The Amu Darya and Syr Darya Rivers were seen as resources to be utilised to allow development, in what has been described as a "hydraulic mission" [68]. Unsustainably high water use, particularly for irrigation, has led to high water stress and resulting environmental consequences, most visibly on the Aral Sea [27,69–72]. Today, key aspects and challenges of the nexus in Central Asia are linked to the historic infrastructural interdependences via water storages, dams and power grids, and high profile competition over the water resources [26–28,67] (Figure 3).

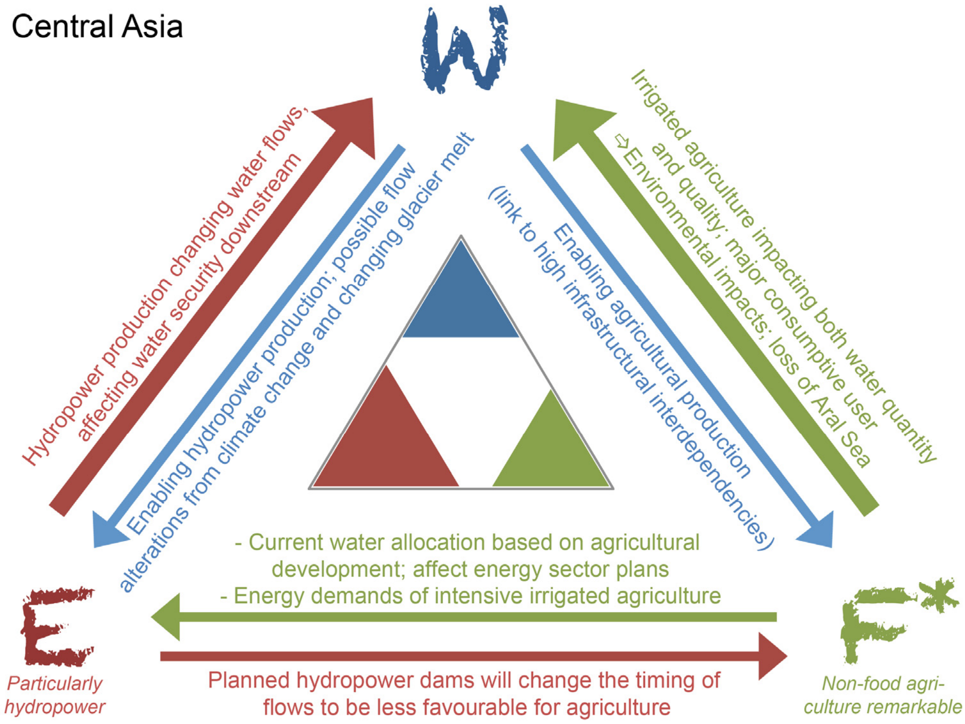

Figure 3. The nexus triangle for Central Asia, with key connections and impacts as well as current levels of security described with text. The F* indicates that food sector also includes a very important non-food crop *i.e.*, cotton. See Figure 2 and text for explanation.

After becoming independent, the Central Asian countries were left in a state of high level interdependency with the individual states increasing their focus on national interests [26]. The view of the nexus shifted to emphasise agricultural development and food security. The expansion of irrigation has resulted in demands by all to increase the historic water quotas [67,71], despite already unsustainably high water use. Water availability for agriculture is also affected by infrastructural interdependencies. For example, Uzbekistan and Turkmenistan have a very tense relationship over water use, as the water storage infrastructure providing water to the region's largest water user Uzbekistan is located in Turkmenistan [67].

Meanwhile, upstream countries are highly dependent on hydropower production (Appendix A) and therefore defend their right to use the hydropower potential of the rivers, much opposed by the downstream countries that are dependent on reliable quantity and quality of water [70]. Instead of emptying the reservoirs in the summer for the irrigation of downstream cotton fields, as they used to do, the upstream riparians now have an interest in storing the water to use for hydroelectric power in the winter [71]. Efforts have been made to maintain or renew Soviet-era bilateral barter arrangements as well as establish regional bodies for cooperation and coordination, such as the Interstate Commission on Water Coordination, International Fund to Save the Aral Sea and Basin Water Management Associations. Difficulties have however arisen over disputed prices, breach of agreements, lack of confidence in regional bodies and mutual distrust [73]. Strategic water management is further undermined by inaccurate and politicised national water use data which skews the discussion on possible cooperative strategies on water management in one way or another [67].

Going forward, successful management of the nexus in Central Asia and its transboundary rivers depends on fostering trust and cooperation, revitalisation and capacity building within public sector organisations [28,73], shared understanding of limits (e.g., environmental needs and water availability) and norms (e.g., contractual obligations) [27], and agreeing on compromises that maximise total benefits across the water-energy-food nexus rather than national benefits that often focus on one of the nexus sectors alone [29] (Figure 3).

3.2. South Asia

South Asia and its major transboundary rivers, the Indus, Ganges and Brahmaputra, cover seven riparian countries: Afghanistan, Bangladesh, Bhutan, China, India, Nepal and Pakistan. Across this vast and very densely populated region (Appendix A), water plays a key role for both food and energy security (Figure 4). Agriculture, particularly in the Ganges and the Indus, is very dependent on intensive irrigation [74,75]. Water for irrigating crops is largely pumped from groundwater, requiring a lot of energy, such that energy use is intensifying: there was a sixfold increase of electricity consumption per 1000 hectares of cultivated land from the year 1980/81 to 1999/2000 [76]. The groundwater extraction lowers the groundwater tables, thus exacerbating current water scarcity and impacting downstream water availability [77].

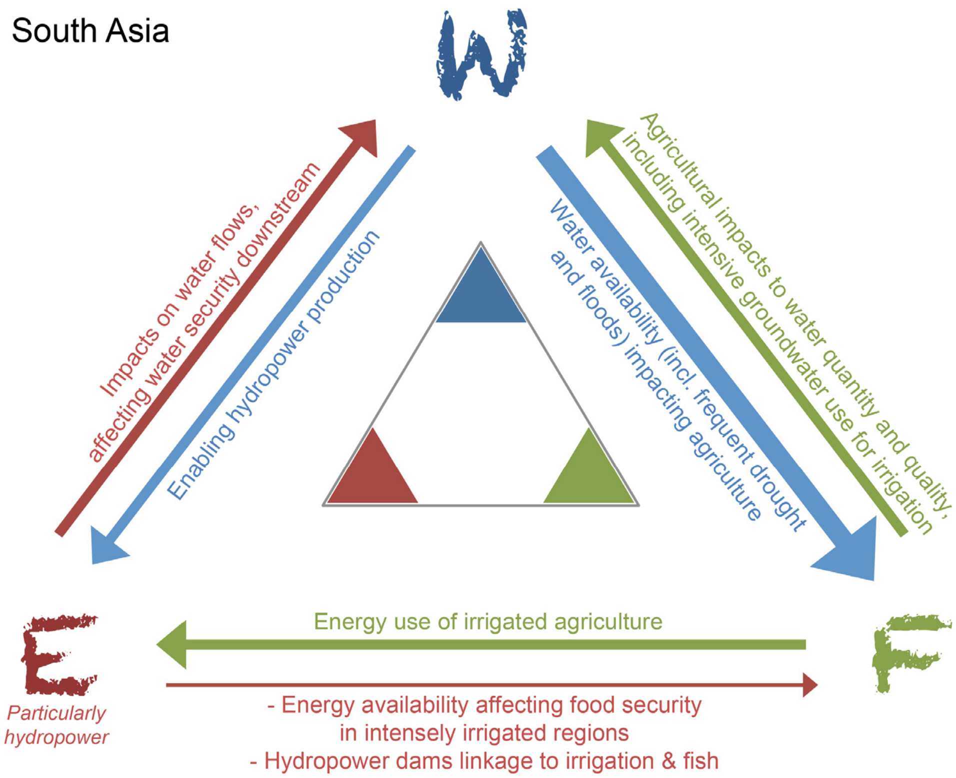

Figure 4. The nexus triangle for South Asia, with key connections and impacts as well as current levels of security described with text. See Figure 2 and text for explanation.

Both the Indus and the Ganges are under extreme pressure. The Indus basin faces severe water scarcity during eight months of the year, while the Ganges River is experiencing decreasing flows during the dry season [75,78,79] (Appendix A). The downstream riparians are highly vulnerable to upstream water use, while having no control of upstream water flows [61,80]. As a large part of the region is energy and water deficient, food production through intensive and energy-consuming irrigation has a significant impact on overall water and energy security.

These complex interdependencies combined with increasing pressures to intensify food and energy production have led to ambitious plans for ensuring water, energy and food security. These include massive plans to tap the abundant hydropower potential of the rivers [80–82]. The proposed dams will have potential transboundary environmental and social impacts, which will create pressures for the other nexus sectors. In terms of energy, the region is also highly dependent on bioenergy such as fuelwood, crop residues and animal dung as a residential energy source [83]. Bioenergy has an important role for the nexus as well, since it is potentially a very water- and land-intensive energy source and can increase the need for energy-intensive chemical fertilizers as animal wastes are diverted to fuel [84]. The shortage of energy has also led to increasing dependence on imported oil in Pakistan, India and Bangladesh, with oil imports doubling in India during 2003–2013 [83]. The region is also extremely dynamic when it comes to urbanization, population growth and industrialization, creating expanding demands and additional challenges for water, energy and food security and their interlinkages [76].

In terms of governance, the region's water, food and energy nexus constitutes a highly complex entity. In India and Pakistan, even the coordination of water and agricultural activities at the provincial level has proven to be quite challenging [85,86]. A number of transboundary water treaties have been signed on sharing the main rivers of the region. The most important among them include the 1960 Indus Water Treaty between India and Pakistan, as well as the 1996 Mahakali Treaty between Nepal and India and the 1996 Ganges Water Treaty between India and Bangladesh [87]. While they provide a fairly good basis for transboundary governance of the Indus and Ganges basins, in practice the water related policy-making is overly nationalistic and integration of policies of nations and sectors has proven to be difficult [88]. The history of Pakistan, India, Nepal and Bangladesh is riddled with distrust and tensions [89], and China's absence from the transboundary treaties makes governance particularly difficult in the Brahmaputra basin.

3.3. Mekong Region

The Mekong Region consists of the six countries sharing the Mekong River: China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. The region is urbanising and developing rapidly, notably with massive plans for hydropower in several rivers [90,91], which has significant implications for environment and natural resources. On the other hand the current levels of water stress in the region's major transboundary rivers—Mekong, Irrawaddy and Salween—are remarkably less than for the rivers in other two study region (Appendix A). Yet, the transboundary Mekong River presents a topical case for the water-energy-food nexus due to its rapid hydropower development and the major importance of water and related resources—including fish and rice, the region's staple food—for regional food security (Figure 5) [32,66,92–95]. The high availability of water has enabled the region to become one of the world's largest rice producers, and the Mekong River itself is considered to be one of the world's most productive inland fisheries [96]. The water-related activities are an important part of the regional economy and provide livelihoods and food security for millions of people [97].

Rapid regional development has led to increasing demand for energy, which has resulted in extensive hydropower development [98,99]. In the Mekong Basin alone, there are currently 57 large hydroelectric dams (height > 15 m) and plans for over 100 more [100,101]. This would remarkably increase the hydropower production capacity in the region: while the existing dams have a capacity of 18,960 MW, the planned dams have a total capacity of 54,830 MW. A large share of the ongoing hydropower development occurs in upstream China and Lao PDR. The construction of hydroelectric dams in China is driven by increasing energy demand, particularly in the eastern parts of China and by the need to reduce emissions from energy production [102,103]. In Lao PDR, the domestic need for electricity is relatively low and the hydroelectric dams are built to generate revenue by exporting electricity to neighbouring countries, such as Thailand [104]. The hydropower development in the region is also fuelled by investments between the countries and outside the region [90,105].

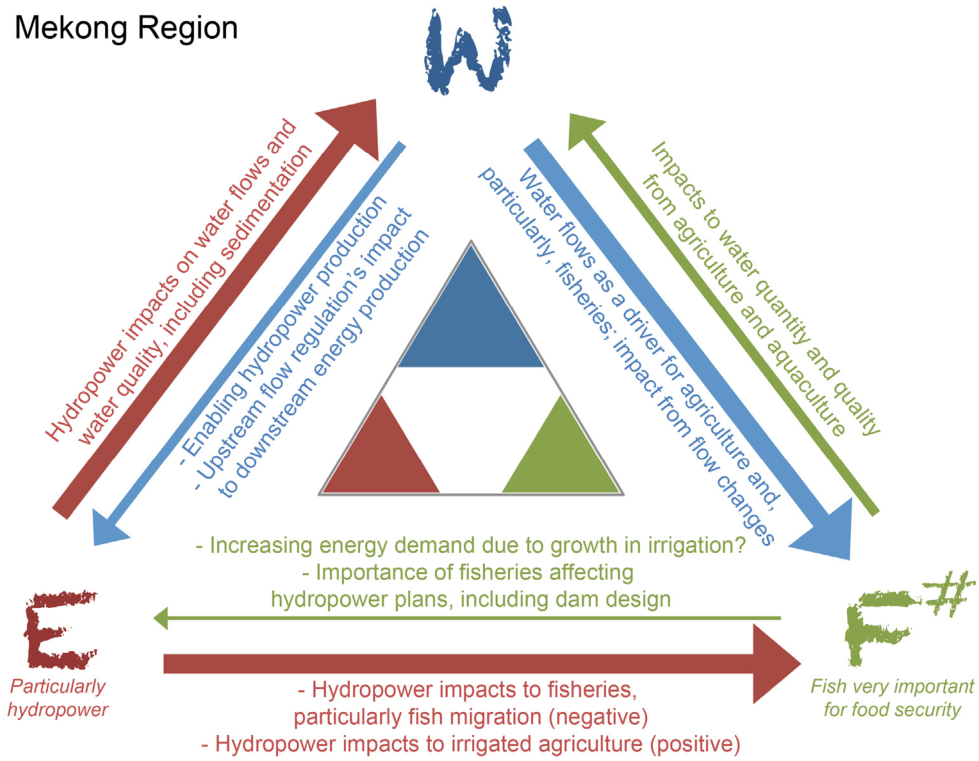

Figure 5. The nexus triangle for the Mekong Region, with key connections and impacts as well as current levels of security described with text. The F# indicates that fisheries' role for food security is remarkable. See Figure 2 and text for explanation.

The hydropower development in the region will improve regional energy security but it will have direct implications on food security. While the dams are expected to improve irrigation opportunities for agriculture [106], they will have major negative impacts on the aquatic ecosystems [96,107,108] and thus on livelihoods and food security [97]. In the Mekong River, the dams will affect the flow regimes [109], sediment [110] and nutrient transport [111] and fish migration [112], which are all key factors of the immense fisheries of the river. The annual wild fish harvest in the lower Mekong Basin is estimated to be 2.2 million tonnes and the value of the fisheries at retail markets is estimated to be 4.3–7.8 billion US$ [108,113]. The interplay between water, energy and food security has strong cross-scale characteristics: while hydropower development is largely taking place upstream and facilitated by regional energy grids, its negative implications, particularly on ecosystem productivity, are accumulating at local scales downstream [30].

In addition to hydropower, bioenergy and imported oil, gas and coal are important sources of energy for Southeast Asia [114]. Bioenergy continues to be the main source of energy for residential energy consumption, while imported oil required for energy production and transport (including those of agricultural products) has been steadily increasing [83,107]. The production of biofuels can have major sustainability implications related to land use, food security, rural livelihoods as well as water and land security [115,116].

The Mekong has existing regional cooperation mechanisms related to water, energy and food, most notably the economic- and energy-focused Greater Mekong Subregion (GMS) Programme and the river basin-focused Mekong River Commission (MRC). The MRC includes the four Lower Mekong riparians as its member countries and structures its activities according to the IWRM principles. On the other hand, the MRC has noted that "the practice of true involvement, and ownership, of the food and energy sectors in IWRM is often lagging behind, which is what the water, energy and food security nexus approach aims to solve" [22]. As a result, the MRC has also recognised the relevance of the nexus approach for its work [22,117]—and for a good reason, given that it has so far been largely sidelined from the massive hydropower development plans in the region [32,118,119].

Finally, it must be noted that there are naturally many "flows" other than the river itself connecting the countries in our study regions and the volumes and directions of transboundary flows of water, energy and food differ remarkably from each other. Appendix B provides an example of such flows for the Mekong Region. As can be seen, some of these flows also have important connections beyond the region itself. For example, given that one of the key questions in the region is how to replace the fish protein lost due to hydropower development [120], the significance of global food trade in ensuring regional food security is likely to increase.

4. Discussion: Implications of Transboundary Water-Energy-Food Nexus

In this article, our view on the nexus is at regional, *i.e.*, transnational, level and on transboundary river basins in particular. The preceding comparative analysis and the findings from other articles in this Special Issue demonstrate the challenges and opportunities for the transboundary water-energy-food nexus. In this section, we discuss these from two opposite viewpoints; first from the viewpoint of what the transboundary context brings to the nexus and then from the viewpoint of what nexus approaches bring to transboundary contexts (Figure 6). Given that nexus approaches are used in different contexts, it is useful to highlight distinctive features in a transboundary context. Given that the nexus is one of many ways to tackle transboundary issues, its particular contributions need to be highlighted. There is a clear link between these two viewpoints, as the contributions of the nexus can only be achieved if the distinctive features of the transboundary context are adequately addressed.

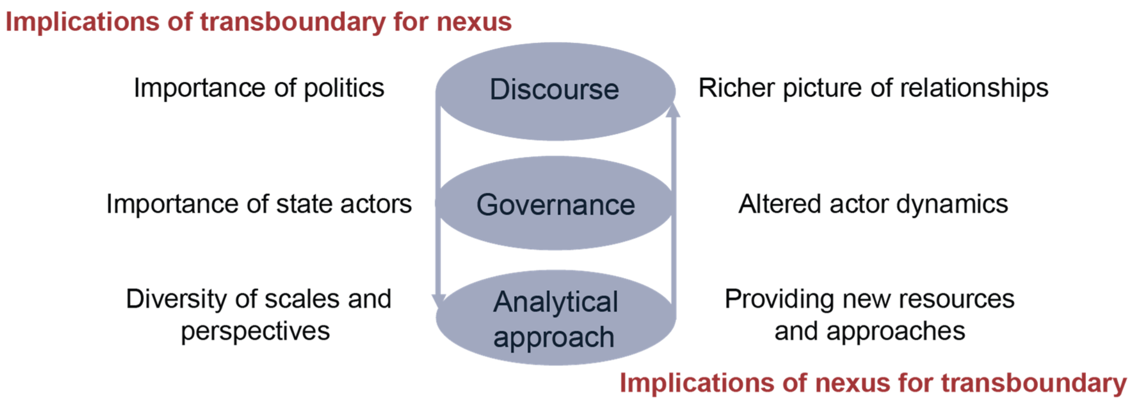

Figure 6. The key findings for transboundary water-energy-food nexus along the three perspectives, looking at the implications of the transboundary context for the nexus (left) and *vice versa* (right).

4.1. Transboundary Context's Implications for the Nexus

We see that the transboundary context impacts the implementation of the water-energy-food nexus in three main ways, which are particularly relevant to the use of the nexus respectively for analysis, for governance and for discourse formulation. Firstly, the transboundary context requires an increased emphasis on multiple geographical scales and on diversity of different perspectives. Secondly, international transboundary contexts have distinctive key players in the nexus, notably nation-states. Thirdly, these two factors emphasise the importance of looking at the political aspects related to the nexus, which may help to broaden the nexus as a concept in that direction.

First of all, looking at the nexus in transboundary river basins and their regions necessitates the consideration of multiple geographical—and related institutional and political—scales, from local to national and to regional scales [121,122]. This kind of multi-scale context brings several challenges, ranging from the difficulty to obtain relevant information to increased complexity of nexus linkages that cross scales. In the Mekong, for example, our comparative analysis indicated that while the most relevant scale to look at food security is regional, even global, the most appropriate scale for energy security is regional and for water security, the basin scale (Mekong) and even local scale (Tonle Sap). More broadly, the characteristics of water, energy and food sectors vary significantly, including the importance of private and public ownership and trade in each of them. Analysis at the transboundary context may therefore face different problems depending on the sector. The multi-scale character of transboundary settings can thus also create scale mismatches [123], where the scale for managing the nexus is different to the (multi-scale) processes that are being managed.

The transboundary context also requires consideration of a *greater diversity of perspectives*, as multiple institutional and political scales usually mean less social cohesion and more heterogeneity on views towards the nexus when compared to a river basin within a single country. The transboundary context unavoidably includes several countries, all of them with their own view and interests towards water, energy and food. This, in turn, is likely to lead to increasing resource politics and even resource and water securitisation. Such a situation is visible in Central Asia, where the change from the centralized Soviet era to independent states inserted an additional institutional and political layer to the transboundary context, leading to very complex and politicized collaboration. In such a setting, the countries view the nexus and its sectors differently: in upstream Tajikistan, water enhances its energy security, while Uzbekistan and Turkmenistan see water as vital for their agriculture. From the nexus point of view, it is also noteworthy that downstream agriculture in the Amu Darya and the Syr Darya basins revolves around a non-food crop, cotton. This reminds us that the nexus may need to be broadened beyond a narrow focus on just water, energy and food.

Turning to the second issue, the transboundary context influences which actors are most prominent and exert power over the nexus. Given that international transboundary river basins by definition cross national boundaries, the *transboundary context easily implies state-centrism, the key actors on negotiating and deciding on the nexus being nation states and their representatives*. While such state-centrism has its problems [124,125], it also means that there are often already existing organisations and institutional arrangements facilitating transboundary cooperation. In our comparative analysis, these include legal agreements such as the Mekong Agreement [31,126] as well as the bilateral treaties in the South Asian river basins [87]. While the existing organisations are commonly water-focused (e.g., river basin organisations), they often extend their activities towards (water-relevant) parts of food and energy sectors (e.g., [17,97,117]).

This brings forward an interesting question: in the context of transboundary waters, should the nexus be implemented through already existing organisations (mainly River Basin Organisations *i.e.*, RBOs), or is it better to establish a novel cooperation mechanism for implementing the nexus? The answer to this question depends also on how we view the nexus; as a water-centred approach to support water resources management or as a process linking the three sectors together on broader and more equal terms. Given that the majority of current nexus analyses are water-centred and the nexus literature emphasises the importance of building on existing institutional settings [2], different river basin organisations have been actively engaged in nexus discussions (e.g., [17,22]). While the nexus can help to refocus the RBOs' activities and extend their understanding and even political leverage [25], we nevertheless feel that the nexus as a multisectoral and multilevel process should preferably not have a single owner. Rather, it would be important to implement the nexus through a multi-stakeholder process [127–129], where key actors from food and energy sectors also take initiative and ownership of the process. It could be, for example, initiated by executive branches of government or by a third party (for example, see [17,46]). As a flow-on effect, such a process could encourage sharing of analyses and data between sectors as well as countries. This may be an opportunity for building trust and transparency but could also be constrained by existing political as well as technical difficulties, as discussed above (see also [130–134]). These changes are consistent with the dominant nexus discourse, in which each sector is expected to take into account their effect on the others. The implication is that the sectors are expected to share their responsibilities (and hence power), at least to some extent.

Thirdly and related to the above, the transboundary contexts are inherently political. Yet, key publications (e.g., [2,4] establishing the nexus as a concept are relatively silent about politics, although several authors have emphasized its importance (e.g., [8,30,51,135]. In our opinion, without consideration of the often highly politicised nature of resource use, the analytical approach to the nexus is at risk of being naïve. As shown in our comparative analysis, *applying nexus in transboundary contexts thus puts an increased emphasis on the importance of politics; this in turn, can help to revise the existing understanding of nexus as a concept to better acknowledge politics*. More broadly, the transboundary context can encourage us to re-consider the "discourse-setting" realities of the nexus. While the nexus may indeed act as a handy boundary concept to challenge the existing discourses on water-energy-food connections, it is by no means neutral. Instead, it also forms a tool that is used to shape such discourses. This is particularly important in areas like South Asia that are experiencing multiple pressures with widespread impacts on all parts of the nexus, such as urbanisation, population growth and industrialisation. Given the current water-centrism of the nexus literature, we should also allow food and energy sectors to forge their own view of the nexus and the way it shapes the discourse related to water-energy-food connections. This may lead to varying conceptualisations of the nexus (in terms of all three perspectives), depending on the context.

4.2. Nexus' Implications for Transboundary Issues

Based on our comparative analysis, we argue that the nexus has three main implications for water, food and energy issues in transboundary river basins and their regions. Similarly to the preceding section, these implications can be linked to using the nexus approaches from the perspective of analysis, governance, and discourse-setting. Firstly, the nexus may provide new resources and approaches for transboundary cooperation. Secondly, the nexus alters actor dynamics by engaging key actors from energy and food sectors. Thirdly, the nexus can help to reset transboundary cooperation between the riparian countries by extending thinking about cooperation from water resources management to broader aspects of water, energy and food security.

The nexus can bring *new resources and approaches for transboundary cooperation*. In addition to setting the focus on selected sectors only, the nexus also emphasises the importance to look at the interconnections and related trade-offs between those sectors. In South Asia, problems of groundwater over-extraction are closely linked with energy pricing policy and sustainability of livelihoods. The comparative analysis shows that nexus approaches are already being used in practice. There is a need and opportunity for tools to mature to provide additional support and help make better cross-sector decisions. This need is doubly pressing given that nexus sectors and their relationships are changing, as with the Mekong shift from subsistence to market economy-based food supply. It becomes more difficult to predict new trade-offs, conflicts and synergies that may emerge. Emerging literature on nexus approaches and methods (e.g., [6,21,136,137]) provides a fruitful ground to reflect and possibly, revise the existing methods and tools used to support transboundary cooperation. The majority of the current discussion on the nexus is however rather water-centred and -driven and we thus see that there is great potential for cross-fertilisation between the three sectors, if water, energy and food researchers and practitioners are brought together (as has already been happening in terms of water-food and water-energy nexus). In addition, the current enthusiasm about the nexus can mobilise additional funding and expertise to look at the interconnections between water, energy and food in transboundary contexts, both through specific funding calls (e.g., [138–141]) and in framing funding proposals.

Active engagement of energy and food sectors can also change the existing actor dynamics in transboundary cooperation by including more actors in its governance. The riparian countries' views towards water-energy-food linkages are by no means monolithic but different ministries may harbor quite differing interests. In the Mekong River Commission (MRC) for example, each of the four member countries is currently represented in the MRC Council only by the water and/or environment ministry [142]. An alternative high-level nexus working group could include representatives also from energy or fisheries-related ministries. Such a setting could result in novel discussions and even new kinds of cross-state alliances where for example, the representatives responsible for energy or fisheries would find common ground. As was also found in a workshop setting [30], explicitly naming the nexus sectors can help to bring the actors together. In this way, the nexus can also complement and even challenge existing power structures related to transboundary governance. However, achieving these outcomes requires existing and evolving political realities to be acknowledged and the food and energy sectors must also buy into the nexus approach, as argued above. Otherwise, some key actors may prefer to act unilaterally, as is the case with Laos and its energy plans in the Mekong.

Cooperation about management of transboundary river basins typically revolves around water and related sectors. While such a focus is obvious, it may also hinder the countries from reaching an agreement about the development of the river by focusing on difficult upstream-downstream relations, as illustrated by all comparative case studies. By extending the discussion into energy and food security and their regional linkages, *the nexus paints a richer picture of the relations between countries and, ideally, a more integrated understanding of the range of linkages between the countries.* It emphasises the need for assessing the total impacts on water, energy and food (including those to economy and the environment) and raises awareness that alternative approaches to water, energy and food issues may exist. In this way, the nexus may open political deadlocks and encourage regional cooperation. In focusing on water, energy and food, it provides a more concrete context to examine benefit-sharing options [29,133,143].

Broadening scope can however carry its own difficulties, introducing new dependencies [27] and requiring new approaches, as argued above. Otherwise, focusing on the nexus may actually make the current situation more difficult rather than easier. For example, in Central Asia, nexus-wide infrastructure and economic arrangements developed in the Soviet era were dependent on centralized economic planning and barter arrangements [68], for which the now-independent states are still struggling to find a durable alternative [27]. In the Mekong Region, the recognition of impacts of dams spanning the nexus has not yet been accompanied by potential solutions that span the nexus, which has paralysed collective action and allowed unilateral action to proceed [59,118,119]. These examples confirm that the possible changes in discourse prompted by the nexus need to be adequately supported by related adjustments in governance and analytical approaches.

These issues of scope extend beyond the nexus: the concepts of sustainable development and IWRM also try to provide a richer picture of relationships, with varying success. Sustainable development encourages cross-sectoral collaboration while emphasising triple bottom line outcomes on environmental, economic and social aspects [144]. IWRM—which has been recognised by several UN processes such as the Sustainable Development Goals (SDGs)—builds on the concept of sustainable development and emphasises how other sectors relate to water management [54]. The nexus provides an intermediate view that explicitly focuses on water, energy and food sectors and their actors and can even be seen to have arisen as a more focused, tractable response to the broad and ambiguous nature of sustainable development [145]. As shown in the comparative analysis, it can be useful to frame problems as arising specifically from the interaction between actors from different sectors rather than as issues of sustainability or integrated water management more generally. It has been argued that the nexus as a concept therefore provides a complementary view, contributing to the diverse ways of thinking about sustainability and water, energy and food issues (e.g., [16,22,30,49]). In the specific context of transboundary river basins, the nexus can also increase political leverage to address complex water-energy-food connections, which IWRM processes and RBOs tend to lack.

5. Conclusions

In this article, we examined the nexus approach to water, energy and food issues, focusing on its application in the context of transboundary river basins. The literature reviewed for the article shows the diversity of nexus-related publications, but also indicates that there is still little practical evidence on nexus and that there is not even commonly agreed definition for the nexus.

We introduced three definitions for the nexus, corresponding to three complementary perspectives, which emphasize the nexus' role as an *analytical approach*, *governance framework* and as an *emerging discourse*. While the nexus discussion often focuses on the linkages between three nexus sectors, we see that due to complexity of water-energy-food connections, it is actually as important to understand cross-level linkages between disciplines and between nexus perspectives as it is to understand cross-sectoral linkages themselves. Hence, an ideal nexus approach would integrate all three of these perspectives. Indeed, given that water-energy-food issues have been well recognised already for decades, integration of the perspectives is important for the nexus to provide added value for current planning and management practices.

We then focused on the implications that transboundary context brings to the nexus as an approach and *vice versa*. Based on our comparative analysis of three Asian regions and related transboundary river basins, we concluded that the transboundary context has three major implications: *the diversity of scales and perspectives, the importance of state actors, and the importance of politics*. On the other hand, introducing the nexus approach in a transboundary context has the potential to *provide new resources and approaches, alter existing actor dynamics, and portray a richer picture of relationships*. These two sets of implications are linked, and also span the three perspectives on the nexus, demonstrating the usefulness of an integrated view (Figure 6).

According to our assessment, the use of transboundary water-energy-food nexus is worth pursuing but there are still issues that need to be addressed in its implementation. The nexus is not a mature concept and experiences on its benefits and caveats—in transboundary and other contexts, and in relation to other approaches—need to be strengthened. One fundamental issue is that the possibility to alter existing actor dynamics means that the ownership of the nexus should not rest on any single, sectoral organisation (such as a River Basin Organisation) but it should be implemented through a multisectoral, multistakeholder process. Such a process would also encourage interest in the nexus approach by food and energy sectors. Given that the nexus is still largely water sector driven, such buy-in is crucial for the success of the nexus approach.

At the same time, we should remember the facts on the ground: the pressures of food and energy production on water and the importance of the river-basin scale for understanding water flow, allocation and use. The issues on which the nexus focuses are fundamental and any effort to better understand and manage them should be encouraged—particularly in transboundary situations, where various approaches related to water, energy and food have been applied but which still regularly remain complicated and 'deadlocked'. Admittedly, the fact that the nexus is not as established a concept as, for example, IWRM means that it may still fade from fashion. In the meantime, however, the nexus could make some researchers and practitioners think about relationships between food, energy and water in new ways. With its focus on three critical sectors and their interlinkages, the nexus has potential as a complementary approach to support water resources management, transboundary cooperation and, ultimately, sustainable development.

Acknowledgments: The work for this article and the related Special Issue was supported by the Academy of Finland funded Nexus Asia project (#269901). T.A.R. received funding also from Maa- ja vesitekniikan tuki ry. The ideas and support provided by Hanna-Mari Juvonen, Aura Salmivaara and Shokhrukh-Mirzo Jalilov helped us to set the focus for the article, while Matti Kummu helped with maps and data. The analyses provided by other authors of this Special Issue helped our comparative analysis and discussion: thank you to all of you. Thank you also for the support of our colleagues at Aalto University's Water & Development Research Group as well as for the well-formulated comments by our three reviewers.

Author Contributions: M.Ke. and O.V. developed the original idea for the article, with all authors contributing to its further development. M.Ke. and J.G. had the main responsibility for structuring and writing the actual article, with M.Ka., M.P. and T.A.R. contributing particularly to comparative analysis and O.V. to discussion and conclusions. M.Ke., J.G. and T.A.R. wrote the majority of the Section 2, M.P. and M.Ke. the majority of Appendix A, and M.Ke. the majority of Appendix B. All authors contributed to finalising the text of the article.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Selected Water-Energy-Food Data on Three Study Regions

The tables below show selected water, energy and food-related data for the three study regions, namely Central Asia (Table A1), South Asia (Table A2) and the Mekong Region in Southeast Asia (Table A3). The data aims to provide a quantitative indication of the issues that are qualitatively described in the nexus triangles. The data is grouped according the countries and/or key transboundary river basins. The definitions and sources for the data are listed in Table A4.

In the tables, hydroelectric production indicates electricity production from hydroelectric sources [% of total], while water shortage is calculated as renewable water resources per capita per year (moderate if 1000–1700 m^3/cap/yr, high if <1000 m^3/cap/yr) and water stress as water consumption/renewable water resources (moderate if 20%–40%, high if >40%). The letters in the parentheses under each transboundary river basin refer to the riparian countries.

Appendix B. Multiple "Transboundarities": Example from the Mekong

The comparative analysis notes that countries in our study regions are connected in multiple ways and are therefore transboundary in multiple ways, when viewed from a nexus perspective. The maps included in Figure A1 show examples of these multiple 'transboundarities' in the Mekong Region.

The Mekong riparian countries are connected by the flow of the river itself, its tributaries and its shared basin from upstream to downstream (a), but this relationship is not only unidirectional, as a result of important fish migration patterns from downstream to upstream (b). From an energy and food perspective, the connections are different again, as shown by the connecting power transmission lines (c) and available data on the regional food trade exports (d). For map d), kindly note that the data on Laos, Myanmar and Vietnam is missing and the size of the arrows and circles is indicative only: for actual values, see the numbers.

Table A1. Selected water-, energy- and food-related data for the countries and transboundary river basins in Central Asia.

Central Asia																	
			Population	**Net Energy Imports**	**Hydro-Electric Production**	**Access to Electricity**	**Energy Used in Agriculture and Forestry**	**Food Supply**	**Food Self-Suffiency**	**Area Equipped for Irrigation**		**Water Shortage**	**Water Stress**	**Share of Water Withdrawals**			
			[millions]	[% of energy use]	[% of total]	[% of population]	[% of energy use]	[kcal/cap/d]	[% of kcal requirements produced domestically]	(% of total land area)	(ha/capita)	[m³/year/cap	[%]	**Irrigation**	**Electricity**	**Manufactur.**	**Domestic**
Countries	**Afghanistan**	A	28.4	-	-	43%	-	-	-	5%	0.106						
	Kazakhstan	Kz	15.9	−120%	9%	100%	2.5%	3225	196%	1%	0.170						
	Kyrgyz Rep.	Kg	5.3	58%	93%	100%	5.1%	2771	79%	6%	0.151						
	Tajikistan	Tj	7.6	26%	99%	100%	17.9%	2134	36%	6%	0.099						
	Turkmenistan	Tk	5.0	−166%	0%	100%	2.2%	2802	102%	5%	0.345						
	Uzbekistan	U	27.8	−18%	19%	100%	5.5%	2502	83%	9%	0.153						
Basins	**Amu Darya** (A, Tj, Tk, U)		30.2							7%	0.140	1636	47%	92%	3%	1%	4%
	Syr Darya (Kz, Kg, Tj, U)		26.6							5%	0.163	1209	52%	77%	12%	3%	7%

Table A2. Selected water-, energy- and food-related data for the countries and transboundary river basins in South Asia. GBM = Ganges-Brahmaputra-Meghna river basin.

South Asia																	
			Population	**Net Energy Imports**	**Hydro-Electric Production**	**Access to Electricity**	**Energy Used in Agriculture and Forestry**	**Food supply**	**Food Self-Suffiency**	**Area Equipped for Irrigation**		**Water Shortage**	**Water Stress**	**Share of Water Withdrawals**			
			[millions]	[% of energy use]	[% of total]	[% of population]	[% of energy use]	[kcal/cap/d]	[% of kcal requirements produced domestically]	(% of total land area)	(ha/capita)	[m³/year/cap	[%]	**Irrigation**	**Electricity**	**Manufacture**	**Domestic**
Countries	**Bangladesh**	Bg	151.1	18%	2%	60%	5.1%	2,413	85%	37%	0.032						
	Bhutan	Bh	0.7	-	-	76%	-	-	-	1%	0.017						
	China	Ch	1360	13%	15%	100%	2.1%	2,915	85%	6%	0.047						
	India	I	1206	31%	12%	79%	3.9%	2,252	94%	20%	0.053						
	Nepal	N	26.8	16%	100%	76%	1.2%	2,333	79%	7%	0.039						
	Pakistan	P	173.1	23%	30%	94%	1.3%	2,315	101%	20%	0.099						
Basins	**GBM** (Bg, Bh, Ch, I, N)		705.0							20%	0.048	1,604	16%	90%	1%	5%	3%
	Indus (Ch, I, P)		243.4							21%	0.100	836	58%	97%	1%	1%	2%

Table A3. Selected water, energy and food-related data for the countries and transboundary river basins in the Mekong Region of Southeast Asia.

			Mekong Region														
			Population	**Net energy imports**	**Hydro-Electric Production**	**Access to Electricity**	**Energy Used in Agriculture And Forestry**	**Food Supply**	**Food Self-Suffiency**	**Area Equipped for Irrigation**		**Water Shortage**	**Water Stress**	**Share of Water Withdrawals**			
			[millions]	[% of energy use]	[% of total]	[% of population]	[% of energy use]	[kcal/cap/d]	[% of kcal requirements produced domestically]	(% of total land area)	(ha/capita)	[m^3/year/cap	[%]	**Irrigation**	**Electricity**	**Manufactur.**	**Domestic**
Countries	**Cambodia**	Cm	14.4	28%	4%	31%	2.5%	2280	109%	3%	0.040						
	China	Ch	1360	13%	15%	100%	2.1%	2915	85%	6%	0.047						
	Lao PDR	L	6.4	-	-	70%	-	2258	117%	2%	0.055						
	Myanmar	M	51.9	−47%	70%	52%	1.0%	2374	111%	3%	0.044						
	Thailand	T	66.4	40%	5%	100%	4.5%	2587	218%	12%	0.097						
	Vietnam	V	89.0	−7%	30%	99%	1.1%	2754	79%	14%	0.051						
Basins	**Irrawaddy** (M + Ch, I)		33.0							4%	0.057	17,352	1%	94%	2%	1%	3%
	Mekong (Cm, Ch, L, M, T, V)		70.6							6%	0.066	6057	4%	79%	10%	4%	6%
	Salween (Ch, M, T)		7.9							1%	0.035	13,518	1%	93%	2%	0%	5%

Table A4. The descriptions and sources for the data listed in Tables A1–3.

Data	Description	Data Source
Country population	UN estimates of total population by country, year 2010	[146]
Basin population	Gridded population data for year 2010, based on HYDE 3.1 and IIASA Population projections	[147]
Energy imports and access to electricity	Net energy imports (% of energy use); Access to electricity (% of population) for year 2012	[148]
Hydroelectricity	Electricity production from hydroelectric sources, by country	[148]
Water withdrawals and consumption	Gridded data on sectoral water withdrawals and consumption	[149]
Energy used in agriculture and forestry	FAO data on energy use related to different sectors.	[150]
Domestic food production & food supply	Dietary energy production by country, year 2005; based on FAOSTAT data.	[151]
ADER	Average dietary energy requirement in kcal/cap by country, years 2004-2006	[152]
Area equipped for irrigation	Gridded data on area equipped for irrigation (AEI); product AEI_HYDE_FINAL_CP.	[153]
Renewable freshwater resources	Calculations based on average annual surface runoff computed from monthly modelled runoff for years 1950–2000	[154]

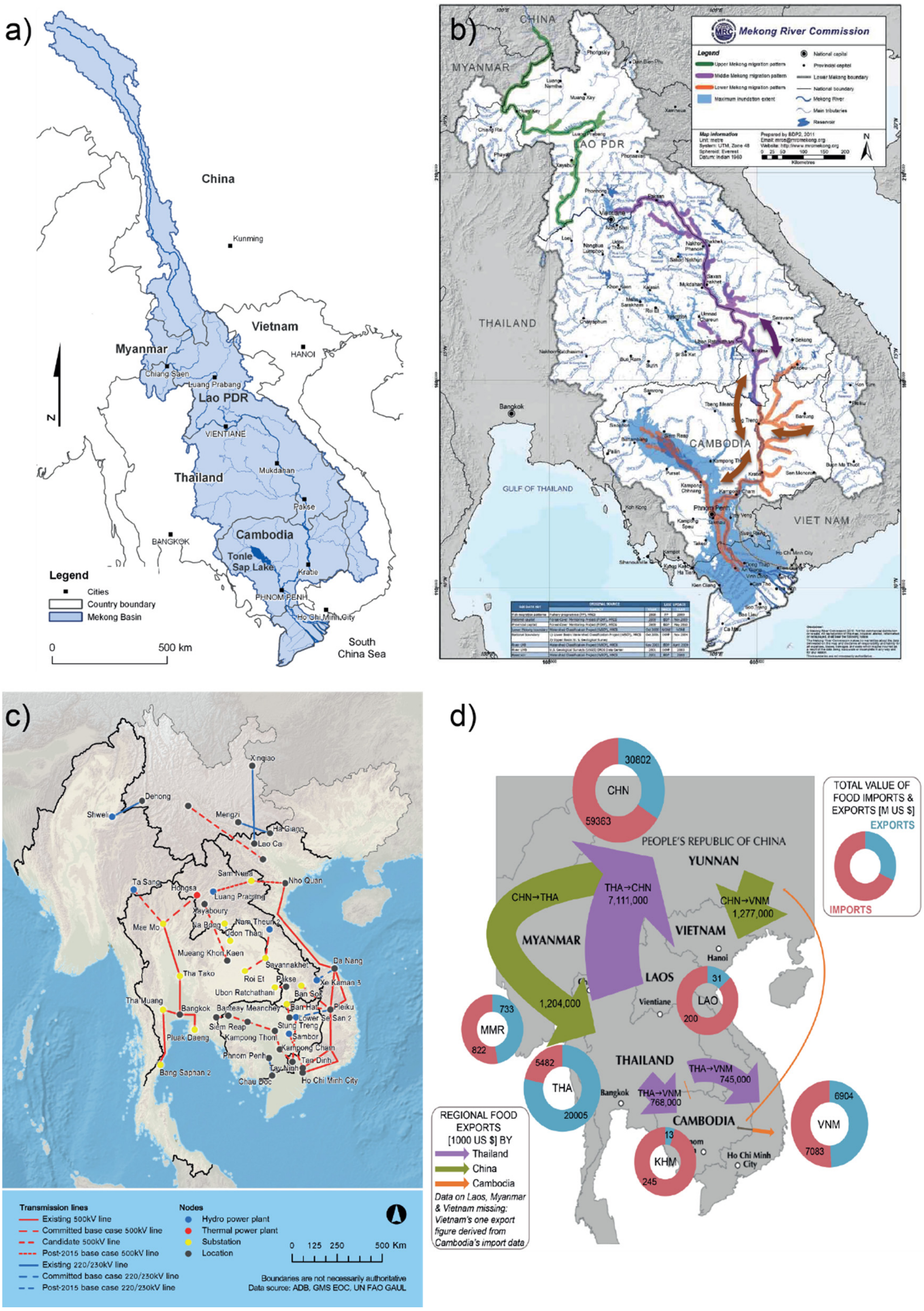

Figure A1. Maps showing example of different transboundary flows in the Mekong Region. (**a**) river basin (map by Matti Kummu, used with permission); (**b**) fish migration patterns (modified from [155]); (**c**) power transmission lines and key power plants [156]; (**d**) indicative information on regional food export flows (arrows) and the total size of food imports and experts per country (blue-red circles). Map d by the authors, based on data available in FAOSTAT Country Profiles [157].

References

1. What's the NEXUS? Messages and Policy Papers. Available online: http://www.water-energy-food.org/en/whats_the_nexus/messages_policy_recommendations.html (accessed on 20 April 2016).
2. Hoff, H. Understanding the Nexus, Background Paper for the Bonn 2011 Conference. In Proceedings of the Bonn2011 Conference, The Water, Energy and Food Security Nexus: Solutions for the Green Economy, Bonn, Germany, 16–18 November 2011; Stockholm Environment Institute: Stockholm, Sweden, 2011; p. 51.
3. Bazilian, M.; Rogner, H.; Howells, M.; Hermann, S.; Arent, D.; Gielen, D.; Steduto, P.; Mueller, A.; Komor, P.; Tol, R.S.J.; *et al.* Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy* **2011**, *39*, 7896–7906. [CrossRef]
4. World Economic Forum. *Global Risks 2011—Sixth Edition*; World Economic Forum: Cologny, Switzerland, 2011.
5. Atakan, E.; Bellet, L.; Bird, J.; Cramwinckel, J.; Dupont, A.; Fernandez, M.-I.; Marre, F.; Mohtar, R.; Newton, J.; Nguyen-Khoaman, S.; *et al.* High-Level Panel: Water, Energy & Food Security. In Proceedings of the 6th World Water Forum, Marseille, France, 12–17 March 2012.
6. Granit, J.; Fogde, M.; Hoff, H.; Joyce, J.; Karlberg, L.; Kuylenstierna, J.L.; Rosemarin, A. Unpacking the water-energy-food nexus: Tools for assessment and cooperation along a continuum. In *Cooperation for A Water Wise World—Partnerships for Sustainable Development*; Jägerskog, A., Clausen, T.J., Lexén, K., Holmgren, T., Eds.; Stockholm International Water Institute: Stockholm, Sweden, 2013; pp. 45–50.
7. United Nations, Economic and Social Commission for Asia and the Pacific (UN ESCAP). *Water, Food and Energy Nexus in Asia and the Pacific*; ESCAP: Bangkok, Thailand, 2013.
8. Allouche, J.; Middleton, C.; Gyawali, D. Technical veil, hidden politics: Interrogating the power linkages behind the nexus. *Water Altern.* **2015**, *8*, 610–626.
9. Muller, M. The "nexus" as a step back towards a more coherent water resource management paradigm. *Water Altern.* **2015**, *8*, 675–694.
10. Allan, T.; Keulertz, M.; Woertz, E. The water-food-energy nexus: An introduction to nexus concepts and some conceptual and operational problems. *Int. J. Water Resour. Develop.* **2015**, *31*, 301–311. [CrossRef]
11. Tickner, D. Is the Water Debate Suffering from a Language problem? Available online: http://www.theguardian.com/sustainable-business/water-debate-suffering-language-problem (accessed on 20 April 2016).
12. Leck, H.; Conway, D.; Bradshaw, M.; Rees, J. Tracing the water-energy-food nexus: Description, theory and practice. *Geogr. Compass* **2015**, *9*, 445–460. [CrossRef]
13. Hussey, K.; Pittock, J. The Energy-water nexus: Managing the links between energy and water for a sustainable future. *Ecol. Soc.* **2012**, *17*, 31. [CrossRef]
14. Kouangpalath, P.; Meijer, K. Water-energy nexus in Shared River Basins: How hydropower shapes cooperation and coordination. *Chang. Adapt. Socio-Ecol. Syst.* **2015**, *2*, 85–87. [CrossRef]
15. Waughray, D. *Water Security: The Water-Food-Energy-Climate Nexus*; Island Press: Washington, DC, USA, 2011.
16. Pittock, J.; Hussey, K.; Dovers, S. *Climate, Energy and Water: Managing Trade-Offs, Seizing Opportunities*; Cambridge University Press: New York, NY, USA, 2015.
17. De Strasser, L.; Lipponen, A.; Howells, M.; Stec, S.; Bréthaut, C. A methodology to assess the water energy food ecosystems nexus in transboundary river basins. *Water* **2016**, *8*, 59. [CrossRef]
18. Biggs, E.M.; Bruce, E.; Boruff, B.; Duncan, J.M.A.; Horsley, J.; Pauli, N.; McNeill, K.; Neef, A.; van Ogtrop, F.; Curnow, J.; *et al.* Sustainable development and the water-energy-food nexus: A perspective on livelihoods. *Environ. Sci. Policy* **2015**, *54*, 389–397. [CrossRef]
19. Howells, M.; Hermann, S.; Welsch, M.; Bazilian, M.; Segerstrom, R.; Alfstad, T.; Gielen, D.; Rogner, H.; Fischer, G.; van Velthuizen, H.; *et al.* Integrated analysis of climate change, land-use, energy and water strategies. *Nature Clim. Chang.* **2013**, *3*, 621–626. [CrossRef]
20. Villarroel Walker, R.; Beck, M.B.; Hall, J.W.; Dawson, R.J.; Heidrich, O. The energy-water-food nexus: Strategic analysis of technologies for transforming the urban metabolism. *J. Environ. Manag.* **2014**, *141*, 104–115. [CrossRef] [PubMed]
21. Endo, A.; Burnett, K.; Orencio, P.; Kumazawa, T.; Wada, C.; Ishii, A.; Tsurita, I.; Taniguchi, M. Methods of the water-energy-food nexus. *Water* **2015**, *7*, 5806–5830. [CrossRef]

22. Bach, H.; Bird, J.; Jonch Clausen, T.; Morck Jensen, K.; Baadsgarde Lange, R.; Taylor, R.; Viriyasakultorn, V.; Wolf, A. *Transboundary River Basin Management: Addressing Water, Energy and Food Security*; Mekong River Commission: Vientiane, Laos, 2012.
23. Kibaroglu, A.; Gürsoy, S.I. Water-energy-food nexus in a transboundary context: The Euphrates-Tigris river basin as a case study. *Water Int.* **2015**, *40*, 824–838. [CrossRef]
24. Scott McLachlan, N. Implementing the water-energy-food nexus at various scales: Trans-boundary challenges and solutions. *Chang. Adapt. Socio-Ecol. Syst.* **2015**, *2*, 94–96. [CrossRef]
25. Lawford, R.; Bogardi, J.; Marx, S.; Jain, S.; Wostl, C.P.; Knüppe, K.; Ringler, C.; Lansigan, F.; Meza, F. Basin perspectives on the water-energy-food security nexus. *Curr. Opin. Environ. Sustain.* **2013**, *5*, 607–616. [CrossRef]
26. Soliev, I.; Wegerich, K.; Kazbekov, J. The costs of benefit sharing: Historical and institutional analysis of shared water development in the Ferghana Valley, the Syr Darya Basin. *Water* **2015**, *7*, 2728–2752. [CrossRef]
27. Guillaume, J.; Kummu, M.; Eisner, S.; Varis, O. Transferable principles for managing the nexus: Lessons from historical global water modelling of Central Asia. *Water* **2015**, *7*, 4200–4231. [CrossRef]
28. Wegerich, K.; van Rooijen, D.; Soliev, I.; Mukhamedova, N. Water security in the Syr Darya Basin. *Water* **2015**, *7*, 4657–4684. [CrossRef]
29. Jalilov, S.-M.; Varis, O.; Keskinen, M. Sharing benefits in transboundary rivers: An experimental case study of Central Asian water-energy-agriculture nexus. *Water* **2015**, *7*, 4778–4805. [CrossRef]
30. Keskinen, M.; Someth, P.; Salmivaara, A.; Kummu, M. Water-energy-food nexus in a transboundary river basin: The case of Tonle Sap Lake, Mekong River Basin. *Water* **2015**, *7*, 5416–5436. [CrossRef]
31. Belinskij, A. Water-energy-food nexus within the framework of international water law. *Water* **2015**, *7*, 5396–5415. [CrossRef]
32. Matthews, N.; Motta, S. Chinese state-owned enterprise investment in Mekong hydropower: Political and economic drivers and their implications across the water, energy, food nexus. *Water* **2015**, *7*, 6269–6284. [CrossRef]
33. Pittock, J.; Dumaresq, D.; Bassi, A. Modelling the hydropower-food nexus in large river basin. *Water* **2016**. in press.
34. Kummu, M.; Gerten, D.; Heinke, J.; Konzmann, M.; Varis, O. Climate-driven interannual variability of water scarcity in food production potential: A global analysis. *Hydrol. Earth Syst. Sci.* **2014**, *18*, 447–461. [CrossRef]
35. Porkka, M.; Gerten, D.; Schaphoff, S.; Siebert, S.; Kummu, M. Causes and trends of water scarcity in food production. *Environ. Res. Lett.* **2016**, *11*, 015001. [CrossRef]
36. Olsson, G. Water, energy and food interactions—Challenges and opportunities. *Front. Environ. Sci. Eng.* **2013**, *7*, 787–793. [CrossRef]
37. Oki, T.; Kanae, S. Global Hydrological Cycles and World Water Resources. *Science* **2006**, *313*, 1068–1072. [CrossRef] [PubMed]
38. Yoshihide, W.; van Beek, L.P.H.; Niko, W.; Marc, F.P.B. Human water consumption intensifies hydrological drought worldwide. *Environ. Res. Lett.* **2013**, *8*, 034036.
39. Varis, O. Water demands for bioenergy production. *Int. J. Water Resour. Develop.* **2007**, *23*, 519–535. [CrossRef]
40. Harris, G. Energy, Water and Food-Scenarios on the Future of Sustainable Development. 2002. Available online: http://ericbestonline.com/bestpartners/pdfs/partners/gerald_harris/g_harris_energy_water_and_food_scenarios.pdf (accessed on 20 April 2016).
41. Hellegers, P.; Zilberman, D.; Steduto, P.; McCornick, P. Interactions between water, energy, food and environment: Evolving perspectives and policy issues. *Water Policy* **2008**, *10*, 1–10. [CrossRef]
42. Mushtaq, S.; Maraseni, T.N.; Maroulis, J.; Hafeez, M. Energy and water tradeoffs in enhancing food security: A selective international assessment. *Energy Policy* **2009**, *37*, 3635–3644. [CrossRef]
43. European Union. *Confronting Scarcity: Managing Water, Energy and Land for Inclusive and Sustainable Growth*; European Report on Development 2011–2012; European Commission, International Cooperation and Development (DG DEVCO): Brussels, Belgium, 2012.
44. Smajgl, A.; Ward, J. *The Water-Food-Energy Nexus in the Mekong Region: Assessing Development Strategies Considering Cross-Sectoral and Transboundary Impacts*; Springer Science & Business Media: Berlin, Germany, 2013.

45. Food and Agriculture Organization of the United Nations (FAO). *An Innovative Accounting Framework for the Food-Energy-Water Nexus—Application of the MuSIASEM Approach to Three Case Studies*; FAO: Rome, Italy, 2013.
46. International Union for Conservation of Nature (IUCN) and International Water Association (IWA). *Nexus Dialogue on Water Infrastructure Solutions: Building Partnerships for Innovation in Water, Energy and Food Security*; IUCN & IWA.: Gland, Swizerland; London, UK, 2012.
47. Star, S.L.; Griesemer, J.R. Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology. *Soc. Stud. Sci.* **1989**, *19*, 387–420. [CrossRef]
48. Mollinga, P. *For a Political Sociology of Water Resources Management*; ZEF Working Paper Series 31; ZEF Center for Development Research, Universität Bonn: Bonn, Germany, 2008.
49. Benson, D.; Gain, A.K.; Rouillard, J.J. Water Governance in a Comparative Perspective: From IWRM to a "Nexus" Approach? *Water Altern.* **2015**, *8*, 756–773.
50. Juvonen, H.-M. Nexus for What? Challenges and Opportunities in Applying the Water-Energy-Food Nexus. Master's Thesis, Aalto University School of Engineering, Espoo, Finland, 2015.
51. Foran, T. Node and Regime: Interdisciplinary Analysis of Water-Energy-Food Nexus in the Mekong Region. *Water Altern.* **2015**, *8*, 655–674.
52. Gasper, D.; Apthorpe, R. Introduction: Discourse Analysis and Policy Discourse. In *Arguing Development Policy: Frames And Discourses*; Apthorpe, R., Gasper, D., Eds.; Frank Cass and Company Limited: London, UK, 1996.
53. Keskinen, M. Bringing back the Common Sense? Integrated Approaches in Water Management: Lessons Learnt from the Mekong. Ph.D. Thesis, Aalto University, Espoo, Helsinki, Finland, 2010.
54. Global Water Partnership (GWP). *Integrated Water Resources Management*; Technical Advisory Committee Background Paper #6; GWP: Stockholm, Sweden, 2000.
55. Max-Neef, M.A. Foundations of transdisciplinarity. *Ecol. Econ.* **2005**, *53*, 5–16. [CrossRef]
56. Varis, O.; Kummu, M.; Salmivaara, A. Ten major rivers in monsoon Asia-Pacific: An assessment of vulnerability. *Appl. Geogr.* **2012**, *32*, 441–454. [CrossRef]
57. Varis, O.; Kummu, M. The Major Central Asian River Basins: An Assessment of Vulnerability. *Int. J. Water Resour. Develop.* **2012**, *28*, 433–452. [CrossRef]
58. Keskinen, M. Water resources development and impact assessment in the Mekong Basin: Which way to go? *Ambio* **2008**, *37*, 193–198. [CrossRef]
59. Keskinen, M.; Kummu, M.; Kakonen, M.; Varis, O. Mekong at the crossroads: Next step for impact assessment of large dams. *Ambio* **2012**, *41*, 319–324. [CrossRef] [PubMed]
60. Salmivaara, A.; Kummu, M.; Keskinen, M.; Varis, O. Using Global Datasets to Create Environmental Profiles for Data-Poor Regions: A Case from the Irrawaddy and Salween River Basins. *Environ. Manag.* **2013**, *51*, 897–911. [CrossRef] [PubMed]
61. Kattelus, M.; Kummu, M.; Keskinen, M.; Salmivaara, A.; Varis, O. China's southbound transboundary river basins: A case of asymmetry. *Water Int.* **2014**, *40*, 113–138. [CrossRef]
62. Rahaman, M.M.; Varis, O. Integrated water management of the Brahmaputra basin: Perspectives and hope for regional development. *Nat. Resour. Forum* **2009**, *33*, 60–75. [CrossRef]
63. Varis, O.; Rahaman, M.M.; Kajander, T. Fully connected Bayesian belief networks: A modeling procedure with a case study of the Ganges river basin. *Integr. Environ. Assess. Manag.* **2012**, *8*, 491–502. [CrossRef] [PubMed]
64. Kattelus, M.; Rahaman, M.M.; Varis, O. Myanmar under reform: Emerging pressures on water, energy and food security. *Nat. Resour. Forum* **2014**, *38*, 85–98. [CrossRef]
65. Keskinen, M.; Chinvanno, S.; Kummu, M.; Nuorteva, P.; Snidvongs, A.; Varis, O.; Västilä, K. Climate change and water resources in the Lower Mekong River Basin: Putting adaptation into the context. *J. Water Clim. Chang.* **2010**, *1*, 103–117. [CrossRef]
66. Mehtonen, K.; Keskinen, M.; Varis, O. The Mekong: IWRM and institutions. In *Managemeng of Transboundary Rivers and Lakes*; Varis, O., Tortajada, C., Biswas, A.K., Eds.; Springer-Verlag Berlin: Berlin, Germany, 2008.
67. Wegerich, K. Hydro-hegemony in the Amu Darya basin. *Water Policy* **2008**, *10*, 71–88. [CrossRef]
68. Abdullaev, I.; Rakhmatullaev, S. Transformation of water management in Central Asia: From State-centric, hydraulic mission to socio-political control. *Environ. Earth Sci.* **2013**, *73*, 849–861. [CrossRef]

69. Stucki, V.; Sojamo, S. Nouns and Numbers of the Water–Energy–Security Nexus in Central Asia. *Int. J. Water Resour. Develop.* **2012**, *28*, 399–418. [CrossRef]
70. Granit, J.; Jägerskog, A.; Lindström, A.; Björklund, G.; Bullock, A.; Löfgren, R.; de Gooijer, G.; Pettigrew, S. Regional Options for Addressing the Water, Energy and Food Nexus in Central Asia and the Aral Sea Basin. *Int. J. Water Resour. Develop.* **2012**, *28*, 419–432. [CrossRef]
71. Allouche, J. The Governance of Central Asian Waters: National Interests versus Regional Cooperation. *Disarm. Forum* **2007**, *4*, 45–56.
72. Varis, O.; Rahaman, M.M. The Aral Sea keeps drying out but is Central Asia short of water? In *Central Asian Waters: Social, Economic, Environmental and Governance Puzzle*; Rahaman, M.M., Varis, O., Eds.; Water & Development Publications—Helsinki University of Technology: Helsinki, Finland, 2008; pp. 3–9.
73. Abdolvand, B.; Mez, L.; Winter, K.; Mirsaeedi-Gloßner, S.; Schütt, B.; Rost, K.T.; Bar, J. The dimension of water in Central Asia: Security concerns and the long road of capacity building. *Environ. Earth Sci.* **2014**, *73*, 897–912. [CrossRef]
74. Cook, S.; Fisher, M.; Tiemann, T.; Vidal, A. Water, food and poverty: Global- and basin-scale analysis. *Water Int.* **2011**, *36*, 1–16. [CrossRef]
75. Sharma, B.; Amarasinghe, U.; Xueliang, C.; de Condappa, D.; Shah, T.; Mukherji, A.; Bharati, L.; Ambili, G.; Qureshi, A.; Pant, D.; *et al.* The Indus and the Ganges: River basins under extreme pressure. *Water Int.* **2010**, *35*, 493–521. [CrossRef]
76. Rasul, G. Food, water, and energy security in South Asia: A nexus perspective from the Hindu Kush Himalayan region. *Environ. Sci. Policy* **2014**, *39*, 35–48. [CrossRef]
77. Rodell, M.; Velicogna, I.; Famiglietti, J.S. Satellite-based estimates of groundwater depletion in India. *Nature* **2009**, *460*, 999–1002. [CrossRef] [PubMed]
78. Shahid, S.; Behrawan, H. Drought risk assessment in the western part of Bangladesh. *Nat. Hazard.* **2008**, *46*, 391–413. [CrossRef]
79. Hoekstra, A.Y.; Mekonnen, M.M.; Chapagain, A.K.; Mathews, R.E.; Richter, B.D. Global Monthly Water Scarcity: Blue Water Footprints *versus* Blue Water Availability. *PLoS ONE* **2012**, *7*, e32688. [CrossRef] [PubMed]
80. Rahaman, M.M. Hydropower ambitions of South Asian nations and China: Ganges and Brahmaputra Rivers basins. *Int. J. Sustain. Soc.* **2012**, *4*, 131–157. [CrossRef]
81. Dharmadikhary, S. *Mountains of Concrete: Dam Building in the Himalayas*; IDEAS: Berkeley, CA, USA, 2008.
82. Grumbine, R.E.; Pandit, M.K. Threats from India's Himalaya Dams. *Science* **2013**, *339*, 36–37. [CrossRef] [PubMed]
83. International Energy Agency (IEA). *IEA Statistics*; IEA: Paris, France, 2016.
84. Lal, R. Soil degradation and environment quality in South Asia. *Int. J. Ecol. Environ. Sci.* **2007**, *33*, 91–103.
85. Yang, Y.C.E.; Brown, C.; Yu, W.; Wescoat, J.; Ringler, C. Water governance and adaptation to climate change in the Indus River Basin. *J. Hydrol.* **2014**, *519*, 2527–2537. [CrossRef]
86. Condon, M.; Kriens, D.; Lohani, A.; Sattar, E. Challenge and response in the Indus Basin. *Water Policy* **2014**, *16*, 58–86. [CrossRef]
87. Rahaman, M.M. Principles of Transboundary Water Resources Management and Ganges Treaties: An Analysis. *Int. J. Water Resour. D* **2009**, *25*, 159–173. [CrossRef]
88. Rahaman, M.M. Integrated Ganges basin management: Conflict and hope for regional development. *Water Policy* **2009**, *11*, 168–190. [CrossRef]
89. Uprety, K.; Salman, S.M.A. Legal aspects of sharing and management of transboundary waters in South Asia: Preventing conflicts and promoting cooperation. *Hydrol. Sci. J.* **2011**, *56*, 641–661. [CrossRef]
90. Urban, F.; Nordensvärd, J.; Khatri, D.; Wang, Y. An analysis of China's investment in the hydropower sector in the Greater Mekong Sub-Region. *Environ. Dev. Sustain.* **2013**, *15*, 301–324. [CrossRef]
91. Grumbine, R.E.; Xu, J. China Shakes the World—and Then What? *Conserv. Biol.* **2009**, *23*, 513–515. [PubMed]
92. Grumbine, R.E.; Xu, J. Mekong hydropower development. *Science* **2011**, *332*, 178–179. [CrossRef] [PubMed]
93. Salmivaara, A.; Kummu, M.; Varis, O.; Keskinen, M. Socio-economic changes in Cambodia's unique Tonle Sap Lake area: A spatial approach. *Appl. Spat. Anal. Policy* **2015**. [CrossRef]
94. Hortle, K.G. *Consumption and the Yield of Fish and Other Aquatic Animals from the Lower Mekong Basin*; MRC Technical Paper #16; Mekong River Commission: Vientiane, Laos, 2007; p. 87.

95. Winemiller, K.O.; McIntyre, P.B.; Castello, L.; Fluet-Chouinard, E.; Giarrizzo, T.; Nam, S.; Baird, I.G.; Darwall, W.; Lujan, N.K.; Harrison, I.; *et al.* Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science* **2016**, *351*, 128–129. [CrossRef] [PubMed]
96. Baran, E.; Myschowoda, C. Dams and fisheries in the Mekong Basin. *Aquat. Ecosyst. Health Manag.* **2009**, *12*, 227–234. [CrossRef]
97. Mekong River Commission (MRC). *State of the Basin Report 2010*; MRC: Vientiane, Laos, 2010.
98. Hennig, T.; Wang, W.; Feng, Y.; Ou, X.; He, D. Review of Yunnan's hydropower development. Comparing small and large hydropower projects regarding their environmental implications and socio-economic consequences. *Renew. Sustain. Energy Rev.* **2013**, *27*, 585–595. [CrossRef]
99. Mekong River Commission (MRC). *Assessment of Basin-wide Development Scenarios: Main Report*; MRC: Vientiane, Laos, 2011; p. 254.
100. Mekong River Commission Secretariat. *Hydropower Database*; Mekong River Commission Secretariat: Vientiane, Laos, 2015.
101. CGIAR Research Program on Water, Land and Ecosystems. *Mekong Dam Database*; CGIAR Research Program on Water, Land and Ecosystems: Vientiane, Laos, 2015.
102. Chang, X.; Liu, X.; Zhou, W. Hydropower in China at present and its further development. *Energy* **2010**, *35*, 4400–4406. [CrossRef]
103. Chen, W.; Li, H.; Wu, Z. Western China energy development and west to east energy transfer: Application of the Western China Sustainable Energy Development Model. *Energy Policy* **2010**, *38*, 7106–7120. [CrossRef]
104. Matthews, N. Water Grabbing in the Mekong Basin—An Analysis of the Winners and Losers of Thailand's Hydropower Development in Lao PDR. *Water Altern.* **2012**, *5*, 392–411.
105. Merme, V.; Ahlers, R.; Gupta, J. Private equity, public affair: Hydropower financing in the Mekong Basin. *Glob. Environ. Chang.* **2014**, *24*, 20–29. [CrossRef]
106. Räsänen, T.A.; Joffre, O.; Someth, P.; Cong, T.T.; Keskinen, M.; Kummu, M. Model-based assessment of water, food and energy trade-offs in a cascade of multi-purpose reservoirs: Case study from transboundary Sesan River. *J. Water Resour. Plan. Manag.* **2015**, *141*, 05014007. [CrossRef]
107. Arias, M.E.; Cochrane, T.A.; Kummu, M.; Lauri, H.; Koponen, J.; Holtgrieve, G.; Piman, T. Impacts of hydropower and climate change on drivers of ecological productivity of Southeast Asia's most important wetland. *Ecol. Model.* **2014**, *272*, 252–263. [CrossRef]
108. Dugan, P.; Barlow, C.; Agostinho, A. Fish migration, dams, and loss of ecosystem services in the Mekong Basin. *Ambio* **2010**, *39*, 344–348. [CrossRef] [PubMed]
109. Lauri, H.; Moel, H.D.; Ward, P.; Räsänen, T.; Keskinen, M.; Kummu, M. Future changes in Mekong River hydrology: Impact of climate change and reservoir operation on discharge. *Hydrol. Earth Syst. Sci.* **2012**, *16*, 4603–4619. [CrossRef]
110. Kummu, M.; Lu, X.; Wang, J.; Varis, O. Basin-wide sediment trapping efficiency of emerging reservoirs along the Mekong. *Geomorphology* **2010**, *119*, 181–197. [CrossRef]
111. Maavara, T.; Parsons, C.T.; Ridenour, C.; Stojanovic, S.; Dürr, H.H.; Powley, H.R.; van Cappellen, P. Global phosphorus retention by river damming. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 15603–15608. [CrossRef] [PubMed]
112. Ziv, G.; Baran, E.; Nam, S.; Rodriquez-Iturbe, I.; Levin, S. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *PNAS* **2012**, *109*, 5609–5614. [CrossRef] [PubMed]
113. Hortle, K.G. Fisheries of the Mekong River Basin. In *The Mekong: Biophysical Environment of a Transboundary River*; Campbell, I.C., Ed.; Elsevier: New York, NY, USA, 2009.
114. Asian Development Bank. *Assessment of the Greater Mekong Subregion Energy Sector Development: Progress, Prospects, and Regional Investment Priorities*; Asian Development Bank: Mandaluyong City, Philippines, 2013.
115. Phalan, B. The social and environmental impacts of biofuels in Asia: An overview. *Appl. Energy* **2009**, *86* (Suppl. 1), S21–S29. [CrossRef]
116. Sasaki, N.; Knorr, W.; Foster, D.R.; Etoh, H.; Ninomiya, H.; Chay, S.; Kim, S.; Sun, S. Woody biomass and bioenergy potentials in Southeast Asia between 1990 and 2020. *Appl. Energy* **2009**, *86* (Suppl. 1), S140–S150. [CrossRef]
117. Bach, H.; Glennie, P.; Taylor, R.; Clausen, T.J.; Holzwarth, F.; Jensen, K.M.; Meija, A.; Schmeier, S. *Cooperation for Water, Energy and Food Security in Transboundary Basins under Changing Climate*; Mekong River Commission: Vientiane, Laos, 2014.

118. Dore, J.; Lazarus, K. Demarginalizing the Mekong River Commission. In *Contested Waterscapes in the Mekong Region: Hydropower, Livelihoods and Governance*; Molle, F., Foran, T., Käkönen, M., Eds.; Earthscan: London, UK, 2009; pp. 357–382.
119. Grumbine, R.E.; Dore, J.; Xu, J. Mekong hydropower: Drivers of change and governance challenges. *Front. Ecol. Environ.* **2012**, *10*, 91–98. [CrossRef]
120. Orr, S.; Pittock, J.; Chapagain, A.; Dumaresq, D. Dams on the Mekong River: Lost fish protien and the implications for land and water resources. *Glob. Environ. Chang.* **2012**, *22*, 925–932. [CrossRef]
121. Kummu, M. Spatio-Temporal Scales of Hydrological Impact Assessment in Large River Basins: The Mekong Case. Ph.D. Thesis, Helsinki University of Technology, Helsinki, Finland, 2008.
122. Dore, J.; Lebel, L. Deliberation and scale in Mekong Region water governance. *Environ. Manag.* **2010**, *46*, 60–80. [CrossRef] [PubMed]
123. Cumming, G.S.; Cumming, D.H.M.; Redman, C.L. Scale Mismatches in Social-Ecological Systems: Causes, Consequences, and Solutions. *Ecol. Soc.* **2006**, *11*, 14.
124. Blatter, J.; Ingram, H. States, Markets and Beyond: Governance of Transboundary Water Resources. *Nat. Resour. J.* **2000**, *40*, 439–473.
125. Dore, J. An agenda for deliberative water governance arenas in the Mekong. *Water Policy* **2014**, *16*, 194–214. [CrossRef]
126. Mekong River Commission (MRC). *Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin*; MRC: Chiang Rai, Thailand, 1995.
127. Warner, J. *Multi-Stakeholder Platforms for Integrated Water Management*; Ashgate: Aldershot, UK, 2007.
128. Dore, J. Multi-stakeholder platforms (MSPs): Unfulfilled potential. In *Democratizing Water Governance in the Mekong Region*; Lebel, L., Dore, J., Daniel, R., Yang, S.K., Eds.; Mekong Press: Chiang Mai, Thailand, 2007; pp. 197–226.
129. Mohtar, R.H.; Daher, B. Water-Energy-Food Nexus Framework for facilitating multi-stakeholderdialogue. *Water Int.* **2016**. [CrossRef]
130. Timmerman, J.G.; Langaas, S. Water information: What is it good for? The use of information in transboundary water management. *Reg. Environ. Chang.* **2005**, *5*, 177–187. [CrossRef]
131. UN-Water. Transboundary Waters: Sharing Benefits, Sharing Responsibilities. 2008. Available online: http://www.unwater.org/downloads/UNW_TRANSBOUNDARY.pdf (accessed on 20 April 2016).
132. Gerlak, A.K.; Lautze, J.; Giodarno, M. *Greater Exchange, Greater Ambiguity: Water Resources Data and Information Exchange in Transboundary Water Treaties*; Global Water Forum (GWF): Canberra, Australia, 2013.
133. Sadoff, C.; Grey, D. A cooperation on international rivers: A continuum for securing and sharing benefits. *Water Int.* **2005**, *30*, 1–7. [CrossRef]
134. Mirumachi, N. *Transboundary Water Politics in the Developing World*; Routledge: London, UK, 2015.
135. Middleton, C.; Allouche, J.; Gyawali, D.; Allen, S. The Rise and Implications of the Water-Energy-Food Nexus in Southeast Asia through and Environmental Justice Lens. *Water Altern.* **2015**, *8*, 627–654.
136. Flammini, A.; Puri, M.; Pluschke, L.; Dubois, O. *Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the context of the Sustainable Energy for All Initiative*; Food and Agriculture Organisation of the United Nations (FAO): Rome, Italy, 2014.
137. Byers Edward, A. Tools for tackling the water-energy-food nexus. *Chang. Adapt. Socio-Ecol. Syst.* **2015**, *2*, 109–111.
138. National Science Foundation. Innovations at the Nexus of Food, Energy and Water Systems (INFEWS). Available online: http://www.nsf.gov/pubs/2016/nsf16524/nsf16524.htm (accessed on 31 March 2016).
139. European Commission. Horizon 2020 Topic: Integrated approaches to food security, low-carbon energy, sustainable water management and climate change mitigation. Available online: https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/240-water-2b-2015.html (accessed on 31 March 2016).
140. The Nexus Network. Funding available. Available online: http://www.thenexusnetwork.org/funding-available/ (accessed on 31 March 2016).
141. Engineering and Physical Sciences Research Council. Sandpit: Water Energy Food Nexus. Available online: http://www.epsrc.ac.uk/funding/calls/sandpitwaterenergyfoodnexus/ (accessed on 31 March 2016).
142. MRC. Organisational structure. Available online: http://www.mrcmekong.org/about-mrc/organisational-structure/ (accessed on 26 January 2016).

143. Sadoff, C.; Grey, D. Beyond the river: The benefits of cooperation on international rivers. *Water Policy* **2002**, *4*, 389–403. [CrossRef]
144. WCED. *Our Common Future*; Report of the World Commission on Environment and Development; Oxford University Press: Oxford, UK, 1987.
145. Hussey, K.; Pittock, J.; Dovers, S. Justifying, extending and applying "nexus" thinking in the quest for sustainable development. In *Climate, Energy and Water: Managing Trade-Offs, Seizing Opportunities*; Pittock, J., Hussey, K., Dovers, S., Eds.; Cambridge University Press: New York, NY, USA, 2015; pp. 1–5.
146. UN. The 2012 Revision of World Population Prospects. Population Division of the Department of Economic and Social Affairs of the United Nations (UN) Secretariat: New York, NY, USA, 2013.
147. Klein Goldewijk, K.; Beusen, A.; Janssen, P. Long-term dynamic modeling of global population and built-up area in a spatially explicit way: HYDE 3.1. *The Holocene* **2010**, *20*, 565–573. [CrossRef]
148. World Development Indicators, The World Bank. Available online: http://data.worldbank.org/indicator (accessed on 21 March 2016).
149. WATCH. EU WATCH: Water and Global Change. Available online: http://www.eu-watch.org (accessed on 18 July 2011).
150. FAO. FAOSTAT: FAO Database for Food and Agriculture. Food and Agriculture Organisation of the United Nations (FAO), Rome. Available online: http://faostat3.fao.org/home/E (accessed on 21 March 2016).
151. Porkka, M.; Kummu, M.; Siebert, S.; Varis, O. From Food Insufficiency towards Trade Dependency: A Historical Analysis of Global Food Availability. *PLoS ONE* **2013**, *8*, e82714. [CrossRef] [PubMed]
152. FAO. Food security indicators, February 09, 2016 revision. Food and agriculture Organization of the United Nations (FAO), Rome. Available online: http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/ (accessed on 21 March 2016).
153. Siebert, S.; Kummu, M.; Porkka, M.; Döll, P.; Ramankutty, N.; Scanlon, B.R. A global data set of the extent of irrigated land from 1900 to 2005. *Hydrol. Earth Syst. Sci.* **2015**, *19*, 1521–1545. [CrossRef]
154. GWSP Digital Water Atlas. *Map 38: Mean annual surface runoff 1950–2000, v. 1.0*; Center for Development Research, University of Bonn: Bonn, Germany, 2008.
155. Mekong River Commission (MRC). *Map on Fish Migration Patterns*; MRC: Vientiane, Laos, 2010.
156. Asian Development Bank (ADB). Overview Map of GMS Crossborder Power Transmission. In *Greater Mekong Subregion Atlas of the Environment*, 2nd ed.; ADB: Manila, Philippines, 2012.
157. Food and Agriculture Organization of the United Nations (FAO). *FAOSTAT Country Profiles*; FAO: Rome, Italt, 2015.