Aalto University
School of Engineering

Hanna-Mari Juvonen

Nexus for what? Challenges and opportunities in applying the water-energy-food nexus

Master's thesis submitted for inspection for the degree of Master of Science in Technology.
Espoo, May 25th, 2015

Supervisor: Prof. Olli Varis
Instructor: D.Sc. (Tech.) Marko Keskinen

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author Hanna-Mari Juvonen

Title of thesis Nexus for what? Challenges and opportunities in applying the water-energy-food nexus

Degree programme Transportation and Environmental Engineering

Major/minor Water and Environmental Engineering **Code** R3005

Thesis supervisor Prof. Olli Varis

Thesis advisor(s) D.Sc. (Tech.) Marko Keskinen

Date 25.05.2015 **Number of pages** 46+2 **Language** English

Abstract

Rapid developments in population growth and consumption patterns are increasing the demand for food, feed and energy and thus stressing the natural resources and causing resource scarcity. Climate change adds to these pressures. The risks related to crossing planetary boundaries have provoked a call for new governance and management approaches to replace the old sectoral ones. The nexus of water, energy and food (the WEF nexus) is the most recent buzzword especially in water resources management and governance. While the nexus approach has been much discussed, there is still no widely accepted definition about the WEF nexus. In general terms, however, the WEF nexus can be defined as water, energy and food resources, their interconnections and the management of the nexus resources.

This thesis studies what new does the WEF nexus approach bring to water resources management, how does it relate to past approaches and how does it correspond to the current issues in different dimensions of water resources management and governance. The WEF nexus is reflected with the help of three dimensions of water resources management recognized in this thesis: paradigms and concepts; governance and policies; and assessments and tools. Through these dimensions, the thesis aims to identify the potential challenges and opportunities in applying the WEF nexus.

The analysis of the WEF nexus in three dimensions reveals how the WEF nexus manifests itself in different settings and forms an overall picture of challenges and opportunities in its application. I argue that the nexus approach does not replace but rather complements the current mind-set and paradigm of water resources management by bringing some new ideas and may guide the research to new direction. This also means that the nexus is not likely to substitute Integrated Water Resources Management (IWRM) as the prevailing “nirvana concept” (Molle 2008).

The unclear definition of the WEF nexus may hinder the adoption and implementation of the approach. At the same time, the flexibility and vagueness of the concept makes it useful in the complex setting of multiple sectors and actors on different levels and scales. The WEF nexus can also serve as a boundary object to be shared by different actors. The nexus approach has already been applied in assessments and some nexus tools have been developed. The WEF nexus approach does hold potential for enhancing the current management of water, energy and food resources but more work is needed especially to assist the practical implementation of the nexus approach. In addition, discussion is needed on the more fundamental implications of the nexus, namely how it potentially influences dominant paradigms and governance settings of water and other nexus resources management.

Keywords water-energy-food nexus, water resources management, natural resources

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

Aalto-yliopisto, PL 11000, 00076 AALTO
www.aalto.fi
Diplomityön tiivistelmä

Tekijä Hanna-Mari Juvonen

Työn nimi Mikä nexus? Haasteita ja mahdollisuuksia vesi-ruoka-energia-nexuksen soveltamisessa

Koulutusohjelma Yhdyskunta- ja ympäristötekniikka

Pää-/sivuaine Vesi- ja ympäristötekniikka **Koodi** R3005

Työn valvoja Professori Olli Varis

Työn ohjaaja(t) TkT Marko Keskinen

Päivämäärä 25.05.2015 **Sivumäärä** 46+2 **Kieli** englanti

Tiivistelmä

Nopea väestönkasvu ja muutokset kulutustottumuksissa lisäävät jatkuvasti ruoan, energian ja rehun kysyntää ja kasvattavat siten paineita luonnonvaroja kohtaan. Ilmastonmuutos lisää osaltaan näitä paineita. Tähän kehitykseen liittyvät riskit ovat herättäneet tarpeen kehittää uusia poikkisektoraalisia lähestymistapoja ja menetelmiä luonnonvarojen käyttöön ja hallintaan. Vesi-ruoka-energia-nexus on termi, jota on viime aikoina käytetty paljon erityisesti vesivarojen hallinnassa, mutta jolle ei ole vielä vakiintunut laajalti omaksuttua määritelmää. Yleisesti vesi-ruoka-energia-nexusta kuitenkin käytetään vesivarojen ja energian- ja ruoantuotannon välisten kytköksien tarkasteluun ja nexukseen liittyvien luonnonvarojen hallintaan.

Tässä diplomityössä tutkitaan mitä uutta vesi-ruoka-energia-nexus tuo vesivarojen hallintaan, miten se liittyy aikaisempiin lähestymistapoihin ja miten se vastaa nykyisiin haasteisiin vesivarojen hallinnassa. Vesi-ruoka-energia-nexusta tarkastellaan kolmen tässä työssä tunnistetun vesivarojen hallinnan ulottuvuuden avulla, jotka ovat: paradigmat ja käsitteet, hallinta ja käytänteet, ja arvioinnit ja työkalut. Näitä ulottuvuuksia hyödyntämällä työssä pyritään tunnistamaan mahdollisia haasteita ja mahdollisuuksia vesi-ruoka-energia-nexuksen soveltamisessa.

Vesi-ruoka-energia-nexuksen tarkastelu tunnistettujen ulottuvuuksien avulla paljastaa, että nexus näyttäytyy erilaisena eri kehyksissä ja yhdistelemällä näitä erilaisia kuvauksia voidaan muodostaa kokonaiskuva nexuksen soveltamisen haasteista ja mahdollisuuksista. Esitän, että lähestymistapana nexus ei korvaa, vaan se ennemminkin täydentää nykyistä vesivarojen hallinnan paradigmaa ja käsityksiä tuomalla esiin uusia ajatuksia ja mahdollisesti ohjaamalla tutkimusta uuteen suuntaan. Siten ei myöskään ole todennäköistä, että vesi-ruoka-energia-nexus korvaisi kokonaisvaltaisen vesivarojen hallinnan (IWRM) vallitsevana ”nirvana-käsitteenä” (Molle 2008).

Epäselvä määritelmä voi hankaloittaa vesi-ruoka-energia-nexuksen omaksumista ja toimeenpanoa, mutta toisaalta käsitteen ympäripyöreys ja joustavuus ovat hyödyksi useiden sektoreiden, toimijoiden, mittakaavojen ja tasojen muodostamissa monitahoisissa puitteissa. Vesi-ruoka-energia-nexus voi myös toimia rajaobjektina eli eri toimijoiden jakamana yhdistävänä tekijänä. Nexus-lähestymistapaa on jo sovellettu erilaisiin nexus-arviointeihin ja nexus-työkaluja on kehitetty. Vesi-ruoka-energia-nexus tarjoaa mahdollisuuksia nykyisen vesivarojen ja niihin liittyvien luonnonvarojen käytön ja hallinnan kehittämiseen, mutta lisää työtä tarvitaan erityisesti lähestymistavan käytännön toteutuksen edistämiseksi. Lisäksi keskustelua tarvitaan nexuksen olennaisista vaikutuksista eli siitä, miten se mahdollisesti vaikuttaa hallitseviin ajattelu- ja menettelytapoihin veden ja muiden nexus-luonnonvarojen hallinnassa.

Avainsanat vesi-ruoka-energia-nexus, vesivarojen hallinta, luonnonvarat

Acknowledgements

This thesis was carried out in the Water and Development Research Group at the Aalto University. The study was funded by Maa- ja vesitekniikan tuki ry and Academy of Finland - funded NexusAsia project (269901).

I would like to express my gratitude to everyone who has helped me along this journey. I would especially like to thank my ever supportive instructor Marko Keskinen for his guidance and enthusiasm during the entire process and my supervisor Professor Olli Varis for his insightful comments and interesting conversations.

I also want to thank all the members of the Water and Development Research Group for their kindness, encouragement and valuable advice. Moreover, thank you to everyone in the water laboratory of Aalto University.

I am grateful to all my friends and family who have always been supporting me and pushed me when needed. My warmest thank you for your love and understanding.

Espoo, May 25th 2015

Hanna-Mari Juvonen

Contents

1 Introduction

Growing population, changing consumption patterns and the following ever-increasing demand for food, feed and energy are stressing the natural resources and causing resource scarcity. Climate change adds to these pressures, which might endanger some ecosystem services that are important for supporting societies (Flammini et al. 2014).

Water as such is an abundant resource, but because of the uneven spatial and temporal distribution it is also indisputably scarce and can provoke tensions between different uses and users (Pahl-Wostl et al. 2010). Also, humans are increasingly altering the water flows of the planet (Rockström et al. 2009). The notions of planetary boundaries and safe operating space for humanity have provoked a call for new and adaptive governance and management approaches to replace the old sectoral ones (Rockström et al. 2009). The global freshwater use is one of these boundaries. The planetary boundaries framework suggests a goal for steering the development, but it does not prescribe the political choices needed to achieve the goal and thus new approaches are necessary (Steffen et al. 2015).

The nexus of water, energy and food (the WEF nexus) is the most recent buzzword especially in water resources management and governance (Warner et al. 2014). The WEF nexus describes the interconnections between water, energy and food and by taking into account these linkages aims to improve water, energy and food securities. Even though it includes three sectors and tries to integrate their management, it is often presented as water centred (see e.g. Hoff 2011; Asian Development Bank (ADB) 2013). The nexus approach has been widely discussed, but there is still no consensus about the definition (Allouche et al. 2015). The WEF nexus can be seen as a part of a series of approaches and concepts - from hydraulic mission to IWRM - which aim to improve the current state of water resources management.

Although different sources offer somewhat different image of the water, energy and food nexus, the following description from the European Report on Development 2012 (Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012) nicely sums up the nexus approach as used in this thesis: “Focusing on the WEL nexus is thus an analytical approach to facilitate the

elaboration of solutions that are based on an integrated assessment of the challenges and opportunities in managing water, energy and land."

This thesis studies what new does the WEF nexus approach bring to water resources management, how does it relate to past approaches and how does it correspond to the current issues in different dimensions of water resources management and governance. I argue that the WEF nexus manifests itself diversely in different dimensions and I have recognized three dimensions where nexus can be applied and analysed: paradigms and concepts, governance and policies and assessments and tools. Based on the reflections of the WEF nexus in these dimensions in relation to water resources management, the thesis aims to identify the potential challenges and opportunities in utilising and implementing the nexus approach.

The thesis makes use of a structured analysis of nexus literature, with the key nexus documents providing a starting point for the analysis. The thesis first looks at the selected nexus reports and through a compilation of these provides an interpretation on how they view the WEF nexus. After, the thesis highlights key aspects of the three dimensions of water resources management and governance, moving from paradigm creation to governance issues and then to practical assessment tools. The thesis concludes with a critical analysis of the literature presenting challenges and opportunities of the WEF nexus in different dimensions of water resources management.

2 Water-energy-food nexus

2.1 Why has the WEF nexus approach emerged?

The nexus approach for natural resources governance and management is based on the understanding that different natural resources are highly interlinked. The water-energy-food nexus considers especially the interconnections between water resources and energy and food production. Focus of the nexus varies according to selected sectors: sometimes land substitutes for food and sometimes climate change is added to the nexus. The nexus approach has also been used to study other combinations, for example the interconnections between energy and water (Scott 2011; Siddiqi & Anadon 2011; Olsson 2013).

There are inevitably local scarcities of natural resources and some planetary boundaries such as greenhouse gas concentrations, freshwater availability, land-use change and biodiversity loss are already being reached (Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012). Crossing these critical thresholds may lead to possibly irreversible system changes (Hoff 2011).

Even though the water, energy and food resources are already under significant pressure, the demand is yet projected to grow (World Economic Forum 2011b). Growing population and changing diets result in increasing meat consumption, which in turn requires more grain production (World Economic Forum 2011a). Energy demand is projected to increase 40% by 2030, most of the growth coming from the demand for electricity (Hoff 2011). Water use will increase 30-40% and is estimated to result in a shortfall of 40% between the demand and availability of freshwater by 2030 (World Economic Forum 2011a; World Economic Forum 2011b). By the year 2050 agricultural production is expected to increase 70% while the demand for agricultural land would grow 10% and the demand of water 20% (Hoff 2011).

To achieve this growth of production intensification is needed. Mechanization, fertilization and irrigation are some means of intensification, but they again imply increased demand for energy, fossil phosphorus and blue water. If the growing demands are combined with non-sustainable management, resource base will eventually become degraded (Hoff 2011).

Energy and food production together cause 56% of the greenhouse gases and are thus major drivers of climate change. More frequent and severe extreme events will especially decrease the reliability of water supplies and agricultural productivity, but droughts and floods may also threaten energy production. Climate change mitigation and adaptation policies will set new demands for the nexus resources through for example promoting biofuel production, intensified irrigation, hydropower and water desalination (Hoff 2011).

The interrelatedness of water, energy and food is easy to comprehend: for example water extraction and distribution require energy; energy production requires water; and food prices are highly sensitive to the cost of energy through fertilizer use, irrigation, transport and processing. The challenge lies in the linkages between resource uses and their impacts for other sectors and resources. A typical example of a nexus trade-off is the policy incentive to reduce vehicle emissions, which promotes increased biofuel use, whereas producing those biofuels would consume 20-100% more water than what is used currently worldwide for agriculture (World Economic Forum 2011a). Another example of the interconnected nature of the nexus sectors is a statement from the Department of Energy of the USA that future energy production will be dependent on water availability (World Economic Forum 2011b). Also, where the pressures for water and land are the highest, food self-sufficiency has already declined (Hoff 2011).

The nexus challenge is further driven by general development and consequent pressures on food, water and energy. Particular drivers for demand are for example population growth especially in the developing countries, urbanization, economic development especially in emerging markets and changing lifestyles, diets and consumption patterns. This rapid growth and more resource-intensive consumption patterns especially in emerging economies will intensify global demands for food, water, and energy in the next twenty years. Together with the environmental pressures from climate shifts and extreme weather events this development will drive resource insecurity. Water, energy and land also play important roles in development: they are basic production factors in the economic system and often provide important means of the income for the poor. Hence insufficient investment in infrastructure and skills constrain the access to water, sanitation and energy, limit the productivity of land and thus hinder development (Hoff 2011; World Economic Forum 2011a; World Economic Forum 2011b; Overseas

Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012).

Globalisation has broadened the flows of resources and international trade keeps growing. Through trade local scarcities can be mitigated while resource extraction and production waste are externalized. Therefore also local disturbances and price shocks are more likely to have global effects. Apart from international trade globalisation has also increased the volume of foreign direct investment. Acquiring agricultural land and importantly the water attached to the land, helps investing countries to meet their demand for e.g. food, feed and wood. This might however challenge local people's access to land and water and thus threaten food security and the livelihoods (Hoff 2011).

The nexus approach is habitually accompanied with a security aspect and instead of resource scarcity, water, energy and food securities are being discussed (see e.g. World Economic Forum 2011a; Hoff 2011; Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012). These securities may refer simply to the supplies of the resources or to wider national security issues (Stucki & Sojamo 2012). Securitization of the water-energy-food nexus may for example shift the decision-making to another level and to different actors.

2.2 Three different views on the WEF nexus

A widely accepted definition of the WEF nexus is still missing (Allouche et al. 2015) and there are quite different interpretations about the WEF nexus. Various organisations have written reports about nexus (see e.g. International Energy Agency (IEA) 2012; Bizikova et al. 2013; Food and Agriculture Organization of the United Nations (FAO) 2014) and academia has produced a host of papers with a nexus approach (see e.g. Bazilian et al. 2011; Siddiqi & Anadon 2011; Granit et al. 2012; Ringler et al. 2013). These come from various fields and some express quite strong sectoral viewpoints.

In this thesis, three nexus reports are substantially introduced. These reports are interesting and noteworthy, because they look at the nexus from different angles and present different aspects of it. *The Global Risks report 2011* (World Economic Forum

2011a) has an economic standpoint and it highlights the risks related to the WEF nexus. It comes from an actor outside the field of water and natural resources management and thus the report has a different public too. The Bonn Nexus conference in 2011 was influential by raising awareness about the WEF nexus and the background paper for the conference *"Understanding the Nexus"* (Hoff 2011) has been cited much in the later nexus writings. The third European Report on Development 2011 *"Confronting scarcity: Managing water, energy and land for inclusive and sustainable growth"* (Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012) is another type of report with a more policy oriented standpoint. It has a strong development agenda and it thus differs from the other two reports.

World Economic Forum was the first to open the debate on the water, energy and food nexus by highlighting the nexus as a key risk in their annual *Global Risks report in 2011* (World Economic Forum 2011a). The report suggests that water, food and energy securities are all likely or very likely risks, but also interconnected and driven by same drivers. World Economic Forum also sees climate change closely linked to this nexus of risks – both as a driver for risks and also influenced by the nexus stresses.

World Economic Forum (World Economic Forum 2011a) claims that nexus approach is needed, because risks in water, food and energy security impede economic growth and social stability. Nexus risks have direct and indirect impacts on governments, society and business. Another reasoning for action is the cost of possible damage to water and food sources in case of inaction. The report calls for research, investment, innovations and reforms for example in resource pricing.

World Economic Forum has also published a book called "Water Security – The Water-Food-Energy-Climate Nexus" (World Economic Forum 2011b). The book states that water scarcity could cause for example agricultural losses, resulting in economic, social and geopolitical effects. Therefore sustainable growth models are required to avoid further pressures to water resources. Civil society and business leaders can support green growth for instance through policy dialogue and innovation.

The nexus of food, water, energy and climate change is still present in the World Economic Forum's Global Risks 2015 report (World Economic Forum 2015). Water crises are presented as a likely risk and as the most important risk in terms of impact. Energy price shocks and food crises are also among the mentioned risks.

"Understanding the Nexus" (Hoff 2011), the background paper for the conference "The Water, Energy and Food Security Nexus – Solutions for the Green Economy" held in Bonn 16-18.11.2011, is one of the first and the most influential papers about the WEF nexus. The Bonn conference was organized in preparation and contribution for the 2012 Rio+20 United Nations Conference on Sustainable Development, in order to promote water, energy and food security and green economy and growth in the Rio+20 process.

The report introduces both current development and projected future pressures on water, energy and food. It shortly describes the three sectors and quite extensively looks at the interactions between the sectors. It also pays attention to the international and geopolitical aspects of water, energy and food and their interdependencies. It calls for more nexus research by listing some knowledge gaps in the nexus, especially highlighting insufficient nexus data. The report suggests that applying the nexus approach could for example help to increase resource productivity, guide the path to green growth, maintain productive ecosystems and advance poverty alleviation.

European Union published in 2012 the third European Report on Development with a title *"Confronting scarcity: Managing water, energy and land for inclusive and sustainable growth"* (Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012). The focus of the report is in four aspects: natural resources management through the WEL (water, energy and land) nexus, analysing the roles and interactions of the public and the private sectors, inclusive and sustainable growth and the following policy implications for the EU and other actors.

As the name suggests, the report is focused on development and particularly on developing country contexts. The report pays special attention to the poorest and analyses how the changes in the WEL nexus affect them. It highlights steering institutions, policies and management and presents the roles of public sector, private

sector and the EU. The aim is to pursue inclusive and sustainable growth, especially in the poorest developing countries, through a better management of the WEL nexus.

World Economic Forum, the background paper for the Bonn conference 2011 and the third European Report on Development all present their reasoning for adopting the nexus approach and some implications for future work. Appendix 1 presents author's interpretation on the notions of the WEF nexus as seen in the selected documents.

3 Approach and analytical frame for examining the WEF nexus

While connecting water, energy and food sectors, the WEF nexus is still quite water centred (see e.g. Hoff 2011; Asian Development Bank (ADB) 2013) and it is being strongly promoted by the water field (see e.g. The Global Water System Project (GWSP) 2014). Accordingly, this thesis has its focus on the WEF nexus in relation to water resources management.

As depicted in the previous chapter, the WEF nexus is a broad, flexible and still vaguely defined concept. It can be applied in different fields, spatial scales and levels of water and other related natural resources management and it can serve multiple purposes. Therefore it is significant to analyse the WEF nexus from various perspectives.

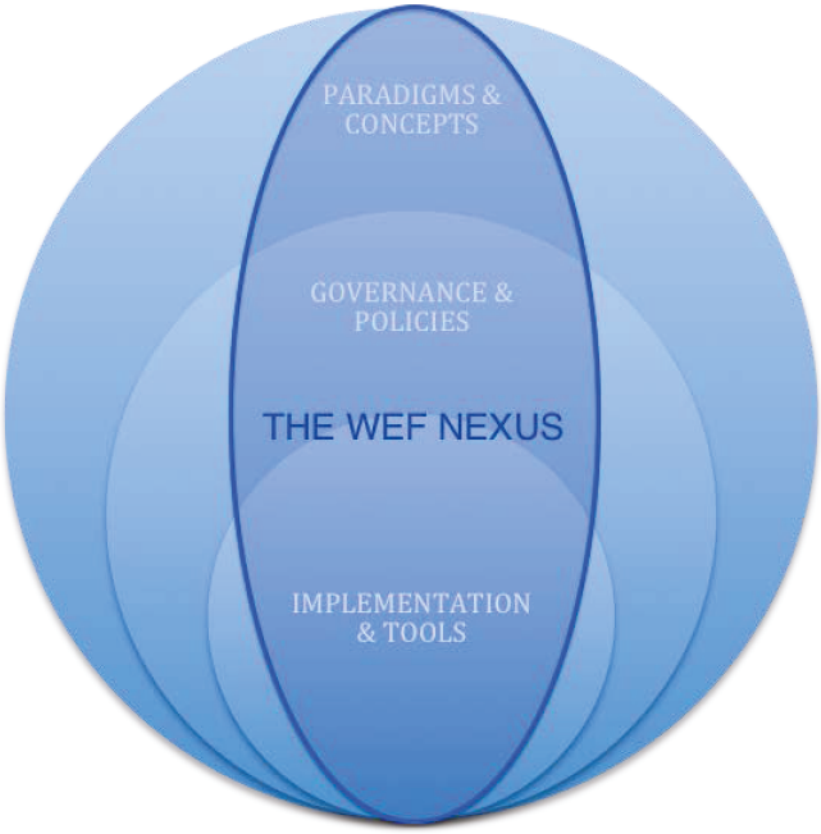
To study the key elements and issues in water resources management, I have divided the governance and management of water resources in three nested dimensions:

- Paradigms and concepts
- Governance and policies
- Assessments and tools

Thus, distinct characteristics of water and its management can be introduced, while gaining an understanding of the whole extent. Each dimension offers a different lens through which to reflect the WEF nexus in relation to water resources management. Studying how the WEF nexus manifests itself in these dimensions forms the analytical framework of the thesis.

Paradigms and concepts is the first, overarching dimension, which affects all the inner dimensions. Underlying values form basis for all ideas and actions, whereas paradigms guide work in a more apparent manner. The second dimension, *governance and policies*, reflects the values and thoughts set by the first dimension and it encompasses for example political realm, institutions, use of power, decision-making and laws for the management of water. The third and the innermost dimension, *assessments and tools*, takes the ideas of the former dimensions into practice. It is the dimension where for example data is produced and applied, models are constructed and assessments are conducted.

Picture 1 illustrates how the WEF nexus extends over the three nested dimensions.



Picture 1 The WEF nexus in three dimensions of water resources management

4 The WEF nexus in three dimensions

4.1 Paradigms and concepts

Research processes, governance, policies and management are all affected by not only paradigms but also by cognition and values (Räsänen 2014). Values of an individual or of a community dictate their ethics and thus their actions, whereas cognition is the process through which people interpret the world around them. Values might be unconscious, but they act as a base for all actions and ideas and have an important impact also on the formation of paradigms.

According to Kuhn (1996) paradigms are accepted models or patterns that have been proved to offer more successful solutions to certain problems than their competitors. However, for a paradigm to take effect, a mere subject matter is not enough, but a group of practitioners or a scientific community is needed. Paradigm is what these people share and what promotes the consensus among them and it is passed on to the students and future professionals through scientific education and literature. Moreover, paradigms are further studied and developed by the scientific community. No rules or standard explanation are needed for a paradigm to exist and even to guide research.

If work is based on a predominant paradigm, which does not fit the problem, complications will follow. Sometimes paradigms may direct the focus on less essential issues, which nevertheless fit the paradigm. Therefore the applied paradigm should be chosen based on the problem, not the other way around (Varis 1999; Räsänen 2014).

4.1.1 Models and best practices

Water governance has been and still is influenced by changing institutional, technological and organizational paradigms and panaceas that guide the management of water. Within paradigms and panaceas, models and best practices have been generated (Gupta et al. 2013b). If paradigms offer frames where to work, different concepts like panaceas, models and best practices then translate the ideas of the paradigms into practice. All these concepts should be understood as social and political constructs as they have been formed by networks and institutions (Molle 2008).

Models and best practices are concepts that are promoted as measures that would be the most effective in delivering a certain result (Lebel et al. 2013), because they have been

found successful and using them is perceived safe. They are based on experience and have been approved by experts and powerful institutions (Molle 2008). In their simplicity models and best practices are appealing to policy makers and donor agencies (Meinzen-Dick 2007).

Because models and best practices are created by decontextualizing experiences, applying them in different settings without considering the societal and cultural context and the necessary conditions may produce diverse outcomes (Meinzen-Dick 2007; Molle 2008; Molle et al. 2008; Gupta et al. 2013b). Considering this, it is obvious that adopting models and best practices requires strong, for example political motives (Molle 2008).

The spreading of concepts such as models and best practices can be described using the snowballing effect (Molle 2008). It is a process through which a concept gains traction and establishes consensus around an idea. Just as with paradigms, for a concept to gain momentum, enough actors are needed to utilise it professionally and for example circulate it in academic literature. These actors support concepts by forming informal groups - epistemic communities or policy networks, which may involve academics, decision makers and other experts. The groups have recognized expertise and competence and they share a common style of thinking and work toward common goals (Haas 1992; Cohen 2011). There are also other significant organisations such as development agencies and particularly international development banks, above all the World Bank, that are influential in promoting new concepts. These institutions play significant roles in "growing the snowballs". If the concept does not acquire enough support and produce publications, it may fail to generate the snowball effect and fade away (Molle 2008).

It should be remembered that concepts are always simplified presentations and therefore also attractive. When concepts become sanctioned, they are often being interpreted as the best and they become normative. This easily excludes other suitable options. When the generic models, best practices and policies are then applied in a context where they do not fit, it may lead to a failure. Constantly discussing and challenging the concepts may prevent neutralisation and exclusion of views and to forestall debate closure (Molle 2008).

Mollinga et al. (2007) use term social engineering to describe water management characterized by models, best practices, lessons learnt, toolboxes and blueprints that illustrate the idea of linear models as prescriptions for changing societies or organisations. Unfortunately social engineering does not take into account the characteristics of social organisations and institutions. Institutions consist of relationships and processes that persist over time and changing them is path-dependent. As for changing social organisations, the complex, non-deterministic and stochastic nature of the organisations and the importance of context specificity should be taken into account. Social engineering over-simplifies institutions as things and looks for policy levers to compel through changes. As institutions are essentially context specific, products of their local socio-cultural, political and physical environment, changing them requires an open-ended and non-linear long-term process. The level of uncertainty in the process of change is high and therefore adaptation and learning are important. Present-day engineering and science are not static and simple, but rather dynamic systems encompassing a variety of differing conditions (Ostrom 2005). That's why simple standard measures don't work well but solutions should always be sought based on an analysis of the specific problems and their context (Pahl-Wostl et al. 2010).

4.1.2 Series of paradigms: focus on the fifth paradigm

Allan (2003) has identified five different paradigms from the history of water resources management: pre-modern, hydraulic mission, green reflexive, economic reflexive and political-institutional reflexive.

The first paradigm reflects the needs of pre-modern communities with limited capacities. The following period of industrial modernity expresses the faith in science and engineering and starts the paradigm of hydraulic mission. Industrial modernity is followed by reflexive modernity and the third, green reflexive paradigm manifests the concerns of the green movement about the environmental role of freshwater. The fourth, economic reflexive paradigm stresses the economic value, pricing, markets and privatisation of water (Allan 2003).

The following fifth paradigm reflects the political nature of water allocation and management. It recognises the water needs of agriculture, industry and communities but also the water needs of environmental services. Participation, consultations and inclusive political processes are promoted as means to manage the water resources and

conflicting demands and interests on them. Civil society, government, NGOs and private sector should all be included in the policy making process (Allan 2003).

The contexts where water management takes place are nevertheless diverse. Different settings require different approaches and for example the needs of the developed North and the developing South differ significantly. The semi-arid North has already adopted the first four paradigms and is at least partially practising the fifth. As for the South, most countries are still widely involved in the hydraulic mission. The transition from hydraulic mission to reflexive modernity didn't happen effortlessly, but it took decades and a persistent pressure from activists together with environmental analyses provided by scientists and environmentalists (Allan 2003).

4.1.3 Technical optimality and political decisions

Decision-makers typically claim to base their investment decisions on technical and economic rationality, and to take into account the social and environmental impacts they employ engineering design, cost-benefit-analyses and increasingly environmental impact assessments and strategic impact assessments (Molle 2009). These measures may however have a limited impact, because the results are often open to interpretation or they only produce nonbinding recommendations. In addition, a lack of scrutiny may lead to outcomes that mainly reflect the hopes and expectations of the investors. The same faith in good science and technical optimization, along with participation and negotiation, can also be seen in the principles of IWRM (Molle et al. 2008).

However, when problems are claimed to be technical and to result from insufficient information, also the solutions sought are technical by nature (Pahl-Wostl et al. 2013). This may divert attention away from the possible shortcomings of governance and disguise the political decisions and trade-offs, which are difficult but inevitable (Molle et al. 2008; Pahl-Wostl et al. 2013). The current technical approach is increasingly considered inadequate and there is demand for a new replacing approach that would acknowledge complexity, pluralities, political nature and human dimension of water resources management and governance processes (Mollinga et al. 2007; Pahl-Wostl et al. 2010; Gupta et al. 2013b).

4.1.4 The WEF nexus and paradigms and concepts

While the WEF nexus fits well the fifth paradigm of water resources management, namely political-institutional reflexive (Allan 2003), it is not really a new paradigm itself. The WEF nexus approach does, however, introduce new viewpoints and might thereby challenge the current mind-set and paradigm.

The WEF nexus as an increasingly popular concept can be positioned within a broader postmodern and integrative paradigm reflecting the values of sustainable development. The WEF nexus can be seen as a successor for IWRM, complementing or possibly replacing it as an integrative water governance option. Both share a common background with the ideas of integration and sustainable development and thus the WEF nexus does not bring about radical changes. It does, however, bring new ideas such as those of water, energy and food securities, it carries strong socio-political motivations such as equality in access to resources and it also introduces ideas of economic risks and gains.

The WEF nexus is claimed to acknowledge the political nature of water allocations and it does for example help to visualise the competition between the sectors and results of the use of one resource in other sectors. In the WEF nexus analyses, usually at least the energy and food production and the water field are taken into account. Further participation of other bodies is not self-evident and it is possible that for example the voices of communities or environment are not being heard. Therefore the WEF nexus approach may be more readily suitable for developed countries, whereas developing countries may still be practising their hydraulic mission and might not be ready for the ideas of the fifth paradigm. Nevertheless, developed countries do promote the nexus approach for developing countries.

The ideas of the WEF nexus about taking advantage of synergies and decreasing trade-offs are definitely optimising, but do not reduce the problems to merely technical ones. Still the naïve faith in win-wins and voluntary cooperation familiar from IWRM should be accompanied with an understanding about the complex interconnections and pluralities within the nexus factors and actors. Absolute synergies and Pareto optima are rarely achievable and so to get all the sectors and actors engaged in the WEF nexus, they should all consider the approach beneficial to them.

As a concept the WEF nexus is very simple and broadly defined and because of that it is also attractive to different parties. It does not prescribe exact measures and is not really a blueprint for the management of water, energy and food. That is what could make the WEF nexus a valuable boundary object (Mollinga 2008; Pascale 2009; Cohen 2011) and offer possibilities for multistakeholder governance: the concept is fairly flexible and can be interpreted according to everyone's needs, so a seemingly common goal can be found.

Even though the WEF nexus has gained support and has a group of practitioners around it, it does not yet direct research like a paradigm. However, the nexus as a research approach may guide the research to a certain model and could possibly provoke a paradigm change. The WEF nexus is not yet a sanctioned concept (see Molle 2008) and it would take a lot for the WEF nexus to replace IWRM as the prevailing nirvana concept as IWRM has such a strong support from epistemic communities and influential organisations like the UN and the World Bank. The WEF nexus is still lacking such an official support. At the same time there are no impediments for the WEF nexus sometime reaching the same position that IWRM has now.

4.2 Governance and policies

Governance has been defined as "the exercise of economic, political and administrative authority to manage a country's affairs at all levels. It comprises the mechanisms, processes and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations and mediate their differences" by The United Nations Development Programme (United Nations Development Programme (UNDP) 1997). Governance encompasses both formal and informal institutions that form the rules and practices and also actors and networks that help formulating and implementing policies (Pahl-Wostl et al. 2012).

4.2.1 Governing water

Water governance can be seen as "all social, political and economic organizations and institutions, and their relationships, insofar as these are related to water development and management" and as "the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society" (UNESCO-WWAP 2003).

To complement these definitions of water governance, it should also be defined what kind of water is governed. Different characteristics of surface water, ground water, green water and virtual water have implications for governance and moreover all these waters are connected (Gupta et al. 2013b). For water governance, however, boundaries are necessary. The search for a suitable scale and boundaries for governance can be guided for example by administrative boundaries, hydrological units and by social, biophysical and political aspects (Gupta et al. 2013b). Different groups may see water differently and highlight different framings of water (Gupta & Pahl-Wostl 2013b). These differing views may lead to conflict but also to dialogue between different groups.

Water governance isn't, however, only about governing water. Many of the drivers of water use and abuse come from outside the water sector and therefore water governance and management are also influenced by decisions made in other sectors (Gupta et al. 2013a). Water resources are affected by e.g. agriculture, food shortages and prices, energy security, climate change and climate variability, demography, economy, society and culture, politics, governance and institutions, infrastructure and technology. Moreover, there are calls to internalize for example ecological sustainability, human development, poverty reduction and democratic governance into water field (Mollinga, Meinzen-Dick & Merrey 2007). In addition to acknowledging all these factors in water sector, it would be important to include considerations about water in the decision-making in the other fields too. In other words, water governance is at the same time hidden inside and behind the issues of other sectors and needs to deal with issues from outside the water sector too (Gupta et al. 2013a).

Because of the cross-cutting nature of water, the sectoral perspective to water governance can be questioned and new approaches should be explored. Integrating water into other bodies and concentrating on the linkages with other sectors (i.e. the nexus approach) has been one of the suggestions for an alternative model for governing water (Gupta et al. 2013a).

In addition to the embeddedness illustrated by the linkages to other sectors and issues, water governance is also characterized by different pluralities and complexity. Mollinga et al. (2007) have recognized *three types of plurality* in water governance, management and use. *The first one is that of multiple actors and organisations in water resources*

management. The policentricity provided by different actors and organisations might actually be an asset, because it allows working together to develop water governance and offers redundancy for example in service production. *Multiple institutions related to water constitute a second type of plurality.* Customary law, religious practices, state law or international treaties, for example, may control water rights. Often several institutions coexist and they might even contradict, so the rules-in-use are commonly outcomes of negotiations. *The third type of plurality comes from the multiple functions that water ecosystems provide.* According to their interests, society and different groups attach values to these ecosystem services and give them voice. However, ecosystem services substantial to the livelihoods of the poor and functions supporting environmental health sometimes lack a strong political voice and some functions may even remain unrecognized.

Stakeholder engagement further increases the number and diversity of actors and challenges the coherence in water resources management (Gupta et al. 2013b). Water governance can be seen filled with action situations (Ostrom 2005), which consist of several variables, e.g. participants, positions filled by participants, possible actions and potential outcomes. These variables are affected by exogenous variables, which generate new interactions between participants and produce new outcomes. Still adding to the complexity, action situations often exist linked to other action situations and to their variables.

Oversimplifying these complexities for example by using "engineering analogies" (Mollinga et al. 2007) may hide important issues and produce false certainties. Therefore monitoring the outcomes and further developing the processes may be forgotten or considered unnecessary (Ostrom 2005). To tackle the embeddedness, pluralities and contextuality in water resources management Mollinga et al. (2007) propose 'a strategic action' approach based on ideas of 'problemshed' and 'issue network'. While widely adopted watershed or basin perspective to water management predefines both the spatial and sectoral boundaries regardless of the problem setting, 'problemshed' perspective would instead approach concrete problem with the boundaries left open in space, time and sectorally. Different actors, their relations and interaction in that particular policy issue would then compose a case-specific 'issue network'.

4.2.2 Actors and arenas of water governance

According to Gupta et al. (2013a) global water governance takes place in different arenas. *The water law arena* covers for example agreements, conventions and laws on the use and protection of watercourses. Many past UN-sponsored conferences dealing with water, water targets in the Millenium Development Goals, some work of development banks and aid agencies and today also UN-Water (established in 2003) belong to *water policy arena*, which is characterized by changing values and paradigms. *Hybrid, public-private policy arena* is where state and non-state actors: experts, policy makers and stakeholders can collaborate. Global Water Partnership (GWP) and the World Water Weeks and Forums are examples from the hybrid policy arena. As water is an economic good too, it is also governed by global trade and investment regimes such as World Trade Organization in *water economics arena*. In the *human rights arena* the most notable case has been recognizing the Human Right to Water and Sanitation by UN General Assembly in 2010. These five arenas show how water governance issues have been spread out among different actors and interests and even though UN-Water coordinates the work in the water sector, there is no single actor or arena that could encompass all water governance issues (Gupta et al. 2013a).

The UN has been successful in making guidelines and setting goals and their recommendations have greater power and legitimacy than those from other actors (Dellapenna et al. 2013). However, UN-Water is a light mechanism with limited mandate and resources and thus might lack power and resources to successfully direct the water related activities of the UN. Hybrid bodies bring together for example members from governments, enterprises, water user associations and academic institutions. They can spread awareness, trigger action and facilitate work across different levels of water sector, but they are weak in generating binding agreements. As water governance also includes financial flows, both the lenders and borrowers are important actors in water governance. Loaning institutions have a possibility to control the use of the loans and so affect the development of water governance by setting loan conditionalities (Gupta et al. 2013a).

Although the state led work in water sector hasn't proved very effective, many externalities and potential market failures has held back the involvement of private sector (Mollinga et al. 2007). However, for example water pricing and tradable water rights may offer opportunities for both business and improved water management.

Markets can help solving some small-scale water management problems but are not so suitable for management in the global scale (Dellapenna et al. 2013).

The state still has a central role in water resources governance (Mollinga et al. 2007). One explanation is that states typically have absolute or limited territorial sovereignty over water that runs within their borders (Gupta et al. 2013b). Biermann et al. (2012) highlights the significance of domestic policies by claiming that the shortcomings of international institutions are mostly due to the shortcomings at the national level. In the last few decades, new types of policy instruments and multi-stakeholder governance have complemented government regulation. These instruments often involve non-state actors such as industry and environmentalist groups and are seen more flexible than government regulation. However, they cannot substitute for national and intergovernmental governance and usually require support and supervision from government (Biermann et al. 2012).

Although the subsidiarity principle pushes water management to the lowest possible governance level, the global dimension should not be ignored either (Gupta & Pahl-Wostl 2013b) and there are arguments suggesting that the scope of water governance should be extended from local and basin level to global scale (Gupta, Pahl-Wostl & Zondervan 2013). The universal nature of the problems, global level drivers of water use, climate change, multinational corporations, virtual water trade and the increasing geopolitical significance of water are in favour of a global approach. Also local phenomena may create global problems and direct and indirect impacts of water management may appear on a global scale. A multilevel approach tries to avoid this contradiction by including the global dimension but not defining the right point of intervention (Dellapenna et al. 2013). The selected scale is significant, because it sets for example the context, the number of actors involved and the relationships of power between them (Thiel 2010). These can be altered through the act of scaling, moving up or down from one level to another on a defined scale.

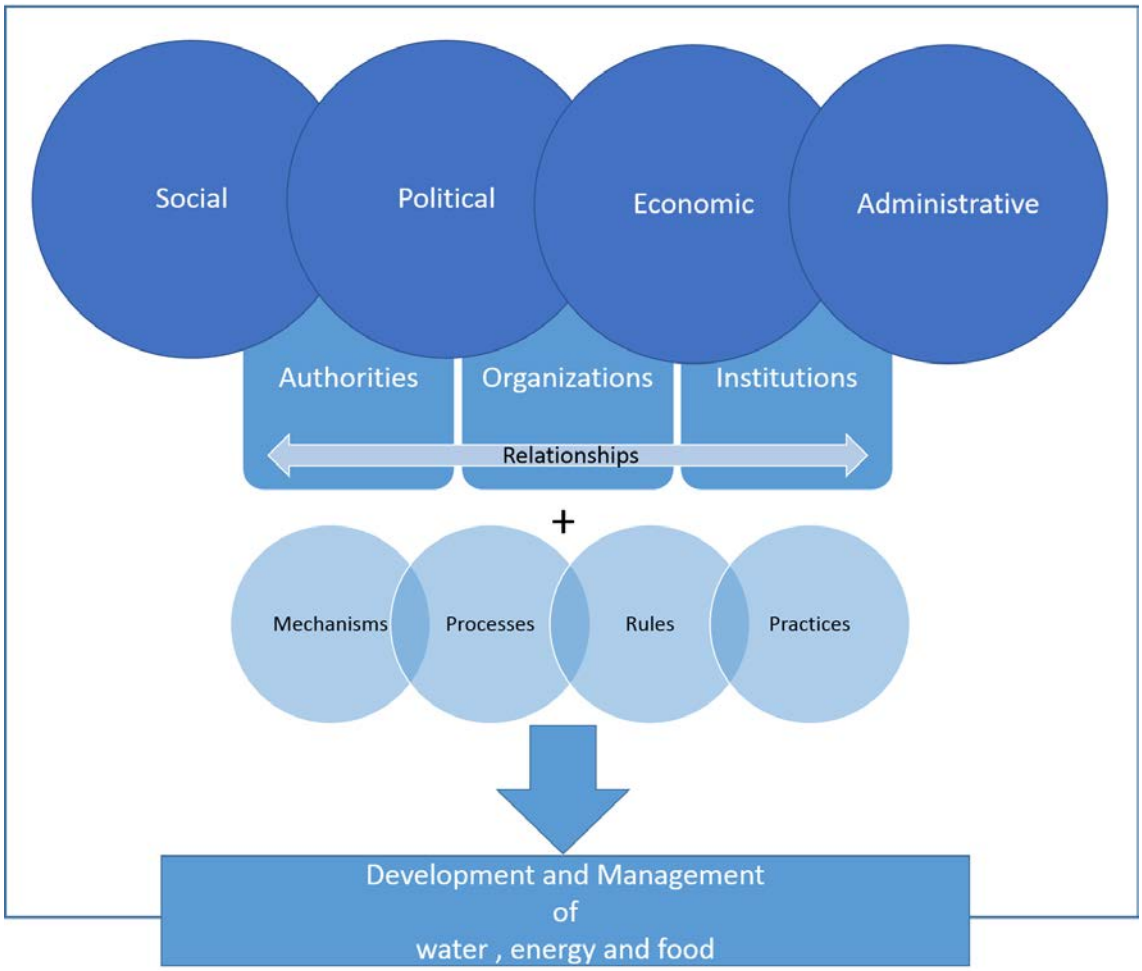
Present global governance institutions are doing well at information generation and sharing, creating forums for discussion, at agenda setting and mobilizing people, but they are weak in terms of generating binding agreements and regulation (Dellapenna et al. 2013; Gupta & Pahl-Wostl 2013a; Gupta et al. 2013a). There is need for global coordination and flexible multiactor networks, but effective water governance also

requires binding decision-making (Gupta & Pahl-Wostl 2013b). Different governance options for water differ not only in the structure of the institution, but also in their level of political feasibility, mandate and resources (Dellapenna et al. 2013).

4.2.3 The WEF nexus and governance and policies

Popularity of a concept does not automatically lead to a successful adoption on a policy level. In order for the WEF nexus approach to be applicable in practice and influential in governance and management of the nexus sectors and resources, there are some issues that should be taken into account and clarified.

For governance purposes, clear definitions are needed. However, applying the definitions of governance to the WEF nexus, nexus governance could be defined as the social, political, economic and administrative authorities, organizations and institutions (formal and informal) and their relationships along with the mechanisms, processes, rules and practices that are related to water, energy and food sectors and their development and management (see picture 2). This definition of the WEF nexus governance conforms well to the fuzziness of the WEF nexus concept in general, but even though it sometimes might offer an asset, the vagueness of the definition poses a challenge for applying the WEF nexus in practice.



Picture 2 Nexus governance defined

When the definition is left open, it is also left open who has the power to define what and who are included in the nexus. The generic definition does not specify for example what waters does the WEF nexus include, what kind of energy production and use is taken into account and what is meant by food. Especially if land is substituted for food, it may cover agriculture, but rules out for example fish. The WEF nexus analysis does not have to be always all-encompassing, but for example even if only surface waters were included in the analysis, it would be necessary to take into account the possible effects on groundwater too.

Moreover, for governance purposes it is necessary to define not only what is governed, but also at which scale. This might pose challenges because the governance of water, energy and food might traditionally take place in different scales and by different organisations.

The WEF nexus approach brings the three sectors closer together, as it illustrates the interconnections between the sectors. By visualising for example the water needs of energy production and the energy needed in water treatment and supply, the nexus approach shows the competition between the sectors. Although the idea is to break down the silos, the WEF nexus approach might also strengthen them by highlighting the different explicitly listed sectors. However, the idea of the nexus is that everything is connected: actions in one sector have effects on other sectors and therefore they should be managed together. This demands cooperation between the sectors and means that no single sector alone can take the responsibility and the ownership of the WEF nexus. The characteristic policentricity and plurality of the WEF nexus offer an asset for example in co-operation and service production, yet there is also negative plurality such as conflicting values, laws and practices and the uncertainty that follows from the complex interactions between the sectors and the resources.

Unlike for example IWRM, the WEF nexus always includes many sectors and even in the water sector alone, there are many relevant actors to apply the nexus approach on different arenas and levels of water governance. While the WEF nexus might not have much to offer in water law and human right arenas, it could possibly take root in water policy arena, it is already entering the hybrid arena and it might have some relevance in economic arena as well. If the WEF nexus keeps gaining momentum, it could complement, challenge and even partly replace IWRM in the water policy arena. Hybrid bodies can support this development by spreading the word and the ideas of the nexus approach and by facilitating the adoption of the WEF nexus. In order to achieve the necessary power and legitimacy for the concept, the WEF nexus would need the support from the UN. For private sector and markets the WEF nexus could potentially offer some business opportunities. The nexus approach could make competing water needs more visible and bring out possibilities to direct water for higher profit uses for example by applying tradable water rights.

As is the case with global governance institutions in general, water governance actors have been successful in producing and sharing information about the WEF nexus, but have not succeeded in creating clear targets and binding agreements. Although the state might not be the most central level for spreading and promoting the WEF nexus, the state and the government are major actors in all water, energy and food sectors. International goals and treaties are often agreed on at a country level and central

government can then enforce the resolutions, such as adopting the WEF nexus approach, at local levels. Moreover, if the government and the relevant ministries are not committed, it is less likely that something like the WEF nexus approach could be successfully adopted at a local level.

It is claimed that the water resources management and governance should have a global perspective without forgetting the local circumstances, and the same applies to the WEF nexus. As an approach the WEF nexus benefits from a broad, even a global view that helps generating an overall picture of the resources, their demand and interconnections, but to apply the WEF nexus as a practical tool, a local perspective and smaller scale are more suitable.

4.3 Assessments and tools

In addition to a more policy oriented approach to the WEF nexus (see e.g. Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012), there are also different views focusing more on the technical applications of the nexus (see e.g. Karlberg et al. 2015). The WEF nexus can be assessed thorough different qualitative and quantitative methodologies such as questionnaires and modelling (The UNECE Secretariat et al. 2013) and these nexus assessments could complement more commonly used environmental assessment methods such as environmental impact assessment (EIA), Strategic Environmental Assessment (SEA) and Integrated Environmental Assessment (IEA). The nexus approach can offer new opportunities for better management of these interlinked resources by revealing trade-offs and synergies and thus provide support for decision-making in and among the WEF nexus sectors if proper data and tools are available.

4.3.1 Nexus data and indicators

To help monitoring the WEF nexus related issues and to help in planning and management of the nexus better data, especially earth observations are needed. This information could be data from experiments and satellites and estimates from models of for example precipitation and crop productivity (GWSP International Project Office 2013).

Data is also needed for development purposes, because to pursue development, targets are necessary. Then setting quantitative targets and monitoring progress towards them, as well as assessing responses to adoption of new approaches and policies require quantitative data. In the case of the WEF nexus, in addition to producing the data to monitor progress, also transparency and trust are needed to enable the flow of information among the nexus sectors and users of the resources. Sharing the data could be especially advantageous for managing the WEF nexus in transboundary contexts (GWSP International Project Office 2013; Lawford et al. 2013; Ringler et al. 2013).

Quantitative data about the WEF nexus resources is also an important input for different WEF nexus assessments. FAO's nexus assessment (Flammini et al. 2014) lists a set of energy and water sustainability and food security related indicators and data to build the indicators that are needed in the assessment. These indicators include for example the change in water used per bioenergy produced, energy produced by hydropower per area of reservoirs and energy consumed per amount of crop produced. Also UNECE (The Royal Institute of Technology (KTH) & The UNECE Secretariat 2014) has listed several basin and national indicators for their nexus assessment. Indicators include water withdrawals, water stress, GDP contribution by sector, energy indicators and other specific data about for example deforestation and hydropower.

4.3.2 Assessment methods

FAO's (Flammini et al. 2014) nexus assessment approach combines quantitative and qualitative methods to first carry out an analysis of nexus context status, then to further analyse different scenarios and visions by applying problem-specific tools and finally to evaluate the performance and impacts of different technical and policy interventions on the given context.

The assessment is a flexible instrument that can be modified to fit the context; the focus should be on the most relevant nexus interactions and the relevant indicators should be prioritised. The type and amount of indicators can be selected according to the focus and other relevant aspects, such as climate change, can be added to the assessment as well. If generating context specific information is not possible, the assessment can be performed using existing data and indicators available from projects or international datasets (Flammini et al. 2014).

UNECE has proposed an assessment on the water-food-energy-ecosystems nexus, which uses a diagnostic framework consisting of four phases. First it creates a description of the overall setting in the basin by analysing the importance of different sectors, the institutional and governance set-up and the biophysical status of the basin among others. Then it analyses the nexus components of the basin using descriptive assessment and indicators. Next step is an analysis of possible benefits of the nexus approach in the basin considering different uses. Last phase is a cooperative analysis about the solutions and next steps for the basin. Necessary information is collected from public databases and using questionnaires and other participatory processes (The UNECE Secretariat et al. 2013).

Other tools for assessing the WEF nexus include for example WEAP (Water Evaluation and Planning) and LEAP (Long Range Energy Alternatives System Planning) models by the Stockholm Environment Institute (SEI) and CLEW (the Climate, Land, Energy and Water) modelling framework (see e.g. Bazilian et al. 2011; Hermann 2012; The UNECE Secretariat et al. 2013). WEAP and LEAP has been applied together with GIS-based models of land-use to offer quantitative information about water resources and food and power production (Jägerskog et al. 2013). The CLEW approach tries to form a framework that interlinks climate, land use, energy and water and their use and to provide tools for resource planning and decision-making (Hermann 2012).

4.3.3 The WEF nexus and assessments and tools

As has been shown to be the case with IWRM (Rahaman & Varis 2005), failure to describe the practical operational steps of a concept hinders its actual implementation. There is a risk that the WEF nexus will face the same challenges as IWRM and that the approach will be adopted but that its implementation does not produce the desired outcomes.

Despite the recent popularity of the WEF nexus concept, there are still few examples of results on a practical level. The adoption of an approach and implementation of policies are more appealing if some direct benefits can be expected through the results. Nexus assessments do promise to reveal trade-offs and synergies in the nexus and thus assist better decision-making and management of the WEF nexus resources. This may lead to even economic benefits. Nexus assessments however require effort: financial and

human resources. Accordingly, it should be agreed, how first the work and then the resulting benefits are divided between different sectors and actors.

The effective use of nexus tools and assessments demands good data. Even though existing data sets can be used, there is also need for new and up to date good quality earth observations about the nexus resources. Data should be produced especially for developing countries, where it might not be readily available.

When conducting nexus assessments, it should be remembered that modelling the complex interactions and non-linear developments of the nexus is difficult. Human behaviour may change demands for resources even rapidly and crossing critical tipping points may permanently change the responses from the environment. Moreover, even if economic valuation of the nexus resources and related ecosystem services may result useful in managing the nexus, it should not overrule the other values associated with the resources.

The WEF nexus assessments should always be applied with caution and considering the specific characteristics of the basin and the case in hand. Indicators should be selected to fit the context but it should also be remembered that the WEF nexus might not be relevant approach in all contexts. It does not necessarily mean that the nexus approach should be abandoned, but assessment might also reveal not a full but a partial nexus in some contexts.

5 Discussion

Managing the nexus of interconnected resources

It is the complexity of the interconnections between different natural resources and between local and global processes of resource use that make the nexus approach necessary. The nexus sectors should not be managed in isolation, but seen as parts of an integrated system and addressed in tandem. In order to avoid negative impacts of the interlinkages, it is crucial to take into account the cross-sectoral effects of sectoral policies - as the solutions to one problem can worsen another - and thus coordination between policies on water, energy and land becomes a necessity (Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012, World Economic Forum 2011b).

So managing nexus is actually managing the linkages between the resources with multiple goals on mind (Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012). The potential of the nexus approach lies in analysing demand between resources and resource scarcity and so discovering synergies and opportunities for sustainable intensification or even substitutions between resources (e.g. reallocating resource intensive production to more suitable location) (Hoff 2011). At the same time trade-offs and externalities, such as improving water security at the cost of energy security or increasing land productivity through irrigation, causing additional blue water requirements and thus increasing energy intensity when compared to rainfed agriculture, can be recognized and reduced.

Pluralities and complexity in water resources management

Water has several dimensions from global to local and connections to other sectors and thus it requires multi-level governance (Gupta et al. 2013a). Water governance consists of complex institutional settings on different levels: global actors, supranational entities, ministries, public agencies, departments and local actors. There are also informal institutions like professional associations, epistemic communities and civil society groups, which also affect water governance (Dellapenna et al. 2013). Each actor has their own interests; they focus on specific aspects and promote their policies in venues apt for their objectives (Gupta & Pahl-Wostl 2013b). Consequently water governance is fragmented between different actors and arenas and it may lead to silo-thinking when

each one is taking care of their area only. Water governance is lacking a master plan, which would coordinate tasks between different levels and actors and thus enhance synergies and reduce duplications (Schubert 2013; Gupta et al. 2013a).

Nexus is a concept, which is easy to adopt and modify according to one's needs. That enables the use of nexus as a boundary object. Boundary object could be useful in the governance and management of water, which is characterized by pluralities arising from many functions of water and from multiple actors involved (Mollinga et al. 2007). Star and Griesemer introduced the notion of boundary object in 1989 (Cohen 2011). Boundary objects can be devices, people, institutions, organisations or procedures - abstract or concrete and general or specific. They are at the same time plastic and robust, which enables them to adapt to different contexts, uses and standpoints but at the same time to offer a common or shared concept to facilitate dialogue between different worlds. These concepts are characterized by flexibility: people interpret them differently in different social worlds. In spite of diverse meanings, boundary objects are common enough to be recognised by different groups and to be employed in coordination, cooperation and negotiations to pursue common goals. When used in an individual world they are highly structured, but when used jointly in common use they are fairly unstructured (Mollinga 2008; Pascale 2009; Cohen 2011).

Nexus is a concept of the Anthropocene: constructed by people, for the problems of people and caused by the demands of people. Therefore people and their needs should be put at centre of the WEF nexus. Nexus can also be seen to belong to the sphere of post-normal science, where both decision stakes and systems uncertainties are high and problems must be solved using applied science accompanied by professional consultancy and post-normal science (see e.g. Funtowicz & Ravetz 1993).

Searching for the right scale and better fit for the WEF nexus

According to Young (in Mitchell 2003), the influence of an institution depends on its fit, or compatibility with the problem it tries to address. In the case of water governance, one way for trying to enhance the fit has been the adoption of a basin perspective, where new institutions have been introduced following hydrological boundaries (Pahl-Wostl et al. 2012). Also the levels of vertical interplay across spatial levels and horizontal interplay across sectors, which illustrate interactions between institutions, affect the success of resource governance (Mitchell 2003). The WEF nexus encompasses several

sectors, institutions and levels, which makes the interplay challenging. Problems may arise when for the sake of fit institutions operate on different scales and interplay declines (Mitchell 2003).

Another example of improving either fit or interplay at the expense of the other is the distribution of authority and responsibility between higher levels of governance such as national and international institutions and local governance (Mitchell 2003). While higher level of governance offers potential for scale advantage, it lacks the local knowledge and contextual understanding offered by lower levels of governance. Respectively, difference between the context and the nature of problems at the local and international levels is considerable and thus Young (in Mitchell 2003) claims that scaling up or down the lessons learnt from one level is difficult.

Scaling might, however, offer a solution when the management of an issue need to be passed on to another level. Scaling can be used for instance to include desired parties in the WEF nexus or similarly to leave out unwanted parties. In addition to the actors, also environment, resources and issues might be different at local and international levels. As different WEF sectors operate at diverse scales, their compatibility could be improved by searching for a convenient point of intervention and cooperation through scaling.

A case-specific approach

The WEF nexus literature (see e.g. Hoff 2011; Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012) uses a lot of case studies to illustrate the challenges and opportunities for managing and governing the nexus and to present achieved results. These offer good examples of how to apply the WEF nexus, but they are context specific regarding for example climate, production systems, social capital and governance cultures and thus not directly transferrable or scalable. Therefore it should be taken care of that the cases would not become unquestioned best practices that are promoted for all the circumstances without checking whether they fit. What should be analysed first is, what is the WEF nexus like in that particular case and context and whether there are some structural problems that should be resolved in the first place. So case studies are a good way to introduce and

explain the WEF nexus and they can demonstrate possibilities, but they should not be considered as best practices for any circumstances.

Although the WEF nexus defines the sectors involved and the integrative approach for searching possible synergies and eliminating trade-offs, it should be always applied case specifically. Thus a strategic action approach based on ideas of problemshed and issue network (see Mollinga et al. 2007) could complement the nexus approach and help avoiding blueprint solutions, which do not consider sufficiently the specific conditions and characteristics of each case. The suitability of the WEF nexus approach depend on the context and conditions, it might be that in some cases the interconnections of water, energy and food sectors do not have a great relevance or the WEF nexus cannot reveal the most important issues. The analysis of the problemshed and issue network could possibly indicate that the nexus approach may not be suitable in those cases.

The analytical frame reconsidered

In this thesis, the WEF nexus concept was reflected through lenses offered by three different dimensions of water resources management. The first, most outer dimension of paradigms and concepts, places the WEF nexus in the context of changing paradigms and in a series of different concepts that affect the management of water. The second dimension of governance and policies is interesting, because that is where the concepts of the first dimension manifest themselves and are being adopted for the application in the third and most inner dimension of assessments and tools. Each dimension offers a different view on the WEF nexus: they reveal divergent needs and prospects for the concept. This is one way to illustrate the plurality in the nexus, but also to show the need for flexibility. Together these views provide an overall picture of the WEF nexus in relation to water resources management and challenges and opportunities in applying the nexus approach.

The division to these three dimensions was made solely for the purposes of this thesis and it does not aim to describe water resources management generally. It is also possible that the WEF nexus does not always bear relevance in all these dimensions or that the WEF nexus can be comprehensively described and analysed using only one or two dimensions, possibly different than here. Even though in the depiction of this thesis the WEF nexus extends over the three nested dimensions, where the outer dimensions affects the inner ones, the WEF nexus can also be applied the other way around starting

from the most inner dimension of assessments and tools. After the overall nexus status of the basin has been analysed, this information can be passed on for example to the next dimension of governance and policies, where the information can be used to formulate well-informed decisions and policies.

6 Conclusions

It is the current state of the world and rapid developments in population growth and consumption patterns, that have made the water, energy and food resources scarce and created an urgent need for change in the way those resources are managed. The water-energy-food nexus responds to this need by providing a new approach that explicitly brings together water, energy and food sectors. Although the concept has gained popularity especially in the water field, it is less water centred than for example IWRM and it can serve as a boundary object for different sectors. It does not hide the political nature of decision-making but illustrates the interconnections between the nexus resources and their use and thus aims at enhancing transparency. The WEF nexus applies economic reasoning in promoting the cooperation, as reducing trade-offs and utilising synergies is expected to bring about profits. The WEF nexus also introduces the notion of social equality in access to resources. It is a strong socio-political motivator for change and may thus further the adoption of the nexus approach. Lastly the WEF nexus related data and assessment tools offer novel means for informed and more holistic management of water, energy and food resources by for example helping to visualise the complexity and risks and offering justification for decision-making.

Water resources management is characterised by changing paradigms, approaches and concepts. The WEF nexus can be placed within the fifth paradigm of political-institutional reflexive, which has evolved building on the previous paradigms of water resources management. The nexus is yet another integrative approach aiming to enhance the management of water and related natural resources by applying a holistic vision of the interconnected resources. Even though they show much similarity, the WEF nexus can be seen complementing IWRM as the current "nirvana concept" (Molle 2008) in water resources management. The WEF nexus echoes the old thoughts of sustainable development but it also brings new ideas about the ecological, economic and social sustainability.

There are still many challenges in implementing the WEF nexus and achieving the desired outcomes. Many obstacles are familiar from the earlier attempts of integrating the management of water and related resources. The vague definition of the WEF nexus leaves open what is included in the nexus, in what scale it is assessed and how are the boundaries of the nexus drawn. Many actors associated with the WEF nexus work in different spheres, networks, levels and scales. The context may change radically if the

scale is extended from basinwide to countrywide or transboundary scale. Like water resources governance and management, the nexus management is also characterized by pluralities resulting from many functions of the nexus resources and from multiple actors involved. Different institutions, policies and customs should be balanced and consolidated and a common way of working should be found. Also the silos should be broken and the sectors that are now being handled separately should be brought to work together. It is still not clear what would be the proper governance level for the WEF nexus and what kinds of institutional structures and policy instruments are needed.

Notions of the WEF nexus in the three identified dimensions of the water resources management provide an overall picture of the challenges and opportunities in applying the nexus approach. The analysis shows how the WEF nexus can be interpreted diversely and so adopted successfully in all three dimensions. Accordingly, analysing the nexus only in one dimension or from a certain fixed viewpoint would not capture such diversity in the concept. The dimension of paradigms and concepts reveals how the nexus approach does not replace but rather complements the current mind-set and paradigm of water resources management by bringing some new ideas and may guide the research to new direction. However, without official support from actors such as UN and the World Bank it is not likely to replace IWRM as the prevailing nirvana concept. In the dimension of governance and policies the unclear definition of the WEF nexus may hinder the adoption and implementation of the approach, but the flexibility of the concept makes it useful in the complex setting of multiple sectors and actors on different levels and scales. As the nexus concept can be interpreted differently in every case and from different perspectives, it can be shared by different actors as a boundary concept. In the dimension of assessments and tools, the WEF nexus has already been applied but the development of tools and data is likely to reveal new possibilities in nexus assessments.

The currently popular concept of water-energy-food nexus is likely to generate even more discussion in coming years. Developments can be expected in the way the WEF nexus is being assessed, in the data collection and in the tools to apply the nexus data. The WEF nexus approach does hold potential for enhancing the current management of water, energy and food resources but more work is needed especially to assist the practical implementation of the nexus approach.

References

Allan, J.A. 2003, "Integrated water resources management is more a political than a technical challenge", *Developments in Water Science,* vol. 50, no. 0, pp. 9-23.

Allouche, J., Middleton, C. & Gyawali, D. 2015, "Technical Veil, Hidden Politics: Interrogating the Power Linkages behind the Nexus", *Water Alternatives,* vol. 8, no. 1, pp. 610-626.

Asian Development Bank (ADB) 2013, *Thinking About Water Differently: Managing the Water-Food-Energy Nexus*, Asian Development Bank (ADB).

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, P., Mueller, A., Komor, P., Tol, R.S.J. & Yumkella, K.K. 2011, "Considering the energy, water and food nexus: Towards an integrated modelling approach", *Energy Policy,* vol. 39, no. 12, pp. 7896-7906.

Biermann, F., Abbott, K., Andresen, S., Bäckstrand, K., Bernstein, S., Betsill, M.M., Bulkeley, H., Cashore, B., Clapp, J., Folke, C., Gupta, A., Gupta, J., Haas, P.M., Jordan, A., Kanie, N., Kluvánková-Oravská, T., Lebel, L., Liverman, D., Meadowcroft, J., Mitchell, R.B., Newell, P., Oberthür, S., Olsson, L., Pattberg, P., Sánchez-Rodríguez, R., Schroeder, H., Underdal, A., Vieira, S.C., Vogel, C., Young, O.R., Brock, A. & Zondervan, R. 2012, "Transforming governance and institutions for global sustainability: key insights from the Earth System Governance Project", *Current Opinion in Environmental Sustainability,* vol. 4, no. 1, pp. 51-60.

Bizikova, L., Roy, D., Swanson, D., Venema, H.D. & McCandless, M. 2013, *The water-energy-food security Nexus: Towards a practical planning and decision-support framework for landscape investment and risk management,* International Institute for Sustainable Development.

Cohen, A. 2011, *From water to watershed: an analysis of rescaled water governance in Canada*, University of British Columbia.

Dellapenna, J.W., Gupta, J., Li, W. & Schmidt, F. 2013, "Thinking about the Future of Global Water Governance", *Ecology and Society,* vol. 18, no. 3.

Flammini, A., Puri, M., Pluschke, L. & Dubois, O. 2014, *Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the Context of the Sustainable Energy for All Initiative*, Food and Agriculture Organization of the United Nations (FAO), Climate, Energy and Tenure Division (NRC).

Food and Agriculture Organization of the United Nations (FAO) 2014, *The Water-Energy-Food Nexus: A new approach in support of food security and sustainable agriculture*, FAO, Rome.

Funtowicz, S.O. & Ravetz, J.R. 1993, "Science for the post-normal age", *Futures,* vol. 25, no. 7, pp. 739-755.

Granit, J., Jägerskog, A., Lindström, A., Björklund, G., Bullock, A., Löfgren, R., de Gooijer, G. & Pettigrew, S. 2012, "Regional Options for Addressing the Water, Energy and Food Nexus in Central Asia and the Aral Sea Basin", *International Journal of Water Resources Development,* vol. 28, no. 3, pp. 419-432.

Gupta, J. & Pahl-Wostl, C. 2013a, "Editorial on Global Water Governance", *Ecology and Society,* vol. 18, no. 4, pp. 54.

Gupta, J., Akhmouch, A., Cosgrove, W., Hurwitz, Z., Maestu, J. & Ünver, O. 2013a, "Policymakers' Reflections on Water Governance Issues", *Ecology and Society,* vol. 18, no. 1.

Gupta, J. & Pahl-Wostl, C. 2013b, "Global Water Governance in the Context of Global and Multilevel Governance: Its Need, Form, and Challenges", *Ecology and Society,* vol. 18, no. 4.

Gupta, J., Pahl-Wostl, C. & Zondervan, R. 2013b, "'Glocal' water governance: a multi-level challenge in the anthropocene", *Current Opinion in Environmental Sustainability,* vol. 5, no. 6, pp. 573-580.

GWSP International Project Office 2013, *Global Water News No. 14*, Global Water System Project International Project Office, Bonn.

Haas, P.M. 1992, "Introduction: epistemic communities and international policy coordination", *International Organization, 1992, Vol.46(1), pp.1-35,* vol. 46, no. 1, pp. 1-35.

Hermann, S. 2012, "Climate, land, energy and water (CLEW) interlinkages in Burkina Faso: An analysis of agricultural intensification and bioenergy production", *Natural Resources Forum,* vol. 36, no. 4, pp. 245-262.

Hoff, H. 2011, *Understanding the Nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus*, Stockholm Environment Institute, Stockholm.

International Energy Agency (IEA) 2012, *World Energy Outlook 2012*, IEA.

Jägerskog, A., Clausen, T.J., Lexén, K. & Holmgren, T. 2013, *Cooperation for a Water Wise World – Partnerships for Sustainable Development. Report Nr. 32.*, SIWI, Stockholm.

Karlberg, L., Hoff, H., Amsalu, T., Andersson, K., Binnington, T., Flores-López, F., de Bruin, A., Gebrehiwot, S.G., Gedif, B. & zur Heide, F. 2015, "Tackling complexity: Understanding the food-energyenvironment nexus in Ethiopia's Lake Tana sub-basin", *Water Alternatives,* vol. 8, no. 1, pp. 710-734.

Kuhn, T.S. 1996, *The structure of scientific revolutions,* 3rd ed. edn, University of Chicago Press, Chicago, IL.

Lawford, R., Bogardi, J., Marx, S., Jain, S., Wostl, C.P., Knüppe, K., Ringler, C., Lansigan, F. & Meza, F. 2013, "Basin perspectives on the Water–Energy–Food Security Nexus", *Current Opinion in Environmental Sustainability,* vol. 5, no. 6, pp. 607-616.

Lebel, L., Nikitina, E., Pahl-Wostl, C. & Knieper, C. 2013, "Institutional fit and river basin governance: a new approach using multiple composite measures", *Ecology and Society,* vol. 18, no. 1, pp. 1.

Meinzen-Dick, R. 2007, "Beyond panaceas in water institutions", *Proceedings of the National Academy of Sciences,* vol. 104, no. 39, pp. 15200-15205.

Mitchell, R.B. 2003, "Young, OR, The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale", *International Environmental Agreements: Politics, Law and Economics,* vol. 3, no. 2, pp. 191-194.

Molle, F., Mollinga, P.P. & Meinzen-Dick, R. 2008, "Water, politics and development: Introducing water alternatives", *Water Alternatives,* vol. 1, no. 1, pp. 1-6.

Molle, F. 2008, "Nirvana concepts, narratives and policy models: Insights from the water sector", *Water Alternatives, Vol.1(1), pp.131-156,* vol. 1, no. 1, pp. 131-156.

Molle, F. 2009, "Water, politics and river basin governance: repoliticizing approaches to river basin management", *Water International,* vol. 34, no. 1, pp. 62-70.

Mollinga, P.P. 2008, "For a political sociology of water resources management", .

Mollinga, P.P., Meinzen-Dick, R.S. & Merrey, D.J. 2007, "Politics, Plurality and Problemsheds: A Strategic Approach for Reform of Agricultural Water Resources Management", *Development Policy Review,* vol. 25, no. 6, pp. 699-719.

Olsson, G. 2013, "Water, energy and food interactions—Challenges and opportunities", *Frontiers of Environmental Science & Engineering, 2013, Vol.7(5), pp.787-793,* vol. 7, no. 5, pp. 787-793.

Ostrom, E. 2005, *Understanding institutional diversity,* Princeton University Press, Princeton, NJ.

Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute/Deutsches Institut für Entwicklungspolitik (GDI/DIE) 2012, *The 2011/2012 European Report on Development, Confronting Scarcity: Managing Water, Energy and Land for Inclusive and Sustainable Growth*, European Union.

Pahl-Wostl, C., Lebel, L., Knieper, C. & Nikitina, E. 2012, "From applying panaceas to mastering complexity: toward adaptive water governance in river basins", *Environmental Science & Policy,* vol. 23, pp. 24-34.

Pahl-Wostl, C., Holtz, G., Kastens, B. & Knieper, C. 2010, "Analyzing complex water governance regimes: the Management and Transition Framework", *Environmental Science & Policy,* vol. 13, no. 7, pp. 571-581.

Pahl-Wostl, C., Palmer, M. & Richards, K. 2013, "Enhancing water security for the benefits of humans and nature — the role of governance", *Current Opinion in Environmental Sustainability,* vol. 5, no. 6, pp. 676-684.

Pascale, T. 2009, "Revisiting the notion of Boundary Object", *Revue d'anthropologie des connaissances, 2009, Issue 1, p.3,* , no. 1, pp. 3.

Rahaman, M.M. & Varis, O. 2005, "Integrated water resources management: evolution, prospects and future challenges", *Sustainability: Science, Practice, & Policy,* vol. 1, no. 1, pp. 15.

Räsänen, T.A. 2014, *Hydrological changes in the Mekong River Basin : the effects of climate variability and hydropower development,* Aalto University, Espoo.

Ringler, C., Bhaduri, A. & Lawford, R. 2013, "The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency?", *Current Opinion in Environmental Sustainability,* vol. 5, no. 6, pp. 617-624.

Rockström, J., Steffen, W., Noone, K., Persson, Å, Chapin, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van, d.L., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. & Foley, J. 2009, "Planetary Boundaries: Exploring the Safe Operating Space for Humanity", *Ecology and Society,* vol. 14, no. 2.

Schubert, S. 2013, "Comparing Global Coordination Mechanisms on Energy, Environment, and Water", *Ecology and Society,* vol. 18, no. 2, pp. 22.

Scott, C. 2011, "Policy and institutional dimensions of the water-energy nexus", *Energy Policy,* vol. 39, no. 10, pp. 6622-6630.

Siddiqi, A. & Anadon, L.D. 2011, "The water-energy nexus in Middle East and North Africa", *Energy Policy,* vol. 39, no. 8, pp. 4529-4540.

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B. & Sörlin, S.

2015, "Planetary boundaries: Guiding human development on a changing planet", *Science,* vol. 347, no. 6223.

Stucki, V. & Sojamo, S. 2012, "Nouns and numbers of the water–energy–security nexus in Central Asia", *International Journal of Water Resources Development,* vol. 28, no. 3, pp. 399-418.

The Global Water System Project (GWSP) 2014, "Sustainability in the Water-Energy-Food Nexus, Conference Report", The Global Water System Project (GWSP), , 19-20.5.2014.

The Royal Institute of Technology (KTH) & The UNECE Secretariat 2014, *Water-Food-Energy-Ecosystems Nexus: Reconciling Different Uses in Transboundary River Basins UNECE Water Convention*.

The UNECE Secretariat, the Food and Agriculture Organization of the United Nations (FAO), the Stockholm Environment Institute (SEI) & the Stockholm International Water Institute (SIWI) 2013, *A proposed approach to assessing the Water-Food-Energy-Ecosystems Nexus under the UNECE Water Convention (Discussion paper)*.

Thiel, A. 2010, "Constructing a Strategic, National Resource: European Policies and the Up-Scaling of Water Services in the Algarve, Portugal", *Environmental management,* vol. 46, no. 1, pp. 44-59.

UNESCO-WWAP 2003, *The United Nations World Water Development Report: Water for People, Water for Life*, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books.

United Nations Development Programme (UNDP) 1997, *Governance for Sustainable Human Development: A UNDP policy paper*, United Nations Development Programme.

Varis, O. 1999, "Dreams and reality in water resources management: A critical view to leading paradigms", *Global Environmental Change, Part A: Human and Policy Dimensions,* vol. 9, no. 4, pp. 255-259.

Warner, J.F., Wester, P. & Hoogesteger, J. 2014, "Struggling with scales: revisiting the boundaries of river basin management", *Wiley Interdisciplinary Reviews: Water,* vol. 1, no. 5, pp. 469-481.

World Economic Forum 2015, *Global Risks 2015, 10th Edition*, the World Economic Forum, Geneva.

World Economic Forum 2011a, *Global Risks 2011, 6th Edition*, World Economic Forum.

World Economic Forum 2011b, *Water security: the water-food-energy-climate nexus,* Island Press, Washington.

Appendix 1 Notions of the WEF nexus as seen in the selected documents

	THE BONN CONFERENCE 2011 BACKGROUND PAPER	THE THIRD EUROPEAN REPORT ON DEVELOPMENT	WORLD ECONOMIC FORUM
MINDSET	Crises may provide an opportunity to gather different actors and institutions behind a common goal and thus create opportunities for capacity building and social learning.	Reform requires major changes in the way people live, in decision making, in governance etc.	
		The change is deeply political process and it requires strong and vigilant civil society, public leadership, decisive state intervention, mobilizing political will and international coordination.	
INSTITUTIONS & MANAGEMENT	There are institutional disconnect and power imbalances between sectors, for example blue and green water are under different ministries and energy is having stronger voice than water or environment.	The more intensively used water resources are, more tensions and trade-offs arise and the need for management and institutions increases.	Water requires government engagement in its management and reform.
	High level of integration (across sectors, institutions, levels and scales) leads to increasing level of complexity and tensions may arise.	Increased pressures increase the need for good governance generally.	"*There is no overall responsibility, accountability or vision for how to address the related problems of climate change, agricultural stress and water technology.*" (Ban Ki-Moon 2009)
	New institutions (such as inter-ministerial bodies or inter-agency programs) may be needed, but it it's more important to strengthen existing institutions to deal with uncertainties and complexities.	Three types of actors and their roles: Public sector sets the regulatory and legal framework, uses public expenditure and coordinates and facilitates. Private sector can make business models more inclusive and sustainable and invest in sustainable outcomes. The European Union (EU) is a major trade and investment partner and a major donor and can thus support poorer countries through internal policies on production and consumption, through contributions to global governance and by promoting better policy coherence for development.	The idea of coordinated global governance implies that it would be necessary to find the capacity and will to embrace more agile structures enabled by global networks and new forms of collaboration.
	Water, energy and food have become global issues, the relevant scale is no longer national or even river-basin wide. Globalization, growing population and economies have led to more resource competition and to avoid conflict, collaboration and co-management are needed.	Public sector can lead response to the new environmental challenges, set targets for improved resource use efficiency, develop policy to manage scarcities and protect the poorest. It could also take care of coordination and facilitation to ensure more inclusive and responsive forms of engagement with the private sector, civil society, local authorities and regional and global actors and promote inter-ministerial coordination. Public sector should also develop legal and regulatory frameworks that guide private-sector development and private investments. Public expenditure on for example R&D policies, national innovation systems and in infrastructure can correct market failures, improve supply and promote efficiency.	Governments should play a leadership role in setting frameworks for improved water management, but many other stakeholders have also to play a role in delivering solutions. Coalitions are needed, such as public-private-civil alliances.
	If nexus is addressed coherently across all scales, through multi-level governance with differentiated but clearly defined responsibilities of institutions, it may reveal large opportunities.	Strong private sector, governed by regulatory framework, can generate and provide access (for example to energy and water), produce goods and services, identify and seize new opportunities, innovate to realise the growth potential and exploit incentives for example for efficiency gains.	Civil society and business leaders can support governments in the reform of water-food-energy-climate-nexus.
	Agricultural trade creates dependency and may thus increase vulnerability.	What can the European Union do in shaping global governance? EU plays a role for example in UN Panels and organisations, in The Rio+20 discussions and networks like WTO and G20. In those forums EU can support nexus-approach.	Managing water is an important political issue in ensuring sustained economic growth, human security and political stability.
	What should be pursued is integrated policy- and decision-making that account for external costs across sectors, space or time.	There is a need for a push for inclusive land policy to ensure access to land and water for the poorest and the most vulnerable.	In many cases policies to manage food, energy or water are well-designed, but implementation fails or doesn't support sustainable resource use.
	Policy changes are often outpaced by the accelerated development, so institutions need to be flexible, adaptive and enabled to cooperate (with other institutions representing other sectors).	Inclusive and sustainable growth requires participation of all stakeholders, efficient regulation, secure and transparent property rights, proper resource pricing and coordinating activities to steer the market. To transform the economy towards inclusive and sustainable growth, a change is needed also in policies and values.	Because users of the resources are the best "guardians" of sustainable consumption, local actors at the community level should be engaged, empowered and incentivized.
	In a transboundary river basin, also water and land use and energy and food availability are transboundary issues.	It is necessary to establish or reform institutions to achieve an integrated approach towards managing resources.	

	Horizontal and vertical policy coherence, political will, change agents, capacity building and awareness raising are all needed.	Institutional change (from isolated and sectoral to integrated approaches) is needed and it might call for new institutions or organisational structures, coordination and institutional capacity must be enhanced (emphasis must be on governance).	
	Water scarcity, energy security and supply dependence might cause security threats and conflicts (national or geopolitical) but also collaboration (e.g. transboundary, economic).	Water sector reforms have been influenced by IWRM, but they are rarely operationalized. Political reality is that decisions are often made in isolated (not integrating) bodies and are rather serving economic goals.	
DATA, TECHNOLOGY & INNOVATION	There are still many knowledge gaps in the nexus: insufficient and scarce data, the impact of policy frameworks such as EU Common Agricultural Policy on water and energy use in food production, harmonized 'nexus database' or analytical framework to monitor and analyse trade-offs and synergies (for example how availability of one resource can help reducing scarcity of another).	Efficiency of resource use must be improved (for example through technology transfer and national innovation systems).	Technological and financial innovation could help managing the nexus. Research and investment in transformative technologies are needed. Innovations require investment for both their development and implementation.
	A nexus knowledge-base and database indicators and metrics should be developed.		New operational management models and access to information are needed to improve efficiencies.
MARKETS & ECONOMY	Agricultural trade can mitigate local scarcities, but externalizes resource extraction and waste products. Makes disturbances and for example price shocks to affect more broadly.	Increase in large-scale land deals (foreign direct investment) causes social and environmental risks but might introduce new technologies and increase productivity. Clear and transparent contracts and consideration of customary rights are necessary.	In many countries resource prices are kept unnaturally low by government subsidies or other regulation (and this leads to increased demand).
	Foreign direct investment helps investors to meet demand for food, feed and wood but cause many challenges to local people. Among investors are China, India and some Arab countries, most investments take place in developing countries (especially Sub-Saharan Africa).	Subsidy reforms and licensing are examples of new responses to improve resource use efficiency.	Prices wouldn't account for many of the negative externalities (of water, food and energy consumption) even though the pricing would be left to market mechanisms.
	Improving resource use efficiency and productivity can help to "create more with less". *(The green economy approach and green growth)*	Appropriate pricing of natural resources (which addresses market failures and internalises externalities, for example costs of CO2 emissions and 'free' water) can steer investment, consumption patterns and incentivise innovation. However the welfare of the poorest must be taken into account.	Water, food and energy security are important factors that can hinder economic growth and social stability. Continuing "business-as-usual" water management practices risk economic growth, human well-being and national securities.
	Sustainable and inclusive intensification and decoupling of resource use and environmental degradation from GDP or HDI development could lead to "green economy".	The concept of inclusive and sustainable growth (ISG): *"Sustained growth that is consistent with the natural cycles that allow ecosystems to replenish resources, absorb waste, and maintain adequate conditions for life, while at the same time providing everybody the opportunity to participate in and enjoy the benefits of increased wealth for this and future generations."*	Sustainable growth models, that take into account environmental constraints and social and economic development, are needed.
	Investment and reductions in economic distortions and unsound subsidies are needed to gain improvements in resource productivity and resource use efficiency.		Green Growth paradigm.
	Economic instruments such as pricing or payments for resources and ecosystems services (including externalities), water markets and tradeable rights can help to invest in environment and to sustain ecosystem services.		
POOR & VULNERABLE	The nexus approach can support and strengthen ecosystem services and maintain a healthy environment. Provisioning of clean water and energy improves health and productivity and green agriculture can generate more rural jobs. All of these produce benefits to the poorest (services on which the poorest depend most strongly).	The most poor and vulnerable people are often the least equipped to overcome the negative consequences of the changes and shocks to which they are also the most unprotected.	In order not to disadvantage poor consumers, market mechanisms must be managed progressively.
		The poorest should be protected against high resource prices and affordability issues should be addressed.	
		When prices for food and energy rise, the poor suffer.	
		Water security (availability of and access to sufficient quantity and quality) for vulnerable populations is a major development challenge and priority.	
		Resilience against shocks and the well-being of the poorest facing the shocks should be improved (e.g. social protection, Corporate Social Responsibility and inclusive land policy).	