Water International

ISSN: 0250-8060 (Print) 1941-1707 (Online) Journal homepage: http://www.tandfonline.com/loi/rwin20

Sustainability in the water–energy–food nexus

Anik Bhaduri, Claudia Ringler, Ines Dombrowski, Rabi Mohtar & Waltina Scheumann

To cite this article: Anik Bhaduri, Claudia Ringler, Ines Dombrowski, Rabi Mohtar & Waltina Scheumann (2015) Sustainability in the water–energy–food nexus, Water International, 40:5-6, 723-732, DOI: 10.1080/02508060.2015.1096110

To link to this article: http://dx.doi.org/10.1080/02508060.2015.1096110

Water International, 2015
Vol. 40, Nos. 5–6, 723–732, http://dx.doi.org/10.1080/02508060.2015.1096110

EDITORIAL

Sustainability in the water–energy–food nexus

Anik Bhaduri[a]*, Claudia Ringler[b], Ines Dombrowski[c], Rabi Mohtar[d] and Waltina Scheumann[c]

[a]*Sustainable Water Future programme (formerly called Global Water System Project), Griffith University, Australia;* [b]*International Food Policy Research Institute, Washington, DC;* [c]*German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE), Germany;* [d]*Department of Biological and Agricultural Engineering, Texas AM University, College Station, Texas, USA*

Introduction

Today we are more than ever convinced that security in food, energy and water is interwoven with human, economic and environmental sustainability, and that this interplay is strengthening under growing natural resource scarcity and climate change. This recognition suggests that policy making and decision making for sustainability could benefit from a holistic nexus approach that reduces trade-offs and builds synergies across sectors, and thus helps reduce costs and increase benefits for humans and nature, as compared to independent approaches to the management of water, energy and food, without compromising the resource basis on which humanity relies. In the past, research and policy work related to the nexus has looked at the interactions between water and food or water and energy, but given political and institutional realities there has been a reluctance to bring forward a broader systemic perspective to capture the dependencies across multiple sectors and resources. At the same time, the cost to the environment of neglecting these linkages has increased. The players in the nexus approach are public, private and civil society at local and broader human scales.

Recognizing the urgent need to focus on sustainability in the water–energy–food nexus (WEF nexus) together with tools to analyze and approaches to govern the linkages at different scales, the Global Water System Project, the United Nations Environment Programme, the Deutsches Institut für Entwicklungspolitik, the Center for Development Research (ZEF), University of Bonn, and the CGIAR Research Program on Water Land and Ecosystems organized an international conference, Sustainability in the Water-Energy-Food Nexus, in Bonn, Germany, in 2014. The conference addressed sustainability in the WEF nexus as a key research-for-action initiative, and included an international policy consultation process to inform, influence and catalyze action of policy makers, nongovernmental organizations, the private sector, educators and researchers towards a nexus approach that both draws on and supports the environment. The conference brought together available information, identified knowledge and action gaps, shared lessons on viable instruments and approaches, facilitated networks, and contributed to consensus on priorities for appropriate investment and action by different actors and stakeholders for moving towards action on the WEF nexus.

This special issue is an outcome of that conference, and contains significant pieces of work on the WEF nexus that were presented at the conference focusing on relevant tools, solutions and governance at different scales. Together, the articles in this special issue

*Corresponding author. Email: abhaduri@uni-bonn.de

contribute to answering two key questions: How can the WEF nexus be implemented across scales? And how can governance and management practices reduce trade-offs and exploit synergies?

The special issue features 12 articles that are divided into two sections according to the two thematic questions. Articles under the scale and implementation theme discuss challenges, assessment tools and solutions for implementing nexus approaches at different scales and how these scales are linked with one another through synergies and trade-offs. Articles under the governance and management theme address different mechanisms and institutional arrangements that can support a paradigm shift away from disjointed policies. Articles also focus on government initiatives that take into account the complexity of linkages between water, food and energy to maximize positive results and minimize harmful impacts.

This introductory article highlights the articles of this special issue, and discusses how to move forward in nexus research and policy, focusing on the capacity development and knowledge synthesis needed for nexus implementation. In the conclusion, the article reflects on some of the priority actions for the implementation of a sustainable nexus approach.

Nexus implementation at different scales

The nexus concept has gained much attention as water, energy and food developments are increasingly interlinked by joint demand, price developments, technology, and resource constraints. These interdependencies and feedback effects are further influenced by trade, markets and speculation, as seen in the joint price movements of agricultural commodity and energy prices (Ringler, Bhaduri, & Lawford, 2013). In addition to supply-side shocks, for example, as a result of climate extreme events and speculation in commodity futures, environmental constraints are increasingly identified as the underlying reason for price volatility in the energy and food sectors.

Policy debates on the 2007–08 food price crisis identified the trade-off between fuel and food as a key cause underlying food price spikes. Rosegrant (2008), for instance, argued that the conversion of agricultural land into the production of biofuel feed stock put upward pressure on food prices; and various experts suggested that maize-based biofuel development accounted for a significant share of global commodity price increases (see e.g. HLPE, 2013; Mueller, Anderson, & Wallington, 2011).

Mirzabaev et al. (2015) in this special issue provide a review of trade-offs and synergies of bioenergy within the WEF nexus, focusing on developing countries. By applying a broader WEF nexus perspective to the topic of bioenergy, the article identifies multiple possible wins across various nexus components.

Energy and water are also very much interlinked and interdependent as today 90% of global power generation relies on water (UN Water, 2014). Moreover, the International Energy Agency's World Energy Outlook of 2012 estimated that within the next two decades water consumption for energy could increase by 85%, along with higher global water withdrawals, due to the transformation towards higher-efficiency power plants with more advanced cooling systems and the increased production of biofuel (IEA, 2012).

The growing demand for limited water supplies puts increasing pressure on water-intensive energy and food producers to look for alternative approaches, particularly in water-scarce areas with large inter-sectoral competition for water. There are several dimensions of uncertainties and risks related to these global environmental changes that further complicate the nexus challenge and make the interrelationship between the sectors

highly dynamic. The ability to achieve water, energy and food security under climatic change, for instance, depends on the understanding of interconnected risks and vulnerabilities to these resources. Given these dynamics policy tools, incentives and regulations need to stay flexible to be able to adapt to changes, integrating innovative ideas and best practices.

Several articles in the special issue showcase assessment tools that can guide nexus implementation at different scales. Meza et al. (2015) modify the traditional WEF nexus concept to emphasize the flows or influences among its components, allowing a better representation of the dynamic nature of the WFE nexus in response to global change drivers. The article applies this dynamic concept to synthesize the status and future challenges of the nexus in four regions of Chile that are currently under pressure due to climate variability and relative water scarcity and experience strong competition for water from different sectors. The article by Daher and Mohtar (2015) presents a different type of WEF nexus modelling tool for scientists and policy makers to evaluate scenarios and identify sustainable national resource allocation strategies at the country level and includes an application to food security in Qatar, a hyper-arid Persian Gulf country.

Mayor et al. (2015) propose an assessment methodology for nexus implementation at the basin level and apply the tool to a case study of the Duero River basin in Spain to illustrate how it can help us understand trade-offs and synergies, diagnose the level of political coordination needed, and identify existing and potential solutions to improve water, energy and food resource management in the region. Some of the most important issues are the limitations posed by rising energy prices for irrigated agriculture due to modernization, limits to treating water, and the emergence of new energy-related water demands in hydraulic fracturing for oil and gas.

As Mayor et al. find, freshwater is increasingly consumed for oil and gas exploration, often in water-stressed areas. Co-optimization of resources is therefore essential to meet energy demands without depleting remaining freshwater reserves. Graham et al. (2015) take this further, discussing available information on water withdrawals and use by the oil and gas industry in the Permian Basin region of south-eastern New Mexico in the US. The article explores different processes for reuse and recycling of water and the operational and policy changes that would help improve our ability to maximize use of all the available water resources in this arid region.

The human and environmental dimensions are and should be the core of the nexus approach, and address the ecological sustainability on which the well-being of future generations depends. Nexus solutions need to clearly and explicitly identify reduced costs and increased benefits for both humans and nature, compared to single-sector strategies for water, land, energy and food. The areas with the largest rural poverty, malnutrition and food insecurity are also those with the greatest water and land degradation (Vosti & Reardon, 1997). This requires an integrated management approach in the context of agro-ecological systems to preserve ecosystem services for humans and nature, and higher investment in integrated land and water resource improvements in these areas. Partial approaches neglecting cross-effects may underestimate or overestimate the consequences of uncoordinated actions and lead to biased policy implications. Such ecosystem-based management approaches have gained greater importance and relevance in WEF nexus debates recently, given the substantial economic and societal benefits to future generations. Since the enormous benefits (and the benefits forgone) are inherently cross-sectoral, and impact different sectors concurrently, it is important that the current discourse on the WEF nexus considers the importance of ecosystems for meeting the demands of both humans and nature.

Vörösmarty et al. (2010) provide an illustration of how dams which were constructed to enhance water availability, flood protection, hydropower and other services are part of the WEF nexus. First, water use for energy production can affect water supplies for agriculture. Dams also inhibit the flow of nutrients and sediments and impact the water cycle by increasing water residence time, thereby affecting the conditions of various ecosystems and their services. However, dams can work most effectively as part of healthy ecosystems, that is, those that are not degraded and eroded, reducing flash flows and retaining sediments on land. An ecosystem-based management approach would bring the elements of energy, food and water into a single viewpoint, and can help mitigate the trade-offs while generating co-benefits (Hoff, 2011).

Implementation of such an ecosystem-centric nexus approach also puts researchers and water managers in a challenging position to improve research tools that will help understand a systematic framework for the organization of information to study the interaction between the different sectors through different kinds of ecosystem services. Hack (2015) in this special issue addresses the potential functional role of payments for hydrological ecosystem services within the concepts of integrated water resources management and the broader WEF nexus. The article discusses the conceptual advantages of this instrument compared to traditional policy instruments regarding spatial and institutional fit and interplay.

Governance of the nexus

Governing the nexus necessarily involves governing the trade-offs between the different sectors and dealing with the plurality and interactions of policies that are in place. It requires appropriate legal, political and administrative arrangements and decisions on applicable and suitable instruments (economic and otherwise) to mitigate trade-offs and ensure access to high-quality water, food and energy services for all while safeguarding the ecosystems that provide these services. Cross-sectoral governance also needs to respond to growing risks and uncertainties, with a focus on processes of change.

In spite of the strong interconnectedness among water, energy, food and the environment, policy makers have continued to address and formulate policies in silos that do not guarantee simultaneous attainment of food, energy and water security as well as environmental sustainability. For instance, governments often design agricultural policies and subsidy programmes, such as those for fertilizer, without taking into account the complexity of linkages with energy and water, forgoing opportunities to maximize positive results and minimize harmful impacts. Similarly, in several countries energy subsidies are provided to agriculture without considering their implications for groundwater depletion and degradation. Institutional arrangements need to recognize such implications, and formulate and coordinate polices to reduce such externalities. Nexus governance entails active coordination. Gain and Giupponi (2015) in this special issue analyze nexus institutional issues in the context of Bangladesh and suggest policy integration for policy implementation. This is both challenging and costly, as sector-specific actions have to be balanced to optimize rather than maximize. It necessitates the minimization of transaction costs as well as optimization of the functioning of the system as a whole.

The optimal arrangement of nexus governance depends on many criteria so that some decision-making powers are decentralized while others are coordinated, while taking into account the values of different stakeholders and interest groups in a fair and transparent manner. This also means that to create formal governance mechanisms for shared benefits

different modes of nexus governance need to be effectively combined, bringing together the private sector, governments and bureaucratic structures, as well as informal networks. Based on an overview of governance challenges, new research should provide insights into policy instruments and experience in their application at the global, national, regional (basin) and local levels.

Nexus governance requires continuous efforts, as much institutional innovation needs a longer horizon for effective implementation. This also requires political support and constant monitoring of targets to bring about sound, responsible and transparent governance principles that mitigate cross-sectoral competition around resource distribution while addressing both human and environmental concerns towards sustainable development. Halbe et al. (2015) present a methodological framework to analyze sustainability innovations in the WEF nexus and strategies for governing transition processes. The framework used in the article is based upon a participatory model-building approach to analyze intersectoral effects and synergies of innovations in Cyprus.

At a local level, institutional innovation is needed to develop democratic and participatory approaches that address the WEF nexus, while at the national and supranational levels development and implementation of binding environmental targets (e.g. water quality standards, land use distribution) are also needed, along with context-specific pathways for different regions to achieve those targets.

Local-level policy implementation can lead to significantly different outcomes. In India, groundwater is an important source of irrigation water for millions of farmers. In order to prevent excessive extraction of water, policies were framed to control unsustainable groundwater use through intervention in the energy sector, such as through pricing of electricity for groundwater use based on metered usage rather than a flat rate in West Bengal, India. The new policy has reduced groundwater usage significantly. In northern India and Gujarat, electricity feeders for agricultural uses have been separated from feeders for domestic and industrial electricity use, which allowed controlling groundwater over-extraction through control of the electricity provided for groundwater usage (Shah, Bhatt, Shah, & Talati, 2008). To solve nexus governance problems, and particularly where ecosystem services are reaching tipping points, such institutional change can play an important role in producing an efficient outcome and in understanding opportunity costs, as well as externalities.

Interdependence of different sectors at different scales can cause unintended trade-offs or support synergistic activities. Mekonnen et al. (2015) find productivity-enhancing effects of water users' associations in Pakistani Punjab for farmers who rely on groundwater and are thus not in the remit of watercourse water users' associations. The article concludes that improving the management of surface water through functioning watercourse-level institutions can be a viable option for reducing over-utilization of groundwater resources and the pressure it creates on the already strained energy situation in Pakistan.

Sometimes, higher-level policy making can have a significant impact on local realities. Whereas hydropower investments often involve decisions by international donors and national governments to secure energy generation, the construction of dams can have a significant impact on access to water for local stakeholders. Particularly when hydropower development takes place in transboundary river basins, cross-sectoral challenges and policy options are interlinked at different levels. Hensengerth (2015) analyzes the limited influence a water-centred organization has on hydropower development, and addresses the issue of authority and hegemony in the field of international development and hydropower policy, using a case study of the Xayaburi Dam in the Lower Mekong Basin. The article

analyzes the strategies of different government actors to safeguard their interests vis-à-vis the Mekong River Commission, donors and the downstream riparians of Cambodia and Vietnam.

The Xayaburi Dam elevates nexus issues to the transboundary level. The number of dams in transboundary river systems with obvious water, energy and food implications is large. Possibly the most notorious, degraded large transboundary river basin is the Aral Sea basin, where nexus trade-offs and strains continue to exacerbate environmental stresses and nexus opportunities are continually discarded in favour of single-sector and single-country strategies, further degrading the environment. Although hydropower generation consumes little water, apart from evaporation and seepage losses from the reservoir, seasonal differences in water release and use requirements for irrigation and energy production can and have caused conflict in this basin, with significant adverse impacts on the local population and the environment. There is a need for agreements between countries and a code of conduct for donor agencies to protect the water use rights of local stakeholders. Specifically, the construction of the Rogun Dam in Tajikistan to increase upstream energy generation in the Amu Darya Basin creates potential trade-offs with existing downstream irrigation needs, due to the different timing of energy and irrigation-water demands. Bekchanov et al. (2015) in this special issue apply a hydro-economic optimization model to quantify the impacts of dam operations on energy production and irrigation-water availability and suggest how cooperation and benefit-sharing can minimize the risks to downstream users while ensuring benefits to all users. Using a case study of the Euphrates-Tigris Basin, Gürsoy and Kibaroglu (2015) suggest that dilemmas of coordination, mismanagement and governance failures among riparian countries can be overcome if the parties concerned show political willingness, which could be supported through a WEF-nexus lens.

Capacity building for the nexus

There are several challenges and therefore significant efforts needed to build capacity for the adoption of nexus approaches – including policy fixes, such as integrated formulation of policy; technological remedies, such as improving synergies between energy and food value chains; and community-based action, including mobilizing public opinion. Capacity is best strengthened for existing institutions to support addressing WEF nexus objectives through developing coordination mechanisms that allow synergies to develop.

A variety of institutions, including national governments, the private sector, international development partners, and civil society organizations can jointly meet capacity development needs to not only improve the understanding of interdependencies but also generate greater system efficiencies through joint management and operations, and increased potential of joint innovations.

Regarding individual capacity development, it must be noted that individual capacities do not develop in isolation but are embedded within wider institutional arrangements, which adds to the complexity of 'capacities'. Emerging evidence shows that capacity development can be effective from the individual to organizational levels, but can take time to achieve impact (Bruns, Ringler, & Meinzen-Dick, 2005). There is therefore a need for careful cost–benefit assessment of the right strategy to design capacity development for the nexus in terms of its effectiveness and efficiency.

Knowledge synthesis for the sustainable implementation of the nexus

Today's decision makers need to evaluate the potentially adverse impacts of policy decisions taken in silos. Integrated information can play a crucial role for efficient and effective decisions under uncertain conditions. Knowledge developed for the WEF nexus in the form of data services – measurements and observations taken in the field or data derived from remote sensing – can ensure that decision processes are broadly supported, transparent and robust. Relevant data for addressing the issues of the nexus sometimes exist but are often difficult to access (Lawford et al 2013).

One of the major challenges impeding nexus analysis is a lack of synthesis of nexus knowledge. This reveals a lack of communication and organization among the institutions that collect data and the decision makers who use these data. Currently, most data-providing portals are scattered, unconnected, and without coherent data structures or access policies.

There is also a gap between data required by decision makers and data which are easily accessible. To develop comprehensive data-sets, synergies between field and remote-sensing data need to be reaped. The first brings in precise measurements on the spot, while the latter can provide larger spatial coverage. To increase capacities for analyzing such integrative data-sets, the next generation of scientists and practitioners needs to be trained in understanding the interconnectedness among water, energy and food. In practice, management bodies need to think and work across administrative boundaries to implement nexus thinking in management practices. Practical steps towards effective knowledge sharing for the nexus include an active integration of decision makers from the WEF nexus into the design of earth-observation services and the establishment of working groups to develop ideas and approaches to advance mainstreaming of nexus thinking in policy and private-sector decisions. Iterative dialogues and concerted information sharing are needed to effectively develop vulnerability assessments, and to build future scenarios and analyze alternative pathways. Resilience and the sustainable management of water, energy and food resources require comprehensive approaches with stakeholders, as well as cooperation and strategic integration with rural areas (e.g. water allocations between urban dwellers and farming activities) and the surrounding biophysical dynamics (e.g. glaciers, precipitation, runoff, etc., that ultimately affect water and energy security).

Conclusion: priority actions for the implementation of a sustainable nexus approach

The Call to Action (http://wef-conference.gwsp.org/call-to-action.html) issued at the con clusion of the international conference on Sustainability in the Water-Energy-Food Nexus reflects many of the messages brought out in the special-issue articles, including the following three.

Responsible governance of natural resources is the necessary first step for action on the water–energy–food nexus

Policies and governance mechanisms must be developed and deployed at different levels to implement a nexus approach. Doing so will help reduce negative impacts of policies on each individual sector, saving resources, minimizing trade-offs, and enhancing synergies. Sector policies need to become more inclusive and better coordinated among each other and should both safeguard the environment and secure rights and access to natural

resources, in particular for the poor. Governments, the United Nations and other international policy organizations need to strive for adaptive management and cross-sectoral coordination. This includes assessing the environmental and social impacts of policy implementation and developing as well as implementing, monitoring and updating environmental management plans that consider the interlinkages between natural resources. It is important to identify economic incentives to enable a nexus approach, e.g. price reforms to better reflect resource scarcities, and to increase efficiencies, as well as targeted subsidies without negative side effects for other sectors and the environment.

The nexus calls for a broad involvement of stakeholders to work collaboratively towards sustainable development

Innovative research and technologies are essential to support the implementation of a nexus framework by governments and other actors. Responsible governance needs to bring together the different stakeholders around water, energy and food security strategies. These stakeholders need mechanisms that allow them to jointly address trade-offs and identify win-win strategies wherever possible, as well as requirements and mechanisms for the implementation of such strategies. The ongoing development and formulation of the Sustainable Development Goals should consider and recognize the importance of a nexus approach to water, energy and food. Doing so will help promote consistency and complementarity among the Sustainable Development Goals. The goals should reflect nexus interactions that can be monitored at different scales to increase the benefits for both humans and nature.

It is essential to greatly expand financial, institutional, technical and intellectual resources for nexus research and applications

The private and public sectors, international organizations and other research-funding entities need to better ensure that research is demand-driven and invest more in research on the nexus. This includes research on agricultural production, energy generation, water supply and sanitation, improvement of water quality and the status of aquatic ecosystems. This research should be solutions-oriented to facilitate technologies and approaches that support increased land, water and energy efficiency in a more integrated way. Resource-efficient technologies for enhanced sustainability operate differently in diverse biophysical and socioeconomic contexts; thus, important groundwork by and with end users is essential. Development of resource-efficient technologies needs to consider the scarcity of other interlinked resources. The research community and other stakeholders need to develop and apply research methods on the nexus and use tools to better inform decision makers. This involves risk assessments, threat indicators, environmental and social impact assessments, and earth observation. The research community needs to compare nexus and business-as-usual approaches for their costs and benefits. Such analyses can strongly support better informed decision making as well as sustainable business models. Taken collectively, the above guidelines can constitute the centrepiece for sustainability in the water–energy–food nexus.

Acknowledgements

This special issue is one of the main outputs of the international conference, Sustainability in the Water-Energy-Food Nexus. We are grateful to the German Federal Ministry of Education and Research, the United Nations Environment Programme, the Deutsches Institut für Entwicklungspolitik, the Center for Development Research (ZEF), University of Bonn, and the

CGIAR Research Program on Water Land and Ecosystems for the financial support provided to organize this organize conference. We are also thankful to UNEP for additional financial support for editing and publication of this special issue. We also thank James Nickum, editor-in-chief of *Water International*, for his editorial support in producing this special issue.

References

Bekchanov, M., Ringler, C., Bhaduri, A. and Jeuland, M. (2015). How would the Rogun Dam affect water and energy scarcity in Central Asia? *Water International*, 40 (5/6), 856–876. doi:10.1080/02508060.2015.1051788.

Bruns, B., Ringler, C., & Meinzen-Dick, R. (Eds.). (2005). *Water rights reform: Lessons for institutional design*. Washington, DC: IFPRI.

Daher, B. T. and Mohtar, R. H. (2015). Water–energy–food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making. *Water International*, 40 (5/6), 748–771. doi:10.1080/02508060.2015.1074148.

Gain, A. K., Giupponi, C. and Benson, D., (2015). The water–energy–food (WEF) security nexus: the policy perspective of Bangladesh. *Water International*, 40 (5/6), 895–910. doi:10.1080/02508060.2015.1087616.

Hack, J. (2015). Application of payments for hydrological ecosystem services to solve problems of fit and interplay in integrated water resources management. *Water International*, 40 (5/6), 929–948. doi:10.1080/02508060.2015.1096122.

Halbe, J., Pahl-Wostl, C., Lange, M. A. and Velonis, C. (2015). Governance of transitions towards sustainable development – the water–energy–food nexus in Cyprus. *Water International*, 40 (5/6), 877–894. doi:10.1080/02508060.2015.1070328.

Hensengerth, O. (2015). Where is the power? Transnational networks, authority and the dispute over the Xayaburi Dam on the Lower Mekong Mainstream. *Water International*, 40 (5/6), 911–928. doi:10.1080/02508060.2015.1088334.

HLPE. (2013). Biofuels and food security. A report by the high level panel of experts on food security and nutrition of the committee on World Food Security, Rome 2013.

Hoff, H. (2011). Understanding the nexus: Background paper for the Bonn2011 Nexus Conference.

IEA. (2012). *World energy outlook*. Paris: IEA.

Kibaroglu, A. and Gürsoy, S. I. (2015). Water–energy–food nexus in a transboundary context: the Euphrates–Tigris river basin as a case study. *Water International*, 40 (5/6), 824–838. doi:10.1080/02508060.2015.1078577.

Lawford, R., Bogardi, J., Marx, S., Jain, S., Pahl Wostl, C. P., Knüppe, K., … Meza, F. (2013). Basin perspectives on the water–energy–food security nexus. *Current Opinion in Environmental Sustainability*, *5*(6), 607–616. doi:10.1016/j.cosust.2013.11.005

Mayor, B., López-Gunn, E., Villarroya, F. I. and Montero, E. (2015). Application of a water–energy–food nexus framework for the Duero river basin in Spain. *Water International*, 40 (5/6), 791–808. doi:10.1080/02508060.2015.1071512.

Mekonnen, D. K., Channa, H. and Ringler, C. (2015). The impact of water users' associations on the productivity of irrigated agriculture in Pakistani Punjab. *Water International*, 40 (5/6), 733–747. doi:10.1080/02508060.2015.1094617.

Meza, F. J., Vicuna, S., Gironás, J., Poblete, D., Suárez, F. and Oertel, M. (2015). Water–food–energy nexus in Chile: the challenges due to global change in different regional contexts. *Water International*, 40 (5/6), 839–855. doi:10.1080/02508060.2015.1087797.

Mirzabaev, A., Guta, D., Goedecke, J., Gaur, V., Börner, J., Virchow, D., Denich, M. and von Braun, J. (2015). Bioenergy, food security and poverty reduction: trade-offs and synergies along the water–energy–food security nexus. *Water International*, 40 (5/6), 772–790. doi:10.1080/02508060.2015.1048924.

Mueller, S. A., Anderson, J. E., & Wallington, T. J. (2011). Impact of biofuel production and other supply and demand factors on food price increases in 2008. *Biomass and Bioenergy*, *35*(5), 1623–1632. doi:10.1016/j.biombioe.2011.01.030

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*, *5*(6), 617–624. doi:10.1016/j.cosust.2013.11.002

Rosegrant, M. W. (2008). *Biofuels and grain prices: Impacts and policy responses* (p. 4). Washington, DC: International Food Policy Research Institute.

Shah, T., Bhatt, S., Shah, R. K., & Talati, J. (2008). Groundwater governance through electricity supply management: Assessing an innovative intervention in Gujarat, western India. *Agricultural Water Management*, *95*(11), 1233–1242. doi:10.1016/j.agwat.2008.04.006

Sullivan Graham, E. J., Jakle, A. C. and Martin, F. D. (2015). Reuse of oil and gas produced water in south-eastern New Mexico: resource assessment, treatment processes, and policy. *Water International*, 40 (5/6), 809–823. doi:10.1080/02508060.2015.1096126.

UN Water. (2014). *The United Nations world water development report 2014: Water and energy.* Paris, France: UNESCO.

Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., … Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, *467* (7315), 555–561. doi:10.1038/nature09440

Vosti, S., & Reardon, T. (Eds.). (1997). *Sustainability, growth, and poverty alleviation: Policy and agroecological perspectives*. Baltimore: Johns Hopkins University Press.