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Unpacking the Water-Energy-Food Nexus: Tools for Assessment and Cooperation Along a Continuum

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This article argues that, in order to achieve sustainable development goals, there is a need to develop and implement systematic approaches that increase understanding of the Water-Energy-Food (WEF) nexus, both at different scales and across multiple sectors. Applying a WEF nexus analysis at different scales would strengthen collaboration between stakeholders, and would also help to identify measures for cooperative governance and management that support outcomes along multiple value chains within the nexus. It would also help to maintain and restore ecosystem goods and services. This article aims to encourage further work in this area by presenting examples of methods and tools to unpack the nexus along a continuum, ranging from qualitative approaches to more data-driven and quantitative modelling approaches (see Figure 1).

Understanding the links between water, energy and food, from local to global scales

At the same time as the availability of natural resources has decreased, due to growing demand for water, food, energy and other goods and services, understanding has increased about the inherent links between these resources (e.g. Hoff, 2011). Projections show that by 2050 the demand for more nutritious and better-quality foods will almost double (FAO, 2009) and the demand for primary energy will increase by almost 80 per cent (IEA, 2010). Furthermore, it is an on-going challenge to provide a sufficient supply of water and adequate sanitation to the world's population, notwithstanding global progress on sanitation targets. Not only is effective water resources management at different scales central to the functioning of water-dependent value chains,[1] it also supports broader socio-economic-ecological services.

As societies look to meet the growing demand for goods and services, new pressures are mounting to decarbonise the energy production chain and reduce greenhouse gas emissions in all sectors. Global efforts to create jobs, support innovation, and secure livelihoods run parallel to these pressures, and are also linked in the WEF nexus. The World Bank (2013) estimates that about 600 million new jobs will be needed by 2020 just to keep

[1] Value chains in this context relate to the full range of activities that are required to bring a product or service from conception, through the different phases of production, delivery to consumers and disposal after use (Kaplinsky & Morris, 2002).

Photo: Jakob Granit, SEI

the ratio of employment to working-age population constant (World Bank, 2013). These coupled environmental and social challenges in the WEF nexus have now entered the on-going debate on an evolution from the Millennium Development Goals to Sustainable Development Goals in the post-MDG (2015) period. However, more work is needed to unpack the WEF nexus at different scales in order to tackle the multiple and interlinked development challenges. By increasing our understanding of the complex links between water use, energy, and food production, including of sustaining ecosystem services, it may be possible to avoid future supply bottlenecks and to provide equitable access to these services for all people, now and in the future (Granit & Claassen, 2013).

There is a lack of data on water use in the context of WEF nexus value chains at local and regional levels. At the sectoral level, however, there is much information on efficiency measures in agricultural water management, water supply and sanitation, and desalination, although the energy production sector lags behind in assessing the impacts of water withdrawal and use for producing power. In most fuel extraction and refinement processes, assessments of consumptive water use are not systematically accounted for. Patterns of water consumption and abstraction vary greatly between different fuel and power generating technologies, depending on the context (IPCC, 2011). Biofuels are consistently water intensive, and hydropower reservoirs may evaporate large volumes of water depending on location, and in many parts of the world, such as in India, China, the Southeastern United States and France, there are already signs that water constraints are set to add additional costs on the energy sector (IEA, 2012). Energy is also used for water management and service delivery, including water treatment. For example, it requires large amounts of energy to keep conventional water supply and sanitation services operating.

A continuum of assessment tools at different scales

Water, land and energy assets are spatially unevenly distributed, often across political boundaries in all the regions of the world, and all geographic regions have different endowments of natural resources, as well as different political and economic contexts. Hence, in order to allocate these resources to their most productive uses and to maintain life supporting ecosystems, it is necessary to improve our understanding of the availability of (and competing demands for) these resources. Concrete analysis needs to be under-

taken at the appropriate geographic scale, and should include macro-economic forecasts that cover trends in production and consumption from global to local scales. Sound assessment tools can provide the basis to support innovation throughout the WEF value chains, as well as create incentives to strengthen collaboration at macro-regional,[2] national and local levels. Such innovation and incentives can generate regional and global benefits by improving food and energy security, reducing greenhouse gas emissions, and supporting job creation and economic growth in a more resource efficient economy.

The WEF nexus can be assessed using methodologies in a continuum, running from qualitative approaches at the start of the continuum, to more data driven and quantitative modelling approaches further along it. A range of factors can determine which approach is chosen, including the goal of the analysis, the level of capacity and trust between competing stakeholders at different scales, sectoral integration, access to data, and capacity for analysis. If common issues and barriers to cooperation were jointly identified, this could help to build collaboration and trust between multiple countries in a macro-region or between sectors. More in-depth fact finding and detailed assessment could then be developed at a later stage to support common policy approaches and investment.

Governance and management solutions that are adapted to different countries and macro-regions must be context-specific, and can only be identified through collaborative partnerships. WEF security in a given transboundary context could be built within the framework of a macro-region, with ecosystem services and climate conditions acting as constraints. In order to achieve WEF security within a macro-region, it is important for actors to identify market-based transactions that add value. Such transactions can occur bilaterally between countries (e.g. flood protection and hydropower generation), at the regional level (e.g. power and food trade), and at the global level (e.g. mitigating and adapting to climate change through the deployment of renewable energy sources). Water underpins the nexus as an intermediary function in all of these examples.

At the local level, nexus assessments might focus on integrated waste management, energy generation, or reuse in agricultural production, actions which if applied could save water, reduce emissions, recycle nutrients, and increase energy and food security. Such approaches respond to the need to develop sustainable and resilient energy and sanitation systems at the local level.[3]

Methodological examples in the water-energy-food continuum

Index building is an example of an assessment that could be carried out in the initial parts of the WEF continuum. Index building addresses the macro-regional scale using a core set of representative parameters for key sectors, thus identifying in securities within the nexus. The index could be built using well-defined surveys that country representatives can respond to, drawing on national data sets that could be combined with publicly available indicators. Specialists could then carry out an initial analysis to determine which issues are important for country stakeholders to consider. A version of such a methodology is described in the Transboundary Waters Opportunity Analysis (TWO) (Phillips *et al.*, 2008). TWO assesses key development opportunities in the nexus, taking into account qualitative assessments of water resource constraints. By collaboratively exploring the positive gains that can be generated and shared, stakeholders can identify barriers to development as well as preferred development options. For example, this approach has been applied in the Orange-Senque River basin in Southern Africa.[4] It added value because it allowed stakeholders to identify key WEF insecurities and how to mitigate them, or to turn them into development opportunities by using limited water resources more efficiently and in innovative ways. This kind of assessment would be a first step towards

[2] A macro-region in the context of the WEF nexus is defined as a territory spread over two or more countries that are connected to a transboundary freshwater system. Such a territory might experience linked energy and food insecurity because of the connective role of water as an intermediary good traded bilaterally or in regional and global market places.

[3] Sustainable sanitation systems protect and promote human health, minimise environmental degradation and depletion of the resource base, are technically and institutionally appropriate, socially acceptable, and economically viable in the long term (Rosemarin *et al.* 2008).

[4] Case study available at: www.waternet.co.za/SADCRBO/two.html (accessed April 2013).

more quantitative analyses of resource use, as well as assessments of common policy and institutional options for collaboration, thereby helping to build trust between riparian countries in a macro-region.

Tools further along the continuum at the macro- and in-country levels might include linked, sector-specific, data-intensive modelling approaches. An example of this is SEI's work on integrating its Water Evaluation and Planning (WEAP) and Long Range Energy Alternatives System Planning (LEAP) models with GIS-based models of land-use (Purkey, 2012). This approach provides quantitative outputs on water resources, food production, land-use, power production and concurrent environmental impacts, as illustrated by the application of the approach in California. If stakeholders are included in the process of setting up these kinds of tools, as well as in developing scenarios and analysing the outcomes, there is an increased likelihood that the tools will provide relevant information. The WEAP-LEAP integration lends itself to exploring trade-offs between water, land and energy needs for agricultural intensification and food, and biofuels and hydropower production in relation to other sectors, such as tourism and water for industry and domestic use. This kind of quantitative and stakeholder-driven approach can provide sustainability criteria for investments and support national and local planning, as is currently being tested in Lake Tana and the Upper Blue Nile basin in Ethiopia (Hoff & Karlberg, 2013).

Hydro-economic modelling is a further example of a nexus assessment approach, as demonstrated in a pilot study for the Euphrates and Tigris region (Granit & Joyce, 2012). This study was carried out by four countries using only publicly available data and remote sensing, and by assessing the nexus in a macro-regional context beyond the transboundary river basin. Its hypothesis was that marginal benefits can be generated by a cooperative approach to managing and developing water resources in relation to hydropower, irrigated agriculture and ecosystem goods and services. To test the hypothesis, the study designed a basic hydro-economic simulation model. The model assessed the extent to which different efficiency measures could save water in hydropower and irrigated agriculture, and put a monetary value on these savings. Shadow values were used for environmental flows. Alongside in-depth dialogue with stakeholders, the model supported a process to identify opportunities for cooperative governance and management in the nexus at different scales. These opportunities included developing power and agriculture markets, and other benefit sharing mechanisms that could support steps towards regional integration.

The World Bank has spearheaded a modified Strategic Environmental Assessment (SEA) approach to explore regional power planning and water resources management in a multi-country perspective, which has been applied at full-scale in the Nile Equatorial Lakes Region (Granit *et al.*, 2011). The approach takes the form of a pre-investment tool that facilitates broad participation by governments, sector experts and civil society. In the initial stages of the planning process the tool combines standard power planning and water resource modelling with data on the cumulative impacts of environmental, economic and social development programmes. Such an approach supports cooperative infrastructure planning that incorporates sustainable energy production for socio-economic development and environmental management. In this process, social and environmental factors are considered to be equally important as technical and economic factors. The modified SEA supports a macro-region development agenda linked to the East African Community (EAC), and provides information to potential investors from domestic, regional and global markets on major development initiatives.

Poor infrastructure for water and wastewater, water scarcity and limited energy supply all hold back potential for human wellbeing and sustainable economic growth at the local and national level. Releasing this potential is the key driver for exploring linked systems of water use, sanitation services, and energy and food production for sustainable urban development (Rosemarin *et al.*, 2008). Innovation in a range of global markets over a period of several years has demonstrated the value of resource-based and productive sanitation techniques at the local level. These techniques show promising potential for decentralised system solutions that focus on safe resource recovery in sanitation.

Figure 1 shows the different methodologies and tools described in this article along a continuum,

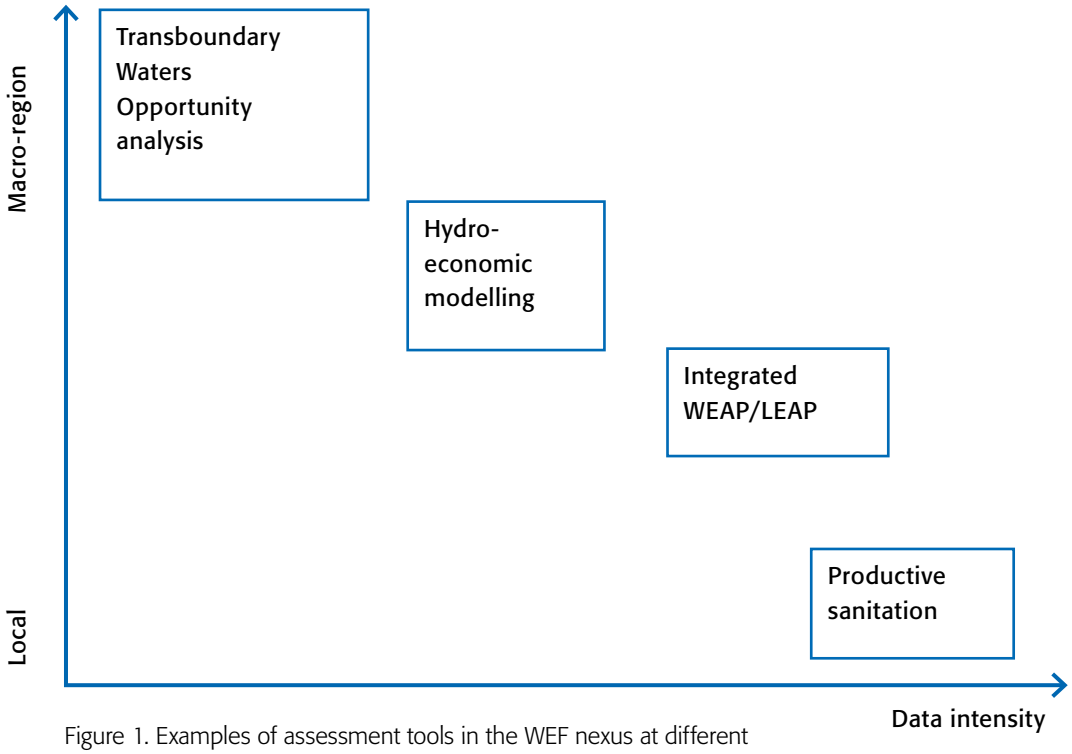

Figure 1. Examples of assessment tools in the WEF nexus at different scales and with different levels of data intensity

ranging from qualitative approaches to more data-driven and quantitative modelling approaches and in the context of the local to macro-region scale. By unpacking the WEF nexus at different scales using different methodologies it is possible to identify measures for cooperative governance and management that support outcomes along multiple value chains within the nexus.

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