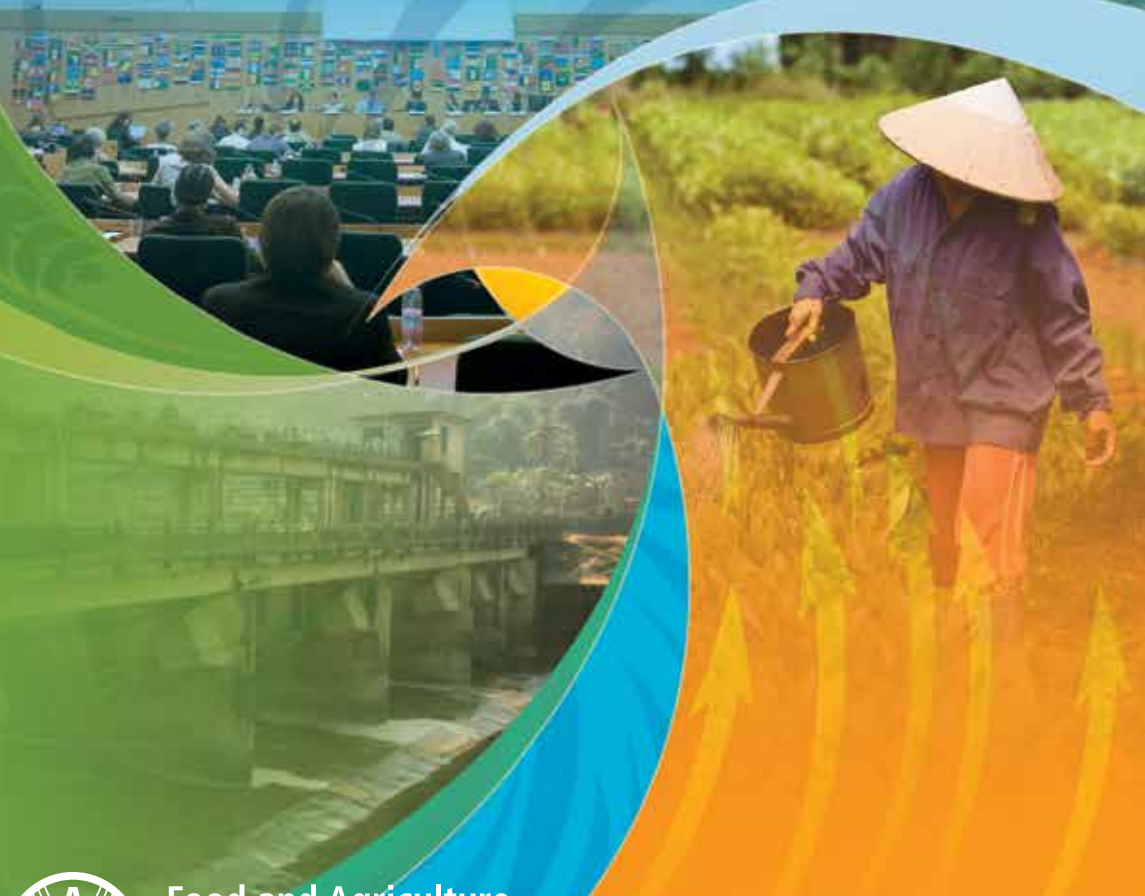
The Water-Energy-Food Nexus

A new approach in support of food security and sustainable agriculture



Food and Agriculture Organization of the United Nations

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Food and Agriculture Organization of the United Nations
Rome, 2014

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This first version was produced in June 2014.

Acknowledgements

This note is the result of an FAO-internal consultative process led by the Land and Water Division (NRL) and the Climate, Energy and Tenure Division (NRC). It has been prepared by Olivier Dubois, Jean-Marc Faurès, Erika Felix, Alessandro Flammini, Jippe Hoogeveen, Lucie Pluschke, Manas Puri and Olçay Ünver. Publishing arrangements and communication strategy were carried out by Nicoletta Forlano. The graphic design and layout was done by James Morgan.

Funding for FAO work on the Water-Energy-Food Nexus was provided in part by the OPEC Fund for International Development (OFID) and the German Federal Ministry of Economic Cooperation and Development (BMZ), which are gratefully acknowledged.

1 The Water-Energy-Food Nexus:

Understanding and managing the complex interactions between water, energy and food

Water, energy and food are essential for human well-being, poverty reduction and sustainable development. Global projections indicate that demand for freshwater, energy and food will increase significantly over the next decades under the pressure of population growth and mobility, economic development, international trade, urbanisation, diversifying diets, cultural and technological changes, and climate change (Hoff 2011). Agriculture accounts for 70 percent of total global freshwater withdrawals, making it the largest user of water. Water is used for agricultural production, forestry and fishery, along the entire agri-food supply chain, and it is used to produce or transport energy in different forms (FAO 2011a). At the same time, the food production and supply chain consumes about 30 percent of total energy consumed globally (FAO 2011b). Energy is required to produce, transport and distribute food as well as to extract, pump, lift, collect, transport and treat water. Cities, industry and other users, too, claim increasingly more water, energy and land resources, and at the same time, face problems of environmental degradation and in some cases, resources scarcity.

This situation is expected to be exacerbated in the near future as 60 percent more food will need to be produced in order to feed the world population in 2050. Global energy consumption is projected to grow by up to 50 percent by 2035 (IEA 2010). Total global water withdrawals for irrigation are projected to increase by 10 percent by 2050 (FAO 2011a).

As demand grows, there is increasing competition for resources between water, energy, agriculture, fisheries, livestock, forestry, mining, transport and other sectors with unpredictable impacts for livelihoods and the environment (FAO 2011c). Large-scale water infrastructure projects, for instance, may have synergetic impacts, producing hydropower and providing water storage for irrigation and urban uses. However, this might happen at the expense of downstream agro-ecological systems and with social implications, such as resettlements. Similarly, growing bioenergy crops in an irrigated agriculture scheme may help improve energy supply and generate employment opportunities, but it may also result in increased competition for land and water resources with impacts on local food security.

The Water-Energy-Food Nexus in the Red River Basin in Vietnam

A series of reservoirs in the upstream reaches of the Red River in northern Vietnam regulate flows and supply much of the electricity needed for Vietnam's modernization and industrialization strategies. The same system is the sole water source for domestic uses and irrigation of almost 750 000 ha of rice-based farming in the Red River delta, which is critical to social stability and food security in Vietnam. Most of the irrigation systems in the delta use pumps, with electricity supplied by the reservoirs, to distribute water to the fields and other users within the irrigation systems.

As water becomes scarce, and competition is growing between the energy and agricultural sectors, there is still a lack of reliable and policy-relevant data and information to guide water allocation choices. Effective cross-sectoral consultation mechanisms are needed to ensure the development of concerted efforts to address this problem, and to make sure that decisions on water release and allocation are taken as part of an integrated, long-term and multi-sectoral strategy.

In this context, the Water-Energy-Food Nexus has emerged as a useful concept to describe and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic and environmental goals. In practical terms, it presents a conceptual approach to better understand and systematically analyse the interactions between the natural environment and human activities, and to work towards a more coordinated management and use of natural resources across sectors and scales. This can help us to identify and manage trade-offs and to build synergies through our responses, allowing for more integrated and cost-effective planning, decision-making, implementation, monitoring and evaluation.

> "The Water-Energy-Food Nexus describes the complex and inter-related nature of our global resources systems"

Nexus interactions are complex and dynamic, and sectoral issues cannot be looked at in isolation from one another. Importantly, they exist within a wider context of transformational processes – or drivers of change – that need to be taken into account. It is important to note that there are different conceptualisations of the Nexus that vary in their scope, objectives and understanding of drivers. Several concepts, frameworks and methodologies have looked at the interlinkages between water, energy and food (Mohtar and Daher 2012; Bizikova *et al.* 2013; ADB 2013; UN-ESCAP 2013), but also land and soil (ERD 2012; Hoff *et al.* 2013), minerals (Andrews-Speed *et al.* 2012), and ecosystems (UNECE 2014; ICIMOD 2012).

> "It is about balancing different resource user goals and interests – while maintaining the integrity of ecosystems"

2 | What is the added-value of a Nexus approach?

A cross-sectoral and dynamic perspective

A Nexus approach helps us to better understand the complex and dynamic interrelationships between water, energy and food, so that we can use and manage our limited resources sustainably. It forces us to think of the impacts a decision in one sector can have not only on that sector, but on others. Anticipating potential trade-offs and synergies, we can then design, appraise and prioritise response options that are viable across different sectors.

A cross-sectoral perspective on groundwater pumping

The introduction of affordable groundwater pumps has transformed irrigated economies and now underpins the food security of countries, such as China, India and Pakistan. However, groundwater pumping has accelerated the depletion of water resources and aquifers. Food production has become increasingly vulnerable to energy prices, often resulting in the farmers' dependency on energy subsidies. At the same time, farmers are left with little choice but to pump water, as services by public irrigation agencies are often poor and unreliable. The solution commonly advocated is to revise tariff and metering systems and to improve the technical efficiency of pumps. Looking at the problem from a Nexus perspective can help us to understand the wider implications for water, energy and food, and broaden the scope of interventions to include water demand management, investment frameworks for public funding for improved surface irrigation, groundwater management, irrigation technologies, agricultural practices, as well as food procurement and trade policies (e.g. Swain and Charnoz 2012). These interventions are likely to have an impact on the drivers and pressures that have led to overpumping in the first place.

Often decisions on how to intervene are made without cross-sectoral coordination, targeting sector-specific optima and, thereby, resulting in risks and uncertainties across sectors and scales. Interventions can substantially alter the conditions under wh ich they were designed. For example, they can indirectly affect societal structures, the state of natural resources or financial flows. In order to ensure the optimal management of trade-offs and the maximization of overall benefits, decision-making processes need to be reflective and take into account the dynamic nature of complex systems.

A cross-sectoral Nexus approach provides an opportunity to engage with stakeholders to do just that. Ideally, this involves a broad range of stakeholders from local to national governments, basin organisations, development banks and agencies, international and regional organisations, research institutes and universities, NGOs, civil society and the private sector. Furthermore, a Nexus approach can encourage intra-organisational collaboration among different technical divisions.

Is the concept of the Water-Energy-Food Nexus just 'the same old wine in new bottles' or does it bring something new to the table?

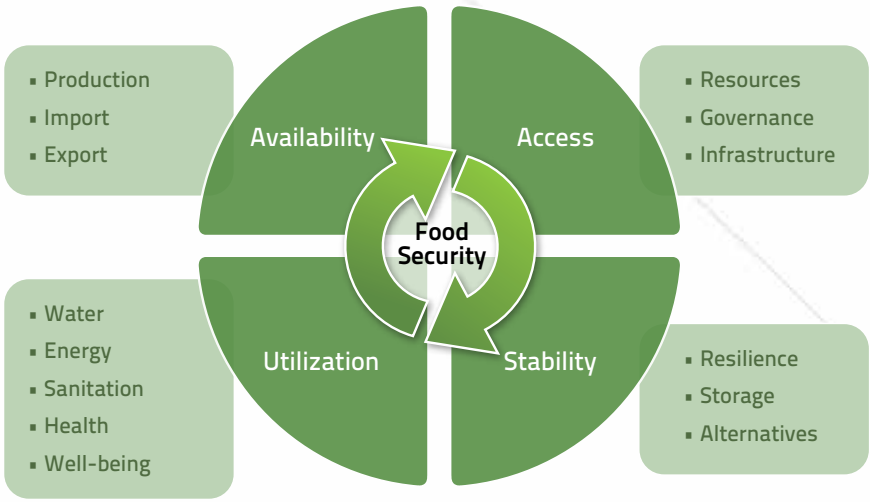
A recurring criticism of the Water-Energy-Food Nexus is that it adds relatively little to already existing integrated approaches to resources management, such as the integrated landscape approach (FAO 2012c) or integrated water resources management (IWRM). For instance, the conceptual framework articulated as IWRM arguably pursues the integrated and coordinated management of water and land as a means of balancing different water uses, while meeting social and ecological needs and promoting economic development. However, by explicitly focusing on water, there is a risk of prioritising water-related development goals over others, thereby reinforcing traditional sectoral approaches. The Nexus approach considers the different dimensions of water, energy and food equally and recognizes the interdependencies of different resource uses to develop sustainably.

3 | The Water-Energy-Food Nexus at FAO

Framing the Water-Energy-Food Nexus within the broader debate on sustainable development

The organisational mandate of achieving food security serves as an entry-point for FAO work on the *Water-Energy-Food Nexus*. FAO defines food security as the state in which 'all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active, healthy life' (FAO 1996). As illustrated in Figure 1, the concept of food security has four dimensions, namely food availability, access, stability of supply, and utilisation.

Figure 1: The Components of Food Security



The *Water-Energy-Food Nexus* is framed within the broader debate on sustainable development and as part of FAO's vision of sustainable food and agriculture to achieve its mandate of eradicating hunger, reducing poverty, and sustainably managing and using natural resources and ecosystems (FAO 2013).

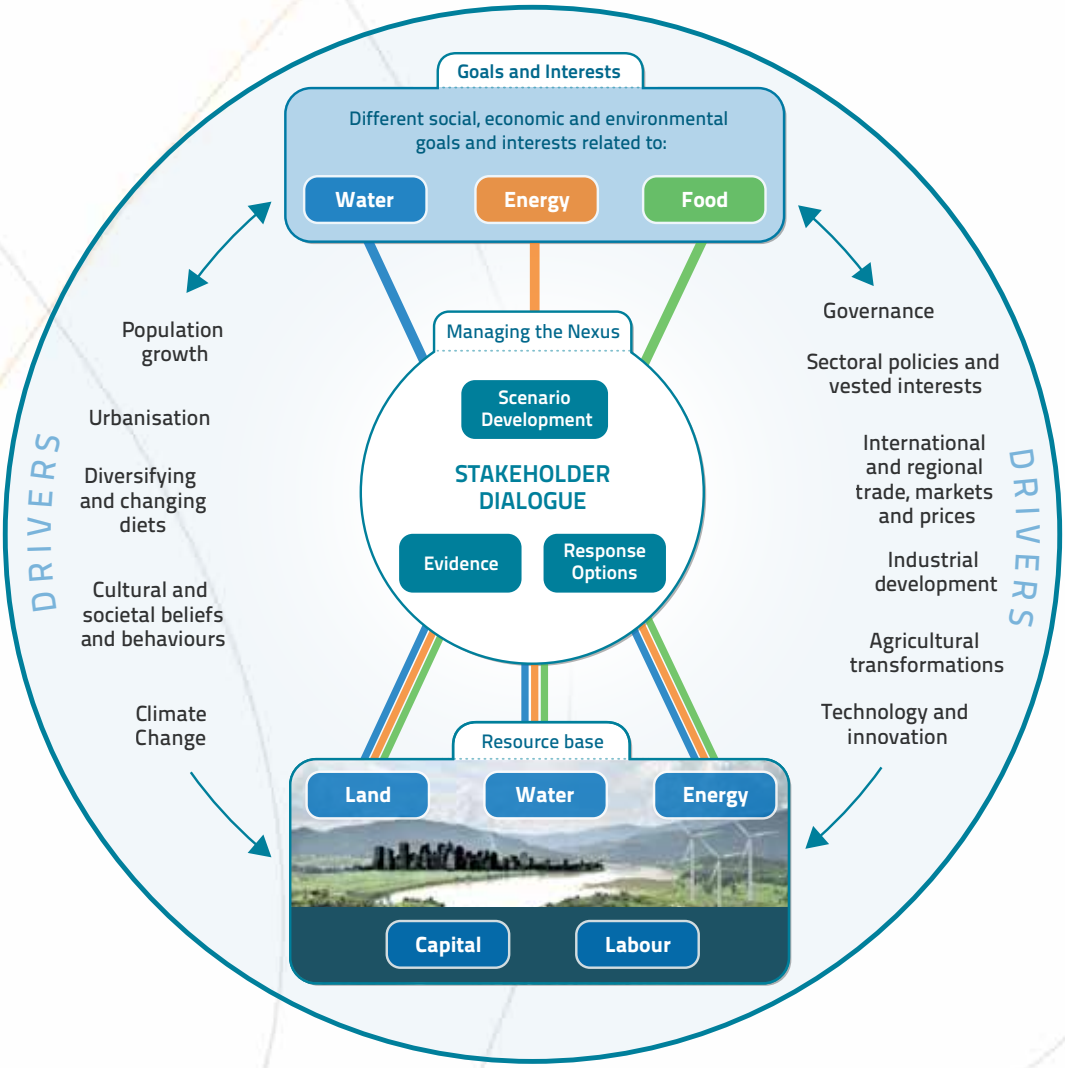
> "Agriculture must meet the needs of present and future generations for its products and services, while ensuring profitability, environmental health, and social and economic equity (FAO 2013, 11)."

Underlying the *Water-Energy-Food Nexus* approach of FAO is a holistic vision of sustainability that recognises and tries to strike balance between the different goals, interests and needs of people and the environment.

It explicitly addresses complex interactions and feedback between human and natural systems (Figure 2). The resource base refers to both natural and socio-economic resources, on which we depend to achieve different goals and interests pertaining to water, energy and food. Nexus interactions are about how we use and manage resource systems, describing interdependencies (depending on each other), constraints (imposing conditions or trade-offs) and synergies (mutually reinforcing or having shared benefits).

Interactions take place within the context of globally relevant drivers, such as demographic changes, urbanisation, industrial development, agricultural modernisation, international and regional trade, markets and prices, technological advancements, diversification and changes of diets, and climate change as well as more context-specific drivers, like governance structures and processes, cultural and societal beliefs and behaviours. These drivers often have a strong impact on the resources base, causing environmental degradation and resource scarcity, but they also affect and are affected by different social, economic and environmental goals and interests.

Figure 2: The FAO approach to the Water-Energy-Food Nexus



4 Working Areas of the Water-Energy-Food Nexus

FAO has identified three working areas to identify, assess and manage Nexus interactions, considering the impacts that any change – a policy decision, a large-scale investment or a change in agricultural practice – may have beyond the intended objectives and scale. The working areas are a) evidence, b) scenario development, and c) response options.

They do not describe a linear set of steps, but rather they are complementary areas of work that are interlinked by stakeholder dialogue. Data, analysis and scenarios are part of a Nexus assessment, which inform stakeholders about Nexus interactions, highlighting trade-offs and synergies between different resource uses. This can provide the basis for a dialogue process to develop and decide on response options to use and manage the resource base in a more coordinated and sustainable manner.

Earth Observations and the Water-Energy-Food Nexus

Satellite observations, combined with in-situ data, provide a unique source of consistent information about the natural environment, on which we rely to produce water, energy and food. Such observations are necessary to begin understanding the complex feed-back processes between the natural environment and human activities. They also provide resource managers with the information they need to assess the current state of the environment, weigh the requirements of different uses by multiple stakeholders, and manage the natural resources and ecosystems in a sustainable manner.

Evidence

In order to assess and analyse Nexus interactions, reliable, pertinent and timely data is needed. Linking to existing and planned observing systems around the world and supporting the development of new systems, tools and services is essential given issues with data availability and quality (Clark *et al.*, 2013). This will help to fill data gaps and to provide key data to decision-makers.

FAO can draw on and continue to build up existing programmes and databases, using a wide range of data from Earth Observations to statistics and indicator-based assessment tools. This data can then be used in the assessment and analysis of the Water-Energy-Food Nexus, providing 1) an overview of the current state and use of natural resources and their links with human resources, and 2) an outlook on key Nexus issues, making explicit the current baseline scenario and trends. Any such analysis can help to inform decision-makers on how to respond to these issues, taking into account the diverse and multiple impacts these responses may have across sectors and over time.

Scenario Development

Scenarios can be useful to explore strategic questions, to review policies and investment decisions, and to create 'common ground' and improved understanding of the interrelations between water, energy and food as well as the underlying drivers. Scenarios describe a set of multiple, equally plausible future developments in an inherently uncertain world. They present plausible evolutions from the current situation, depending on how major driving forces (differentiating between uncertain and predetermined elements) develop and interact, and they help to assess the implications of specific decisions (policy, investment, technical intervention, etc.).

Scenario-Thinking in the Aral Sea Basin

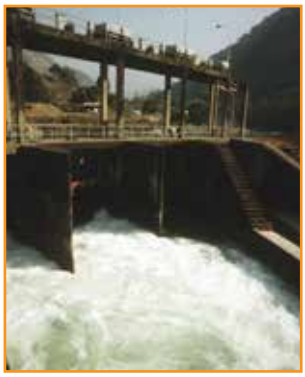
The management of water resources in the Aral Sea basin is a highly complex process that is further complicated by rising demand for energy and food, environmental degradation and increased pressures on the region's finite water resources due to economic development, demographic trends and climate change.

Given the importance of water resources to the national economies, FAO together with the Executive Committee of the International Investment Fund for Saving the Aral Sea (EC-IFAS) and the UN-Regional Centre for Preventive Diplomacy in Central Asia (UNRCCA) adopted a scenario-thinking approach to work towards a shared vision for the socio-economic development of the Aral Sea basin based on the sustainable management and use of water resources. The scenario-thinking approach helped to stir away from narrow problem definition to an open and highly participatory debate about the complex structure of the water-energy-agriculture nexus in Central Asia (FAO 2012d).

The development of scenarios poses a methodological challenge, which can be addressed using systematic approaches that strengthen cross-sectoral perspectives and highlight links between sectors. These can be tools, models and accounting frameworks as well as visioning exercises, like the forward-looking scenario-thinking approach (FAO 2012d), agent-based social simulation and structured expert panels (Smajgl and Ward 2013). This can help decision-makers to anticipate, plan and manage transitions successfully (e.g. demographic changes, climate change, economic development, etc.) and to re-think policies and strategies in a world of complexity and uncertainty.

Response Options

The third working area refers to a) the planning and implementation of new policies, investments, regulations and incentives (such as subsidies, promotion of appropriate business models, institutional mechanisms, financial instruments and funds/finance facilities, legislation, policy instruments and support mechanisms), capacity development and training, and technical interventions; and b) the process of evaluating and comparing the impacts of different interventions.



Ideally, these response options are informed by evidence-based assessments and developed through a continuous process of stakeholder dialogue, allowing for better understanding of the interlinked nature of local and global resources systems. In so doing, the *Water-Energy-Food Nexus* can help to avoid some of the negative implications of poor sectoral coordination, institutional fragmentation, and inadequate capacity, and to address sectoral interests and political sensitivities in a more participatory and open manner.

5 | Stakeholder Dialogue

The evidence-based analysis of Nexus interactions and the development of scenarios, strategic visions and response options are carried out through a stakeholder dialogue. Ideally, the dialogue process helps to make explicit the different goals, interests and uses of stakeholders and offers a process to reconcile these differences. It helps to raise awareness of the interlinked nature of global resources systems and build common ground among the different stakeholders.

Stakeholder involvement is also needed to source relevant information at the needed aggregate level and scale. Finally, the stakeholder dialogue helps to create a sense of ownership among stakeholders and to legitimise decision-making processes.

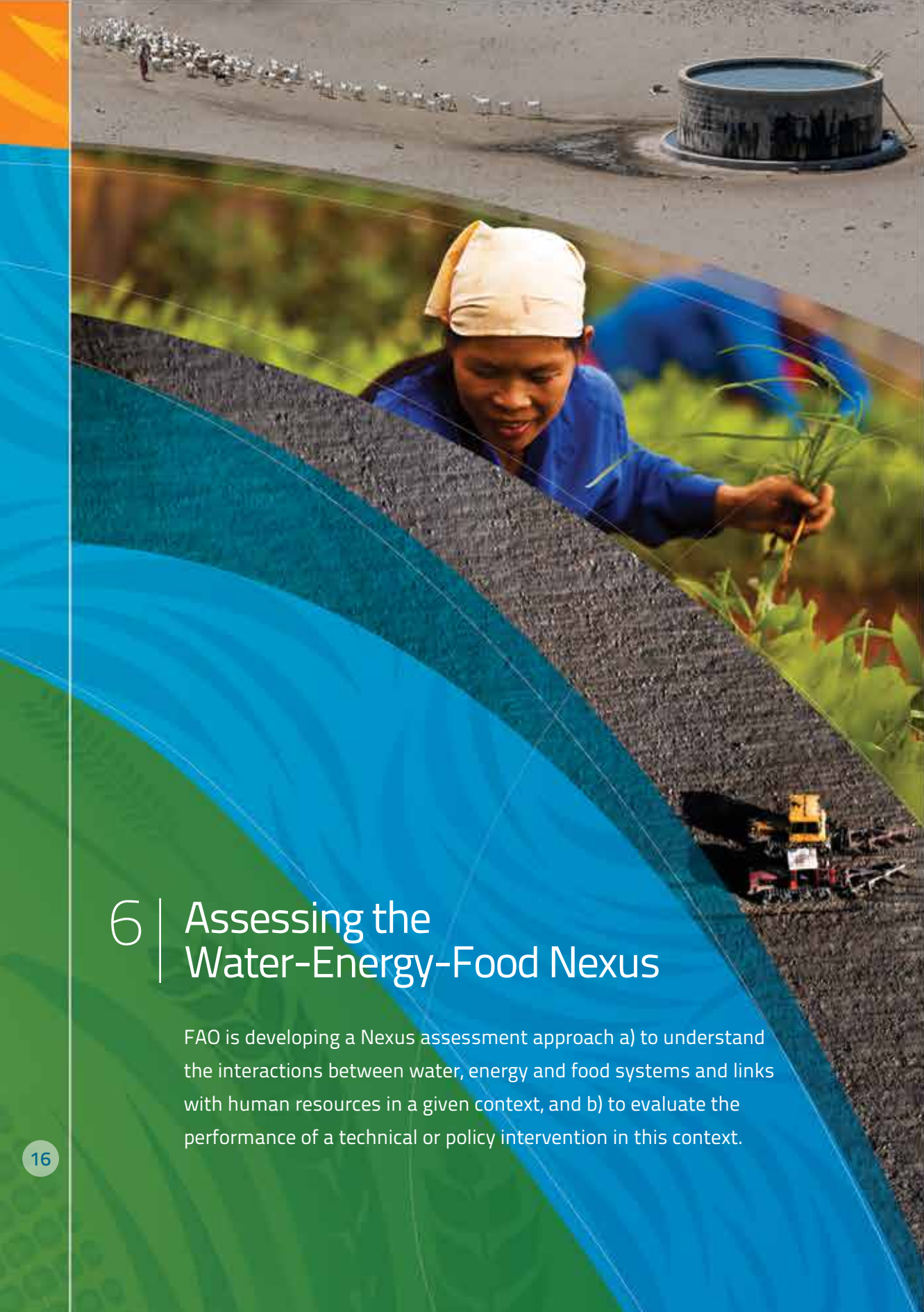
Why do we need stakeholder dialogues?

- To engage and bring together actors from different sectors and levels of governance
- To develop a shared understanding of the national, regional and international context in which future interventions will be embedded and to ensure that these interventions are aligned with national needs and priorities
- To directly link to ongoing and emerging decision-making processes
- To create momentum to move from assessment outcomes to action, instilling a sense of ownership, leadership and mutual accountability

It is a continuous process, specific to context – regional, national, local or basin level – and problem, e.g. to evaluate a national policy on water, energy and food systems, or to decide on how to intervene in a problem. The extent to which stakeholders participate and engage with the process varies widely from mere exchange of information to shared decision-making and action.

Stakeholder Dialogue: Linking to global political processes

FAO is co-leading in the Sustainable Energy for All (SE4ALL) High Impact Opportunity on the Water-Energy-Food Nexus together with the German Federal Ministry for Economic Cooperation and Development (BMZ). SE4ALL is an initiative launched by the UN-Secretary in 2011 to promote energy efficiency, increase the use and production of renewable energy and increase access to modern energy services in rural areas (FAO 2012a).



6 | Assessing the Water-Energy-Food Nexus

FAO is developing a Nexus assessment approach a) to understand the interactions between water, energy and food systems and links with human resources in a given context, and b) to evaluate the performance of a technical or policy intervention in this context.

Part a) of the assessment focuses on the **context analysis**, providing information on:

- The current state and pressures on natural and human resources systems;
- Expected demands, trends and drivers on resources systems;
- Interactions between water, energy and food systems;
- Different sectoral goals, policies and strategies in regard to water, energy and food. This includes an analysis of the degree of coordination and coherence of policies, as well as the extent of regulation of uses.
- Planned investments, acquisitions, reforms and large-scale infrastructure;
- Key stakeholders, decision-makers and user groups.

Following the context analysis, a number of **problem-specific tools** are suggested for a more in-depth, quantitative analysis of the impacts of different resource uses and for the development of scenarios.

Part b) of the assessment looks specifically at the **performance of technical and policy interventions** in terms of resource use efficiency and productivity. Importantly, the performance of interventions should be also assessed against a given context. A set of basic indicators is suggested, out of which the final selection should take place in consultation with stakeholders. It is also possible **to compare different interventions**, based on how efficiently they make use of water, energy, food/ land, employment and financial capital.

Key stakeholders should be actively engaged in the assessment process to build consensus on strategic issues across sectors and scales and to decide on how to respond to these issues.

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If a decision is made at the national level to increase the share of bioenergy, what implications does this have for water, land and energy? How do electricity subsidies contribute to groundwater depletion and what can be done about it? How can we ensure that sectoral policies and strategies consider the potential trade-offs for other sectors? Finding answers to these questions is the main challenge of the Water-Energy-Food Nexus. By describing the complex and interrelated nature of our global resource systems, the Nexus approach helps us to better understand and systematically analyze how we can use and manage our resources in light of different, often competing interests and goals.

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