GLOBAL COMMISSION on the ECONOMICS OF WATER

TECHNICAL REPORT

Towards Operationalising the Water-Energy-Food Nexus

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Executive summary

The world is rapidly approaching tipping points in terms of climate change, biodiversity and water consumption. Business as usual is increasing cascading and systemic risks that link across multiple systems; especially, water, food and energy. Despite a water-food-energy crisis in 2007–08 that had severe and negative global impacts, another nexus crisis emerged in 2021–22 which plunged tens of millions into severe food insecurity and compromised the nutrition of hundreds of millions of people. Against this background, there needs to be a transformational shift from silo thinking to nexus thinking and nexus doing. This requires: a much better way of "connecting the dots" in understanding and responding to risks at multiple scales; improved international collaboration, especially in relation to food trade restrictions; more inclusive decision-making; and policies that prioritise system resilience as a key objective. Without a change in how decision-making is practised the world will face increasingly frequent, and of greater magnitude, global nexus crises.

Key findings

- The water-energy-food nexus is a critically important framework for understanding systemic and cascading risks across multiple systems at regional and global level.
- Water-energy-food nexus crises at a global scale are reoccurring. The 2021–22 nexus crisis is as great as the 2007–08 crisis and the lessons that should have been learned (e.g. avoid food export restrictions, maintain sufficiently large food stocks) have not.
- Nexus concepts need to be operationalised to respond to water and energy risks and the impacts on food security. This requires an alignment of resource and trade policies, more inclusive governance, better global governance, and strategic planning and responses to nexus crises.

List of abbreviations and acronyms

LMICs	low- and middle-income countries
GFSI	Global Food Security Index
IWRM	Integrated Water Resources Management
SDGs	Sustainable Development Goals
PES	payments for ecosystem rights
EFRs	environmental flow requirements

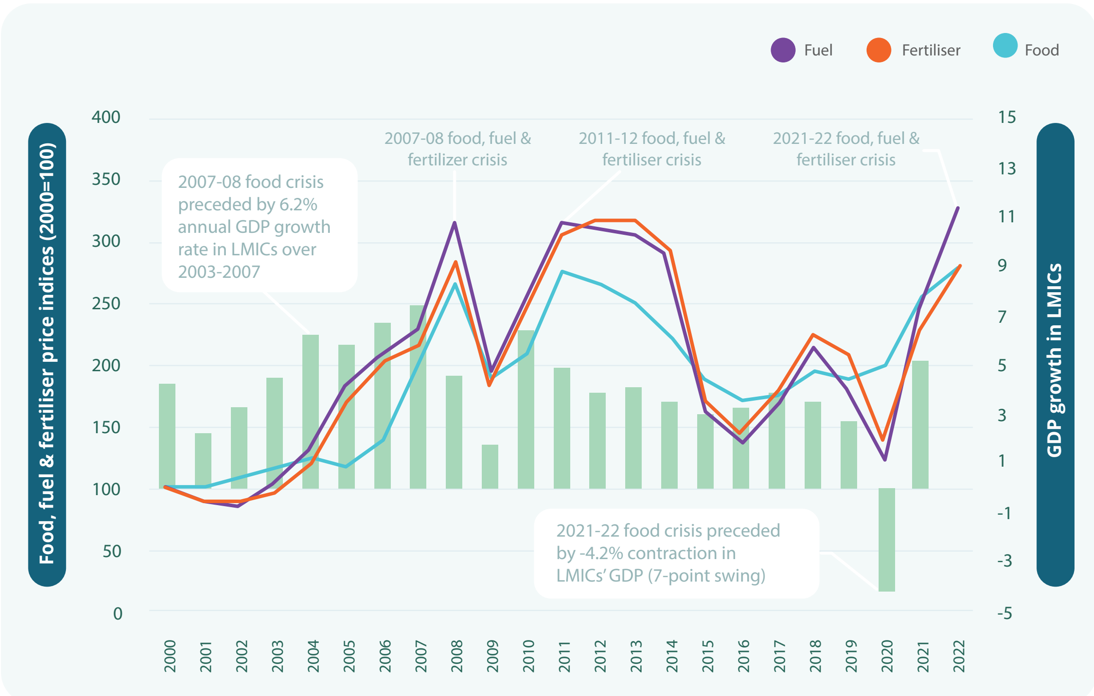
1 Interconnected global resource risks: From chronic shortages to chronic crises

1.1 Interlinked food, water and energy crises through time

It seems that joint water, food and energy crises have become the norm. Three have occurred in just the last 15 years (2007–8; 2010–11; 2021–22) and have been driven by extreme weather events and human-made crises such as COVID-19 and the Russia-Ukraine war. All three crises dramatically pushed up food and energy prices, as well as prices of fertilisers, and led to an increase in the number of undernourished people worldwide (Figure 1). The number of hungry has now been on the rise for almost a decade (FAO, IFAD, UNICEF, WFP and WHO, 2022), and more than 1.4 billion people in 83 countries face extreme water stress (IEP, 2022). It is unclear if, or when, the global community will come together to implement interventions to prevent resource crises from becoming a chronic phenomenon.

The 2007–08 crisis was triggered by innovations in bioenergy development – especially the use of maize as transportation fuel, putting food and fuel production in direct competition with each other. It was further compounded by higher oil prices, a depreciated US dollar and a series of extreme weather shocks (Figure 2). While water issues are not seen as a key driver of the crisis, extreme climate events did affect agricultural production levels and water was diverted to grow crops for biofuels, thus reducing water availability for food production and other human needs (Headey and Fan, 2010). The 2007–2008 food crisis (and the high food price rebounds in 2011) not only revealed deep structural problems in the global food system, but also demonstrated that water, food and energy systems are interlinked.

Figure 1. Food, fuel and fertiliser prices and GDP per capita in low- and middle-income countries: 2000–2022



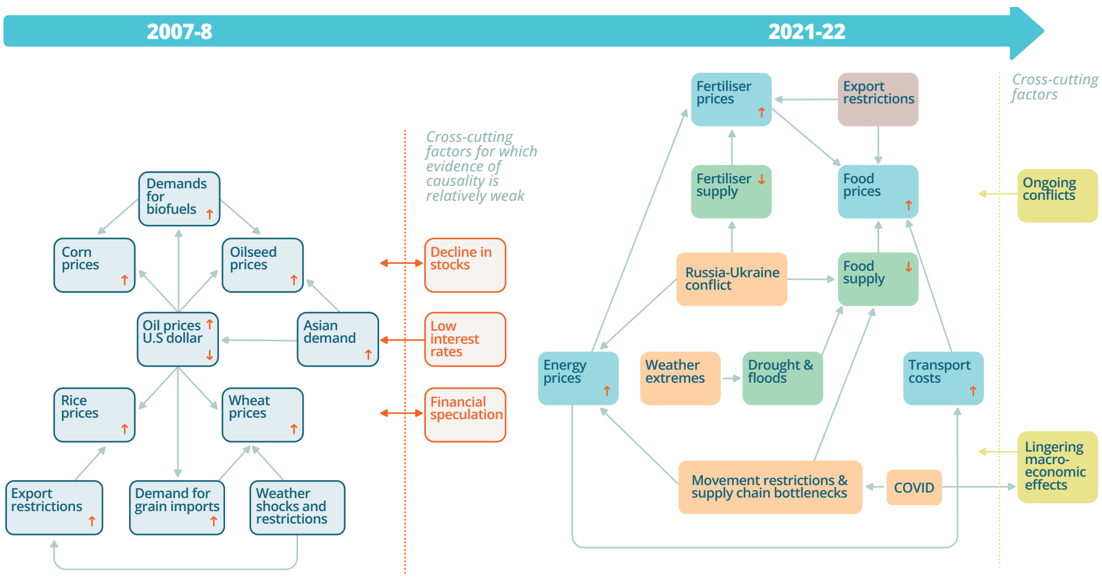
Source: Headey and Hirvonen, 2022

Researchers and policy makers have increasingly emphasised the importance of the complex relationships between water, energy and food – also called the FEW (Food-Energy-Water) or WEF (Water-Energy-Food) nexus and referred to in this report as "the nexus" for simplicity – which are often overlooked in narrowly focused actions, investments and policies. Numerous global initiatives have emerged to promote the nexus by raising awareness, emphasising the urgency of related challenges, providing forums for international dialogue, and suggesting policy and investment recommendations.

Despite developments in the nexus framework to help decision makers better understand risks, so they can respond proactively and mobilise quickly in times of crises, the world is facing another crisis in 2023, which began with the COVID-19 pandemic. The unprecedented fiscal and monetary measures that governments used to respond to the COVID-19 pandemic, along with associated supply chain disruptions and the food, fuel and fertiliser impacts of the war in Ukraine, resulted in the cereal price index again rising sharply in 2021 and 2022, reaching its levels of 2008 and 2011. The crisis has been partially made worse by the growing number of food trade restrictions put in place by countries with a goal to increase domestic supply and reduce prices. As of October 2022, 20 countries had implemented 25 food export bans, and eight have implemented 12 export-limiting measures (The World Bank, 2022).

As in previous crises, a series of climate shocks, heat waves, droughts, floods and cyclones reduced food production in key breadbasket regions, as well as energy access and use and water security. But in contrast to 2007–08, most low- and middle-income countries (LMICs) in 2023 are in an especially weak fiscal position to deal with food, fuel and fertiliser inflation in the wake of the COVID-19 pandemic. Indeed, it is possible the strong agricultural supply responses observed in LMICs in the wake of the 2007–08 crisis may not be replicated because of the more limited fiscal capacity of LMIC governments to facilitate a strong supply response, and due to exceptionally tight fertiliser supplies (Headey and Hirvonen, 2022).

Figure 2. Summary models of the principal causes of the 2007–8 and 2022 nexus crises



Source: Headey and Fan 2010 and authors' own production

Besides the centrality of water-energy-food interlinkages, another factor these crises share is that they come at a huge and unequal economic cost. The rise in relative food prices is regressive for at least two reasons. First, once again, as in 2008, the overwhelming concentration of large increases in real food prices are in low-income countries. This time, sub-Saharan Africa and Emerging Europe and central Asia are the regions with the most pronounced sustained food price increases to date. They are also among the regions most affected by the Russia-Ukraine war, given the structure of their imports. Second, in low-income countries, food can account for up to 30–45% of household expenditures, or 2–3 times the share in high-income economies (Table 1), magnifying the impacts of price changes in household budgets (The World Bank, 2022). According to an IMF paper, USD 5 billion to USD 7 billion in further spending is needed to assist vulnerable households in 48 countries most affected by the higher food and fertiliser import prices. An additional USD 50 billion is required to end acute food insecurity over the next 12 months (Rother et al., 2022).

Table 1. Food share by income group

Income group	Food share in expenditure
Low-income	42%
Middle-low-income	40%
Middle-high-income	29%
High-income	15%

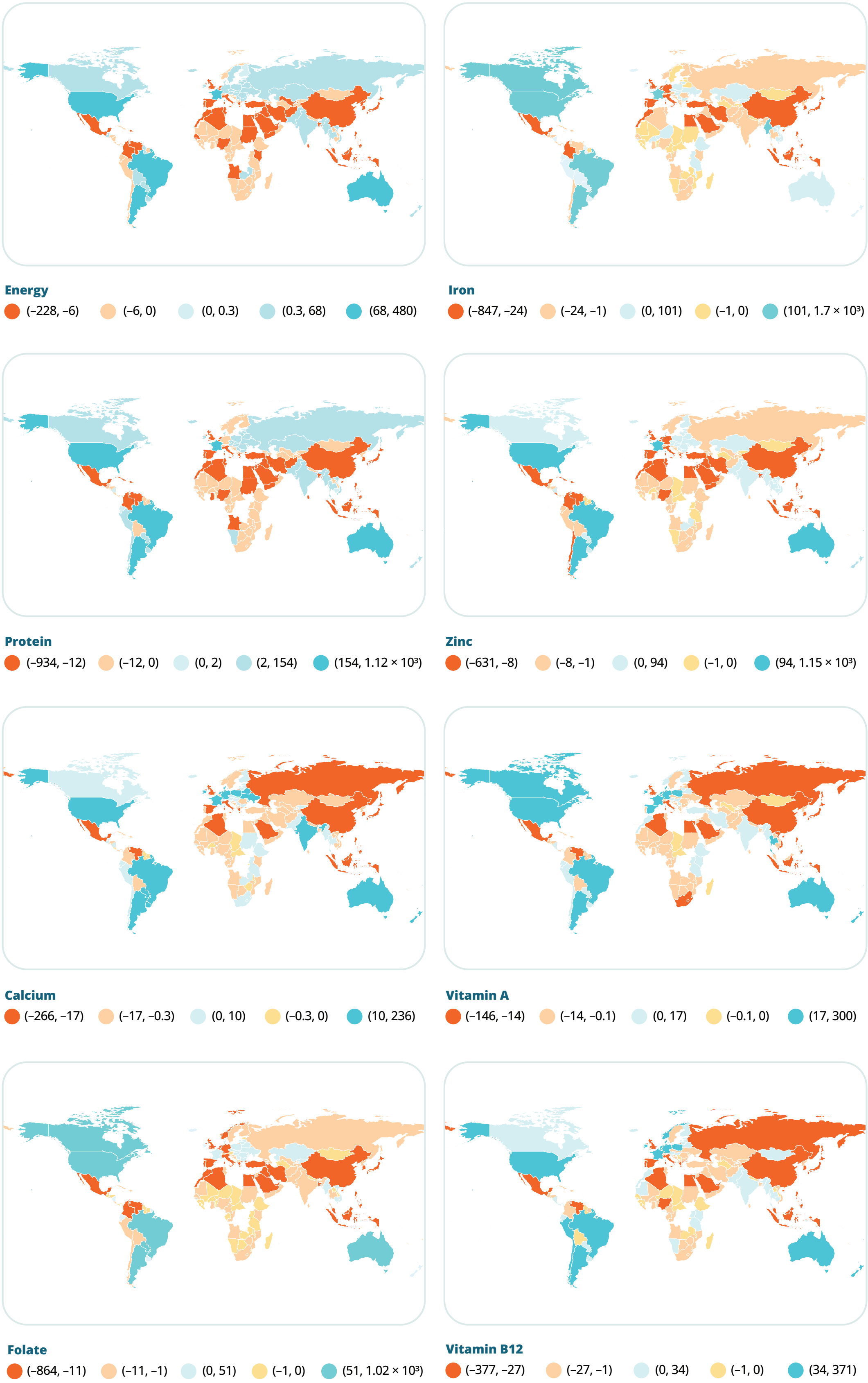
Source: Von Luckner, 2022

1.2 Trade, food security and resource sustainability

Increasing environmental and socio-economic interactions around the world is a distinct feature of the Anthropocene. As these recurring food, water and energy crises demonstrate, this is a time in history marked by interconnected, large-scale global resource challenges (Grafton et al., 2016). Traditional approaches to both research and management are alone unable to handle such complexity, due to the tendency to focus on single places and to remain entrenched within individual "silos" (Liu et al., 2013, 2015). To prevent further crises, we need to not only acknowledge the interconnected nature of water, energy and food systems, but also move away from the dichotomy of "local" versus "global" decision making, thus transcending a traditional nested paradigm.

This global and fluid interconnectedness is notably realised in the growing importance of food trade in achieving food security, and its impact and dependence on water and energy resources. Over the last 40 years, the share of food (measured in calories) crossing an international border rose from 12.3% to more than 19% (Laborde and Deason, 2015). Beyond energy, international food trade is essential to nutrient access and enables poorer countries to nourish up to hundreds of millions of people, noting that 20% of the supply of cereals in low-income economies is imported (FAO, 2022a). Globally, trade contributes to between 146 and 934 million people being nourished, depending on the nutrient (Figure 3). Further, trade in the current global food system is associated with greater equality of nutrient access. That is, the ability of many countries – especially low-income countries – to meet their aggregate nutritional needs in today's world would be less without trade (Wood et al., 2018).

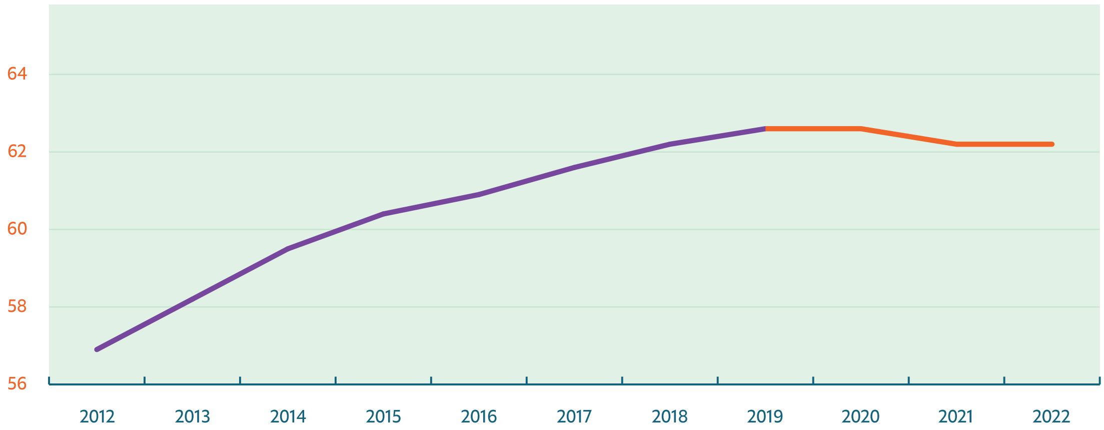
Figure 3. Change in the number of people who could be nourished without trade



Source: Wood et al., 2018

Given the importance of trade to the abilities of countries to meet their nutritional needs, changes in trade flows may have serious negative consequences for global nutritional security. Since 2020, more frequent and extensive shocks – including COVID-19, conflict and extreme weather events – have led to rising food costs and weakening trade freedom, dragging down the Global Food Security Index (GFSI) (Figure 4). Indeed, the 2022 GFSI showed a strong link between trade freedom and food security (Figure 5), as recent food export restrictions have had dire consequences for vulnerable people in food-importing countries, increasing prices and exacerbating issues of food insecurity (The Economist Group, 2022). In November 2022, food and fertiliser export restrictions affected about 18% of globally traded calories, with South Asia, the Middle East and North Africa most impacted (Figure 6).

Figure 4. GFSI average overall score, global 2012–22

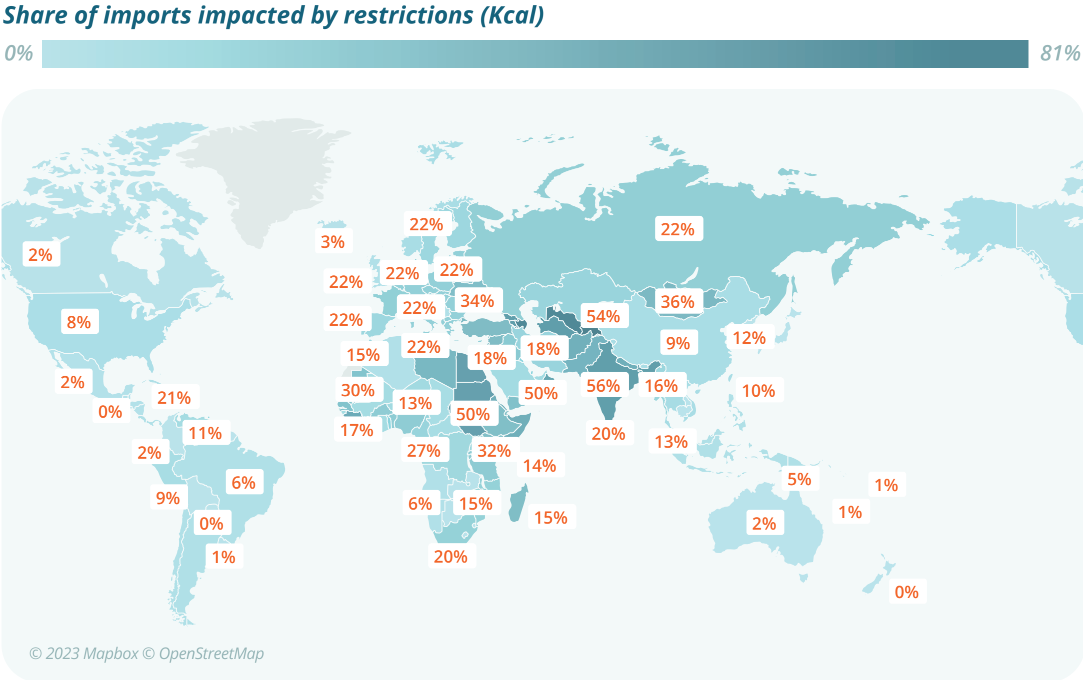


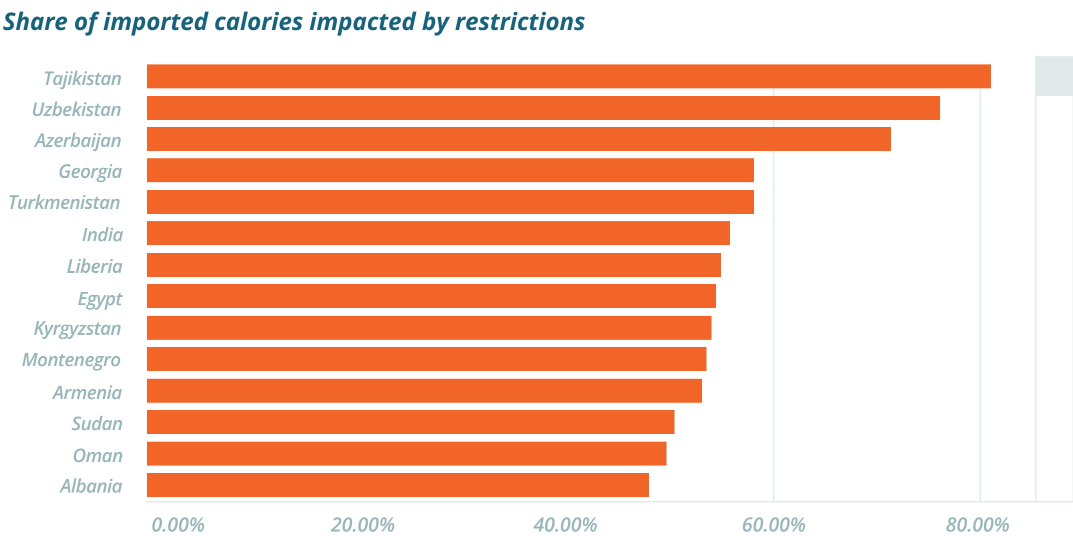
Source: The Economist Group, 2022

Figure 5. Trade freedom and GFSI

Source: The Economist Group, 2022

Figure 6. Map of Impact of Food Export Restrictions on Imported Calories



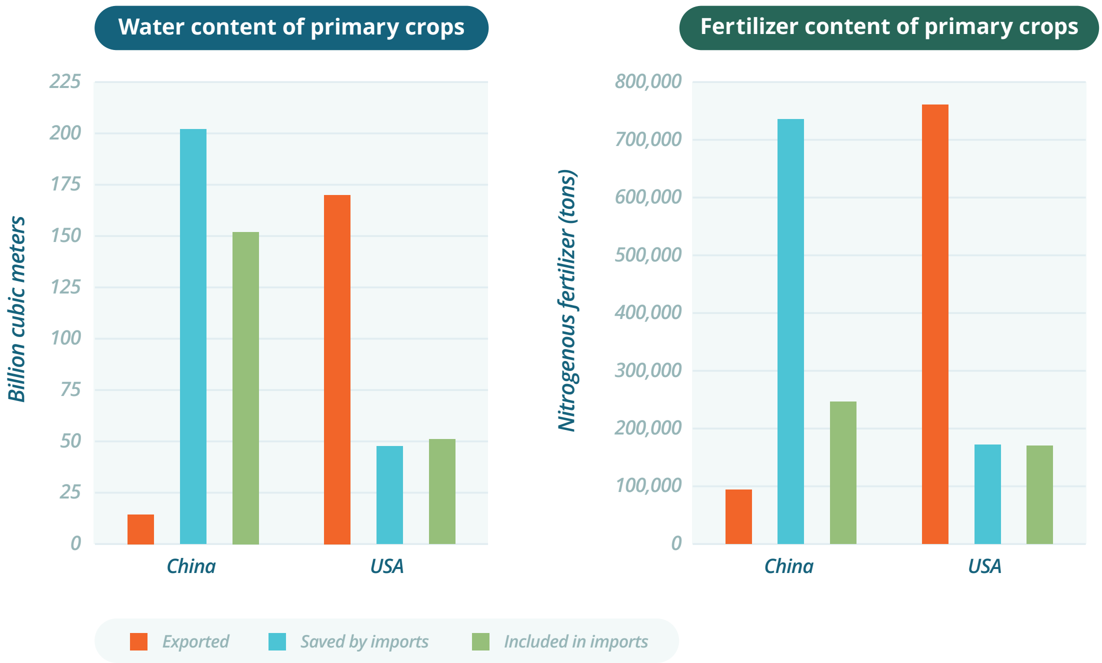


Source: Laborde, 2022

Trade can contribute to the sustainability of food, water and energy systems and reduce both the risk of overexploitation of natural resources and negative environmental impacts linked to production (unless it leads to specialisation on environmentally harmful crops, such as large-scale oil palm plantations). By reducing the need to rely on domestic supply, trade in agricultural products can reduce local water and fertiliser use in countries where these inputs are relatively scarce.

An analysis of the main crops of the world's two largest exporters, the United States and China, shows the magnitude of these impacts (Figure 7). While the United States is a net exporter of "virtual" water – the water used to produce agricultural goods that is embedded in the traded products – and "virtual" fertilisers, China, whose domestic resources are already strained, saves substantial resources through imports, partly because its partners use technology that is less fertiliser- and water-intensive than China would have to use to replace these imports (IFPRI, 2018). Nevertheless, recent evidence at the global level indicates that when both physical and economic water scarcity are considered, almost half of water volumes flow from countries where water is scarcer than in recipient countries, increasing the vulnerability of water and food systems to external shocks (Vallino et al., 2021).

Figure 7. Water and fertiliser content embedded in international trade

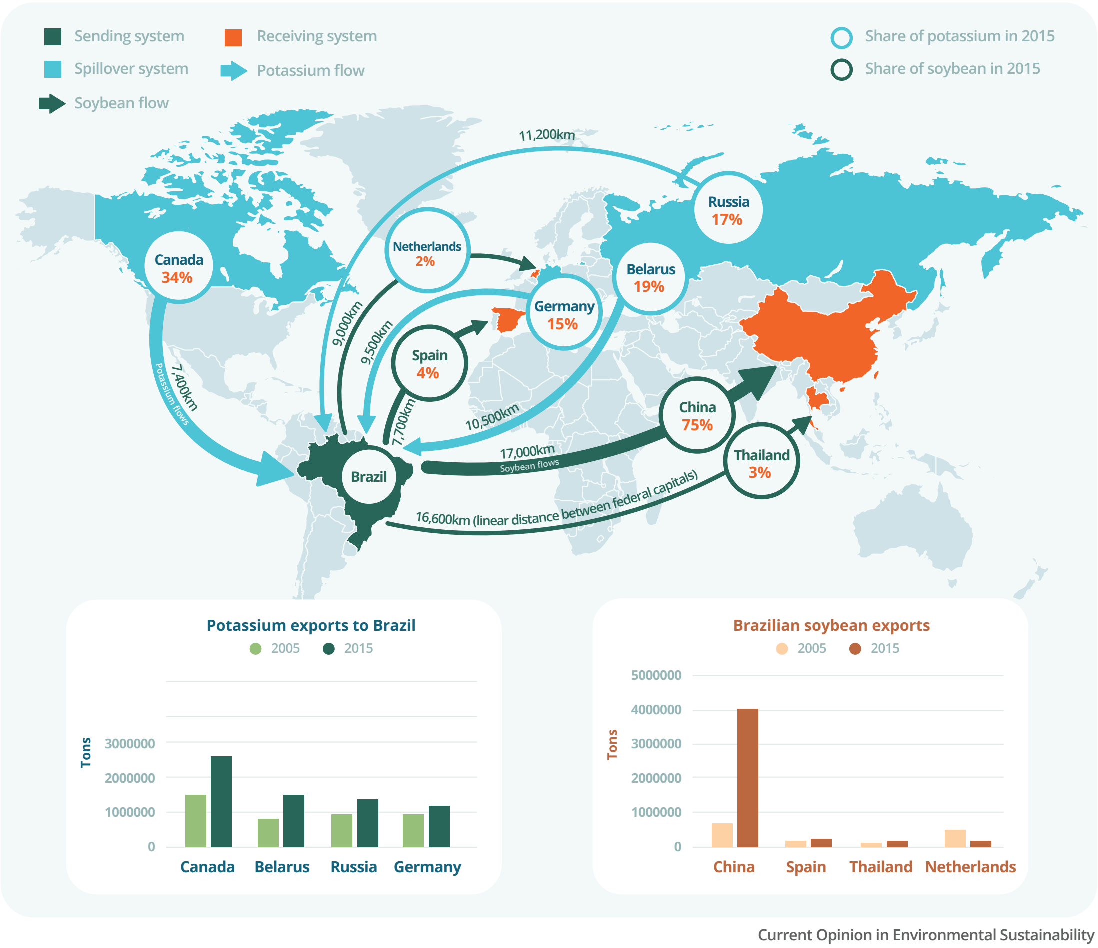


Source: IFPRI, 2018

How can we better prepare for the future of trade in water, energy and food systems under different shocks? Current models, such as IFPRI's Impact Model and Food and Fertilizer Export Restrictions Tracker, and the Global Trade Analysis Project database, are very good at showing global food trade flows and the current effects of trade restrictions. Nevertheless, decision makers still lack systems for predicting how stressors, such as droughts and conflict, may disrupt that trade and the consequences this may have on water, energy and food security. Recent efforts, inspired by the framework of "telecoupling" (a process that connects distant systems), promise to produce consistent and harmonised projections of global food demand and supply balance, and bilateral trade, under climate and global change, such as the MIT's Jameel Index for Food Trade and Vulnerability (Blais, 2022).

It is not only important to understand who is at the sending and receiving ends of food trade flows. Spillover systems are widespread and are a key piece of the sustainability puzzle in a telecoupled world. For example, in the global food trade system, many countries (e.g. Canada) can be viewed as spillover systems because they are affected by or affect soybean exports from Brazil (sending system) to China (receiving system, the largest soybean-importing country in the world, Figure 8). Another example is given by increased seawater encroachment at the Yangtze Delta (spillover system) due to the South-North Water Transfer Project in China (Liu et al., 2016). Significant knowledge gaps remain when it comes to recognising explicitly and systematically characterising spillover systems affected by water, energy and food flows.

Figure 8. Flows of soybean from Brazil to importing countries and the spillover systems affected by the increased Brazilian demand for fertilisers

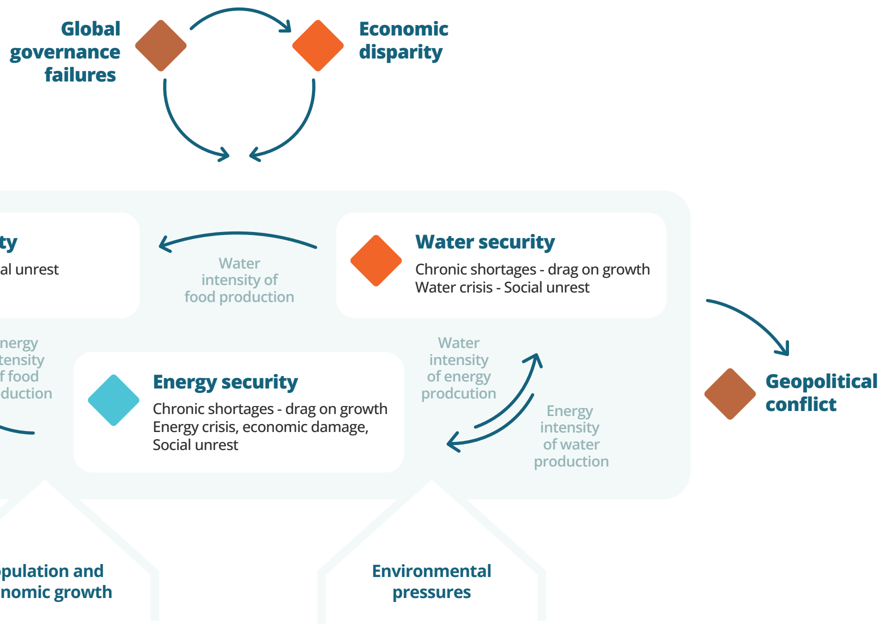


Source: Liu et al., 2018

2 The nexus as a framework to manage interconnected resource risks

Nexus thinking emerged around the 2007–8 crisis and was coined as the preferred solution to manage and identify interconnected and cascading risks to resource security (Cairns and Krzywoszynska, 2016). Although there were academic studies on the complex interrelated threats to water, energy and food security, it was not until 2011 that nexus approaches were elevated in the international political agenda. The World Economic Forum addressed the issue in its 2011 Water Security Report (Figure 9), and in November 2011, more than 550 people representing diverse stakeholder groups gathered at a conference in Bonn, Germany, to explore the ways the nexus approach might be employed to achieve sustainability and promote the transition to a green economy. The results and messages of this conference were a specific German contribution to the UN Conference on Sustainable Development "Rio2012".

Figure 9. System diagram for risks associated with the nexus



Source: WEF, 2011

The nexus concept (in particular addressing Water, Energy and Food: the WEF nexus) is rooted in earlier integrated resource management concepts, e.g. Integrated Water Resources Management (IWRM). Considering the need to provide water for people, food, nature, industry and other users (GWP, 2010), IWRM conceptually captures some aspects of the nexus concept (Benson et al., 2015), but its scope of integration is clearly sectoral (Roidt and Avellán, 2019), thus missing many potential trade-offs as well as synergies. It can be argued that the nexus concept, by making the respective interconnected sectors and resources explicit, offers greater scope for integration than IWRM with its water-centred perspective.

Under the nexus paradigm, line ministries and key sector actors are guided to consider and integrate priorities of other sector mandates and actors. This can require compromises or accepting decisions that may not initially be seen as optimal for a single sector, but which a nexus perspective provides the knowledge and decision-sharing framework to identify and view trade-offs as being strategically beneficial for all sectors involved (UNESCO, 2021).

If the IWRM framework did not manage to make any long-term impact in the water sector (Biswas and Tortajada, 2010), why would the nexus, with broader integration ambitions, avoid becoming another vague, indefinable and un-implementable concept? Currently the water, energy and food nexus has become a global "catchword". Every country talks about the need and urgency of coordination, but after decades of rivalry between ministries, it will not be easy to break through the barriers, both institutionally and mentally. Hence, the need for the nexus approach will endure (Grigg, 2019).

2.1 Theoretical evolution of nexus approaches

The role of nexus approaches was originally closely linked to the motifs of "efficiency" and "win-win" outcomes and was mainly investigated through technocratic approaches. Much of the early nexus discourse was underpinned by an apolitical "integrative imaginary" and largely ignored crucial questions of power (of sectors, disciplines, forms of legitimate knowledge, stakeholders). As a result, the nexus has been often characterised as an "ambiguous and troubling concept", seemingly used to perpetuate "neoliberal environmentalism" and sidestep more fundamental political economy questions about the role of industrial development in environmental degradation and social inequality (Cairns and Krzywoszynska, 2016).

To respond to concerns over the vagueness and ambiguity of the nexus concept, nexus approaches are increasingly being used in quantitative research, employing a wide range of methods from multi-sectoral systems and scenario analysis (Walker et al., 2014; Yang et al., 2016) to geographic information systems and water balance models (Daccache et al., 2014). In addition, many frameworks have emerged to operationalise and institutionalise the term as a tool for action. Much of this research remains framed purely in relation to categories rooted in natural sciences (such as watersheds), not contesting the normative resonance of the concept, and turning the nexus into a "matter of fact" rather than a "matter of concern" characterised by controversy (Cairns and Krzywoszynska, 2016).

An emergent body of qualitative and quantitative work examines nexus challenges as spaces where ecological processes and societal needs are brought together, and where issues are constructed, understood and managed through hybrid (socio-ecological) "problem-sheds" framings. In particular, the creation and management of "problem-sheds" has been aided by three recent trends.

Firstly, the importance of actively involving stakeholders in the identification of nexus challenges, data collection and scenarios development, and the formulation of policy recommendations, has underpinned many major cross-country collaborations, such as the SIM4NEXUS project (Purwanto et al., 2021b). This involves recognising that structuring interventions along a mostly linear process, from knowledge generation to dialogue and planning, and ultimately implementation, has worked against nexus policy integration (or policy coherence) as an outcome. An alternative way is to look at WEF policy integration as an iterative process of learning, which takes place through cross-sector interaction in response to specific problems (Medinilla, 2021).

Secondly, there have recently been several advances in qualitative methods to bridge the traditional technical narrative the WEF nexus with a more political one, including institutional network analysis and environmental justice frameworks (Middleton et al., 2015; Villamayor-Tomas et al., 2015).

Finally, after years of the nexus literature being silent on why fragmented policies pose problems, and what exactly policy coherence entails (Weitz et al., 2017), the governance of the nexus has recently received growing attention. Several governance challenges have been analysed in the WEF nexus, underlying the need to pay close attention to issues of power, contestation and negotiation, in addition to the analysis of institutional design (Pahl-Wostl et al., 2021). In this space, previously overlooked scale-related issues for WEF nexus governance have been scrutinised to help probe structural (fit), agency (strategies), procedural (interplay) and complexity (uncertainty) dimensions of governance.

2.2 Empirical evidence

Reviews of the empirical nexus literature reveal a substantial amount of work – in many regions, by many actors, and on a variety of subjects (Galaitsi et al., 2018). Nevertheless, it is the diversity and flexibility of the nexus concept that have produced important limitations in contemporary empirical nexus research. Cohesion is an inherent challenge, owing to the breadth of the nexus concept.

The WEF nexus encompasses three sectors that are critical to human and natural systems and are foundational to all life. Each sector is itself complex, and the complexities are multiplied by cross-sector linkages and place specificity. What results is a topic with myriad points of entry and connections to a vast array of questions in the social and natural sciences (Table 2). This "outcome gap" can be bridged by improving outcome evaluation methodologies, accounting for scale-related governance challenges, and emphasising participatory and co-production approaches.

Table 2. Multiplicity of entry points used by empirical nexus studies

Key constraints	Intervention points	Potential outcomes
Climate change and variability	Culture and society	Adaptive capacity
Crop productivity	Economy	Avoidance of geopolitical conflict
Demand	Environment	Enhanced livelihoods
Economic growth and inequality	Finance	Enhanced resource efficiency
Environmental limits and planetary boundaries	GHG emissions	Equitable and sustainable growth
Global governance failures	Governance and institutions	Human well-being
Land use change	Innovations	Improved health
Population growth	Natural and built systems	Resilient, productive environment
Technological change	Politics	Social justice
Urbanisation	Regulation	Water/energy/food security
	Society	
	Trade/business	
	Waste	

Source: Galaitsi et al. 2018

2.3 Future research needs

2.3.1 Impact evaluation and SDGs

The nexus approach is considered to be an essential tool for achieving progress towards sustainable development (Carmona-Moreno et al., 2021). The Organization for Economic Co-operation and Development estimated that the biophysical and economic consequences of policy inaction regarding the interlinkages among land, water and energy resource availability are severe and more pronounced in the most fragile regions of the world – particularly countries with strong bottlenecks in economic activities that cannot be substituted or imported, as well as regions with strong decreases in crop yields and higher production costs (OECD, 2017). Until recently, no studies have explicitly quantified the contributions of nexus approaches to progress toward meeting the Sustainable Development Goals (SDGs) (Liu et al., 2018).

Important steps have been taken to facilitate direct connections between nexus research and SDGs. For instance, some indices in nexus studies overlap with SDG indicators (Karnib, 2017), such as CO_2 emissions and environmental footprints. Another example is the use of computer simulations that evaluate temporal nexus dynamics in the absence of long-term empirical data, and project when SDGs may be achieved (Purwanto et al., 2021a). There is also great potential to integrate existing "big data" frameworks across sectors of the nexus, including remotely sensed data such as those from the Global Earth Observation System of Systems.

The presence of big data brings research opportunities and challenges. The opportunities lie in the significant improvement of data quality and quantity, which allows for analyses that were previously impossible (Einav and Levin, 2014). Nevertheless, big data are complicated and messy by nature; therefore, identifying causal relationships between variables can be challenging (Shiffrin, 2016). A comprehensive data warehouse, which integrates all kinds of data sources such as satellite images, farm-level precision farming equipment, public surveys, as well as climate and market data, while protecting data privacy, would facilitate the rigorous evaluation of nexus approaches on resource and welfare outcomes.

Achieving SDGs in one place, however, may enhance or compromise SDGs in other places. The current nexus conceptual frameworks often focus on a specific place or context. More widely applicable nexus frameworks are needed to address simultaneously nexuses in multiple places, given the increasing impact of trade on nexus resources, which may reallocate costs and benefits across different places (Liu et al., 2018).

2.3.2 Nexus and scale

Water, energy and food resource systems are multi-level, and thus, attention to scale issues in the nexus is critical. Given its wide scope, the nexus concept is particularly suited to addressing resources management across spatial scales and governance levels. Some studies have started to implement the integrated framework of metacoupling (socio-economic and environmental interactions across space) to account for nexuses within a specific place (intracoupling), between adjacent places (pericoupling), and between distant places (telecoupling) (Liu, 2017).

Another aspect of spatial scales is the levels or the units of analysis that are located at different positions on a scale (local, provincial, national, etc.). The strong focus of the nexus on integration across sectors (horizontal coordination of actors and institutions at similar administrative levels) has meant that insufficient attention has been given to the vertical relationships among actors working at different administrative levels (Benson et al., 2015; Pahl-Wostl, 2019). Thus, it often remains unclear at which governance level, and when in the policy cycle, specific types of interventions might be most effective (Weitz et al., 2017).

Recent scholarship suggests that ignoring the multi-level nature of the governance systems to be coordinated is likely to be an important obstacle to successfully addressing the challenges of governing the nexus. Progress to date in understanding multi-level governance and the importance of scale have been driven by sectoral studies, including large bodies of work on water, energy and food systems. The importance of multi-level interactions in sectoral governance strongly suggests that the influence of such interactions may be even more pronounced in nexus governance as the number and complexity of institutions and actors multiplies (Young, 2017). There is a nascent literature that assesses how space and time scales matter for the effective governance of the WEF nexus and provide useful starting points to gain a more profound understanding of the scale-related challenges in nexus governance, and to develop adequate responses to them (Table 3).

Table 3. Scale-related nexus governance challenges

Nexus challenge	Description of challenge	Diagnostic queries
Scalar fit	Processes in water, energy and food systems operate on different scales and levels, and these do not correspond to the structural levels of governance at which they are currently dealt with	What are the most important scale mismatches in the nexus, and which can be ignored?
Scalar strategies	Key actors in water, energy and food sectors are strategic in how they engage with issues on different scales and levels, reflecting interests, competency and opportunities to exercise power	How are actors contesting and negotiating levels and scales in the nexus? Which actors have agency?
Institutional interplay	Key institutions in water, energy and food sectors may respond to, or drive changes in, other institutions in the same sector at other levels, and in different sectors	Is vertical or horizontal interplay in the nexus present, and if so, is it constructive or disruptive?
Uncertainty	Uncertainties arise from how resource processes, actor strategies and institutions interact on different scales and levels across the nexus	How do interactions increase the uncertainty of the outcomes from efforts to govern the nexus?

Source: Pahl-Wostl et al. 2021

2.3.3 Participation, equity and coproduction

Interlinked questions of equity, participation, transparency and conflict management have not been sufficiently included in nexus studies. While concepts of participation in natural resource management gained ground in the early 1990s, how participation is conceptualised and applied in the nexus approach remains relatively less understood (Urbinatti et al., 2020). A few studies promote participatory approaches to respond to nexus problems and support the development of a systemic understanding among sectors and actors to search for innovative ways to cooperate and collaborate (Gain et al., 2015; Howarth and Monasterolo, 2016; Halbe et al., 2015). In particular, and related to the aspect of scale, one promising participatory approach entails the elicitation of stakeholder perspectives across varying temporal and spatial scales through the use of future scenarios (Bizikova et al., 2013). Plausible future scenarios are developed around the most important and/or uncertain drivers of change to elicit insights from stakeholders and researchers on nexus resource management opportunities and threats, as well as identifying adaptive actions (Kahane, 2012). By collaboratively developing future nexus scenario narratives, disparate stakeholders can jointly create a vision of system function and ask questions relevant to achieving sustainable resource management trajectories (Chaffin et al., 2016).

The science produced towards the WEF nexus is still little open to different knowledge systems and worldviews, such as those of Indigenous Peoples. The United Nations World Water Development Report 2020 examined the challenges of governing the nexus in view of climate change and social inequality, both for Indigenous Peoples and others, impoverished or marginalised (UNESCO and UNW, 2020). The report makes social equity and climate justice central to its analysis of the water–energy–food nexus by identifying how the uneven impacts of climate change will affect those least responsible for greenhouse gas emissions. Indigenous peoples, and Indigenous knowledge in particular, feature prominently in the report as global policies promoting sustainable development continue to grapple with colonisation.

Effective nexus governance responses to multi-scale challenges must align action with values of social justice and democracy, and must validate the legitimacy of diverse knowledge systems including resource change and the strategies used to navigate the impacts of these changes (Armitage, 2008; Henry and Dietz, 2011). Evidence and action are urgently needed on mechanisms to construct "ethical spaces" and bridge diverse knowledge systems in ways that are sensitive to a moral, political and process-based approach.

3 Operationalisation of the nexus approach: A question of governance?

Has nexus research moved us forward on mitigating nexus risks? While evidence in the literature of the *potential* benefits of "nexus doing" is well established, documentation of the *actual realisation* of intended benefits of nexus approaches remains limited. Further, although the costs of nexus approaches are seemingly higher than those of silo approaches, no quantitative information is available about the additional expertise, time, coordination and financial resources required (Liu et al., 2018). It may simply be a question of time for processes to be documented, but it could also be related to incongruities between empirical nexus findings and current governance structures (Galaitsi et al., 2018).

Despite ensuing calls for more integration and coordination of sectoral policy and management, research into nexus governance remains largely detached from governance practice. One reason is that a "technical and administrative" view on governance prevailing in much of the WEF nexus literature (Cairns and Krzywoszynska, 2016) is not conducive to overcoming the barriers to effective governance in practice. This is because it frequently fails to account for the political negotiations required among stakeholders with different interests (Allouche et al., 2015; Weitz et al., 2017; Morrison et al., 2019).

Recent research examines how political institutions, namely regime type (given by a continuum from pure democracy to pure autocracy) and state capacity (as a prerequisite for public policy design and implementation), influence coordination in the nexus (Srigiri and Dombrowsky, 2022). The evidence suggests that democracies allow for a greater role of non-state actors but are not a sufficient condition for effective governance of interdependencies, as majoritarian decisions may put sustainability at risk. By contrast, autocratic conditions lead to even shorter planning cycles and centralised decision-making tends to reinforce silo thinking. State capacity plays a role in policy enforcement and funding at sub-national level but is not always used to foster ecological sustainability and social inclusion.

3.1 Institutionalisation of the nexus approach

While coordinating governance activities across complex nexus systems falls largely to national governments (George and Schillebeeckx, 2018; Head, 2018; Wiegleb and Bruns, 2018), it is frequently the smaller semi-autonomous environmental public agencies that are the key actors responsible for ensuring the delivery and implementation of the complex management and governance of these nexus systems (George and Schillebeeckx, 2018). Unfortunately, public agencies are not naturally disposed towards the interdisciplinarity, and complexity posed by nexus thinking. Indeed, disciplinary siloing within public agencies is rational where it enhances transparency, specialisation and accountability reporting (Russel and Benson, 2014).

There is a dearth of studies exploring how public agencies are responding to the WEF nexus imperative. While there is an increasingly significant literature detailing the advantages of nested multi-scalar environmental governance configurations to meet contemporary nexus challenges (e.g. Lyle, 2015; Morrison, 2007; Mwangi and Wardell, 2012), there have been few accounts of public environment agencies as actually purposely designed (in terms of their architectures and processes) as multi-scalar organisations to mirror nexus complexities and considerations. One of these examples is Natural Resource Wales (NRW), which can be characterised as a multi-scalar, hybrid, adhocratic organisation designed to meet nexus challenges (Box 1).

3.2 Payments, power and equity within the nexus

Are popular economic instruments promoted to internalise externalities capable of fostering an integrated WEF nexus perspective? In the context of hydropower development, payments for ecosystem rights (PES) may discursively frame clean energy, sustainable development and public utility, while breaking up existing socio-ecological relationships and aligning water users, rights and uses in new hydro-political network hierarchies. Actors’ strongly divergent economic and political powers may lead to prioritising certain securities related to the WEF nexus, while suppressing others (IIASA, 2018). Thus, examining the on-the-ground politics of PES and the WEF nexus is key to understanding their impact on the equitable and sustainable provision of water, energy and food (Box 2).

In response to the issues of justice, “integrity” has recently emerged as a concept to be operationalised towards achieving equity and sustainability in the water, energy, food and environment sectors, by strengthening transparency, accountability and participation, along with reinforced anti-corruption measures in every aspect of natural resources governance.

BOX 1 Public-agency responses to nexus complexity: The case of Natural Resource Wales

The multi-scalar form of Natural Resource Wales (NRW) entails a national office in Cardiff (the capital city of Wales) which manages central functions (e.g. HR, finance and leadership) and 15 place-based area teams within six geographical and administratively cognate regions. Each inter-disciplinary team comprises a mixed group of experts and specialists, so that disciplinary silos can be broken down by encouraging place-based, multi-team co-produced solutions to complex multi-faceted problems. By entrusting place-based teams with significant decision-making responsibilities and accountabilities, it opens the opportunity for scale-appropriate decision-making. This offers the co-benefit of driving greater local public engagement with decision-making processes through the visible and engaging place-based teams, and, if these teams function correctly, it is hoped it will lead to increased plural public participation in local-scale natural resource decision-making (Kirsop-Taylor and Hejnowicz, 2020).

NRW designed six core innovations to meet nexus challenges. These are the area statements, the State of Natural Resources Report (SoNaRR), public service boards, place-based area teams, digital communications and training. The SoNaRRs act as visible and tangible artefacts that can be used to inform, support and evidence multi-scale decision-making, including engaging with meeting public expectations and accountabilities on the natural environment. The four-yearly nature of the SoNaRR cycle, coupled to its plural and partnered data collection processes and its position in meeting statutory executive accountabilities, drives adaptability, and more generally, in managing nexus complexity over time, potentially acts as an iterative and adaptive feedback system.

NRW's example suggests that institutionalising a nexus approach involves a dual set of processes, in which some innovations are engineered into the design of the agency while others emerge and develop iteratively. In NRW's case, many aspects of the "architectures" and "processes" were instituted via design, for instance, SoNaRR, Area Statements and place-based teams, while other elements that were "not known", "not anticipated", or simply "no one has done this before", gradually developed over time (Kirsop-Taylor and Hejnowicz, 2020).

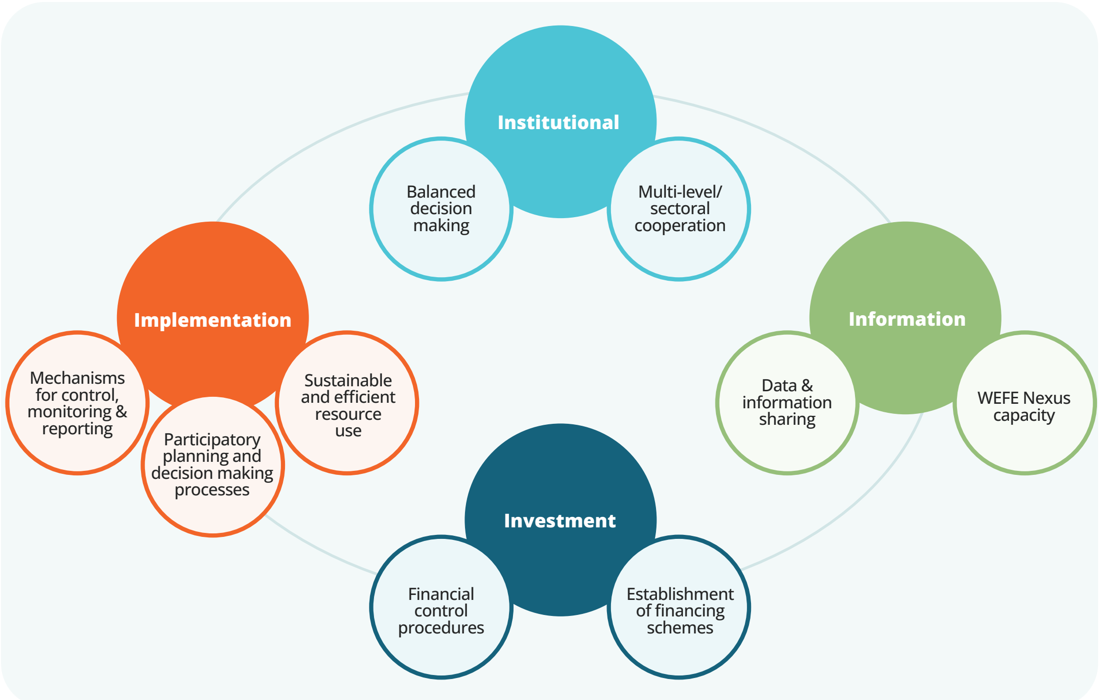
The project "Identifying Integrity Risks and Developing Integrity Guidelines on the Water-Energy-Food-Ecosystems Nexus" by the Water Integrity Network seeks to respond to governance and integrity concerns within the nexus approach. The framework identifies risks in four components within the establishment and operationalisation of nexus projects: institutional, information, investment and implementation. The Water Integrity Network also provides guidelines and tools to address these risks (Figure 10).

BOX 2 Economic instruments in hydropower development and equity within the nexus

The Hidrosogamoso hydropower plant in Colombia uses PES (payments for ecosystem rights) to pay for the conservation of upstream forests to improve water provision, reduce sedimentation and offset environmental impacts. An analysis of the socio-environmental impacts (costs and benefits) for different actors at different scales up- and downstream, shows that the PES scheme successfully provides water security (SDG 6) for hydropower production (SDG 7). Despite the PES scheme and an Environmental Impact Assessment (EIA), the plant negatively affects the water and food securities of marginalised communities further downstream. In particular, the principle of prior and informed consent was not applied in the EIA.

This example illustrates how in hydropower development it is common to provide greater social legitimacy for large-scale water diversions and reallocations, while disregarding the underlying power dynamics that underpin marginalisation. The interests, perceptions and values held by local communities, with alternative, territory-grounded ideas on water rights, ecological dynamics, environmental problems and, in particular, locally embedded cultural understandings and meanings attached to nature and livelihood construction, are often sidelined. Rather than confirming and conforming to neutralising, depoliticising and naturalising nexus approaches, solutions should address underlying structures of inclusion and exclusion, resource deviation, unequal access, and appropriation (Duarte-Abadia et al., 2015).

Figure 10. The Integrity Framework for water, energy, food and environment (EFE) nexus



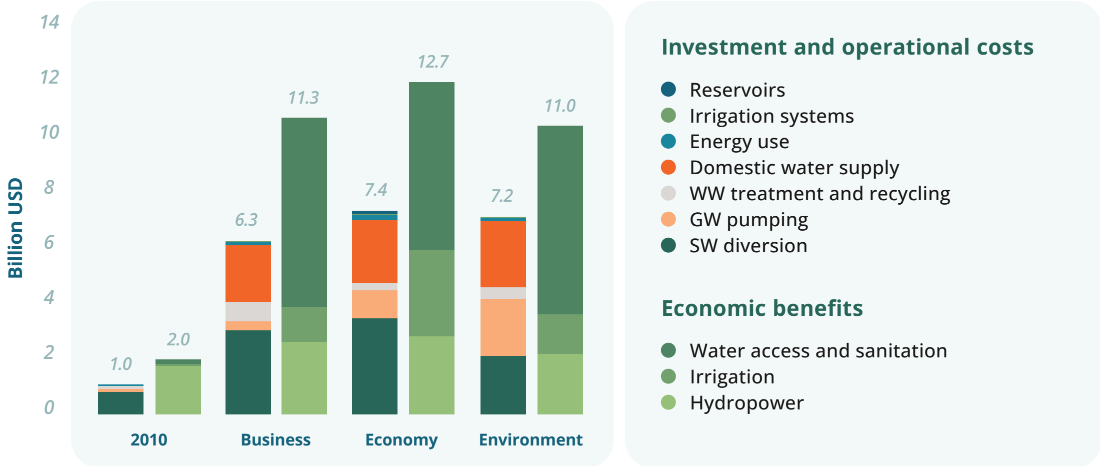
Source: Water Integrity Network, 2022

4 The way forward: Recommendations for decision-makers

4.1 Rely on the evidence for "nexus doing"

There is now ample and rigorous evidence of the economic, social and environmental benefits of promoting greater cooperation across sectors, moving away from siloed planning towards the adoption of an integrated approach to policy and planning. Evidence from multiple parts of the world shows that investing in strategies seeking to minimise trade-offs across sectors and with the environment will not compromise economic returns – instead it will deliver large social and environmental benefits. Scenario modelling in the Zambezi Basin shows that the net benefits in a business-as-usual response are similar to the returns that will be generated under the environment first scenario, which incorporates cross-sectoral measures such as improving irrigation efficiency and supporting crop diversification policies for staple crops, and strict policies aimed at protecting environmental stream flows and reducing deforestation and associated land use emissions (Figure 11). Further, returns from investments in access to piped drinking water and sanitation multiply the investment costs by 2.5, highlighting the importance of such investments to support socio-economic development in addition to many non-monetary benefits (IIASA, 2021).

Figure 11. Economic benefits and costs of alternative development pathways of the Zambezi Basin



Source: IIASA, 2021

4.2 Leverage existing modelling tools to adopt inclusive governance approaches

There are different views on how integrated and cooperation pathways can materialise. Some believe that development pathways should maximise the use of available natural resources for socio-economic well-being. Conversely, others envision a pathway were cooperation goes hand in hand with strategies seeking to minimise trade-offs across sectors and with the environment to maintain natural capital and support green development.

There are multiple tools available to help identify development pathways that recognise the interconnectedness of water, energy and land resources, thus minimising negative cross-sectoral impacts and maximising the reach of limited financial resources, such as WEAP (Water Evaluation and Planning), LEAP (Long-range Energy Alternatives Planning), GAEZ (Global Agro-ecological Zones) and CLEW (Climate, Land-use, Energy and Water). Nevertheless, we highlight that the alternatives that are planned for the management of the interrelationships of the nexus require transformative changes that critically depend on institutional and governance considerations. Changes in policy, institutional and technical domains that disrupt business-as-usual responses may be required. That is, governing interlinkages requires responding to the role of asymmetrical power balances and the politics behind interconnected social and biophysical systems (IIASA, 2018).

Inclusive governance approaches for policy action in the nexus include: multi-stakeholder collaboration to draw on various knowledge systems, values and experience; polycentric governance systems with shared governance responsibilities across decision-making at various levels of governance; experimentation and flexibility in testing policy interventions; and social and adaptive learning that builds on multi-stakeholder collaboration (FAO, 2022b). Recent methodological innovations based on the concept of network of action situations have the potential to operationalise the analysis of polycentric governance systems in the context of WEF nexus.

Instead of delineating action situations based on sectoral boundaries, the application of the “problem shed” concept focuses the analysis on the actual issues facing the coordination problem so that the coordination can be assessed for its conditions and performance in solving the problem. Various methodological guidelines have also been developed to strengthen institutional capacities in the design, implementation and evaluation of nexus actions. For instance, The Economic Commission for Latin America and the Caribbean has published a methodological guide on the design of actions with a focus on the nexus between water, energy and food for Latin American and Caribbean countries (Naranjo and Willaarts, 2020). The bridge from “nexus thinking” to “nexus doing” has already been crossed in some regions. For instance, in 2020, the SADC Water-Energy-Food (WEF) Nexus Governance Framework was approved by the ministers responsible for energy and water from the Southern African Development Community (SADC) (GWP, 2021). The framework provides guidance for: (i) coordinating the three sectors (water, energy and food) policy and decision-making level (i.e. ministerial level); (ii) coordinating the three sectors at the regional technical level; (iii) coordinating the units responsible for the WEF sectors within the SADC Secretariat; (iv) coordinating with regional implementing entities and other partners; and (v) strengthening multi-stakeholder platforms.

4.3 Effectively engage actors in participatory policy making and decision-making

Engaging diverse stakeholders in policy decisions about nexus governance brings multiple sources of knowledge, values and information to the table, contributing to building trust, social cohesion, and the rule of law. Participatory policymaking and decision-making also help defuse conflict and reframe issues holistically by identifying trade-offs and synergies across constituencies (FAO, 2022b). Meaningful engagement is often challenging, requiring substantial efforts to build relationships, facilitate collaboration, and build the capacity of marginalised stakeholders to participate and link these processes to policy outcomes. The actors involved need to ensure that decisions are binding and aligned with agreed roadmaps for policy implementation, with defined roles and responsibilities for all actors involved.

There are several ways to design and manage a participatory process, but no clear principles exist to help stakeholders choose the most successful approach. Nevertheless, there is an increasing body of work providing recommendations on how to develop a policy tool to assist those interested in designing and implementing a participatory policymaking process (Rodriguez and Komendantova, 2022).

4.4 Promote an integrated tenure rights-based approach

A key aspect of nexus governance is tenure, which can be defined as the relationship, whether legally or customarily defined, between people, as individuals or groups, with respect to natural resources. Secure tenure plays a critical role in ensuring sustainable livelihoods, good governance, environmental protection and sustainable economic development (FAO, 2022b). While contemporary water laws tend to de-couple water rights from land tenure, the land/water nexus persists in many ways and can have an important impact on the realisation and security of the various water rights, particularly those constituting the customary water tenure of traditional and other rural communities.

An integrated, tenure rights-based approach has the potential to unpack the relationship between rights to water, land and other terrestrial resources, helping to identify gaps and synergies across sectoral legislation or practices, and enabling a more integrated approach that promotes inter-sectoral harmonisation. This requires consideration of the various ways in which the nexus shapes the recognition and protection of various water tenure regimes. And, in particular, the role of customary water tenure practiced by traditional communities, as well as the opportunities the nexus poses for more integrated and sustainable approaches to terrestrial and freshwater resource management and development (FAO, 2020).

4.5 Align trade and economic policies to water, energy and food security

To protect freshwater by meeting environmental flow requirements (EFRs) and supply sufficient food for future generations, increased inter-regional trade in agricultural products is needed to supply the world's population with sufficient food. The combined impact of climate change and EFRs would increase net trade by up to 15% globally compared with a business-as-usual scenario (Pastor et al., 2019). Trade liberalisation can potentially have significant consequences for regional crop production, leading to increased imports, and this could have negative consequences for food security in the importing countries and for the environment in the exporting countries. To reduce the negative effects of agricultural expansion policies, exporting countries could establish expansion limits for agricultural land dedicated to export crops and intensification policies (to avoid expansion). It is important for a regime with more food trade to be combined with policies guaranteeing food access and affordability because sufficient production does not guarantee access to food for all.

Removing harmful subsidies and aligning incentives across the three dimensions of the nexus is key to getting the appropriate levels of investment, innovation and resources. Fossil fuel subsidies imply a host of economic, fiscal, social and environmental costs. Subsidies reduce the incentive to invest in new infrastructure, distort prices, and are inefficient at transferring income to the poor. Removing misaligned subsidies on water, energy, food and land, has been described as a "nexus no-brainer" (Ringler et al., 2013).

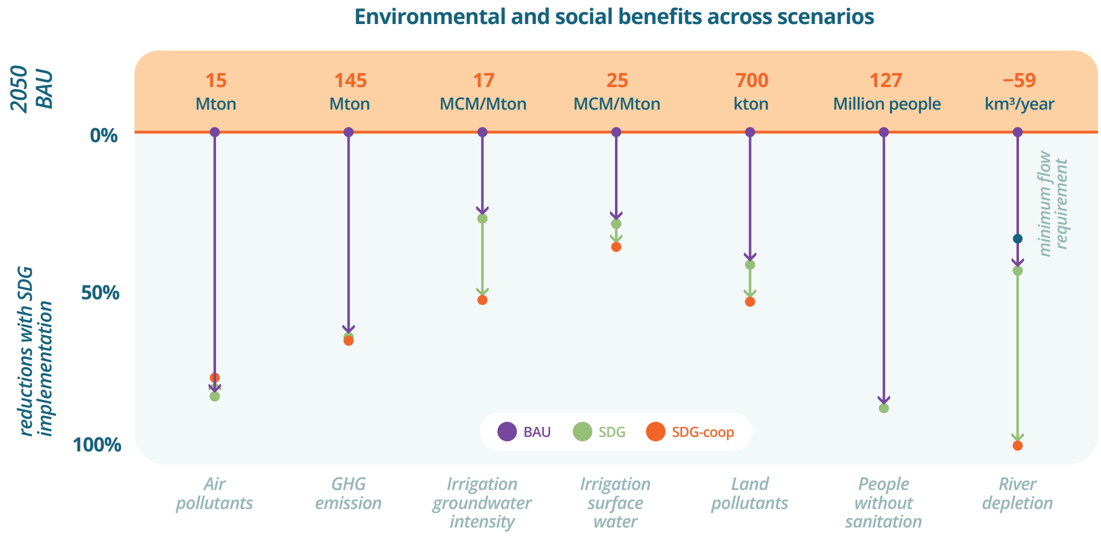
4.6 Change accountability processes to plan for the long-term

In many cases, trade-offs are caused by short-term, reactive and hurried policy, and so represent “false dichotomies”. It is not necessary to trade biodiversity for economic growth, for example. In this regard, it is fundamental to increase the accountability of the decision-making process, combining evidence and data from decision makers and narrowing the gap between short-term policy objectives and long-term frameworks of measures to manage nexus shocks. For instance, Norway has introduced a “model” approach, where sectoral reporting is no longer conducted and cross-sectoral analysis has been dropped altogether (Lafferty et al., 2008).

4.7 Improve articulation at the global level

Protection of the planetary system, efforts to strengthen social cohesion, and global cooperation are three linked concepts. Evidence suggests that countries in the Indus basin, with a rapidly growing population of 250 million, could lower costs for development and reduce soil pollution and water stress by cooperating on water resources management and electricity and food production. Indus basin countries need to increase investments to USD 10 billion per year to mitigate water scarcity issues and ensure improved access to resources by 2050, but costs could shrink to USD 2 billion per year, with economic, social and environmental gains for all, if countries pursued more collaborative policies (Figure 12).

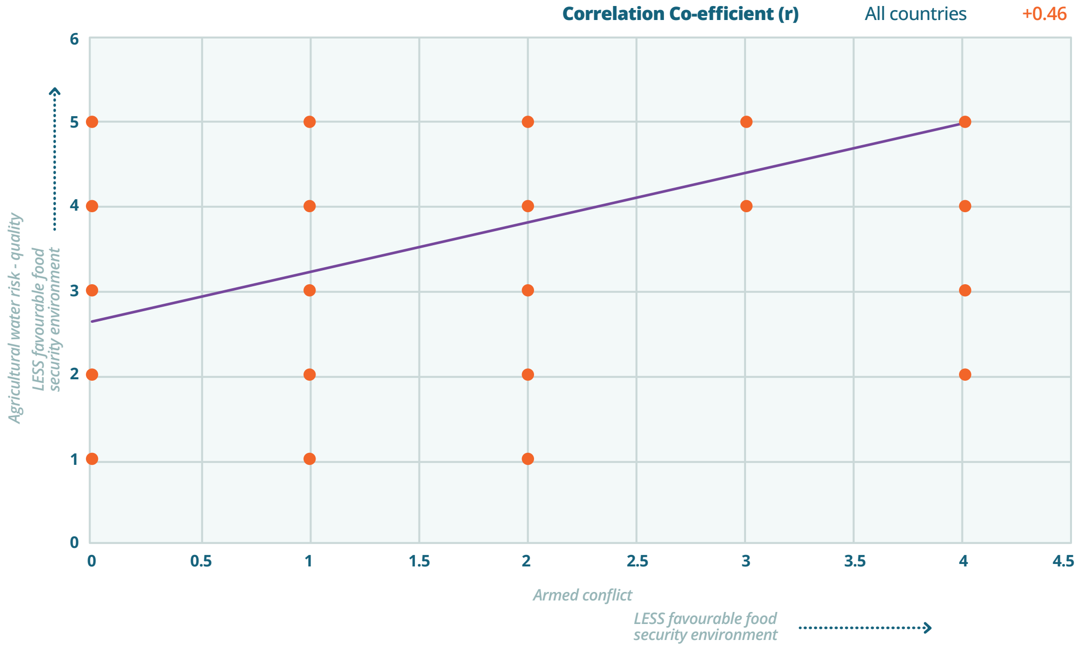
Figure 12. Indus basin development scenarios



Source: Vinca et al., 2021

The main finding from the 2022 Ecological Threats Report is that without concerted international action current levels of ecological degradation will substantially worsen, thereby intensifying a range of social challenges, including malnutrition, forced migration and illness. Current conflicts will escalate and multiply as a result, creating further global water, energy and food insecurity (IEP, 2022). The GFSI shows that armed conflict is strongly linked to lower food security scores (The Economist Group, 2022). Conflict is also closely connected to climate change. Of the 25 nations most vulnerable to climate change, 14 are mired in conflict (ICRC, 2020). The GFSI also shows a link between armed conflict and water pollution, with conflict impacting the quality and availability of this key resource (Figure 13).

Figure 13. Correlation between armed conflict and water quality



Source: The Economist Group, 2022

The cyclic and systematic relationship between ecological degradation, societal resilience and conflict cannot be over emphasised. And a sectoral-based approach is not helping. International coordination is vitally important to implement a holistic approach to reach the next level of understanding of the very complex socio-environmental dynamics that have driven us into the current sustainability conundrum. Climate change and nexus sustainability are global challenges that transcend borders, and national policies have strong international spillover effects. Policy makers are well placed to scrutinise and rethink domestic policies – but ultimately all countries need to act together to effectively address the global and interconnected threats to our water, energy and food systems.

4.8 Including and operationalising resilience

Resilience thinking encompasses is the notion of system's ability to "bounce back" following a negative shock (Folke et al. 2010; Holling 1973). For systems where the state before the shock is a refereed to the state after the shock, resilience offers benefits. The challenge with operationalising to maintain or improve resilience is that this depends on the systems and the possible shocks.

A useful set of questions for including and operationalising resilience is for decision-makers to respond to seven key questions: (1) Resilience of what objects (system, system component or interaction);is being managed?; (2) For whom (stakeholders) is resilience being managed?; (3) What are the metrics of system performance for the identified stakeholders; (4) What are the viability (or safety) goals of the stakeholders (and associated metrics) for key system variables that allow a system to retain its identity?; (5) What adverse events or causes, in relation to resilience, are being considered?; (6) How are the three Rs (resistance, recovery and robustness) measured in relation to system performance and in response to adverse events?; and (7) What are the expected net benefits, currently and over time and space, of resilience-management actions? (Grafton et al. 2019).

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