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Policy Brief

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Task Force 3: Science and Digitalization for a Better Future

Sustainable and Scalable Food, Water, and Land Systems through Technology, Innovation, and Inclusion

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Abstract

The increasing pressure on food, water, and land systems demands an urgent transition toward more sustainable practices. Increasing access to and use of science, technology, and innovation is an important part of the solution, especially access to digital technologies. However, addressing the complex and interrelated problems affecting food, water, and land systems requires not only quantitative improvements in access to technology but also profound changes in the **direction** of the governance of these systems. This policy brief highlights that: (i) **Digital technologies** are fundamental

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for system-wide change in food-water-land systems by improving the monitoring, access, and use of new data and evidence for decision making, as well as helping scale up existing innovations that have transformative potential at the grassroots/community level. (ii) **Participatory modes of governance** need to be prioritized as the standard practice for sustainable food-water-land systems. This approach recognizes that effective governance requires the active participation of stakeholders, particularly local communities, in decision-making processes related to the management of food, water, and land resources. (iii) **Policy experimentation** is essential for the implementation of sustainable food-water-land systems, as it can help identify and test new approaches to complex challenges based on participatory approaches and build experience in using evidence in designing policy solutions.

Challenges

Our current food, water, and land systems are stretching the planetary capacity at an unprecedented and alarming rate. These escalating pressures are primarily explained by the dominant agricultural practices and extractive activities, which cause land degradation, pollution, and excessive depletion of surface water and groundwater resources. Human-induced deterioration of land and water resources has further domino effects on access to nutritious food, as well as on the biodiversity and environmental services that underpin resilient livelihoods.

The current systems are not resilient to shocks and stresses, such as those created by climate change, which, in turn, brings an additional loop of disruptions, exacerbating the impacts of natural disasters on food, water, and land systems and their social effects. For instance, extreme weather events that destroy crops and disrupt supply chains also affect land and water scarcity that can exacerbate inequalities and lead to social conflicts. In other words, food, water, and land systems are tightly interconnected, with complex feedback loops that potentially amplify the risks and negative impacts that need to be managed. The adverse effects are more heavily felt in rural communities, especially among women and in developing countries, where the dependency on these resources is more direct and alternative livelihood options are limited.

Food, water, and land systems require urgent and profound transformation to become sustainable. Evidence and history indicate that science, technology, and innovation (STI) can play a pivotal role in driving this transformation (Kraemer-Mbula and Wamae 2010; Kraemer-Mbula et al 2023; Perez 2013). The uneven access and use of STI across countries and regions is often seen as a central part of the problem, perpetuating poor agricultural practices and the subsequent degradation of water and land systems. Therefore, increasing access to and use of STI is often regarded as central to the solution.

For instance, it is essential to improve the access of small-scale farmers to the latest farming technologies and digital technologies as well as information on sustainable farming practices. This improved access would allow them to not only increase their productivity but also improve the quality of their crops. However, limited connectivity, resources, and capabilities impede widespread technology adoption among small-scale farmers. Similarly, rural communities lack access to modern water management technologies, such as water treatment plants or irrigation systems, due to limited skills, resources, and infrastructure.

Access to digital technologies matters, as it can contribute to economic development and to climate change mitigation (Paris Agreement) as well as the attainment of several other United Nations Sustainable Development Goals (SDGs). Earth observation technologies (e.g., satellite and remote sensing technologies), the Internet of Things, robotics, and artificial intelligence can improve energy efficiency and management in all sectors and play a strong role in relation to energy systems with high shares of renewable energy. Digitalization can enable emission reductions by increasing energy efficiency and promoting the adoption of low-emissions technologies while also creating new market opportunities (IPCC 2022a). Digital technologies, however, also raise broader sustainability concerns due to their use of rare materials and associated waste, high energy demand, and their potential to reduce equality in access and employment (IPCC 2022b).

Digitalization could facilitate a fast transition to sustainable development and low-emission pathways by contributing to efficiency improvements, cross-sectoral coordination, and a circular economy with new information technology services and decreasing resource use. During the coronavirus disease (COVID-19) pandemic, for example, consumers turned to online shopping for food and personal hygiene and disinfection products, a practice that could reduce greenhouse gas emissions due to sharing platforms. Several synergies between digitalization and the SDGs could emerge in terms of energy, food and water access, health, and education, as well as trade-offs, for example, in relation to reduced employment in particular in low-paying jobs, increasing energy demand, and increasing demand for services. Problematically, without major investments in internet access, developing countries with limited internet access and poor infrastructure would to a large extent be excluded from the benefits of digitalization (IPCC 2022c). While digital technologies offer a lot of promise to catalyze change, wider policies—including those of sustainability and investments to ensure access in all parts of the world—are vital to move toward low-emissions ways of living and working and to shape technology development to deliver positive outcomes to the planet (Royal Society 2020).

As important as improving access to technologies is, especially digital technologies, improved access is unlikely to solve these problems alone. Many technologically focused solutions to complex and interrelated challenges, such as those affecting food, water, and land systems, fail to achieve their intended goals. This track record demonstrates that technology alone cannot fix these systems and points to the importance of participatory, discursive methods for effective policy making under conditions of deep uncertainty.

Addressing the urgent, complex, and interrelated problems affecting food, water, and land systems requires **innovative responses that lead to transformative changes**, which often involve reimagining the current system and challenging the status quo. These transformative changes refer to fundamental and widespread changes to the structures, policies, and practices that underpin the current food, water, and land systems and result in system-level changes that are sustainable and equitable. Such changes require not only quantitative improvements in the access to technology but also changes in the **direction** of the governance of these systems—changes in the direction of policy, regulation, and investment.

Supporting transformative innovation requires a multifaceted approach that involves the co-creation of solutions among multiple stakeholders; bottom-up, participatory approaches to policy making and governance; and policy experimentation (Ghosh et al. 2021; Schot and Steinmueller 2018). Governments, nongovernment organizations, the private sector, and civil society all have roles to play in addressing these challenges and ensuring that the benefits of technological advances in the food and water systems are available to all.

In light of this background, some concrete challenges remain:

Firstly, we need to improve the access to digital technologies. Digital technologies are fundamental for system-wide change in developing countries. They are reshaping all segments of society, including economies, governance, and civil society—almost every aspect of people's lives. The exponential pace of the digital revolution and its profound consequences demand a better understanding of the new context, as well as the intentional and inclusive design of digital transformation efforts to ensure that no one is left behind. Digital transformation should be made inclusive in order to realize the SDGs. Deeper, fairer, and inclusive digital transformation means that countries will enjoy important economic and social benefits, thus unlocking new opportunities, supporting economic growth, reducing poverty, improving public service delivery, and accelerating social protection programs (UNDP – Chief Digital Office 2022).

Secondly, we need to better identify and scale up other types of innovations that have transformative potential—those that, if deployed extensively, could reduce the negative impacts of current food-water-land systems while addressing overarching challenges such as climate change and inequality. These include innovations that are already taking place in developing countries, often at the grassroots level and often involving vulnerable communities. Many of these innovations remain invisible and at a very small scale despite their transformative potential.

Thirdly, none of these innovative responses can go far without effective governance. However, many of the agents of change remain excluded from the governance. This scenario implies that key actors are not represented in the policy design and implementation process and rarely have a voice in the design and implementation of policy interventions. We must promote and support inclusive forms of land and water governance in order to create the transformative changes needed to achieve patterns of sustainable agriculture that can enhance income and sustain livelihoods while protecting and restoring the natural resource base.

Proposals

Improve Access to Digital Technologies and the Capacity to Develop Them

We must improve access to existing digital technologies and build people's capacity to develop new ones, with particular focus on **improved measurement**, **data quality**, and **monitoring** for food-water-land system linkages, as well as with climate change. Improving access refers to addressing issues related to restricted access, slow adoption of data standards, and digital agriculture sector fragmentation. Improving the capacity to develop digital technologies requires addressing issues related to skills and infrastructure, which requires training and upskilling for digital technologies to develop, for example on the relevant digital technologies like weather forecasting, agro-advisories (crop choice, irrigation and fertilizer timing, etc.), market information, and digital payments. Addressing such issues related to skills and infrastructure requires long-term investments in global monitoring of a variety of hydrological and food-related key indicators. For instance, the World Resources Institute (WRI), a research organization, has been working on developing a global map by using satellite data to monitor forests in association with topography, hydrology, and land use

change.[1] This user-friendly online platform could be accessible everywhere an adequate internet network reaches.

The digital divide more adversely affects women farmers in multiple ways. Analyses of household surveys show that women receive lower prices for their produce at the market across various low- to middle-income countries; this is illustrated for the cases of Bangladesh, Malawi, Peru, Uganda, and Tanzania in Dickson and Koo (2022). Women farmers also have less access to digital platforms that provide access to financial services (e.g., credit), education, and social media. Similarly, women farmers have less access to market information and are less likely than their male counterparts are to access extension services or own a mobile phone (CGIAR 2023). Efforts to bridge the digital divide should consider the specific needs and challenges faced by women farmers.

Better Identify and Scale Up Existing Innovations with Transformative Potential

There are multiple examples of transformative innovations in developing countries, often at the community/grassroots level. These include (i) agroforestry (sustainable agricultural practices that involve planting trees and crops together in the same area to improve soil quality, reduce erosion, and increase crop yields), (ii) integrated pest management (a holistic approach to pest management that focuses on long-term prevention of pests or their damage through a combination of techniques including cultural and biological control methods), (iii) drip irrigation (a water management system that delivers water directly to the roots of plants, reducing water waste and increasing crop yields), (iv) rainwater harvesting (which involves collecting rainwater for use in agriculture and other purposes), and (v) community-based natural resource management, where local communities work together to manage and protect natural resources, such as forests, rivers, and wildlife.

While these transformative innovations are often based on traditional practices and principles, their efficiency, accessibility, and sustainability can be improved through the integration of digital technologies. For instance, the community-based water management system for farming called subak in Bali, Indonesia (UNESCO n.d.) can be digitalized through the introduction of digital sensors and water monitoring, geographic information system (GIS) technology to map the subak system, use of mobile application and digital payment systems to facilitate transitions, and digital platforms to facilitate collaboration and knowledge sharing systems. Overall, digitalizing sustainable practices such as the subak system can help to modernize and scale them while preserving their core values and principles.

In emphasizing the ability to rapidly step up existing innovations, using simple technologies like communicating weather and agricultural advisories over the radio can be surprisingly effective (Ingabire 2021). Big data and artificial intelligence enable scientists to search gene banks and select specific crop traits for breeding improved crop varieties (Xu 2022). Other innovations include monitoring and enhancing water productivity or connecting solar irrigation pumps to data platforms that help to manage and mitigate against excessive depletion of surface water and groundwater resources (IWMI 2022).

[1] This map is accessible at the online platform of Global Forest Watch: https://www.globalforestwatch.org/.

Facilitate and Promote Participatory Modes of Governance

Participatory modes of governance can help to ensure inclusive, equitable, and sustainable processes for making decisions that affect food-water-land systems in developing countries. They can help to empower local communities, promote sustainable practices, and build trust between stakeholders. Participation in governance enables stakeholders to examine the implications of possible future changes and to navigate emergent difficulties and opportunities so that environmental challenges can be addressed effectively. Participatory methods allow participants to imagine radically different configurations of the food-water-land systems and examine ways in which technologies can be more effective and culturally acceptable.

One example is the "farmer-to-farmer" method, a participatory approach to agricultural development that involves farmers sharing knowledge and best practices with each other. In this method, farmers are supported by volunteers, technicians, professionals, and local development organizations through training, collaboration, and small-scale experimentation, while farmers remain the protagonists in the process of generating and sharing technologies. Building on these experiences, La Via Campesina, a global peasant movement, has been at the forefront of promoting agroecology and building the capacity of small-scale farmers to adopt agroecological practices. As part of this effort, La Via Campesina has created a network of agroecology schools that provide technical and political education to farmers while promoting experimentation, innovation, and the sharing of best practices. A second example is participatory plant breeding, which recognizes the knowledge and expertise of farmers in the development of new crop varieties that are better adapted to local conditions, more resilient to pests, and better suited to meet the local needs. A third example of participatory methods is water user associations, which are community-based organizations that are responsible for managing water resources at the local level. These organizations are typically made up of water users, including farmers, and are responsible for the management, maintenance, and distribution of water resources.

Support Policy Experimentation

Growing uncertainty and complexity in a rapidly changing context calls for flexible and novel approaches to policy. In many cases, there is a clear need to try and test new policy approaches or interventions.

One concrete example of policy experimentation in food-water-land systems that has been implemented is payments for ecosystem services (PES) programs. These programs involve paying farmers and landowners to provide ecosystem services, such as maintaining forests and air quality or preventing soil erosion, which in turn will benefit society as a whole. PES programs have been implemented in several countries, including Costa Rica (Garbach, Lubell, and DeClerck 2012), Ecuador, and Nepal. In the cases of Ecuador and Nepal, the positive socioeconomic and environmental outcomes of PES programs were enhanced by the addition of technical assistance in conservation technologies. One such technical assistance project is the Knowledge-Based Integrated Sustainable Agriculture in Nepal (KISAN) project (Kumar et al. 2020).

Another relevant example of policy experimentation is the practice of providing incentives to farmers to adopt agroforestry practices. For example, India, Brazil, and Ghana have implemented different types of incentive programs to promote agroforestry practices—such as the Programa Agricultura de Baixo Carbono (Low Carbon Agriculture Program) in Brazil and the National Tree

Crop Development Plan in Ghana, which guides the provision of financial incentives and technical assistance to farmers who adopt agroforestry practices.

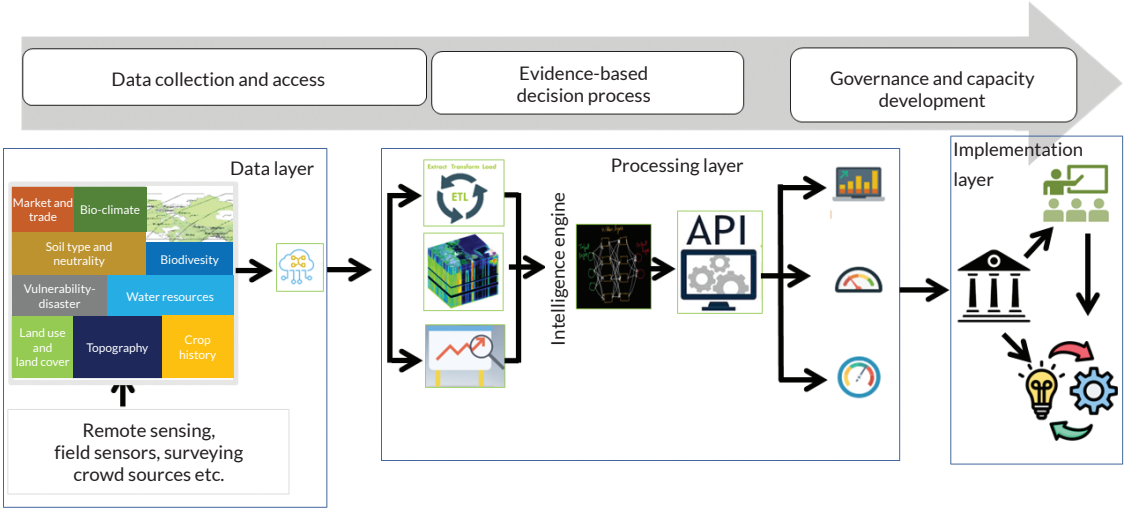
By experimenting with policies and interventions, governments can learn what works and what does not in the governance of food-water-land systems and develop policies that are more effective and responsive to local needs.

Implementation

Transformative innovations like conservation agriculture, agroforestry, and integrated pest management can aid in enhancing soil fertility, conserving water resources, reducing the use of agrochemicals, and improving the resilience of agroecosystems. Adopting these innovations and practices can enable farmers to produce more food while conserving natural resources and promoting sustainable development.

Innovative technologies, such as precision agriculture, digital platforms, and artificial intelligence, can revolutionize the agricultural sector—to cite one example—by improving productivity, sustainability, and efficiency. To make use of these technologies, a wide range of data sets is required, which can be collected using various techniques and sources, including remote sensing, field surveys, governmental agencies, development agencies, and crowdsourcing through equipped information and communication technology infrastructure. These technologies and data collection approaches can help farmers make evidence-based decisions, optimize their operations, and achieve sustainability. Combining these approaches and supporting them with appropriate policies and governance frameworks, we can work toward creating a sustainable future for our

Figure 1: Typical Framework for the Use of Innovative Technology to Generate Food and Land Systems at Scale



API = application programming interface.
Note: Icons obtained from different sources.
Source: Authors.

food, water, and land systems. This can be done through the implementation of three stages: (i) data collection and access, (ii) evidence-based decision process, and (iii) supportive governance and capacity development. Figure 1 shows a general framework to implement such a system.

Data Collection and Access

Access to data is crucial for evidence-based decision making as it informs decision makers through the analysis of patterns, trends, and relationships between variables. The methods for collecting data in food, water, and land systems need to be improved. In recent decades, a large number of sensors and mobile devices and the Internet of Things have revolutionized the collection of precise data sets at unprecedented spatiotemporal scales. Additionally, the advancement of technologies such as cloud-based storage, high-performance computing, and advanced machine learning algorithms (Delgado et al. 2019) enables the automatic extraction of necessary data from diverse sources (Khanal, Fulton, and Shearer 2017). Still, a huge gap exists in developing countries in terms of collecting, preprocessing, and accessing the data.

Improving data collection and access in developing countries requires a multifaceted approach that involves the following actions:

(i) Develop the necessary technical expertise for data collection. This includes widespread advanced digital skills programs.
(ii) Invest in digital technology infrastructure, such as mobile devices, sensors, and remote sensing technologies, in order to collect data in a cost-effective and timely manner.
(iii) Enhance data sharing through the creation of data-sharing platforms, establishing data standards, and promoting collaboration among stakeholders.
(iv) Improve data quality by developing quality control measures, improving data validation processes, and enhancing data cleaning procedures.
(v) Address data gaps, which may involve engaging with local communities through participatory data collection approaches and investing in innovative data collection methods.
(v) Ensure data privacy and security by establishing appropriate regulatory frameworks such as data protection laws and data security protocols.
(vi) Support open data platforms, which can provide access to data that can be used for decision making, including to inform policy decisions.

Evidence-Based Decision Process

Information extraction from the available data is crucial, as it enables decision makers to identify patterns, trends, and relationships among variables. After adopting a solution, data can be used to measure program impact, enabling decision makers to adjust their strategies accordingly. Access to data, along with advanced computing facilities and tools, can further help to extract information necessary for the decision makers. Such information makes it easier to identify areas of need, measure progress, and collaborate effectively with stakeholders, improving the transparency in resource allocation and decision-making processes. Additionally, such information can help individuals better manage resources. For example, farmers can use crop monitoring data to keep track of irrigation status, nutrient requirements, and vegetation health conditions. Then, they will be able to adjust irrigation, nutrients, and crop management plans in a way that can improve productivity and, consequently, profit.

Improving the use of evidence in decision-making processes requires several efforts. Firstly, it requires developing institutional and organizational capacities for evidence analysis; e.g., establishing advanced computing facilities, thematic observatories, and specialized research centers. Secondly, it requires improving organizational tools, resources, and processes (OECD 2020), including tool kits, knowledge management protocols, organizational strategies and evaluation frameworks, and dedicated funds for commissioning research. Thirdly, it requires developing specialized and intensive training for government officials to use and analyze evidence for decision making. Finally, it implies creating participatory dissemination mechanisms to improve users' capacity to utilize the data/evidence tailored to local requirements, with easy and/or free access for users.

Governance and Capacity Development

A sustainable future for our food, water, and land systems requires effective governance. This includes the development of policies, regulations, and frameworks that ensure the responsible and ethical use of technologies. It also includes capacity development to ensure that people use the technologies sustainably.

Improving governance of food-water-land systems implies that:

(i) Participatory governance modalities should be prioritized as the standard governance practice for sustainable food-water-land systems. This approach recognizes that effective governance requires the active participation of stakeholders, particularly local communities, in decision-making processes related to the management of food, water, and land resources.
(ii) Policy experimentation is essential for the implementation of sustainable food-water-land systems, as it can help identify and test new approaches to complex challenges based on participatory approaches and build experience in using evidence to design policy solutions.

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