Plenary session - grappling with complex systems: the water-energy-food nexus experience

Overview of the session

New paradigms regarding agriculture as an integral part of interlinked value chains that promote sustainable growth, food and energy security and waste reduction are emerging. The Water-Energy-Food nexus embodies several trade-offs/synergies between food, environment, health/nutrition. The main focus of the session is on ways in which we can reconcile the many interactions in this complex system and use these approaches to improve the way CGIAR research is designed and implemented.

One way of dealing with complex systems is through models. Models are tools: their real usefulness stems not only from their ability to predict the outcome of management interventions, but rather in their power to foresee the likelihood and severity of opportunities and consequences that might arise from a combination of climate, soil, plant, animal and human interactions. The difference between prediction and foresight might appear subtle, yet it is profound: predicting an outcome transfers all power to the person making the prediction (usually a scientist), while foreseeing likelihoods and consequences empowers actors to choose and actively create the desirable future they envision while avoiding undesirable outcomes.

Two background papers were commissioned to guide the discussions in this session, and their findings are summarized below.

1. The climate-land-energy and water nexus: Implications for agricultural research. Vignesh Sridharan, et al.

This paper reviews the evidence on the relationship among the SDGs. In particular, the authors examine how progress towards SDG2 “Zero hunger” and the related CGIAR System-Level Outcome 2 “Improved food and nutrition security” intersects with each of the targets in SDG6 on clean water and sanitation, SDG7 on affordable and clean energy, and SDG13 on climate action. The initial mapping relates simply to whether a trade-off or a synergy has been documented. Does progress towards zero hunger come at the cost of progress on clean water and sanitation or on the targets for energy and climate action? Or are there potential win-win solutions that allow us to progress on these objectives in tandem? See table 1 for a summary of the key synergies and trade-offs at the SDG level.

A tremendous amount of literature has been sifted through, coded and analyzed – the 231 papers cited in the report are testament to this. In this initial mapping, the existence of a single study showing either a trade-off relationship or a synergistic relationship is sufficient for that relationship to be coded. Consequently, given the sheer breadth and contested nature of the evidence base for each of these relationships, it is not surprising that most relationships are coded for both. Indeed each of these relationships is arguably sufficiently important to be subject of a systematic review – a transparent and systematic search and evaluation strategy applied to the literature, with studies being filtered out for quality – which would allow us to get closer to seeing, both the weight of evidence, and to learn more about the conditions under which a trade-off or synergy could be expected.

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Table 1. *Key identified synergies and trade-offs at the SDG level*

Key Synergies with SDG2/SLO2	Key Trade-offs with SDG2/SLO2
• Water, sanitation and hygiene all needed for addressing malnutrition • Sustainable agriculture to improve water supply and ecosystems	• Ending hunger and malnutrition could affect water availability and quality for other uses
• Food systems could be coupled with energy systems (e.g. biogas) • Energy is a vital component for productive food systems	• There could be competition for resources for food production vs renewable energy development (especially true for bioenergy)
• Climate action can improve agricultural productivity and adaptive capacity of the food system • Sustainable and efficient food systems can better adapt to climate change	• Smallholders could be left behind in climate action • Land use for climate mitigation could affect land availability for food production

However, this is well beyond reasonable expectations for one paper. Therefore, this paper should be regarded as an essential first step towards scoping the evidence and examining major thematic or evidential gaps. The annex tables give a very helpful overview of the specific causal factors that could be at play in shaping the direction and strength of the relationships.

The paper highlights the complex nature of the numerous, causal relationships. In order to make sense of this complexity, the paper helps us to effectively incorporate agriculture into Integrated Assessment Models. These are large, complex models that allow the analyst to quantitatively examine the interactions of biophysical systems with the broader economy using a single framework. There are many such models, each with their own principles and assumptions that form the building blocks of modelled relationships. These simplified, stylized representations allow us to simulate the impact of different scenarios. In some models, agriculture is at the heart of the analysis, with the rest of the economy faded to the background. In others, agriculture is just one sector among many within a whole economy model. They each have their place, as long as we ask the right questions!

In terms of shaping the agricultural research agenda, the main message from the authors is that interactions between agriculture and other sectors are complex and would benefit from greater clarity. The process of mapping and modelling within and between sectors is incomplete, and the specific entry points for effective policy intervention to achieve synergistic outcomes are poorly understood: in essence, we are still "ill-equipped to develop an efficient societal response – and articulate agriculture's role". Despite this overall cautionary conclusion, there are some low-hanging fruit, ready to be actioned now. This will lead to more effective incorporation of agriculture into Integrated Assessment Models. These suggestions are as follows:

1. **Energy requirements in agricultural food chains need updated, fine-grain data**: Agriculture needs to be integrated into energy development models. This is particularly important for LDCs where the energy/agriculture nexus is strongest.
2. **Quantity AND quality matters when addressing interactions between agriculture and water systems**: A comprehensive inventory and assessment of water use is needed across agricultural chains in terms of input, use and discharge. As water availability can be limited and of varying quality, understanding the latter's relationship with each production step is needed. Clear and transparent methods for integrated water-agricultural analysis is needed, which necessarily requires some level of energy assimilation.
3. **Climatic impacts on agriculture and food systems need a comprehensive approach**: For some critical causal factors we are missing data, lacking harmonization, or in some cases these feedback mechanisms are not incorporated in the model (e.g. CO_2 fertilization effects, pest propagation, salinity, acidification in fisheries, temperature effects on livestock and fisheries).

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4. **Harmonize and integrate diverse models:** This ranges from developing clear databases for the agriculture sector to understanding what level of detail and integration is required for what question. In each of the cases outlined above, the research agenda needs to focus on those elements which can feasibly be influenced by policy.

2. Water-Energy-Food Nexus and Agriculture Research for Development: The case for integrative modelling via place-based observatories. Mathew Kurian

This paper explores a number of concepts related to the Water-Energy-Food (WEF) Nexus, stating that it has the potential to enhance the societal relevance of global public goods research. This assertion is supported by the definition of the Nexus as an approach that supports integrative modelling trade-offs within socio-ecological systems with the objective of informing decisions relating to management of environmental resources, delivery of public services and associated risks that have the potential to impact upon water, energy and food security and planetary boundaries. A planetary scale analysis can theoretically capture the full range of causal relationships, but runs the risk of being disconnected from the context and location-specific policy environment. A summary of interlinkages in the WEF nexus is also presented (results are summarized in the figure below).

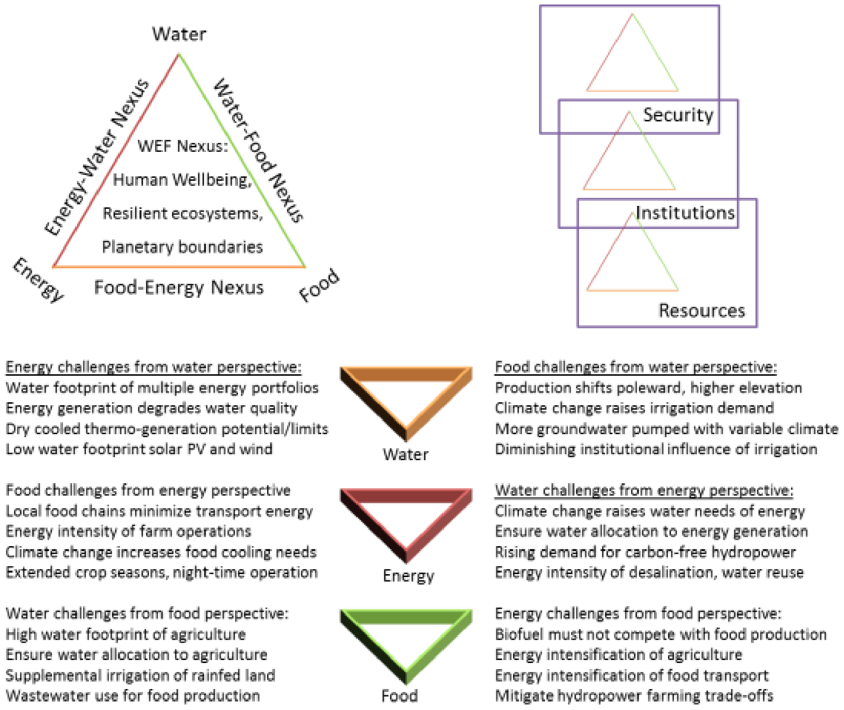

Figure 1. *Interlinkages and challenge perspective at multiple levels in the water-energy-food nexus (adapted from Scott et al. 2015)*

The author takes the example of Wastewater Reuse Effectiveness Index (WREI) as a tool for combining biophysical, institutional and socio-economic data, and focuses in on the monitoring of SDG 6.3. By incorporating this kind of composite index in a "Place-Based Observatory", the author argues that we can narrow the gap between planetary scale imperatives and the institutional incentives that are required to adjust to bring about the changes necessary for addressing them. The author suggests that "composite indices, online learning portals, remote sensing and data visualization techniques" be combined to help realize this vision and that "conventional research skills will need to be combined with skills of political negotiation and strategic communication with UN agencies and Member States".

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The paper closes with four questions for CGIAR and partner organizations to consider when adopting the water-energy-food nexus concept in agricultural research for development:

1. **Typologies:** What typologies of nexus trade-offs can be identified based on a characterization of a circular economy with implications for reuse/recycle of environmental resources?
2. **Place-Based Observatories:** How can place-based observatories leverage the power of remote sensing, social network analysis, big data and in-situ data collection using GPS/mobile technology to model "thresholds to public action" in response to risks that have been identified through an engagement with bio-physical, institutional and socio-economic data?
3. **Integrative monitoring:** What open source software can be developed to support continuous improvement of visualization, data transformation, benchmarking and scenario analysis tools with potential to enhance integrative monitoring of socio-ecological systems?
4. **Online learning:** What pedagogical and didactic innovations can be fostered to enable online learning to support construction of longitudinal case studies based on reuse of datasets and co-design of nexus principles in development practice?