A framework for interdisciplinary research in food systems

Global food systems have complex, diverse and coupled multisectoral dynamics that present challenges for progressive interdisciplinary research. We propose a framework for inclusive, flexible and iterative integration across disciplines to support the entire research process.

Kathryn Grace, Sauleh Siddiqui and Benjamin F. Zaitchik

Global food systems have complex, diverse and coupled multisectoral dynamics. Inclusive food system research extends beyond the scope of any single discipline and, like all interdisciplinary research (IDR), is innovative at the intersection of multiple disciplines, rather than through multidisciplinary aggregation of knowledge[1]. Interdisciplinary research is difficult; when research teams span disciplines, they often face significant unanticipated barriers to advancing science through collaboration[2]. Barriers include challenges with discipline-specific terminology; challenges in coalescing around a common research question, goal or motivation; and difficulty in pursuing a shared vision in terms of the societal, political or scientific impact of the research. Emerging research has highlighted the importance of rethinking IDR and rebuilding approaches beginning with the theory of IDR and its foundation — the research framework for collaboration. Here, we propose an IDR framework that supports inclusive, dynamic and iterative integration across disciplines for the entire research process and provides policy-relevant insights into how this process may impact funding and research-related products. We demonstrate the framework through examples within the food, energy and water nexus applied to countries at different stages of economic development, highlighting the value of a flexible research process for the integration of data, techniques and theories in IDR.

IDR in food systems

One of the major attractions of IDR is the idea that something innovative will emerge through the disciplinary confluence. Integration is implicit in IDR[3]. Integration can be developed through a sequenced chain of multidisciplinary projects that innovate through successive points in the analysis chain. The links in the chain can be thought of as the analysis tools used to integrate knowledge from multiple fields. When considering land use, energy and water dynamics to develop climate change mitigation strategies, a team would develop distinct model representations for the individual energy, water and land use sectors separately, and integrate for IDR by selecting characteristics between these distinct sectors to connect through quantitative modelling[4]. Put in another way, a climate model is developed by the climate scientists, results of this model are used in a resource production model by the economists or engineers, and then independent variables from this model are used by health geographers in regression models of human health. The team, as an ensemble, may then summarize the findings to recommend some policies or programmes.

IDR can be developed through a single integrated model of knowledge from all contributing fields. This approach strives to embody knowledge from all contributing fields into a single model. Examples include integrated assessment models (IAMs)[5] and food systems models that incorporate agriculture, markets, hydrology, climate and other relevant sectors[6]. Even when IAMs have been updated with open-source and nexus themes in mind (for example, Huppmann et al.'s MESSAGE$_{ix}$ framework[5]), the new modelling structure places methods before research questions, and is not designed to be flexible or iterative. In contrast to the sequenced analysis chain, these single-integrated models prioritize the connections between sectors and build individual sector details beyond those connections. A single integrated model provides a valuable and sometimes necessary platform for addressing research questions at the intersection of disciplines; the innovation in IDR lies in deductive analysis of the output from these integrated models.

Research groups committed to the use of IDR often focus on the development of an integrated modelling structure at the early stages of research. Representatives of the different disciplines must present their data needs and theoretical approaches, and the project leads must try to distill the resulting mass of ideas into a few integrated models. These modelling strategies are refined and formalized by the core research team and then distributed amongst the group for further refinement. Eventually this immutable modelling structure guides the remainder of the IDR and team members fall back on it throughout the project.

A danger here is that enforcing a model structure too early in the research process can silence team members, privilege certain disciplines and ultimately blunt the power of diverse disciplinary approaches to knowledge[7,8]. These challenges have been pointed out before[7]. An example from biofuels research is instructive. Much effort was spent to assess the sustainability of biofuels from the perspectives of greenhouse gas emissions, land use, water and the economy, using highly integrated models[9]. In parallel, researchers and interest groups whose perspectives were not embodied in these deductive models sought to highlight issues of local food access, biodiversity, governance and gender equity associated with biofuel-oriented development patterns[10,11]. As these diverse concerns were excluded from the dominant modelling paradigm, policy-makers were left with decision-making tools that ignored critical dynamics, and researchers lost an opportunity to integrate inductive approaches to knowledge across disciplines to address a pressing food systems issue.

For both forms of integration — sequence chain and single model — innovation can be identified with reasonable clarity at the outset of the project. In some sense this is a strength, as it provides a pathway towards achievable goals. But in another sense, it is limiting. While it is still quite possible to encounter spontaneous IDR innovation in the course of a project developed under one of these extremes, the restrictive design

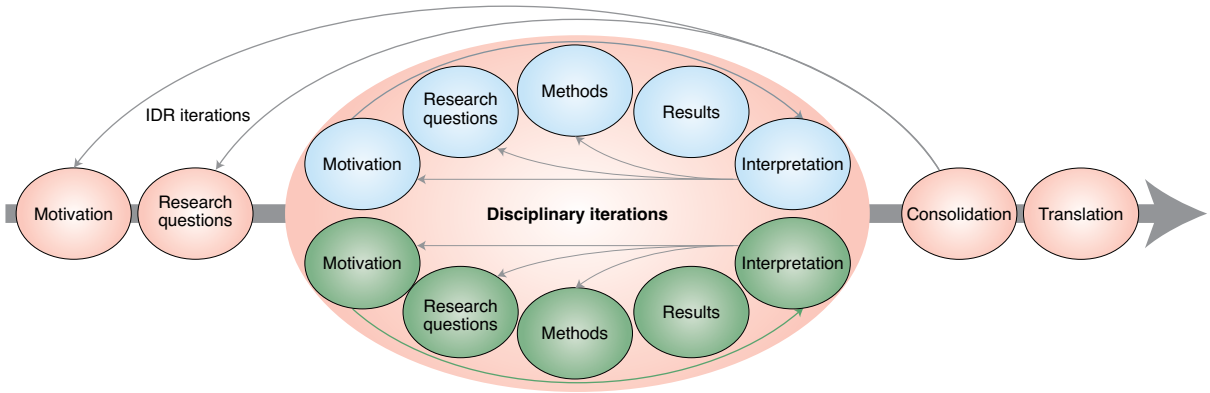

Fig. 1 | A new framework for interdisciplinary research. The framework couples outer interdisciplinary research (IDR) iterations with central disciplinary research processes.

of such projects inherently limits their IDR horizons. Designing with no intent to integrate beyond confined methodological transactions, on one hand, or designing with a final integrating model structure in mind, on the other, restricts the IDR discourse in a way that can stunt the collaborative effort.

A new approach to IDR

As an alternative to these standard approaches, we propose a framework that supports inclusive, dynamic and iterative integration across disciplines for the entire research process (Fig. 1). It does not argue against integrated modelling or the use of computational tools, but rather that the integrated modelling structure should not be fixed at the beginning of the research process and should change as the research evolves. Such an approach to IDR collaboration encourages each discipline to bring their information, data, techniques, tools, perspectives, concepts and/or theories throughout the duration of the project. The framework is built on three principles of the research process. The first principle is a loose coupling of the research process between disciplines, as opposed to strict integration of information, data, techniques, tools, perspectives, concepts and/or theories in a single tool. Second, the research process must be iterative, dynamic and flexible to allow re-evaluation of the modelling framework, making it a network of activities as opposed to a linear process. Third, the research process must be explainable. In other words, the process of building the framework can be examined and analyzed separately and should be reproducible for other teams that seek to integrate input from a range of stakeholders throughout the research process.

In particular, this integrative framework allows for coupling of motivation, research objectives, methods, results and interpretation in any order, as opposed to standard IDR that forces disciplines to engage linearly. It encourages ongoing revision of the research process as new information is gained and the project innovates (Fig. 1). We define disciplinary spaces as central to the process that can iterate and be responsive to interdisciplinary innovations. We propose that individuals with different disciplinary perspectives work best when they have the freedom to go through their individual research process rather than modify their own approach to research to adhere to the needs of an IDR goal, as the best IDR projects require specialists to operate at their full potential, and generalists to support integration. During a project, the challenge takes the form of balancing the rigidity that comes with implementation, particularly for advanced computational models, with the flexibility required for IDR iteration. This balance requires compromise across the research team, as the need to implement inevitably narrows the range of available conceptual framings as the project progresses.

This approach may add extra steps and time, but the delivery of new innovations from the intersection of ideas from every discipline has value[12,13]. Because disciplines operate within their research processes, the inner iteration limited to a single discipline moves much more quickly, allowing for scientific advancements along the way[14]. The central disciplinary iterations respect the continued role of individual disciplines and allow response to outer interdisciplinary iterations. Note that the outer iterations do not imply that the process restarts; the outer iterations are designed to tweak and revise new insights from the disciplinary iterations and consolidation. Further, because most of the methods in this framework start off within disciplines, considerable time is saved in attempting to integrate tools as described above. While the framework might not appear to be particularly radical, it does require a flexibility in team building and in the art of writing funding proposals that can cut against the expectations of research institutions and funding agencies[8]. For example, interdisciplinary proposals often require fixed research questions to be finalized at the beginning of the process, and roles of team members to be well-defined and inflexible. A management plan, often required in larger grants, sees the process as steps that work linearly from start to finish. A proposal that stated flexible research questions would almost always be reviewed unfavourably since it would be considered ill-defined. Our framework pushes against this type of evaluation for IDR projects — the process that works well for focused problems cannot work for IDR in food systems. While most of our examples involve computational approaches, the framework could be even more amenable to projects with flexible, conceptual models.

Framework in action

An example of this framework in action comes from a recent set of interdisciplinary projects focused on understanding how agricultural production in Ethiopia is impacted by climate factors, small holder farmer behaviours, and economic development[15–19]. Investigations were originally focused on farm-based resilience strategies, and then began to ask questions about policy-enabling environments and development aid strategies[19]. At the same time, it was recognized that the single integrated model approach could miss unquantifiable cultural and social community dynamics that emerge during rapid economic development[18], which led to complementary agent-based modelling efforts that integrated some, but not all disciplines, to address

questions of cross-scale interactions in the food, energy and water nexus[20]. Throughout the process, iterative IDR dialogue pushed the team to new questions, new models and, ultimately, translation to guide policy-makers for their most relevant issues. Here, the translation flows from the full IDR process, as stakeholders are engaged throughout. Project outcomes emerge as an ongoing dialogue, rather than being delivered to an external audience at project completion. An example of this translation comes from our stakeholder-informed work on eucalyptus. Pressed by regional government agencies to examine this problem, we generated landscape-scale maps of eucalyptus expansion and estimated production and consumption impacts on food and energy, which could be directly used for those agencies' ongoing land resource assessments[19].

At a larger organizational scale, institutions like the Bill & Melinda Gates Foundation (BMGF) and USAID's Famine Early Warning Systems Network (FEWS NET) have employed aspects of this framework in their data collection efforts (see FEWS NET's livelihood zone data and BMGF performance monitoring and accountability data). To generate useful and innovative data, BMGF seeks engagement with local residents, policy-makers and in-country researchers with an understanding of cultural norms and values as they relate to women's health, nutrition and childcare. This approach ensures higher quality and richer survey data. FEWS NET merges locally generated qualitative information with quantitative data to derive rich and insightful livelihood maps. The qualitative-based insight comes from the unique contributions of stakeholders in separate country settings, reflecting different contexts and livelihoods. Consistent with our framework, FEWS NET, incorporates a dynamic and flexible approach to consider individual and local land use conditions at a given time and place.

Conclusions

The approach that we described establishes a framework that gives equal voice to participants by encouraging deep engagement and learning throughout the research process. Many of society's biggest and most pressing problems, including questions of food systems and security, cannot be clearly defined and addressed through one disciplinary perspective. Using an interdisciplinary lens is an important step towards advancing scientific and policy understanding of these problems, but it is vital that the interdisciplinary research process forces scientists out of old disciplinary process limitations to generate truly transformative research. ❐

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