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Transforming agricultural research and development systems to meet 21st Century needs for climate action

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Introduction

Climate shocks to agriculture threaten food security, especially in the Global South. Poverty and malnutrition are rising and there are dire warnings of what is to come. Agricultural research and development systems need to generate multiple game-changing innovations in order to transform our agricultural systems and ensure that they are climate-resilient, productive, sustainable, and equitable. The challenge is immense and there are no shortages of sound advice on required directions for research. This is particularly the case for CGIAR, a global partnership that unites international organizations engaged in research to reduce rural poverty, increase food security, and improve human health and nutrition, while fostering sustainable management of natural resources.

At the 2022 Conference of the Parties (COP26) in Glasgow, 45 world leaders launched “*The Breakthrough Agenda Report*” as part of a commitment to make clean technologies and sustainable practices more attractive, affordable and accessible by 2030. The Report argues that for the agriculture sector, the breakthrough goal is that “*Climate-resilient, sustainable agriculture is the most attractive and widely adopted option for farmers everywhere by 2030*” (IEA et al., 2023, p. 141). Merrey et al. (2023, p. 4) report that there is no single transformative agricultural innovation to realize this goal, but rather “*synergistic interactions among multiple game-changing innovations in hundreds of national and local agricultural systems*” that cumulatively lead to the transformation of global agriculture. A transformation which is urgently needed to address climate challenges.

For agricultural researchers the challenge of food systems transformation is immense, but so are the opportunities. The journal *Food Policy* has published a number of viewpoints that detail the type of research that CGIAR should focus on (Coffman et al., 2020; Haddad, 2020; Nelson, 2020; Thornton et al., 2022). Lynam et al. (2024) outline organization changes required specifically for CGIAR, while Conti et al. (2024) address this issue more broadly for agricultural research organizations. Simultaneously, CGIAR has not escaped criticism. Some question its ability to respond to the challenge of ensuring food security under climate change (McIntire and Dobermann, 2023).

As agricultural researchers, we relate to the multifarious suggested priority research areas, recommendations and critiques of CGIAR and other agricultural research organizations. We believe, however, that discussions to date obscure fundamental and wider aspects about how research is done to ensure that it contributes to the needed radical

transformation of food, land and water systems to meet 21st Century needs. We recognize the huge contribution that a plethora of agricultural research and development systems have made and continue to make toward meeting these needs. It is not our intention to question the *raison d'être* of legions of committed professionals. On the contrary, we seek to make constructive suggestions and provoke discussions that we believe will render these systems even more effective, efficient and impactful. A fundamental first step is an urgent and radical transformation in the way that we conceptualize the research process and undertake research.

Research paradigms that were suitable for 20th Century challenges—e.g., the Green Revolution, an innovation system which CGIAR played a pivotal role in terms of both the science and practice—need to give way to those better suited to 21st Century challenges. The Green Revolution relied heavily on technology transfer and undoubtedly contributed to significant increases in food production and reductions in poverty. However, it tended to benefit men rather than women, large-scale farmers rather than small-scale ones, and it had less beneficial impact in marginal production environments (Pingali, 2012).

The International Science Council (2023) in its report *Flipping the Science Model: A Roadmap to Science Missions for Sustainability* captures an example of the paradigm shift required. A change from a traditional science model, which is characterized often by siloed science funding, intense competition and a lack of trust among stakeholders, to a model “that encourages science to cater directly to societal needs. This can be achieved by co-creating actionable knowledge and finding solutions tailored to the intricate sustainability issues identified by both local and global stakeholders (International Science Council, 2023, p. 6). Additional paradigms guiding agricultural research must also address social justice, environmental stewardship, and indigenous knowledge (Pretty et al., 2010).

A fundamental point that may or may not be self-evident when considering the need for game-changing innovations to transform agriculture is that agricultural innovation systems are embedded within societal contexts. Hence, to encourage science to cater more to societal needs, social scientists need to play a more prominent role in building a global transdisciplinary research process that fosters the co-design and co-production of research and action, and encourages more inclusive collaboration among science, policy-makers and civil society (Dolinska et al., 2023). At present, as we elaborate below, the role of social scientists is all-too-often peripheral to agricultural research.

We, hence, focus our opinion piece on two themes: (i) the urgent need to engage social (together with natural) scientists in transdisciplinary research processes; (ii) the importance of the co-creation of knowledge via more democratic partnerships that genuinely address power asymmetries, as well as different stakeholders' roles (and responsibilities). We highlight discrepancies in the mix of social and natural science agricultural research, and also what may come across as a tepid commitment to partnerships despite the best intentions of many researchers. The short-termism of research projects stymies the establishment of genuine partnerships and there may be an inherent power imbalance because of who holds the purse strings and the structure

of research funding. Such partnerships are often further stymied by a lack of consensus on the roles, responsibilities and *modus operandi* of key stakeholders, ones that include public research and extension institutions, universities, private firms, producers, donors, and consumers (Hellin et al., 2020).

A greater role for social science in transdisciplinary research

The need to tackle climate change will require major adjustments in a number of sectors, including research. The way many organizations do agricultural research needs to change substantially in order to meet the climate challenge. While technical challenges abound, the game-changing innovations referred to by Merrey et al. (2023), are embedded in society and it is notoriously difficult to bring about deliberate societal change. The funding of climate research still appears to be largely based on the assumption that (natural) scientists need to focus on the causes, impacts, and technological answers to climate change, and then when exposed to solutions, targeted stakeholders (including farmers) will change their behavior. The assumption is flawed. Climate change has less to do with technology and more to do with society and political economy (Vermeulen et al., 2018; Davidson, 2022). Innovation is shaped by people, and they are also the drivers of climate action (Devine-Wright et al., 2022). Insights on societal change and dynamics from the social sciences are critical when it comes to transforming climate change research into action (Weaver et al., 2014). The social sciences (and humanities) contribute critical and invaluable perspectives that provide context, framings, approaches, reflection and impacts on societal transformation (Fisher et al., 2022).

Despite its importance, social science is still hugely underrepresented in climate change research. Overland and Sovacool (2020), for example, analyzed a dataset of research grants from 333 donors worldwide and with a cumulative value of USD 1.3 trillion from 1950 to 2021. On issues related to climate change, the natural and technical sciences received 770% more funding than the social sciences. The preponderance of funding for natural as opposed to social science climate research can encourage ‘climate reductionism’ whereby science removes climate change from its environmental and social contexts (Rigg and Mason, 2018). The salutary reality is that “the questions and challenges in climate science are at once political, moral, socioeconomic, cultural, psychological and historical—in addition to scientific and technical. Yet, it is the predictive natural sciences (earth, environmental, meteorological, atmospheric sciences), not the critical and interpretative social sciences and humanities, that set the terms of the climate change debate, leading to disciplinary reductionism” (Rigg and Mason, 2018).

It is time we overturn business as usual and embrace business unusual in order to stimulate the opposite of ‘climate reductionism’. In the words of The International Science Council (2023), we need more ‘mission-led science’ that will “require continued investments in basic, social, and natural sciences, both as disciplinary and interdisciplinary approaches and with a focus on ensuring practical outcomes.” We believe that organizations dedicated to agricultural

research for development (AR4D) need to employ a larger cadre of social scientists from diverse disciplinary backgrounds. Others have made similar calls (e.g., Venot et al., 2015), but there is still some way to go especially in terms of the diversity of social science disciplines.

Among the social scientists in many AR4D organizations, agricultural economists predominate. There is very often a dearth of other social science disciplines that are critical to mission-led science. These include sociologists (Davidson, 2022), anthropologists, psychologists (Shah, 2020) geographers (Castree, 2015), political scientists, development studies and gender specialists, plus those best positioned to communicate climate change research to policy makers and the public (Nature Climate Change, 2019) and work with local communities to identify pathways to achieving the changes in behavior needed. Furthermore, social scientists are often perceived to be service providers to those engaged in biophysical research (Cullen et al., 2023).

Working across the natural and social sciences is not easy; some may feel that their entire *raison d'être* is challenged, while others may find it difficult to embrace different ways of analyzing a similar problem. We struggle, for example, with the notion that Randomized Control Trials (RCTs) are a gold standard for evaluating the effectiveness of agricultural interventions such as climate-smart agriculture. Similar concerns are shared by others e.g., Glover et al. (2016) and Kabeer (2020). A call for interdisciplinary approaches does not require all researchers to modify their approach. We fully recognize the need for continued strong disciplinary research, be it from the natural or social sciences. Agricultural research and development systems still need specialists but they also require an open mindset and ability to engage outside disciplinary boundaries.

The payoffs of agricultural research giving more attention to social dimensions are often substantial. Examples include a better match between crop improvement and farmers' realities in terms of crop breeders recognizing the significance of traits such as taste, color and nutritional value rather than an undue focus on yields (Cullen et al., 2023). Another example is the need to understand gender and social norms to foster equitable agricultural development (Badstue et al., 2020).

There is also a need for more generalists who can support integration (Grace et al., 2021). As Castree et al. (2014) wrote in the context of Geography's contribution to climate change research, we need more scientists who can play the role of a "weaver" in contrast to those working in specialist subjects who tend to be "spinners." Brown et al. (2015) use the term "T-shaped" researchers, those able to flourish in their own discipline and also look beyond it and embrace others.

What emerges from accommodating different disciplinary perspectives is a "*messier intellectual landscape of climate understanding*" (Schipper et al., 2021a), one that lends itself to identifying global environmental challenges and opportunities for transformation while also recognizing the relevance of people's varied agency and capacity for change (Fisher et al., 2022). This is something that many researchers may find discomfiting, but it is critical to encourage a systems approach to climate research. Holistic inter-disciplinary thinking helps create the conditions

for systems transformation and a paradigm shift that enables a transition to sustainability (Voulvoulis et al., 2022).

Roles, responsibilities and power asymmetries in transdisciplinary partnerships

Another bottleneck to agricultural research and development systems being more impactful is that too often the importance of developing genuine partnerships, and the time that trust-building takes, is over-looked. Cundill et al. (2019a) note that climate change research funds are shifting toward large collaborative research networks and pose significant challenges (we would add also significant opportunities) for researchers. Researchers increasingly need to forge transdisciplinary networks and participatory process with other stakeholders. The ensuing climate action requires "*integrated and multiscale research that is simultaneously cutting edge, problem-oriented, and that creates space for other ways of knowing, beyond western science alone*" (Cundill et al., 2019b).

A transformative climate response requires actionable interdisciplinary science and strong partnerships among researchers and broader society (Hernandez-Aguilera et al., 2021). This requires doing research differently, embracing both qualitative and quantitative research approaches (Schipper et al., 2021b) and placing more emphasis on action research, stakeholder engagement and social learning (Miller et al., 2010). A concerted effort is needed to shift from output-directed to process-oriented research during which diverse stakeholders with different cultural backgrounds, including researchers and policy-makers, co-produce knowledge (Miller et al., 2010). Collaborative knowledge generation can encounter obstacles, particularly when participants from the Global South and North work together. The distinction between "co-creation" and traditional participatory approaches is currently unclear, leading to questions about what is a co-creation process, and how to avoid it being a means of scientific exploitation (Keikelame and Swartz, 2019) and/or perpetuating coloniality (Fúnez-Flores, 2023).

Building trustful partnerships takes time (Newig et al., 2019; Thornton et al., 2024) often far longer than the 3-to-5 year lifetimes of many agricultural research projects. There are often power and finance asymmetries with insufficient ownership by Southern partners compared to their Northern colleagues (Cundill et al., 2019a; Schneider et al., 2019; Cullen et al., 2023). The pressure to articulate and develop research proposals and realize outcomes very often does not allow for the establishment and nourishment of (research) partnerships. There is a danger that short-termism (dictated by truncated funding cycles) gives the impression that research organizations are not a reliable partner. The impression is often an erroneous one but we should not forget that perception is reality. Power asymmetries also manifest themselves in terms of whose knowledge counts. Local and indigenous knowledge is still under-represented in climate change research although the situation is changing (Head, 2020; Kassam et al., 2023).

As Reed and Fazey (2021) note, the "publish or perish" mantra has been coupled with an additional one: "impact or implode." Too often the understandable pressure from donors

and policy-makers to demonstrate impact means that there is a tendency for researchers to focus on “quick wins” rather than the longer-term and more obdurate transformations that are needed (Hainzelin et al., 2017). In the words of Leeuwis et al. (2018), “there is an urgency to demonstrate how today’s research activities will contribute to tomorrow’s development.” There is pressure to report high numbers of farmers who have adopted certain technologies, or received training. Whilst important, these numbers are only one aspect of the development story. They reveal little about human development, the dangers of trade-offs and maladaptation (Schipper, 2020) and the sustainability of any innovation (there are numerous examples of farmers abandoning agricultural innovations once external support is withdrawn).

As researchers ourselves, we totally empathize with the pressures to demonstrate rapid results that we all find ourselves under. We argue for more honest conversations about the contribution of agricultural research to game-changing innovations, and critically the time, trust, and relationship building it takes to realize impact. The required transformations of land, water and food systems take far longer than the life-times of the majority of agricultural research projects (Hainzelin et al., 2017). Many stakeholders have roles and responsibilities in and along an impact pathway (or rather a web of impact pathways) that connects research activities, research outputs, impacts and outcomes (Blundo-Canto et al., 2018).

Researchers should be held accountable for the delivery of “outputs”; this is in their sphere of control. It is also incumbent on them to embrace working with non-researchers, and to identify suitable mechanisms and changes to the policy, institutional and governance environments that drive the transformation process. Realizing impact, however, largely falls outside the control of researchers and within the operating spaces of governments, civil society and private sector. It is these stakeholders who are better best placed to nurture the organizational and institutional processes that underpin transformative change (Hellin et al., 2020).

The design and use of more comprehensive theories of change e.g., Brown (2020) would allow for greater transparency and understanding about stakeholders’ roles and responsibilities while also capturing learnings from what has not worked in the research process. Too often, so-called “failures” during the research process are under-reported; a technology that did not work; a research partnership that never got off the ground or disintegrated in acrimony. There are few incentives to report these failures or setbacks in agricultural research. Failure is not failure if one can learn from what did not work as we had hoped. In agricultural research, failures (or should we call them opportunities for learning?) are inevitable on the road to success. There are, however, few incentives within research organizations to learn from mistakes. One way forward could be journal sections specifically geared to publications that focus on what did not work, why and what can we learn going forward.

Lessons from history

Agricultural research and development systems need to generate multiple game-changing innovations in order to transform our agricultural systems and ensure that they are

climate-resilient, productive, sustainable, and equitable. Social scientists can provide urgently needed insights on societal dynamics that are critical when it comes to transforming climate change research into action. Transdisciplinary partnerships are the foundation of transforming research into action; partnerships characterized by trust, accountability, a heavy dose of “intellectual humility” on the part of all stakeholders, including researchers (Palmer, 2023), and integrating the different needs of the global North and South (Schneider et al., 2022).

Co-creation in transdisciplinary research signifies a more profound dedication among the parties involved, who must collaborate to conceptualize, plan, and generate knowledge that benefits everyone, drawing on transformative learning in critical and dialogical research (Freire, 2005). For global agricultural research and development systems to be truly fit-for-purpose and contribute to the needed radical transformation of food, land and water systems to meet 21st Century needs, greater numbers of ‘T-shaped’ researchers i.e., weavers, are needed. This part depends on changed incentive schemes at universities and research centers.

History can provide some of the answers. In an essay entitled *Humboldt for the Anthropocene*, Jackson (2019) cites the example of Alexander von Humboldt, the German geographer who fused science and humanism, and whose “combination of empathy, humility, confidence, and rigor can serve as a model for engaging the public on matters of urgent concern.” Climate action is one of these urgent concerns. A big (and realistic step) would, perhaps, be for research organizations to employ more von Humboldts as part of a radical transformation in the way that we conceptualize and do research. In this way can come genuine breakthroughs in transformative action to address climate challenges through sustainable agriculture, without the threat of breakdowns in the very agricultural systems that sustain life.

Author contributions

JH: Conceptualization, Writing—original draft, Writing—review & editing. EF: Conceptualization, Writing—original draft, Writing—review & editing. MB: Conceptualization, Writing—original draft.

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References

- Badstue, L., Elias, M., Kommerell, V., Petesch, P., Prain, G., Pyburn, R., et al. (2020). Making room for manoeuvre: addressing gender norms to strengthen the enabling environment for agricultural innovation. *Dev. Pract.* 30, 541–547. doi: 10.1080/09614524.2020.1757624
- Blundo-Canto, G., Triomphe, B., Faure, G., Barret, D., de Romemont, A., Hainzelin, E., et al. (2018). Building a culture of impact in an international agricultural research organization: process and reflective learning. *Res. Eval.* 28, 136–144. doi: 10.1093/reseval/rvy033
- Brown, B. Y. M. (2020). *Unpacking the Theory of Change*. The Stanford Center on Philanthropy and Civil Society at Stanford University.
- Brown, R., Deletic, A., and Wong, T. (2015). How to catalyse collaboration. *Nature* 525:315. doi: 10.1038/525315a
- Castree, N. (2015). Geography and global change science: relationships necessary, absent, and possible. *Geogr. Res.* 53, 1–15. doi: 10.1111/1745-5871.12100
- Castree, N., Adams, W. M., Barry, J., Brockington, D., Buscher, B., Corbera, E., et al. (2014). Changing the intellectual climate. *Nat. Clim. Change* 4, 763–768. doi: 10.1038/nclimate2339
- Coffman, W. R., Acevedo, M., Davidson Evanega, S., Porciello, J., Tufan, H. A., McCandless, L., et al. (2020). Viewpoint: five recommendations for an inclusive and collaborative One CGIAR. *Food Policy* 91:101831. doi: 10.1016/j.foodpol.2020.101831
- Conti, C., Hall, A., Percy, H., Stone-Jovicic, S., Turner, J., McMillan, L., et al. (2024). What does the agri-food systems transformation agenda mean for agricultural research organisations? Exploring organisational prototypes for uncertain futures. *Glob. Food Secur.* 40:100733. doi: 10.1016/j.gfs.2023.100733
- Cullen, B., Snyder, K. A., Rubin, D., and Tufan, H. A. (2023). "They think we are delaying their outputs": The challenges of interdisciplinary research: understanding power dynamics between social and biophysical scientists in international crop breeding teams. *Front. Sustain. Food Syst.* 7, 1–16. doi: 10.3389/fsufs.2023.1250709
- Cundill, G., Currie-Alder, B., and Leone, M. (2019a). The future is collaborative. *Nat. Clim. Change* 9, 343–345. doi: 10.1038/s41558-019-0447-3
- Cundill, G., Harvey, B., Tebboth, M., Cochrane, L., Currie-Alder, B., Vincent, K., et al. (2019b). Large-scale transdisciplinary collaboration for adaptation research: challenges and insights. *Glob. Challenges* 3:1700132. doi: 10.1002/gch2.201700132
- Davidson, D. J. (2022). Climate change sociology: past contributions and future research needs. *PLOS Clim.* 1:e0000055. doi: 10.1371/journal.pclm.0000055
- Devine-Wright, P., Whitmarsh, L., Gatersleben, B., O'Neill, S., Hartley, S., Burningham, K., et al. (2022). Placing people at the heart of climate action. *PLOS Clim.* 1:e0000035. doi: 10.1371/journal.pclm.0000035
- Dolinska, A., Hassenforder, E., Loboguerrero, A. M., Sultan, B., Bossuet, J., Cottenceau, J., et al. (2023). Co-production opportunities seized and missed in decision-support frameworks for climate-change adaptation in agriculture – how do we practice the "best practice"? *Agric. Syst.* 212:103775. doi: 10.1016/j.agsy.2023.103775
- Fisher, E., Brondizio, E., and Boyd, E. (2022). Critical social science perspectives on transformations to sustainability. *Curr. Opin. Environ. Sustain.* 55:101160. doi: 10.1016/j.cosust.2022.101160
- Freire, P. (2005). *Freire Paulo Pedagogy of the Oppressed*. New York, NY: Continuum International Publishing Group Inc.
- Fúnez-Flores, J. I. (2023). Anibal quijano: (dis)entangling the geopolitics and coloniality of curriculum. *Curric J.* 35, 288–306. doi: 10.1002/curj.219
- Glover, D., Sumberg, J., and Andersson, J. A. (2016). The adoption problem; or why we still understand so little about technological change in African agriculture. *Outlook Agric.* 45, 3–6. doi: 10.5367/oa.2016.0235
- Grace, K., Siddiqui, S., and Zaitchik, B. F. (2021). A framework for interdisciplinary research in food systems. *Nat. Food* 2, 1–3. doi: 10.1038/s43016-020-00212-6
- Haddad, L. (2020). A view on the key research issues that the CGIAR should lead on 2020–2030. *Food Policy* 91:101824. doi: 10.1016/j.foodpol.2020.101824
- Hainzelin, E., Barret, D., Faure, G., Dabat, M.-H., and Riomphe, B. (2017). Agricultural research in the Global South: steering research beyond impact promises. *Perspective* 42, 1–4. doi: 10.19182/agritrop/00009
- Head, L. (2020). Transformative change requires resisting a new normal. *Nat. Clim. Change* 10, 173–174. doi: 10.1038/s41558-020-0712-5
- Hellin, J., Balié, J., Fisher, E., Blundo-Carto, G., Meah, N., Kohli, A., et al. (2020). Sustainable agriculture for health and prosperity: stakeholders' roles, legitimacy and modus operandi. *Dev. Pract.* 30, 965–971. doi: 10.1080/09614524.2020.1798357
- Hernandez-Aguilera, J. N., Anderson, W., Bridges, A. L., Hansen, W. D., Maurer, M. L., Ilboudo Nébié, E. K., et al. (2021). Supporting interdisciplinary careers for sustainability. *Nat. Sustain.* 4, 374–375. doi: 10.1038/s41893-020-00679-y
- IEA, IRENA, and UN Climate Change High-Level Champions (2023). *Breakthrough Agenda Report 2023*. Paris: IEA (International Energy Agency).
- International Science Council (2023). *Flipping the Science Model: A Roadmap to Science Missions for Sustainability*. Paris: International Science Council.
- Jackson, S. T. (2019). Humboldt for the Anthropocene. *Science* 365, 1074–1076. doi: 10.1126/science.aax7212
- Kabeer, N. (2020). Women's empowerment and economic development: a feminist critique of storytelling practices in "randomista" economics. *Fem. Econ.* 26, 1–26. doi: 10.1080/13545701.2020.1743338
- Kassam, K.-A. S., Charles, M. T., and Johnson, S. M. (2023). Significance of different ways of knowing in responding to the climate crisis: the necessity for Indigenous knowledge. *PLOS Clim.* 2:e0000237. doi: 10.1371/journal.pclm.0000237
- Keikelame, M. J., and Swartz, L. (2019). Decolonising research methodologies: lessons from a qualitative research project, Cape Town, South Africa. *Glob. Health Action* 12:1561175. doi: 10.1080/16549716.2018.1561175
- Leeuwis, C., Klerkx, L., and Schut, M. (2018). Reforming the research policy and impact culture in the CGIAR: integrating science and systemic capacity development. *Glob. Food Secur.* 16, 17–21. doi: 10.1016/j.gfs.2017.06.002
- Lynam, J., Byerlee, D., and Moock, J. L. (2024). The organizational challenge of international agricultural research: the fifty-year odyssey of the CGIAR. *Food Policy* 124:102617. doi: 10.1016/j.foodpol.2024.102617
- McIntire, J., and Dobermann, A. (2023). The CGIAR needs a revolution. *Glob. Food Secur.* 38:100712. doi: 10.1016/j.gfs.2023.100712
- Merrey, D. J., Loboguerrero, A. M., and Zeppenfeldt, L. (2023). *An Enabling Innovation Ecosystem to Accelerate Agriculture Breakthroughs*. Utrecht: Clim-Eat.
- Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., et al. (2010). Resilience and vulnerability: complementary or conflicting concepts? *Ecol. Soc.* 15:11. doi: 10.5751/ES-03378-150311
- Nature Climate Change (2019). Scientific uncertainty. *Nat. Clim. Change* 9:979. doi: 10.1038/s41558-019-0627-1
- Nelson, R. (2020). Viewpoint: international agriculture's needed shift from energy intensification to agroecological intensification. *Food Policy* 91:101815. doi: 10.1016/j.foodpol.2019.101815
- Newig, J., Jahn, S., Lang, D. J., Kahle, J., and Bergmann, M. (2019). Linking modes of research to their scientific and societal outcomes. Evidence from

- 81 sustainability-oriented research projects. *Environ. Sci. Policy* 101, 147–155. doi: 10.1016/j.envsci.2019.08.008
- Overland, I., and Sovacool, B. K. (2020). The misallocation of climate research funding. *Energy Res. Soc. Sci.* 62:101349. doi: 10.1016/j.erss.2019.101349
- Palmer, J. (2023). Try a touch of intellectual humility. *Nature* 622, 2020–2022. doi: 10.1038/d41586-023-03063-w
- Pingali, P. (2012). Green revolution: impacts, limits, and the path ahead. *Proc. Natl. Acad. Sci. USA* 109, 12302–12308. doi: 10.1073/pnas.0912953109
- Pretty, J., Sutherland, W. J., Ashby, J., Auburn, J., Baulcombe, D., Bell, M., et al. (2010). The top 100 questions of importance to the future of global agriculture. *Int. J. Agric. Sustain* 8, 219–236. doi: 10.3763/ijas.2010.0534
- Reed, M. S., and Fazey, I. (2021). Impact culture: transforming how universities tackle twenty first century challenges. *Front. Sustain* 2:662296. doi: 10.3389/fsufs.2021.662296
- Rigg, J., and Mason, L. R. (2018). Five dimensions of climate science reductionism. *Nat. Clim. Change* 8, 1030–1032. doi: 10.1038/s41558-018-0352-1
- Schipper, E. L. F. (2020). Maladaptation: when adaptation to climate change goes very wrong. *One Earth* 3, 409–414. doi: 10.1016/j.oneear.2020.09.014
- Schipper, E. L. F., Dubash, N. K., and Mulugetta, Y. (2021a). Climate change research and the search for solutions: rethinking interdisciplinarity. *Clim. Change* 168:18. doi: 10.1007/s10584-021-03237-3
- Schipper, E. L. F., Eriksen, S. E., Fernandez Carril, L., Glavovic, B., and Shawoo, Z. (2021b). Turbulent transformation: abrupt societal disruption and climate resilient development. *Clim. Dev.* 13, 467–474. doi: 10.1080/17565529.2020.1799738
- Schneider, F., Giger, M., Harari, N., Moser, S., Oberlack, C., Providoli, I., et al. (2019). Transdisciplinary co-production of knowledge and sustainability transformations: three generic mechanisms of impact generation. *Environ. Sci. Policy* 102, 26–35. doi: 10.1016/j.envsci.2019.08.017
- Schneider, F., Llanque-Zonta, A., Andriamihaja, O. R., Andriatsitohaina, R. N. N., Tun, A. M., Boniface, K., et al. (2022). How context affects transdisciplinary research: insights from Asia, Africa and Latin America. *Sustain. Sci.* 17, 2331–2345. doi: 10.1007/s11625-022-01201-3
- Shah, H. (2020). Global problems need social science. *Nature* 577:295. doi: 10.1038/d41586-020-00064-x
- Thornton, P., Dijkman, J., Herrero, M., Szilagyi, L., and Cramer, L. (2022). Viewpoint: aligning vision and reality in publicly funded agricultural research for development: a case study of CGIAR. *Food Policy* 107:102196. doi: 10.1016/j.foodpol.2021.102196
- Thornton, P., Mason D'Croz, D., Kugler, C., Remans, R., Zornetzer, H., and Herrero, M. (2024). Enabling food system innovation: accelerators for change. *Glob. Food Secur.* 40:100738. doi: 10.1016/j.gfs.2023.100738
- Venot, J. P., Giordano, M., and Merrey, D. J. (2015). On the sidelines: social sciences and interdisciplinarity in an international research centre. *Water Altern.* 8, 415–432.
- Vermeulen, S. J., Dinesh, D., Howden, S. M., and Cramer, L., and Thornton, P. K. (2018). Transformation in practice: a review of empirical cases of transformational adaptation in agriculture under climate change. *Front. Sustain. Food Syst.* 2:65. doi: 10.3389/fsufs.2018.00065
- Voulvoulis, N., Giakoumis, T., Hunt, C., Kioupi, V., Petrou, K. N., Souliotis, I., et al. (2022). Systems thinking as a paradigm shift for sustainability transformation. *Glob. Environ. Change* 75:102544. doi: 10.1016/j.gloenvcha.2022.102544
- Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., et al. (2014). From global change science to action with social sciences. *Nat. Clim. Chang.* 4, 656–659. doi: 10.1038/nclimate2319