frontiers | Frontiers in Sustainable Food Systems

TYPE Methods
PUBLISHED 17 May 2023
DOI 10.3389/fsufs.2023.1132465

OPEN ACCESS

EDITED BY
Ximena Rueda,
University of Los Andes, Colombia

REVIEWED BY
Fabio Bartolini,
University of Ferrara, Italy
Julie Ingram,
University of Gloucestershire, United Kingdom

*CORRESPONDENCE
Alexandros Gasparatos
✉ gasparatos@ifi.u-tokyo.ac.jp

RECEIVED 27 December 2022
ACCEPTED 18 April 2023
PUBLISHED 17 May 2023

CITATION
Gasparatos A, von Maltitz G, Ahmed A, Dompreh EB, Jarzebski MP, Saito O, Luhanga D, Rigolot C and Lozano Lazo DP (2023) Mobilizing participatory approaches to introduce transdisciplinary research elements when exploring the interface of commodity crop production and food security in Sub-Saharan Africa.
Front. Sustain. Food Syst. 7:1132465.
doi: 10.3389/fsufs.2023.1132465

Mobilizing participatory approaches to introduce transdisciplinary research elements when exploring the interface of commodity crop production and food security in Sub-Saharan Africa

Alexandros Gasparatos[1]*, Graham von Maltitz[2], Abubakari Ahmed[3], Eric Brako Dompreh[1], Marcin Pawel Jarzebski[4], Osamu Saito[5], Davies Luhanga[6], Cyrille Rigolot[7] and Denise Patricia Lozano Lazo[8]

[1]Institute for Future Initiatives, The University of Tokyo, Tokyo, Japan, [2]South African National Biodiversity Institute (SANBI), Cape Town, South Africa, [3]Department of Planning, SD Dombo University of Business and Integrated Development Studies, Wa, Ghana, [4]Institute for the Advanced Study of Sustainability (UNU-IAS), United Nations University, Tokyo, Japan, [5]Institute for Global Environmental Strategies, Hayama, Japan, [6]World Bank Malawi Office, Lilongwe, Malawi, [7]UMR Territoires, National Research Institute for Agriculture, Food and Environment (INRAE), Aubière, France, [8]WorldFish, Penang, Malaysia

The production of commodity crops such as oil palm, sugarcane, cotton or cocoa has important ramifications for sustainability at multiple spatial and temporal scales. Food security is among the most heavily debated impacts of commodity crop production, especially in developing regions characterized by high rates of malnutrition and food insecurity such as Sub-Saharan Africa (SSA). Studies have identified diverse pathways through which commodity crop production can have positive or negative impacts on the different pillars of food security. This Methodology paper outlines how different participatory approaches can be mobilized to introduce transdisciplinarity research elements when exploring the adoption and impacts of commodity crop production, especially in developing regions such as SSA. It draws from the lessons learned during the design and implementation of five research projects that explored the food security outcomes of commodity crop production in different countries of SSA. Collectively these research projects mobilized very diverse participatory approaches such as expert interviews, Focus Group Discussions (FGDs), participatory mapping, mediated modeling, and participatory scenario analysis. Beyond being instrumental for data collection, these participatory approaches served multiple other research functions. In particular they helped (a) identify research priorities, knowledge gaps, and underlying phenomena, (b) formalize impact mechanisms and develop methodology, and (c) interpret data and validate findings. Furthermore, they contributed to the credibility and relevance of the research, and to a lesser extent to the legitimacy and effectiveness, all of which are considered important principles of transdisciplinary research. Through these diverse contributions they were instrumental in integrating valuable insights from stakeholders holding very complementary expertise in commodity crop value chains at different scales. In this sense they can act as valuable entry points to introduce transdisciplinary research elements in projects exploring the interface

of food security and commodity crop value chains (or food systems more broadly), especially in contexts that truly transdisciplinary research is not feasible or desirable.

KEYWORDS

expert interviews, Focus Group Discussions, mediated modeling, participatory scenario analysis, transdisciplinary, sustainability, cash crop, industrial crop

1. Introduction

Commodity crop production is a significant agricultural activity in many parts of Sub-Saharan Africa (SSA). Some commodity crops[1] such as cocoa, coffee, and cotton, have been produced for centuries in different parts of the region. Others such as jatropha, sugarcane and oil palm have received substantial attention in the past decades for bioenergy or input in the food industry (Gasparatos et al., 2015; Ordway et al., 2017). The selection, promotion, and production of commodity crops often experiences boom-and-burst cycles, due to various national and international circumstances (Brown and Gibson, 2006; Clough et al., 2009). Despite these cycles, commodity crops have been promoted for radically different reasons between countries and can have radically different impacts at different spatial scales across the region, as discussed below.

A common reason driving the promotion and adoption of commodity crops is the perceived competitive advantages of producing countries (Ahmed and Gasparatos, 2021a), as well as efforts to modernize the agricultural sector and integrate SSA countries into the global economic system and farmers in global value chains (Van Vliet et al., 2015; Mellor and Malik, 2017). Sometimes, commodity crop production dominates the agricultural sectors and national economies of some countries, e.g., cotton for Burkina Faso (Vitale, 2018), cocoa for Ivory Coast and Ghana (Breisinger et al., 2008), and sugarcane and tobacco for Malawi (Chinangwa et al., 2017). Commodity crops are often seen as cornerstones of (a) national economic growth, (b) foreign exchange and employment generation, and (c) rural development and poverty alleviation (Schoneveld, 2014; Gasparatos et al., 2015). Sometimes they have become focal points in coordinated efforts to enhance energy security (e.g., sugarcane in Malawi) (Gasparatos et al., 2015).

However, commodity crop production in not uniform. It can be undertaken in different types of landscapes and through different models, both in terms of extent (e.g., large-scale plantations, smallholder-based production), market orientation (e.g., local use, sales in national and international markets), or intensification. Crops such as cotton, cocoa, coffee and tobacco are overwhelmingly grown by smallholders, relying on rainfed conditions and unimproved techniques (UNCTAD, 2015). Other crops such as oil palm and sugarcane can be produced ether in smallholder settings or large plantations, but their production tends to benefit from the economies of scale facilitated by large plantations (Gasparatos et al., 2015; Hall et al., 2017). In terms of markets, as they cannot mostly be consumed directly for food[1], they are produced for sale in national and international markets. Thus they are essentially cash crops produced for income generation after integrating farmers in national and international value chains (Achterbosch et al., 2014).

Commodity crop production has multiple impacts at different scales, that can be positive or negative depending on the crop, production model, scale of analysis and political, socioeconomic and environmental context. Usually, land mediates most of local impacts through land use change (Hess et al., 2016), sometimes associated with deforestation and/or the loss of ecosystem services and biodiversity (Strona et al., 2018; Ordway et al., 2019; Semie et al., 2019). Conversely, commodity crops offer income opportunities to smallholders and plantation workers in rural contexts that lack such formal opportunities. However, the actual income and employment generation potential depends substantially between crops and models, especially for low-value crops with unstable/immature markets (e.g., jatropha) (Romijn et al., 2014; Hall et al., 2017). Often the engagement and the outcomes of commodity crop production are contested and gendered (Fonjong, 2017).

Food security is perhaps the most controversial impact, as in SSA many of the rural and national contexts of commodity crop expansion in SSA are characterized by high rates of malnutrition and food insecurity. Critics point to the fact that by diverting staple food crop production, commodity crops reduce food availability at the local and the national scale, while the proponents point that by providing stable alternative income sources, commodity crop production improves food security by enhancing access to food (Jarzebski et al., 2020). In reality there are many more context-specific mechanisms mediating the food security outcomes of commodity crop production (Jarzebski et al., 2020). From enabling food crop yield gains due to better access to credit, irrigation and agricultural inputs (von Maltitz et al., 2019) to shifting gender dynamics and norms in areas of commodity crop

1 Commodity crops are defined in this paper as those crops that either have no food-related uses (e.g. cotton, tobacco, jatropha, coffee, cocoa), or are components of the food industry without being staple food crops (e.g. sugarcane, oil palm). Some of the non-food uses include bioenergy (e.g. jatropha, sugarcane), fiber (e.g. cotton) or recreation (e.g. tobacco). Sugarcane and oil palm are very multi-functional commodity crops that beyond their central position in the food industry, they can be used for bioenergy or biomaterials. Commodity crops are overwhelmingly grown for selling to external markets, rather than own use within the producing households. In this sense they have the characteristics of cash crops, with the added characteristic that their production has the potential to cause direct and indirect competition for land, resources and labor with staple food crop production.

production (Fonjong, 2017), improving infrastructure (Smalley, 2013) or affecting food prices.

This large impact variability is partly due to the fact that multiple stakeholders are involved in commodity crop value chains, as producers, consumers or facilitators (e.g., Hunsberger, 2010; Dompreh et al., 2021c). For example, producers include from smallholder family farmers producing commodity crops as a secondary livelihood activity, to specialized smallholders, parttime/fulltime plantation employees or large commercial producers (Hall et al., 2017; von Maltitz et al., 2019). There is also a high diversity of intermediaries and ancillary players (e.g., from government, civil society, certification agencies, international organizations, academia) with very different vested interests in commodity crop production. Such actors facilitate or hinder industrial crop production by, for example, creating amenable policy conditions (or barriers), providing funding, knowledge or engaging in advocacy activities (Hunsberger, 2010; Dompreh et al., 2021c).

Considering this multiplicity of uses, modes, impacts, and stakeholders, some scholars have argued for the need to adopt transdisciplinary research (TDR) approaches to both understand the characteristics, adoption and impacts of commodity crop production systems and value chains in SSA, as well as design appropriate interventions (Musvoto et al., 2015; Phiri et al., 2020; Schut and Giller, 2020; Vincent et al., 2020; van Ewijk and Ros-Tonen, 2021; Thompson et al., 2022). Some approaches have included multi-stakeholder dialogues and workshops (Minh et al., 2020), t-labs (Pereira et al., 2018; van Zwanenberg et al., 2018), participatory modeling and scenario analyses (Enfors et al., 2008; Schmitt Olabisi et al., 2018), and participatory mapping (Webber and Hill, 2014). By definition, TDR entails the integration of multiple disciplinary perspectives (interdisciplinarity) and the inclusion of stakeholders in the process of knowledge production and mobilization (Lang et al., 2012) (see Section 2.1 for a deeper explanation). However, despite this emerging literature, TDR research approaches have very rarely been employed at the interface of commodity crop production and food security in SSA. The underlying reasons are not clear but based on the experience of the authors they likely reflect resource constraints, fragmentation of expertise and the often controversial nature of the topic for some crops (e.g., biofuel crops), which collectively makes challenging to engage meaningfully relevant stakeholders at different levels in truly transdisciplinary research. However, even if it is challenging to undertake purely transdisciplinary research in some contexts, it might be possible to introduce certain transdisciplinary elements.

The aim of this paper is to critically discuss how the mobilization of participatory approaches can introduce transdisciplinary elements in research that explores the interface of commodity crops and food security in SSA. We draw lessons from five international and interdisciplinary research projects conducted between 2011-2022, which though not transdisciplinary in the strict definition of the term, they engaged heavily with stakeholders through various participatory approaches (Section 2). The paper has three research questions (a) how can *different* participatory approaches provide research functions beyond data collection that are considered central in transdisciplinary research, (b) how can *different* participatory approaches strengthen research principles that are considered essential for transdisciplinary research, and (c) how can participatory approaches be mobilized better to achieve the two points above. To meet (a) we outline how different techniques were used to (i) identify research priorities, knowledge gaps, and underlying phenomena (Section 3.1), (ii) formalize impact mechanisms and develop methodology (Section 3.2), (iii) interpret data and validate findings (Section 3.3). To meet (b) we reflect how the mobilization of different participatory approaches contributed to the relevance, credibility, legitimacy, and effectiveness of the research (Section 3.4), all of which are considered important principles of quality for transdisciplinary research (Belcher et al., 2016). To meet (c) we critically discuss some of the lessons learned implementing these techniques (Section 4.1), as well as the challenges, opportunities and future research trajectories to use them to unravel phenomena at the interface of commodity crop production and local sustainability, as well as design interventions to enhance their performance (Section 4.2).

Before embarking to this Methodology paper we need to point that we do not perceive transdisciplinary research as inherently superior to other research approaches (e.g., disciplinary, multidisciplinary, interdisciplinary). The selection of a research approach should depend on the questions and the complexity of the problem at hand, as transdisciplinarity is especially relevant for so-called "wicked" problems[2] that lack clarity in both their aims and solutions (Pohl et al., 2017). Instead, here we distill the lessons learned on how the mobilization of participatory approaches can provide some of the benefits of transdisciplinary research in contexts that truly transdisciplinary research is not feasible or desirable.

2. Methodology

2.1. Research approach

The five projects used to draw experiences in this paper, adopted research approaches that were broadly anchored in the field of sustainability science. In particular, all five projects adopted the four key aspects of sustainability science (Kates et al., 2001; Komiyama and Takeuchi, 2006; Kates, 2011), namely (a) a lens that clearly links the ecological and social components of the study systems, (b) a problem-based and solutions-oriented approach, (c) an interdisciplinary and (less so) transdisciplinary mindset, and (d) an open mindset to include knowledge from different knowledge systems (e.g., modern science, experiential knowledge, traditional and local knowledge).

In more detail, for (a) the starting point of all projects was the understanding that commodity crop production is a major driver of landscape transformation, which has a series of economic, social and environmental impacts for different groups (Section 1). At the same time in each area the decision to engage in commodity crop production and the mechanisms mediating impacts (and their effects to different groups) reflected the different socioeconomic

2 Wicked problems occur especially when stakeholders' values are contrasted and knowledge is incomplete or contradictory, which has been described as the context for "post-normal science" (Funtowicz and Ravetz, 1994).

and political circumstances in each context. For (b) all projects had a clear mandate to engage in research on socially-relevant challenges and at the same time generate novel and state-of-art knowledge that can be useful for policy and practice (see also Section 2.2, Supplementary Box S1). For (c) the research team comprised of experts from the social and natural sciences, and used highly interdisciplinary terms (e.g., food security, ecosystem services) and mixed-methods (Section 2.2). For (d) we engaged throughout the project with different knowledge holders such as practitioners, bureaucrats, and local communities to elicit and integrate their unique insights in the research.

Although all projects espoused many of the ideals of transdisciplinary research such as an attention to problem orientation, stakeholder engagement, and epistemological integration (Belcher et al., 2016), they were not purely transdisciplinary in the sense that they did not co-design, co-create or mobilize actual solutions on the ground in order to reduce the negative impacts and/or enhance the positive impacts of commodity crops (Sections 2.2 and 4.2).

When looking critically at the conceptual framework of transdisciplinary research for sustainability science proposed by Lang et al. (2012), these research projects engaged in Phase A (problem framing) and Phase B (knowledge generation), but not with Phase (C) (re-integration and application of knowledge). Although participatory approaches were expected for the design stage to provide critical information for each project (i.e., act as a source of information), they were also seen as avenues to inform certain research tasks commonly associated with Phase A and B. This expectation was based on the significant literature suggesting that beyond information gathering participatory methods can offer multiple other benefits within the sphere of control of research projects [i.e. project activities and outputs that are (mostly) under the control of the project] (Belcher et al., 2016).

The above suggest a certain overlapping but also the clear distinction between the concepts of a participatory approach and transdisciplinary research. By definition, transdisciplinary research requires the participation of stakeholders at all stages of the process of knowledge production, from the definition of projects' objectives to knowledge co-production and implementation (Lux et al., 2019). Stakeholder's participation at these different stages can have diverse objectives, from political action and empowerment to more functional aims such as involving end users such as farmers in the process of technology development (Neef and Neubert, 2011). Similarly in Arnstein's ladder of citizen participation (Arnstein, 1969), stakeholders' engagement can be equally diverse, from information gathering or dissemination of research findings only, to high degrees of social learning (Collins and Ison, 2009). Transdisciplinary research aims to achieve the deepest levels of stakeholder engagement at all research stages, as this can make more diverse contributions to knowledge and social processes, and have a greater influence across more impact pathways (Belcher et al., 2019). However, this often raises a number of difficult challenges (Kok et al., 2021), which means that though transdisciplinary research can offer many advantages it is not always feasible or desirable.

Based on this premise, in this paper we distill the lessons learned about the ancillary benefits of participatory approaches when mobilized beyond simple data collection and dissemination. In particular we focus on how they can introduce valuable transdisciplinary research elements to projects that were not designed to be transdisciplinary per se.

For the first research question (i.e., how can *different* participatory approaches provide research functions beyond data collection that are considered central in transdisciplinary research) we draw from the transdisciplinary research framework proposed by Lang et al. (2012). Upon reflection and collaborative discussions, the research team inductively identified three major such functions, namely to (a) identify research priorities, knowledge gaps, and underlying phenomena (Section 3.1), (b) formalize impact mechanisms and develop methodology (Section 3.2), and (c) interpret data and validate findings (Section 3.3). The first function mainly relates to Phase A of transdisciplinary research, while the latter two functions mainly relate to Phase B. In Section 3.1-3.3 we offer critical reflections of the extent to which the *different* participatory approaches mobilized in the five projects can contribute to each of these three functions.

For the second research question (i.e., how can *different* participatory approaches strengthen research principles that are considered essential for transdisciplinary research) we use the Transdisciplinary Quality Assessment Framework (Belcher et al., 2016, 2019), that focuses on the principles of relevance, credibility, legitimacy, and effectiveness.[3] According to this framework these four principles are fulfilled if a series of actions are implemented during the design and implementation of a research project. In Section 3.4 we cross-map how each type of participatory approach contributed to such actions, and as an extent to the desirable principles of transdisciplinary research.

For the third research question (i.e., how can participatory approaches be mobilized better to achieve the two points above), we critically reflect on the design and implementation of the participatory approaches within the five projects. We elicit in Section 4.1 some of the lessons learned on how to improve the design and implementation of participatory approaches for the functions and principles outlined above.

We need to acknowledge two important points at this stage. First, the extent to which different participatory approaches contribute to research functions (Research Question 1) and principles of transdisciplinary research (Research Question 2) reflects the collective perspective of the author team during the development of this paper. Although to some extent this is subjective, it still elicits rather well the collective experiences of

3 Relevance refers to the "importance, significance, and usefulness of the research project's objectives, process, and findings to the problem context and to society", which includes the "appropriateness of the timing of the research, the questions being asked, the outputs, and the scale of the research in relation to the societal problem being addressed" (Belcher et al., 2016, p. 8). Credibility refers to "whether or not the research findings are robust and the knowledge produced is scientifically trustworthy", which includes "clear demonstration that the data are adequate, with wellpresented methods and logical interpretations of findings" (Belcher et al., 2016, p. 8). Legitimacy refers to whether "the research process is perceived as fair and ethical by end-users" (Belcher et al., 2016, p. 12). Effectiveness refers to research that "contributes to positive change in the social, economic, and/or environmental problem context (Belcher et al., 2016, p. 8).

TABLE 1 Main foci of the five research projects.

Project	Main concepts/impacts	Main focus	Crops/sites	Deliverables
ESPA1	- Ecosystem services	- Impacts at local level	- Jatropha (Malawi, Mozambique)	- Primary empirical research on ecosystem services (von Maltitz et al., 2016). - Reviews and conceptual advances (von Maltitz et al., 2014; Gasparatos et al., 2015).
ESPA2	- Ecosystem services - Food security	- Impacts at local level	- Jatropha (Malawi, Mozambique) - Sugarcane (Eswatini, Malawi)	- Primary empirical research on land use change and ecosystem services (Romeu-Dalmau et al., 2018; Nyambane et al., 2020), livelihoods (Mudombi et al., 2021), poverty alleviation (Mudombi et al., 2018) and food security (Gasparatos et al., 2022). - Reviews and conceptual advances (Gasparatos et al., 2018b; Schaafsma et al., 2021). - Data descriptors (Gasparatos et al., 2018a)
Belmont Forum	- Food security	- Impacts at local level - Potential of upscaling at national level	- Cocoa (Ghana) - Coffee (Kenya) - Cotton (Eswatini, Ghana) - Jatropha (Ghana, Malawi) - Tea (Kenya) - Tobacco (Malawi) - Oil palm (Ghana, Guinea) - Rubber (Guinea) - Sugarcane (Ghana, Eswatini, Malawi)	- Primary empirical research on land use change and ecosystem services (Ahmed et al., 2018a), livelihoods (Ahmed et al., 2019a; Dompreh et al., 2021a), poverty alleviation (Ahmed et al., 2019a; Dompreh et al., 2021a), energy poverty (Ahmed and Gasparatos, 2020a), gender equality (Ahmed and Gasparatos, 2021b) and food security (Dam Lam et al., 2017; Balde et al., 2019; Dompreh et al., 2021b). - Institutional analysis (Chinangwa et al., 2017; Ahmed et al., 2018b, 2019b,c; Boafo et al., 2018; Ahmed and Gasparatos, 2020b; Gasparatos et al., 2021) - Reviews and conceptual advances (Ahmed et al., 2017; von Maltitz et al., 2019; Jarzebski et al., 2020)
ESPA3	- Ecosystem services - Food security	- Impacts at local and national level	- Sugarcane (Malawi)	- NA
Asahi Glass Foundation	- Food security - Livelihoods	- Adoption of sustainable practices at local level - Impacts at local level	- Cocoa (Ghana) - Jatropha (Ghana) - Oil palm (Ghana) - Sugarcane (Ghana)	- Primary empirical research on livelihoods (Ahmed et al., 2019a; Dompreh et al., 2021a), poverty alleviation (Ahmed et al., 2019a; Dompreh et al., 2021a) and food security (Dompreh et al., 2021b). - Institutional analysis (Dompreh et al., 2021c)

the team after designing, implementing and interpreting these participatory approaches over a decade. Second, and allied to the previous point, it does not mean that the specific participatory approaches cannot contribute to other functions or principles, if mobilized in other ways or within projects that have different aims (e.g., projects that include a knowledge reintegration element, Phase C). If anything, the findings within this Methodology paper reflects the needs, structure, and functionalities in the context of the study projects, and should be kept in mind when generalizing the reflections of this study in other research contexts.

2.2. Study projects

In this paper we share the observations generated during five multi-partner international and interdisciplinary projects that explored the impacts of different commodity crop production systems on ecosystem services, livelihoods and food security in SSA. Collectively these five projects focused on providing empirical evidence about the local-level impacts of different commodity crops throughout SSA. The projects were highly interdisciplinary using a series of concepts and tools from the social and the natural sciences. Table 1 contains the basic characteristics of each project, with more detailed information found in Supplementary Boxes S1–S5. Figure 1 shows the distribution of the study sites among the different projects.

These projects resulted in the three major sets of academic deliverables (Table 1). The first set consisted of peer-reviewed papers and book chapters reporting primary empirical evidence for a series of impacts. The second set of deliverables consisted of peer-reviewed papers and book chapters that combined institutional analysis, expert interviews and sometimes fieldwork to elicit rich qualitative information about different phenomena deemed interesting at the interface of commodity crop production and sustainability in the different study countries (see also Section 3.1). The third set of deliverables consisted of peer-reviewed papers that generated conceptual advances, including through narrative and systematic reviews.

When looking critically at their funding sources and calls, all these projects were essentially academic in nature. In other words, the main selection criterion was the potential to generate innovative research through interdisciplinary teams. However, a common underlying theme in research calls was the "request" to develop novel policy-relevant knowledge that could help generate social impact. In other words, while the development and implementation of actual interventions to solve sustainability issues on the ground was not a requirement of these calls, it was expected that the generated knowledge could inform and guide the development and implementation of such interventions. In order to facilitate

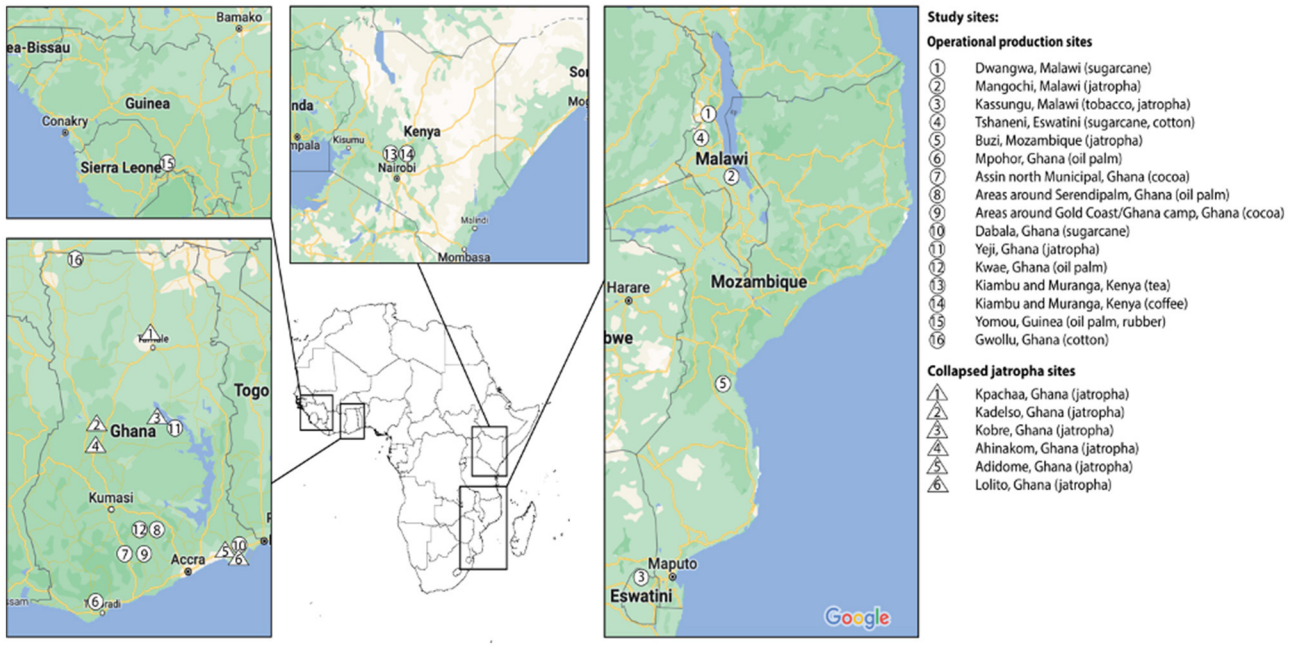

FIGURE 1
Case study locations and crops.

the generation of socially-relevant research there was a conscious effort to partner with different knowledge users in the ESPA2 and Belmont Forum[4] projects, including the Roundtable for Sustainable Biomaterials (RSB), BonSucro, the New Partnership for Africa's Development (NEPAD), CleanStar, and Solidaridad. These organizations helped the research team identify research priorities and existing knowledge gaps and needs to help frame better the research.

The underlying research projects received ethical approval from the University of Tokyo Life Sciences Committee (reference: 15–186) and the University of Oxford Central University Research Ethics Committee (CUREC).

2.3. Participatory approaches

Between them the different projects contained a very diverse set of participatory approaches that engaged different stakeholders (Table 2). Overall, the different participatory approaches served very different research functions such as to: (a) identify research priorities, gaps, phenomena, (b) inform methodology development, (c) interpret data and validate findings. Below we briefly summarize the main characteristics of each of these participatory approaches, with more information in Supplementary Boxes S2–S6. Sections 3.1–3.3 outline how they were employed to perform the three functions mentioned above, and in Section 3.4 our reflections of how they contributed to strengthen research principles that are considered essential for transdisciplinary research.

Expert interviews[5] were in depth discussion with individual stakeholders and/or community members engaged in, affected by, interested in or otherwise knowledgeable in commodity crop value chains. Usually, the interviewed stakeholders were identified through comprehensive institutional mapping exercises that systematized the main institutions associated with commodity crop value chains (e.g., policies, organizations, initiatives). Supplementary Box S2 outlines the general approach followed for expert interviews, the research questions they usually focused on, and related publications.

Focus Group Discussions (FGDs) entailed semi-structured groups interview/discussions that involved several community members in the different study areas experiencing commodity crop production. FGDs usually engaged 5–12 local community members that could provide general information about the social-ecological context of the study area, the history of commodity crop production, and the impacts and persons affected. Despite their functionality as primary data collection instruments, FGDs mostly served to provide a good understanding of the different study sites and the possible linkages between commodity crops and the studied

4 For example, the Belmont Forum puts some emphasis on social implementation, transdisciplinary research and stakeholder participation. Refer to: https://www.belmontforum.org/about.

5 Expert interviews can be found in several forms in the literature, such as key informant interviews or personal interviews, among others. For the purpose of this paper, we use the concept of expert interviews to show the good knowledge of the interviewed participants in relation to the specific topic. In other words, these interviews did not elicit perceptions over a topic that the participants had a peripheral engagement and/or knowledge, but instead they sought to elicit deep insights from participants holding different types of knowledge (e.g. scientific, practical, experiential).

TABLE 2 Participatory approaches employed in the different projects.

	ESPA1	ESPA2	Belmont Forum	ESPA3	Asahi Glass Foundation
Expert interviews	✓	✓	✓	-	✓
FGDs	✓	✓	✓	-	✓
Participatory mapping	-	-	✓	-	✓
Mediated modeling	-	-	✓	-	-
Participatory scenario analysis	-	-	-	✓	-

impacts (i.e., mechanisms). For this reason, with the exceptions of the studies mentioned above, FGDs results were not widely reported in the different project outputs. Supplementary Box S3 outlines the general approach followed for FGDs, the research questions they usually focused on, and related publications.

Participatory mapping was conducted with groups of local community members in some of the study areas, and especially areas containing large plantations established in the recent past (e.g., 10–15 years before fieldwork). The participatory mapping exercises largely had a similar functionality as the FGDs in that it they helped the research team obtain a good understanding of the study areas, and especially some of the land use change dynamics and the benefits that local communities obtain from the landscape (e.g., ecosystem services) compared to some previous state (e.g., prior to plantation development). Overall participatory mapping exercises helped in eliciting rich qualitative information that could supplement remote sensing analysis, especially providing information that could not be obtained from satellite pictures (e.g., parts of the landscape exploited for different uses). Supplementary Box S4 outlines the general approach followed for participatory mapping, the research questions it usually focused on, and related publications.

Mediated modeling, also referred as "group modeling building," (GMB) in the literature (Antunes et al., 2006)– approaches created a space of collaboration between the research team and experts from outside the consortium. They created a space for structured dialogue and joint understanding to inform specific research elements, and, in particular, to formalize the main impact mechanisms to be considered in the study and to inform methodology development. This was done through the co-development of causal loop diagrams (Sterman, 2000; Meadows, 2008; Inam et al., 2015; Coletta et al., 2021) that depicted the main impacts of commodity crops and how they were expected to be unfolded at the local level (i.e. mechanisms). The underlying logic of mediated models is that, by providing the conditions for stakeholders to collectively disclose, visualize and confront their "mental models" regarding a complex problem, it is possible to reach a deeper and common understanding of the problem's elements, interactions and trade-offs (Antunes et al., 2006; Eker et al., 2018). In particular, causal loop diagrams (CLDs) are qualitative tools belonging to the system dynamics modeling family of techniques (Sterman, 2000), that constitute a key output of mediated modeling (Stankov et al., 2021). While simple enough to be understood by non-academic stakeholders, CLDs allow for the recognition of patterns in the behavior of a given system (i.e. complex problem constituted by elements and their interactions) through the identification of balancing or reinforcing feedback loops, and in turn, identify potential points of intervention (Eker et al., 2018; Purwanto et al., 2019). The use of the CLD allows for the mapping and visualization of interactions within complex systems in an unambiguous and easily understandable manner. This allows for a facilitate discussions between non-technical local experts, other stakeholders and researchers in a way that allows for a verified and common identification of issues and interconnections between issues. It further ensures that a holistic view is develop around problems where all the interlinkages can be identified (Inam et al., 2015) The use of CLDs also aids in the identification of complex interactions and feedbacks that could destabilize a system but that are not radially apparent (Groundstroem and Juhola, 2021). Supplementary Box S5 outlines the general approach followed for mediated modeling and the research questions it mainly focused on.

The participatory scenario exercise was designed following an established approach (see Reed et al., 2013a,b), customizing it to fit the study context (i.e. impacts of sugarcane production) and locations (i.e., Malawi and Dwanga). The underlying logic is that scenario analysis can enable the exploration of possible causal relationship, drivers of change and future uncertainties (Wollenberg et al., 2000; Frittaion et al., 2010; Carlsson et al., 2015), by encouraging critical thinking, improving stakeholder exchanges, broadening the understanding of current situations, and anticipating future changes (Wollenberg et al., 2000). In this sense, scenarios can help identify potential trade-offs or conflicts between different activities, including in the bioenergy sector (Haatanen et al., 2014; Sterling et al., 2017). Participatory scenario analysis was integrated in four dissemination workshops in Malawi during the ESPA 3 project. Supplementary Box S6 outlines the general approach followed for participatory scenario analysis and the research questions it mainly focused on.

3. Findings and observations

3.1. Identify research priorities, knowledge gaps and underlying phenomena

Expert interviews were conducted in each study country before moving for the local-level fieldwork at the study areas (Figure 1). These expert interviews essentially occurred during the early parts of the research in each country. These interviews were a key avenue to understand some of the local context and identify research priorities and knowledge gaps by putting

into perspective the information identified in the literature[6] and the previous experiences of the members of the research team. Beyond their importance for receiving concentrated information about national dynamics, these expert consultations were also somewhat justified by the fact that all funding schemes implicitly "requested" the generation of policy-relevant knowledge that can have societal impact. In this sense engagement with policymakers and practitioners was viewed as a necessary pre-condition to appreciate the main priority research areas, and how our research can/should contribute.

For example, the literature reviews conducted at the beginning of the ESPA1 project (early 2011), coincided with the rapid expansion of bioenergy crop production in SSA (Gasparatos et al., 2011, 2015). This period was characterized by a general lack of comparative understanding and robust assessments about the impacts of bioenergy crops (and their mechanisms) at the local level, especially between those crops (i.e., jatropha vs. sugarcane) and production models (i.e., large-scale vs. smallholder-based) considered as the most relevant in the SSA context. Expert interviews at the beginning of the project reaffirmed that the lack of this comparative understanding is a major research gap and a research priority at the regional level. It was pointed by several experts that such information is essential in informing the then ongoing discussions throughout the region about whether/which of the different bioenergy options are sustainable, and if/how they should be promoted through national policies and on-the-ground projects. The broad insights generated from these early expert interviews influenced the team to expand the scope of subsequent projects (ESPA2, Belmont Forum) and seek to capture impacts for multiple crops and production models. Such multi-crop and multi-model impact assessments that follow comparative, cohesive and robust methodological protocols became the main output of the different projects, spanning impacts such as carbon storage (Romeu-Dalmau et al., 2018), ecosystem services (von Maltitz et al., 2016; Ahmed et al., 2018a; Nyambane et al., 2020), livelihoods (Ahmed et al., 2019a; Dompreh et al., 2021a; Mudombi et al., 2021), and food security (Dam Lam et al., 2017; Balde et al., 2019; Dompreh et al., 2021b; Gasparatos et al., 2022), among others.

A second example is how expert interviews helped appreciate better certain national research gaps and priorities during the early phases of subsequent projects (i.e. Belmont Forum, Asahi Glass). These included, among others, (a) why is jatropha production collapsing and whether there can be future in southern Africa and Ghana, (b) whether there is differentiation in the promotion, uptake and performance of oil palm and cocoa certification in Ghana, (c) whether there are acceptable market-based instruments to reduce land use change and deforestation from tobacco and sugarcane in Malawi (and how they might look like), (d) why has the cotton sector collapsed in Ghana but flourished in neighboring Burkina Faso, (e) how land consolidation processes and traditional institutions have mediated the impact of commodity crop production in Ghana. Compared to the broader regional-level gaps and priorities outlined above, these constitute gaps/priorities that are much more relevant in the specific national contexts. As such they were included in the research agenda, and were treated in dedicated publications exploring jatropha collapse and future prospects in Ghana and southern Africa (von Maltitz et al., 2014; Ahmed et al., 2019b), oil palm and cocoa certification differences in Ghana (Dompreh et al., 2021c), acceptability and architecture of possible PES schemes in Malawi (Chinangwa et al., 2017) and differentiated performance of the cotton sector in Ghana and Burkina Faso (Boafo et al., 2018).

A third, example is how FGDs offered reality checks that the knowledge gaps and research priorities identified at the regional and local level, were also relevant at the local level. As FGDs were one of the main data collection mechanisms they were conducted in tandem with household surveys in the study areas, but serving different purposes. However, in contrast to household surveys that entailed the exhaustive elicitation of quantitative information (see Gasparatos et al., 2018a for the actual protocols), FGDs provided a livelier discussion opportunity where community members provided information about the history, modalities, and impact of commodity crop production in each study site. During FGDs it was not uncommon to hear skepticism and uncertainty about the viability of jatropha projects (even around operational at that moment projects in Ghana, Malawi, and Mozambique), especially considering the emerging records of collapse in the respective national and regional contexts. Furthermore, there were concerns of how to enhance the performance of such crops or market viability. Although the participatory encounters during FGDs did not shape the research agenda to the same extent as the expert interviews, they provided valuable reality checks that indeed the explored topics are important in the local context. Furthermore, they informed dissemination actions by providing insights about which results are locally relevant.

Beyond their centrality for identifying research priorities and gaps, expert interviews and FGDs helped the research team to appreciate some underlying phenomena that upon closer examination mediated very strongly the local impacts of commodity crop production but were not initially flagged as important from the literature review or the conceptualization process. These mainly reflected institutional issues such as (a) land rights reconfiguration, lack of compensation, or (often unconstructive) mediation of traditional authorities during large-scale land acquisition processes (e.g., Ahmed et al., 2018b, 2019c; Ahmed and Gasparatos, 2020b), (b) land consolidation and differentiated access to irrigation infrastructure (e.g., Roland, 2019; Gasparatos et al., 2021), or (c) payment structures and modalities between different groups engaged in commodity crop production, e.g., certified vs. non-certified smallholders (Dompreh et al., 2021a,b), outgrowers vs. independent growers (Ahmed et al., 2019a). The early identification of such underlying phenomena was essential to understand ultimately how the actual impacts

6 The research team undertook extensive literature reviews to (a) understand the research landscape about the drivers and impacts of commodity crop expansion in SSA (e.g. Ahmed et al., 2017; Gasparatos et al., 2017; Jarzebski et al., 2020), (b) systematize the impact mechanisms and move the state-of-art in the conceptualization of the links between commodity crops with ecosystem services (Gasparatos et al., 2011, 2018b) and food security (Jarzebski et al., 2020). These literature reviews and conceptualization exercises were conducted at different points of the span of the overall research, but usually coincided with the early stages of the respective projects (i.e. ESPA1/ESPA2 for ecosystem services, Belmont Forum for food security).

TABLE 3 Contribution of participatory approaches to major research functions.

	Identify priorities, gaps, phenomena	Develop methodology/formalize impact mechanisms	Interpret data/validate findings
Expert interviews	++	+	+
Participatory mapping	+	+	+
Focus Group Discussions	+	+	++
Mediated modeling	+	++	-
Participatory scenario analysis	+	-	++

(++) Implies that a participatory approach can have a major contribution for a specific research task, (+) that it has a smaller contribution, and (–) that it has no or minimal contribution.

are mediated. Although this did not significantly affect the development of the main research instruments (i.e., household survey, see Section 3.2) it provided a valuable lens as to how to put into perspective and interpret the elicited differentiated impact levels between groups across some (or all) of the study sites.

When looking more critically the contribution of the different types of participatory approaches to the identification of priorities, gaps and phenomena, we find different potential and ability among approaches (Table 3).

3.2. Formalize impact mechanisms and develop methodology

Mediated modeling exercises constituted the main participatory approach used to select and formalize the main impact mechanism to be included in the study, and inform the development of the main methodology for primary data collection, namely the household surveys. Mediated modeling was only used during the Belmont Forum project, as the size of the funding did not enable this option in the other projects.

The mediated modeling exercise with international experts followed an iterative process, starting with the development of a "straw" model by members of the research team depicting the impact mechanisms expected to be studied and how they unfolded. This was mainly informed by previous literature reviews (see Section 3.1) and the accumulated experience of team members from previous projects (i.e., ESPA1 and ESPA2) and other research experiences. Subsequently this was refined through the joint exchanges between the research team with external experts. In particular, following multiple breakout sessions and plenaries the participants jointly elaborated the initial "straw model," developing in the process two refined models linking commodity crop production and food security, one for large-scale production and one for smallholder-based production. This dialogue helped achieve a shared understanding between the research team and the external experts (but also interestingly between members of the research team) of: (a) which impacts are important to study, (b) what are the mechanisms mediating these important impact, (c) in which scale to study the impacts, and (d) how broader commodity crop production systems and value chains operate.

Regarding (a) and (b) Figure 2 illustrates the final versions the causal loop diagrams co-developed by the research team and external experts. Some of the main mechanisms identified were: (a) cropland displacement and/or natural vegetation loss (negative effect on food security), (b) development and maintenance of infrastructure (positive effect on food security), (c) improved access to agricultural knowledge (positive effect on food security), (d) improved access to markets, both via local crop production diversification and better access to transportation (positive effect on food security), (e) changes in water access via improved irrigation (positive effect on food security) or water diversion to plantations and processing industries (negative effect on food security), (f) policy distortions such as economic incentives or taxes for commodity crops (variable effect on food security), and (g) income generation and changes in household budget control through different pathways (generally positive effects on food security). It is worth noting that although some new impacts and/or mechanisms were identified during the mediated modeling exercise that were not included in the "straw" model, there were not many alterations from the original.

Regarding (c) the international mediated modeling exercise was instrumental in binding the spatial scale of analysis (local level) and what impacts/mechanisms are relevant locally and which are relevant in different scales (i.e., national, international). Furthermore, it was agreed that the unit of analysis was the household, meaning that within-household food security impacts would not be a research focus, nor the overall impacts on national food self-sufficiency. Furthermore, it was agreed that the focus of analysis would be the small-scale farmers directly impacted by commodity crop production either as smallholders or resident in areas affected by the industrial crop expansion (i.e., control groups) and plantation employees. As such, it was decided not to specifically look at non-farmers within the case study areas (i.e., salaried workers or businesses with no direct link to agriculture), or impacts in urban areas as secondary consequences of the industrial crop expansion (e.g., effects of improved energy security or fuel switch to nutrition).

Regarding (d) we realized that there were many other factors at the interface between commodity crops and food security that were not exactly impacts or components of the impact mechanisms. These we named "drivers of model outcomes," as they could somehow effect the interactions between commodity crop production and food security. These were divided into policy drivers and other drivers. Due to the hugely complex nature of how these drivers could interact with other aspects of the model, we did not attempt to show the linkages. However, listed these drivers (and in some cases how some drivers interact with each other) (see Figure 2). These drivers are, in essence, variables that may

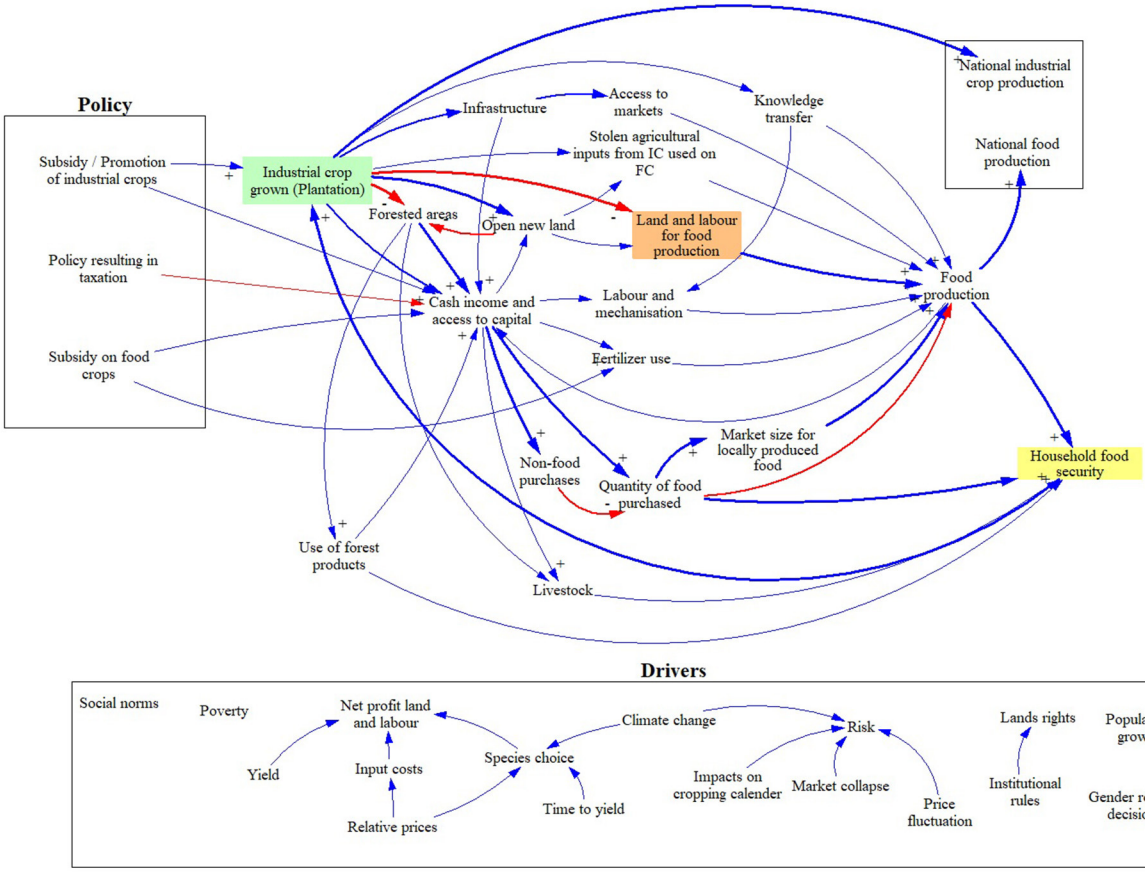

FIGURE 2
Sample causal loop diagram depicting linkages between commodity crop production and local food security for large-scale production systems.

change the magnitude or direction of the food security outcomes of commodity crop production, and was important to understand whether they were at play in the different study contexts. This was usually done through expert interviews and FGDs.

The follow-up mediated modeling exercises at the local level refined and customized the causal loop diagrams developed through the international expert workshop. The focus here was specifically sugarcane and tobacco production. The need for local exercises (and for the specific crops) was based on the emerging understanding within the research team (which was reinforced by the international expert workshop) that the hybrid plantation-smallholder models have certain complexities due to their broad area effects, while the tobacco smallholder sector has particularly unique contractual agreements (see below examples for both). The refinement process was undertaken through four fieldwork sessions (two in Malawi and two in Eswatini), where local experts and stakeholders were engaged individually or in groups to refine the causal loop diagrams with members of the research based on their understanding. It should be noted that in contrast to the international workshop, many of the local experts and stakeholders provided insight only into particular segments of the overall causal loop diagrams, based on their specific expertise, knowledge or interest. Some local expert/stakeholder engagements happened in the field, and thus was not always possible to conduct the real time refinement. This required very detailed note taking, and verification from the expert.

These local mediated modeling exercises helped identify important context-specific impacts and drivers that needed to be considered in the specific studies. For example, one key refinement for sugarcane reflected the fact that due to the large investment required for sugarcane production, sugarcane projects inject significant amounts of capital to areas with little money circulation. As shown in Figure 3, this can lead to new opportunities for entrepreneurs to generate wealth via other spin-off businesses (this was also confirmed with expert interviews that indicated new forms of wealth generation). These included opportunities linked directly to the sugar cane production process such transportation drivers as well as unrelated businesses such as grocery shops and food stalls that became profitable due to the salaried employment in the projects. Furthermore, the perceived benefits of the sugarcane sector were identified as an important (but abstract) variable in the causal loop model, which although not physically measurable it is an important factor in this system.

Collectively these exercises informed the development of the household survey, which was the main data collection tool for the Belmont Forum project. By agreeing on and systematizing the impact mechanisms, scale of analysis, and possible influencing factors, these exercises practically dictated the measurable variables

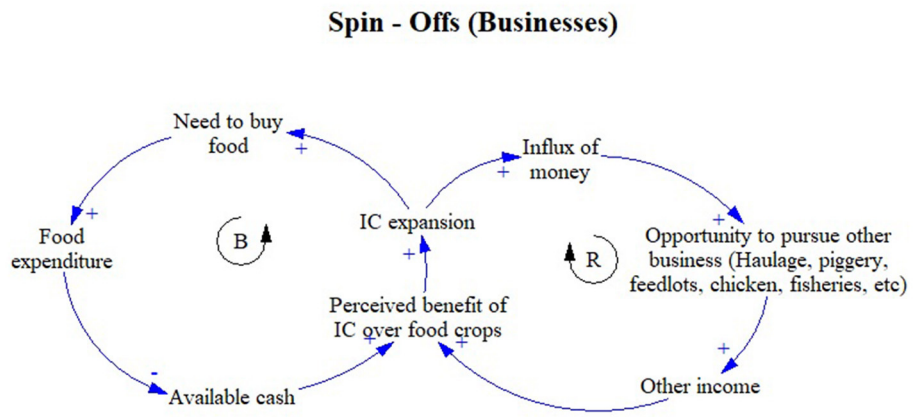

FIGURE 3
Example of diagrams refinements/additions through local exercises in sugarcane areas.

to be integrated in the survey, the statistical tests to be used for analysis, and the overall experimental design. Furthermore, these exercises were instrumental in identifying new tools that were not previously used by the research team, such as anthropometric measures that could capture long-term food (in)security more robustly.

However, beyond their huge contribution for methodology development, the mediated modeling exercises had several "intangible" research benefits. In particular they forged: (a) a common understanding and consensus within the research team about the focus of the research, (b) a sense of certainty within the team that the study phenomena have been identified and captured properly, and (c) a "common language" for the various study phenomena. The utility of the last point is not to be underestimated for the effective operation of our interdisciplinary research group, whose individual members initially defined and understood key research terms such as "food security" or even "impact" through disciplinary lenses. The common "definition" of such terms during the deliberations at the international workshop (where all team members were present), arguably improved the communication within the research team and essentially helped the cohesion of the actual research.

We should note, that expert interviews and FGDs helped to a lesser extent identify and formalize the impact mechanisms. This was particularly true for the non-Belmot Forum projects, for which it was not possible to conduct mediated modeling exercises. For example, depending on the context of the expert interviews or FGDs, on some occassions there were specific questions to elicit which impacts were deemed important (or how they unfolded) while in others this was elicited by using information from multiple questions. Similar to the mediated modeling exercises, some of this information informed directly our methodology by, for example, reconsidering certain methodological choices or adding new methodological elements. An example of the former is the reformulation of questions regarding ecosystem services impacts around a jatropha plantation in Mozambique (ESPA1/ESPA2 projects), as engagements with local experts and FGDs pointed to the very different local understanding and values around nature compared to other study sites. An example of the latter was the addition of an additional fieldwork round in Malawi and Swaziland (Belmont Forum project) to understand how the then ongoing El-Nino effect affected the commodity crop-food security interface by disrupting some of the initially identified mechanisms.

Such participatory approaches have certain benefits and challenges. One of the benefits is that during expert interviews respondents did not feel constrained to speak freely as in group settings, while both expert interviews and FGDs can provide very context-specific information. Conversely, expert interviews might insert biases due to personal views of what are the most important impacts or the uncertain elicitation of impact mechanism due to incomplete understanding. In the case of mediated models, facilitation is key to guarantee equal participation and to avoid dominance of specific stakeholders during the construction of CLDs, specially when lack of consensus exists (e.g., polarity of relationship between two variables).

Similar to Section 3.1, different participatory approaches contributed in different extents to formalize impact mechanisms and develop methodology (Table 3).

3.3. Interpret data and validate findings

Although expert interviews, FGDs and participatory mapping are inherently data collection mechanisms, they can also be used to provide deep insights about some of the observed patterns. In this sense the expertise and experiences of the engaged participants (whether as groups or individuals) can be mobilized by the research team to help interpret research findings. In our case we often used expert interviews and FGDs to explain the direction of some associations between variables and/or identify the possible factors mediating these associations. This was mainly geared toward the highly quantitative variables for the livelihoods and food security impacts.

Before explaining how this was done, it is important to appreciate why it was necessary. As mentioned above the main data collection instrument was a household survey that elicited the impact of engagement in different types of commodity crop activities, namely smallholder-based production, plantation employment or no engagement (i.e. control households). This approach was selected because it was not possible to have for the same household accurate quantitative data for the main livelihood and food security impact variables prior to engagement. This meant that the impact of engaging in commodity crop production at the household level was achieved through group comparisons using different statistical tools such as Propensity Score Matching (PSM), Inverse Probability Weighting Analysis (IPWA) or Endogenous Treatment Effect Regression (ETER) (e.g., Balde et al., 2019; Dompreh et al., 2021a,b; Mudombi et al., 2021; Gasparatos et al., 2022). However, although such approaches provided robust information about the impact of engagement, they fail to clearly explain why some of these patterns emerge. One such example was the differentiated performance of two indicators of food security (one measure of diet diversity and one measure of perceived hunger) for some group comparisons, such as plantation workers vs. other groups in a sugarcane plantation in Malawi. Through expert interviews it was possible to identify that the possible factor mediating the different performance of these two indicators were concern over job security (see Gasparatos et al., 2022). Another example was differentiated performance of livelihood indicators among independent and contracted oil palm smallholders in Ghana, which was linked to different payment modalities and market options (see Ahmed et al., 2019a; Dompreh et al., 2021a,b).

The participatory scenario analysis helped partly "validate" some findings. The underlying logic of the participatory scenario exercises was to (a) enable participants to absorb the research results during the dissemination presentations of the morning sessions, (b) critically assess the relevance/validity of these results considering their own experience and understanding of the situation on the ground, and (c) utilize the research results fully or partially if considered valid. In particular, for each of the thirteen impacts considered in each of the four scenarios (see Supplementary Box S6) we developed narratives that depicted the impact mechanism and possible outcomes, as identified through our empirical research. The narrative varied for each of the combinations of scenario-impact in terms of impact direction and possible outcome. For example, for sugarcane expansion scenarios the impacts related to livelihoods and employment impacts were positive and improving and environmental impacts were negative and worsening. Conversely the opposite narratives were used for sugarcane collapse scenarios. By asking the participants to rate the likelihood and magnitude of these impact based on these narratives for each scenario, in a sense we received some short of qualitative feedback about the validity of some research findings. During the group rating exercises the teams were asked to justify each of their decisions, including whether the narrative made sense or needed to change if deemed erroneous. This process provided important concentrated information about the nature and mechanisms of each impact, which helped validate these research findings. In this sense this process essentially enabled us to receive deeper and more active feedback about our findings compared to a standard Q&A session after the dissemination presentations. However, we need to point the possibility of inserting some bias in this process, as some of the ratings might have been affected by the information provided during the presentations. To reduce this likelihood during the group justifications, we always asked whether the narrative made sense according to the experience of the participants.

Finally, similar to the previous sections, the different participatory approaches contributed in different extents to interpret data and validate findings (Table 3).

3.4. Strengthen transdisciplinary research principles

Table 4 cross-maps how each type of participatory approach contributed to actions/tasks associated with the four main principles of transdisciplinary research, namely relevance, credibility, legitimacy and effectiveness (see Section 2.1). We note that different participatory approaches have different capacity and ability to strengthen these principles of transdisciplinary research.

The mobilized participatory approaches where particularly valuable in helping define the social-ecological context, identify social relevance, improve engagement of the research team with the problem context, and enhance relevance/appropriateness of research objectives and design. Furthermore, they contributed to enabling broad preparation, facilitating clear research problem definition, facilitate statement of objectives and ensuring fitness-for-purpose. The above are related mostly to the credibility and relevance principles.

The mobilized participatory approaches did not strengthen substantially to the legitimacy and the effectiveness of the research. This is not surprising considering that all research projects mainly undertook activities related to Phase A and Phase B of transdisciplinary research, rather than Phase C (Section 2.1). However, participatory approaches such as mediated modeling and participatory scenario analysis contributed to some extent to the legitimacy and the effectiveness principles (Table 3).

4. Discussion

4.1. Lessons learned and research recommendations

4.1.1. Involve appropriate experts and stakeholders

We believe that there is generally no silver bullet approach to involve experts and stakeholders, but it is highly context-specific. In our case this required a strong reflection from the part of the research team before each participatory approach to understand what was expected (e.g., identify priorities/gaps, inform methodology, interpret data). Hence, fitness-for-purpose was the main guiding criterion employed to identify and engage experts and stakeholders, especially when considering that their participation was often unfunded and challenged by their generally busy schedule. The second key guiding criterion was to achieve

TABLE 4 Contribution of participatory approaches to transdisciplinary principles.

Principles	Task/criterion	Expert interviews	FGDs	Participatory mapping	Mediated modeling	Participatory scenario analysis
Relevance	Define clearly social-ecological context	+	++	++	-	-
	Identify societal relevance	++	++	-	++	-
	Improve engagement with problem context	++	++	++	++	-
	Create explicit theory of change	-	-	-	-	-
	Enhance relevance/appropriateness of research objectives and design	++	+	+	++	-
	Ensure appropriate project implementation	-	-	-	++	-
	Enable effective/appropriate communication	-	-	-	+	++
Credibility	Enable broad preparation (i.e., integrated foundation)	+	+	+	++	-
	Facilitate clear research problem definition	++	++	+	++	-
	Facilitate statement of objectives	+	+	-	++	-
	Enhance project feasibility	+	+	-	-	-
	Improve the competencies of the research team	-	-	-	++	-
	Ensure fitness-for-purpose of the research	++	++	+	++	-
	Enable clear presentation of arguments/findings	-	-	-	-	+
	Facilitate transferability/generalizability of research findings	-	-	-	+	+
	Improve statement of limitations	-	-	-	+	-
	Enable ongoing monitoring and reflexivity	-	-	-	-	-
Legitimacy	Facilitate disclosure of perspective	+	+	+	++	-
	Enable effective collaboration	-	-	-	++	++
	Facilitate genuine and explicit inclusion	+	+	+	++	++
	Confirm ethics of research	+	+	-	++	-
Effectiveness	Build social capacity	-	-	-	-	++
	Contribute to knowledge	-	-	-	+	++
	Facilitate practical application	-	-	-	-	+
	Facilitate significant outcomes (i.e. solution of targeted problem)	-	-	-	-	+

(++) Implies that a participatory approach can have a major contribution for a specific task/criterion, (+) that it has a smaller contribution, and (–) that it has no or minimal contribution.

inclusivity, in order to ensure the comprehensive and multi-dimensionality of the input generated from the different processes. This need for diversity in terms of disciplinary lenses, ways of knowing, and type of engagement has been pointed extensively in the transdisciplinarity literature (Leventon et al., 2016; Ghodsvali et al., 2019; Kok et al., 2021; Lawrence et al., 2022). For FGDs particularly, as a matter of community entry strategy, there is the need to engage neutral first points within existing social conflicts. This will help gather knowledge from the different sides of the community stakeholders without artificially putting you into existing factions. Whiles this process may be laborious, it is important to take appropriate steps to start on the right person.

As argued by Klerkx et al. (2017), the institutional context plays a major role, leading to very contrasted degrees of propensity and preparedness for participatory approaches. It remains difficult to identify appropriate participants from some types of organizations, especially for some of the more technical tasks such as method co-development. Such an example are government agencies where the political personnel generally remain in the posts for short durations of time (quick turnover), which precludes achieving the necessary deep expertise for some issues. To overcome this particular problem we tried to engage with bureaucrats/civil servants rather that political personnel, as they tend to have a lower turnover and opportunities to gain deeper knowledge and understanding of the issues at stake (e.g., OECD, 2017). Generally, we tended to engage mid- or senior-career practitioners and bureaucrats/civil servants that were senior enough within their organizations to understand well the issues at hand, while at the same time being able to reflect the position of their respective

organization beyond their personal understanding/expectations. One challenge here was to prevent self-censoring or fear of expressing opinion considering that commodity crops were a rather contentious topic in most study countries (see Section 1). We tried to achieve this by clearly explaining the purpose of each participatory engagement, the expected type of contribution from them, and how it will be used internally (i.e., within research team) and externally (e.g., publication). In individual settings we gave them the opportunity to talk off the record if they felt it necessary, but in reality only few participants used this option and for few topics. This means that as much we received valuable information from relevant stakeholders, there are possibilities of self-censoring without necessarily, prompting the research team.

4.1.2. Be aware of social differentiation, positionality and vested interests

This is because of conscious or unconscious efforts to either bias answers, provide a fragmented understanding, or even manipulate for own interest the gap/priority identification or co-design. This has been pointed in several studies in the transdisciplinarity (Akerlof et al., 2020; Lawrence et al., 2022). We believe that this is largely an offshoot of their different engagements in commodity crop value chains, and is only logical to emerge considering that in many cases we asked deliberately the participants to reflect the perspective of their organization. This very fine line between asking participants to reflect their organization's perspective but at the same time prevent/identify possible biases (Lawrence et al., 2022). In our case it required a constant process of reflection from the part of the research team.

Here we need to point that social differentiation and vested interests can cause major challenges, especially in local contexts where the participants engaged in participatory approaches actually experience the impacts of commodity crops. Practically, in all study areas some participants benefited from commodity crops (e.g., producers, staff of commodity crop companies), others faced negative impacts (e.g., control groups) and some groups had very differentiated benefits (e.g., independent smallholders vs. outgrowers). The research team needed to be well-aware of such differentiated experiences, especially before the community-based participatory approaches (i.e. FGDs, participatory mapping), to avoid creating further social tensions (see Thompson et al., 2017). For example, in most cases the FGDs and participatory mapping participants were divided between commodity crop producers and non-producers or when not segregated the participatory approach sought to avoid contentious topis by framing the process accordingly. The issue here was how to synthesize the different outcomes of the participatory approaches, as it was not possible to obtain consensus for some issues (e.g., research priorities). This need to keep in mind the social tensions in community participatory exercises has been re-iterated in many studies (Thompson et al., 2017), and is arguably particularly relevant in the context of food systems or social-ecological systems in developing countries where local communities rely substantially on natural resources for their livelihoods.

4.1.3. Ensure inclusivity in participatory approaches

That said, even though it is important to ensure the proper representation of participants (Section 4.1.1) and understand their positionality and vested interests (Section 4.1.2), it is equally important to enhance inclusivity through trust and ensuring that all voices are heard. This is particularly important for participatory approaches in local settings, which can be characterized by complex community dynamics, pre-existing social conflicts, or certain gender norms (see also Section 4.1.2). For example, reflecting the large body of literature showing that women and men engage differently with landscapes and commodity crop chains in many parts of rural SSA (e.g., Fonjong, 2008; Kiptop, 2015; Tantoh et al., 2021; Duguma et al., 2022) and that women might feel reluctant to be vocal in mixed gender groups, we divided local participatory approaches such as FGDs and participatory mapping by gender. Furthermore, language selection was a very important consideration in local participatory approaches and needed to be thought very well to avoid creating preconditions for exclusion, especially in areas that have very unique dialects. This was the case in several of our study sites, where the local languages were different to the predominant national language (and sometimes did not have a written form). This required very careful moderation of local participatory exercises through partnering with local institutions and hiring local facilitators and enumerators.

While language and gender norms might not be a constraining factor in more technical exercises such as participatory scenario analysis, mediated modeling or even interviews with national experts, there should be a clear explanation of the focus of the participatory exercises and good moderation from the research team. These go a long way to ensure that participants feel safe to express their opinions, especially in situations where group consensus is not always possible (Lawrence et al., 2022). Clear examples of lack of consensus were observed in the participatory scenario analysis, where participants with different vested interests viewed the emergence and severity of some impacts through very different lenses, especially if their organizations were somehow responsible or affected (e.g., irrigation demand and agrochemical use by large plantations, loss of communal land for local authorities). In such cases it was important to enable these differences in opinion to be heard, capture them, and at the same time not manipulate or close the debate, as it might convey to participants that the research team has certain biases. In these contexts careful moderation/facilitation is necessary, whether from members within the team or even external to the research project (see also Hoffmann et al., 2017).

4.1.4. Manage expectations for the participatory approaches

Although participatory approaches can generate a lot of excitement to some stakeholders, it is important to be clear about their aim, approach and expected outcomes. This is necessary for avoiding creating unreasonable expectations or demands, both

from the side of the stakeholder and the research team (Thompson et al., 2017; Lawrence et al., 2022; Veisi et al., 2022).

To prevent unreasonable expectations from both sides, from the onset of the research the project teams were conscious about the possibility of our motives being misunderstood by different stakeholders. For example, local communities or producer associations might have perceived our research as seeking to generate a tangible technology/practical output that could improve their production (i.e. agronomic research rather than impact assessment), facilitate the implementation of interventions directly or by lobbying other stakeholders that can improve their livelihoods (e.g., increase crop prices, provide irrigation/agrochemicals, develop infrastructure) or even lobby other value chain actors to alter their operation (e.g., lobby plantations to stop landscape modification or increase salaries/crop prices). In this case the participatory approaches ran the risk of being perceived as platforms to express demands or grievances, rather than elucidate how commodity crop production unfolds in the specific study areas. This possibility of misunderstanding participatory approaches as opportunities to receive benefits or initiate advocacy has been discussed extensively in the literature (Marshall et al., 2018; Maasen and Dickel, 2019; Kok et al., 2021). Conversely, companies might misunderstand that our impact assessment research sought to criticize or attack their practices, as corporate practices for some commodity crops such as jatropha, tobacco or oil palm had been receiving some criticism at that time. In this case the participatory approaches ran the risk of being perceived as arenas to publicly attack some value chain actors in front of other stakeholders and articulate demand for changes in corporate practices. These are only some examples of how participatory approaches might be derailed from their original aim, if the expectations of participants are not clearly identified and managed through proper information and honesty about the motives of the participatory approach and the roles of the participants (Thompson et al., 2017; Veisi et al., 2022).

The research team also needed to ensure that the requirements engaging in the participatory approaches were not unreasonable. For example, it was important to be very explicit about the expected type of contribution and time investment, as well as possible renumeration. As already mentioned the local participants in the FGDs and participatory mapping exercises (and some expert interviews) were usually poor farmers. Conversely the participants in expert interviews, mediated modeling, and participatory scenario analysis were experts from the government, civil society, academic/research and the private sector, and can be quite busy. For the former, it was necessary to undertake the participatory approaches during periods that do not interfere with their livelihoods (e.g., avoid cultivation and harvesting seasons), while for the latter there it was necessary to be extremely specific about the required time and that their engagement was not a consultancy but voluntary and unpaid. Overall, there was no renumeration for the expert interviews, FGDs, participatory mapping and mediated modeling, and some small renumeration for the participatory scenario analysis. However, for FGDs and participatory mapping we ensured to cover the transport expenses of the farmers, provide food and beverages during the participatory engagement, and offer some small useful gifts such as salt and rice. All of these were made clear at the time of the invitation to avoid misunderstandings. This need about clarity regarding the engagement requirements has been identified as a very important consideration to avoid compromising the participatory approaches.

4.2. Limitations and research recommendations

We need to remind that the major limitation of our research projects in terms of transdisciplinarity was that no intervention or practical solution was co-developed and/or implemented with the engaged stakeholders (Phase C), as a means of enhancing the sustainability of commodity crop production in the study areas (Section 2.1). This was due to two interlinked reasons. First, the projects (and especially the first two ESPA projects) were developed during a period of rapid bioenergy crop expansion in SSA, largely for export to the EU (jatropha projects) or domestic energy security needs (sugarcane projects) (Gasparatos et al., 2017). During this period, which was roughly 2011–2014, there were still very basic research gaps about the impacts of jatropha and sugarcane production, which were considered to be the most promising biofuel feedstocks in SSA (Gasparatos et al., 2017). Although there was a clearly articulated need for this type of research, it was practically impossible to co-develop possible interventions without the clear understanding of the different impacts, their mechanisms, and how they interacted. The second was that the funding calls did not explicitly request the development of particular interventions or practical solutions, and had relatively short durations and available budgets, which made infeasible the co-development and uptake of response options.

As outlined in Section 1, the aim of this paper was not to highlight fully-mature transdisciplinary research, but rather processes, practices and lessons learned that can enhance transdisciplinarity. This is closer to the softer notion of consulting transdisciplinarity (compared to participatory transdisciplinarity) proposed by Mobjörk (2010). This complements previous research which shows some progress on how to foster the contribution of stakeholders to knowledge production and information on the complex relationships between commodity crops production and food security (Musvoto et al., 2015).

Overall, our research and the lessons discussed throughout this paper shows that indeed participatory approaches can play different roles and have different effects in such softer transdisciplinary research projects. Although we did not use all participatory approaches in any single project (Table 2), in retrospect we can reflect how they might be combined effectively to maximize their useful contributions for the tasks outlined in Table 4. First, initial literature reviews and institutional analyses can help outline the main research questions and identify relevant stakeholders. Subsequently, comprehensive expert interviews and a limited amount of local FGDs could inform any possible revisions of the research question(s) and conceptual framework(s). Mediated modeling exercises can then guide methodology development by rationalizing the study phenomena and their importance. Subsequently pilot surveys in local contexts and limited extra

expert consultations can help finetune the final method(s) and data collection mechanism(s). During data collection the bulk of the FGDs and participatory mapping exercises could help obtain useful information about the possible expected causalities and factors affecting the study phenomena. Finally, following data analysis, dissemination workshops with embedded participatory modeling exercises can further help the research team interpret results and validate findings. We need to of course point that the above nested out structure might not be applicable to all types of research projects, but would be ideal for projects focusing on impact assessment and relying on household surveys for primary data collection. Furthermore, and beyond the considerations outlined in Section 4.1, the ultimate selection and sequence of the participatory approaches should reflect the project aims, and in our opinion will depend substantially on the project timelines and the budget/expertise constraints within the research team.

Considering the lessons learned and limitations discussed throughout this manuscript, future studies can mobilize the rich quantitative and qualitative findings elicited from these exercises to undertake transdisciplinary research seeking to design and implement appropriate interventions to enhance the sustainability of commodity crop production in SSA. In such endeavors, particularly useful would be studies that (a) identified the expected impact mechanisms and methodological protocols (e.g., Gasparatos et al., 2018a,b; Jarzebski et al., 2020), (b) established causality between study groups (e.g., see Ahmed et al., 2019a; Dompreh et al., 2021a,b; Mudombi et al., 2021; Gasparatos et al., 2022), and (c) identified the stakeholder acceptability of different production systems and response options (e.g., Chinangwa et al., 2017; Ahmed et al., 2019b; Dompreh et al., 2021c).

Such studies could be designed following some of the emerging transdisciplinary research frameworks (e.g., Kondo et al., 2019; Horcea-Milcu et al., 2022), and promising techniques such as transformation/sustainability labs (Pereira et al., 2022) communities of practices (Matsumoto et al., 2021), multi-stakeholders platforms (van Ewijk and Ros-Tonen, 2021), and Innovation Platforms (Davies et al., 2018), among others. In any case the selection of the appropriate frameworks and techniques should be guided by reflecting important factors such as the aim/focus of the transdisciplinary process, the local acceptability and needs, and the possible constraints in terms of expertise, time, and funding (DeLorme et al., 2016; Belcher et al., 2019; O'Donovan et al., 2022). Such exercises should make every effort possible to engage the most appropriate stakeholders in a safe setting that can ensure that all relevant contributions and perspectives are heard and valued (Section 4.1). This is particularly important but also difficult in the context of commodity crop value chains that are characterized by substantial power and knowledge differentials between actors (Ahmed and Gasparatos, 2021b).

5. Conclusions

In this paper we synthesized the lessons learned from the implementation of different participatory approaches as parts of five research projects that explored the interface of commodity crop production and food security in SSA. In particular, we outlined how mobilizing diverse participatory approaches such as expert interviews, Focus Group Discussions (FGDs), participatory mapping, mediated modeling, and participatory scenario analysis can contribute to such projects beyond data collection, by introducing different transdisciplinary research elements. Our experiences suggest that such participatory approaches can contribute to important functions such as: (a) identify research priorities, knowledge gaps, and underlying phenomena, (b) formalize impact mechanisms and develop methodology, and (c) interpret data and validate findings. Furthermore, they can enhance the relevance, credibility, legitimacy and effectiveness of the research, all major principles associated with transdisciplinary research.

However, the different participatory approaches have different capacity to achieve these. For example, when seeking to identify research priorities, knowledge gaps, and/or underlying phenomena, expert interviews could be ideal, with the rest of the techniques also holding promise. When seeking to formalize impact mechanisms and/or develop methodology, then mediated modeling has the most potential, with most of the other techniques also having some potential. Finally, when interpreting data and/or validating findings, participatory approaches such as FGDs and participatory scenario analysis have the highest potential. Similarly, in the context of this study the participatory approaches mainly strengthened the relevance and credibility of the research, rather than the legitimacy and effectiveness. This is somewhat expected considering the focus of the projects on problem framing (Phase A) and knowledge generation (Phase B), rather knowledge re-integration and application (Phase C).

Finally, although the underlying research projects were not transdisciplinary in the strong sense of the term, the mobilization of these participatory approaches arguably introduced some valuable transdisciplinary research elements by integrating valuable insights from stakeholders holding very diverse expertise in commodity crop value chains at different scales. In this sense such techniques can be very useful for integrating diverse voices when conducting research at this interface. However, according to our experience, in order to maximize their potential, it is important to (a) involve appropriate experts and stakeholders, (b) be aware of social differentiation, positionality and vested interests, and (c) ensure inclusivity in the participatory approach.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by University of Tokyo Life Sciences Committee (reference: 15–186) and University of Oxford Central University Research Ethics Committee (CUREC). Written informed consent for participation was not required for this

study in accordance with the national legislation and the institutional requirements.

Author contributions

AG, GM, AA, ED, MJ, and DLu designed the methods, collected data, and conducted data analysis. MJ and DLo designed the figures. AG wrote the first draft of the manuscript and received the funding for the ESPA3 and Asahi Glass Foundation project. AG and GM received the funding of the ESPA1, ESPA2, and Belmont Forum projects. All authors revised the manuscript. All authors contributed to the article and approved the submitted version.

Funding

The five research projects analyzed in this paper have received funding from the UK Ecosystem Services for Poverty Alleviation Programme (ESPA) (Grants: EIRG-2011-180, NE/L001373/1, and ESPA/ROF/2016-17/04), the Japan Science and Technology Agency (JST) for the Belmont Forum project FICESSA, and the Asahi Glass Foundation for a Humanities and Social Sciences Grant and a Continuation Grant for Young Researchers.

Conflict of interest

DLu was employed by World Bank Malawi Office. DLo was employed by WorldFish.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1132465/full#supplementary-material

References

Achterbosch, T., Van Berkum, S., Meijerink, G., Asbreuk, H., and Oudendag, D. A. (2014). *Cash Crops and Food Security Contributions to Income, Livelihood Risk and Agricultural Innovation*. LEI Report, 2014–15, Wageningen.

Ahmed, A., Abubakari, Z., and Gasparatos, A. (2019c). Labelling large-scale land acquisitions as land grabbing: procedural and distributional considerations from two cases in Ghana. *Geoforum* 105, 191–205. doi: 10.1016/j.geoforum.2019.05.022

Ahmed, A., Campion, B., and Gasparatos, A. (2019b). Towards a classification of the drivers of jatropha collapse in Ghana elicited from the perceptions of multiple stakeholders. *Sustain. Sci.* 14, 315–339. doi: 10.1007/s11625-018-0568-z

Ahmed, A., Campion, B. B., and Gasparatos, A. (2017). Biofuel development in Ghana: Policies of expansion and drivers of failure in the jatropha sector. *Renew. Sustainable Energy Rev.* 70, 133–149. doi: 10.1016/j.rser.2016.11.216

Ahmed, A., Dompreh, E. B., and Gasparatos, A. (2019a). Human wellbeing outcomes of involvement in industrial crop production in Ghana: evidence from sugarcane, oil palm and jatropha sites. *PLoS ONE* 14, e0215433. doi: 10.1371/journal.pone.0215433

Ahmed, A., and Gasparatos, A. (2020a). Multi-dimensional energy poverty patterns around industrial crop projects in Ghana: exploring the energy poverty alleviation potential of rural development strategies. *Energy Policy* 137, 111123. doi: 10.1016/j.enpol.2019.111123

Ahmed, A., and Gasparatos, A. (2020b). Reconfiguration of land politics in Community Resource Management Areas in Ghana: insights from the Avu Lagoon CREMA. *Land use policy* 97, 104786. doi: 10.1016/j.landusepol.2020.104786

Ahmed, A., and Gasparatos, A. (2021a). "Changing agrarian dynamics in oil palm and jatropha production areas of Ghana: A feminist political ecology perspective," in Political Ecology of Industrial Crops, eds. A. Ahmed, and A. *Gasparatos (London: Earthscan/Routledge)* 173–197 doi: 10.4324/9780429351105-11

Ahmed, A., and Gasparatos, A. (2021b). *Political Ecology of Industrial Crops*. London: Earthscan/Routledge. doi: 10.4324/9780429351105

Ahmed, A., Jarzebski, M. P., and Gasparatos, A. (2018a). Using the ecosystem service approach to determine whether jatropha projects were located in marginal lands in Ghana: implications for site selection. *Biomass Bioen.* 114, 112–124. doi: 10.1016/j.biombioe.2017.07.020

Ahmed, A., Kuusaana, E. D., and Gasparatos, A. (2018b). The role of chiefs in large-scale land acquisitions for jatropha production in Ghana: insights from agrarian political economy. *Land Use Policy* 75, 570–582. doi: 10.1016/j.landusepol.2018.04.033

Akerlof, K., Allegra, A., Webler, T., Heath, E., Cloyd, E. T., Washbourne, C. L., et al. (2020). New methods in creating transdisciplinary science policy research agendas: the case of legislative science advice. *Sci Public Policy* 47, 536–547. doi: 10.1093/scipol/scaa033

Antunes, P., Santos, R., and Videira, N. (2006). Participatory decision making for sustainable development—The use of mediated modelling techniques. *Land Use Policy* 23, 44–52. doi: 10.1016/j.landusepol.2004.08.014

Arnstein, S. R. (1969). A ladder of citizen participation. *J. Am. Plan. Assoc.* 35, 216–224. doi: 10.1080/01944366908977225

Balde, B., Diawara, M., Rossignoli, C., and Gasparatos, A. (2019). Smallholder-based oil palm and rubber production in the Forest Region of Guinea: an exploratory analysis of household food security outcomes. *Agriculture* 9, 41. doi: 10.3390/agriculture9020041

Belcher, B. M., Claus, R., Davel, R., and Ramirez, L. F. (2019). Linking transdisciplinary research characteristics and quality to effectiveness: a comparative analysis of five research-for-development projects. *Environ. Sci. Policy* 101, 192–203. doi: 10.1016/j.envsci.2019.08.013

Belcher, B. M., Rasmussen, K. E., Kemshaw, M. R., and Zornes, D. A. (2016). Defining and assessing research quality in a transdisciplinary context. *Res. Evaluat.* 25, 1–17. doi: 10.1093/reseval/rvv025

Boafo, Y. A., Balde, B., Saito, O., Gasparatos, A., Lam, R. D., Ouedraogo, N., et al. (2018). Stakeholder perceptions of the impact of reforms on the performance and sustainability of the cotton sector in ghana and burkina faso: a tale of two countries. *Cogent Food Agric.* 4, 1477541. doi: 10.1080/23311932.2018.1477541

Breisinger, C., Diao, X., Kolavalli, S., and Thurlow, J. (2008). *The Role of Cocoa in Ghana's Future Development*. International Food Policy Research Institute. Available online at: http://www.ifpri.org/publication/role-cocoa-ghanas-future-development (accessed December 2022).

Brown, O., and Gibson, J. (2006). Boom or Bust Developing countries' rough ride on the commodity price rollercoaster. International Institute for Sustainable Development (IISD). https://www.iisd.org/system/files/publications/security_boom_or_bust.pdf (accessed December 2022).

Carlsson, J., Eriksson, L. O., Öhman, K., and Nordström, E-. M. (2015). Combining scientific and stakeholder knowledge in future scenario development — A forest landscape case study in northern Sweden. *For. Policy Econ.* 61, 122–134. doi: 10.1016/j.forpol.2015.08.008

Chinangwa, L., Gasparatos, A., and Saito, O. (2017). Forest conservation and the private sector in Malawi: the case of Payment for Ecosystem Services schemes in the tobacco and sugarcane sectors. *Sustain. Sci.* 12, 727–746. doi: 10.1007/s11625-017-0469-6

Clough, Y., Faust, H., and Tscharntke, T. (2009). Cacao boom and bust: sustainability of agroforests and opportunities for biodiversity conservation. *Conserv. Lett.* 2, 197–205. doi: 10.1111/j.1755-263X.2009.00072.x

Coletta, V. R., Pagano, A., Pluchinotta, I., Fratino, U., Scrieciu, A., Nanu, F., et al. (2021). Causal Loop Diagrams for supporting Nature Based Solutions participatory design and performance assessment. *J Envir Manag.* 280, 111668, doi: 10.1016/j.jenvman.2020.111668

Collins, K., and Ison, R. (2009). Jumping off Arnstein's ladder: social learning as a new policy paradigm for climate change adaptation. *Environ. Policy Governa.* 19, 358–373. doi: 10.1002/eet.523

Dam Lam, R., Boafo, Y., Degefa, S., Gasparatos, A., and Saito, O. (2017). Assessing the food security outcomes of industrial crop expansion in smallholder settings: Insights from cotton production in Northern Ghana and sugarcane production in Central Ethiopia. *Sustain. Sci.* 12, 677–693. doi: 10.1007/s11625-017-0449-x

Davies, J., Maru, Y., Hall, A., Abdourhamane, I. K., Adegbidi, A., Carberry, P., et al. (2018). Understanding innovation platform effectiveness through experiences from west and central Africa. *Agric. Syst.* 165, 321–334. doi: 10.1016/j.agsy.2016.12.014

DeLorme, D. E., Kidwell, D., and Hagen, S. C. and Stephens, S. H. (2016). Developing and managing transdisciplinary and transformative research on the coastal dynamics of sea level rise: Experiences and lessons learned. *Earth's Future* 4, 194–209. doi: 10.1002/2015EF000346

Dompreh, E. B., Asare, R., and Gasparatos, A. (2021a). Do voluntary certification standards improve yields and wellbeing? Evidence from oil palm and cocoa smallholders in Ghana. *Int. J. Agric. Sustain.* 19, 16–39. doi: 10.1080/14735903.2020.1807893

Dompreh, E. B., Asare, R., and Gasparatos, A. (2021b). Sustainable but hungry? Food security outcomes of certification for cocoa and oil palm smallholders in Ghana. *Environ. Res. Lett.* 16, 055001. doi: 10.1088/1748-9326/abdf88

Dompreh, E. B., Asare, R., and Gasparatos, A. (2021c). Stakeholder perceptions about the drivers, impacts and barriers of certification in the Ghanaian cocoa and oil palm sectors. *Sustain. Sci.* 16, 2101–2122. doi: 10.1007/s11625-021-01027-5

Duguma, L. A., Nzyoka, J., Obwocha, E., Minang, P., Wainaina, P., and Muthee, K. (2022). The forgotten half? Women in the forest management and development discourse in Africa: A review. *Front. For. Glob. Change* 5, 948618. doi: 10.3389/ffgc.2022.948618

Eker, S., Zimmermann, N., Carnohan, S., and Davies, M. (2018). Participatory system dynamics modelling for housing, energy and wellbeing interactions. *Build. Res. Inf.* 46, 738–754. doi: 10.1080/09613218.2017.1362919

Enfors, E. I., Gordon, L. J., Peterson, G. D., and Bossio, D. (2008). Making investments in dryland development work: participatory scenario planning in the Makanya Catchment, Tanzania. *Ecol. Soc.* 13, 242. doi: 10.5751/ES-02649-130242

Fonjong, L. (2017). *Interrogating Large-Scale Land Acquisition and its Implications for Women's Land Rights in Cameroon, Ghana and Uganda*. Ottawa: International Development Research Centre (IDRC).

Fonjong, L. N. (2008). Gender Roles and practices in natural resource management in the North West Province of Cameroon. *Local Environ.* 13, 461–475. doi: 10.1080/13549830701809809

Frittaion, C. M., Duinker, P. N., and Grant, J. L. (2010). Narratives of the future: suspending disbelief in forest-sector scenarios. *Futures* 42, 1156–1165. doi: 10.1016/j.futures.2010.05.003

Funtowicz, S. O., and Ravetz, J. R. (1994). Uncertainty, complexity and post-normal science. Environmental toxicology and chemistry. *Int. J.* 13, 1881–1885. doi: 10.1002/etc.5620131203

Gasparatos, A., Johnson, F. X., von Maltitz, G., Luhanga, D., Nyambane, A., Gondwe, T., et al. (2017). Biofuels in Malawi: local impacts of feedstock production and policy implications. *(ESPA* Policy and Practice Brief), ESPA, Edinburg, Available online at: https://www.espa.ac.uk/files/espa/Biofuels%20in%20Malawi_Local%20impacts.pdf (accessed October 15, 2022.).

Gasparatos, A., Mudombi, S., Balde, B., von Maltitz, G., Johnson, F. X., Romeu-Dalmau, C., et al. (2022). Local food security impacts of biofuel crop production in southern Africa. *Renew. Sustain. Energy Rev.* 154, 111875. doi: 10.1016/j.rser.2021.111875

Gasparatos, A., Romeu-Dalmau, C., von Maltitz, G., Johnson, F. X., Shackleton, C., Jarzebski, M. P., et al. (2018b). Mechanisms and indicators for assessing the impact of biofuel feedstock production on ecosystem services. *Biomass Bioenergy* 114, 157–173. doi: 10.1016/j.biombioe.2018.01.024

Gasparatos, A., Stromberg, P., and Takeuchi, K. (2011). Biofuels, ecosystem services and human wellbeing: Putting biofuels in the ecosystem services narrative. *Agric. Ecosyst. Environ.* 142, 111–128. doi: 10.1016/j.agee.2011.04.020

Gasparatos, A., von Maltitz, G., Johnson, F. X., Lee, L., Mathai, M., Puppim, d. e. Oliveira, J., et al. (2015). Biofuels in Africa: Drivers, impacts, and priority policy areas. *Renew. Sustain. Energy Rev.* 45, 879–901. doi: 10.1016/j.rser.2015.02.006

Gasparatos, A., von Maltitz, G., Johnson, F. X., Romeu-Dalmau, C., Jumbe, C., Ochieng, C., et al. (2018a). Survey of local impacts of biofuel crop production and adoption of ethanol stoves in southern Africa. *Nature: Sci. Data* 5, 180186. doi: 10.1038/sdata.2018.186

Gasparatos, A., von Maltitz, G., Roland, N., Ahmed, A., Mudombi, S., Jarzebski, M., et al. (2021). "Institutional and socioeconomic transformation from sugarcane expansion in northern Eswatini," in *Political Ecology of Industrial Crops*, eds. A. Ahmed, and A. Gasparatos (London: Earthscan/Routledge) 244–275 doi: 10.4324/9780429351105-15

Ghodsvali, M., Krishnamurthy, S., and Vries, d. e,. B. (2019). Review of transdisciplinary approaches to food-water-energy nexus: a guide towards sustainable development. *Environ. Sci. Policy* 101, 266–278. doi: 10.1016/j.envsci.2019.09.003

Groundstroem, F., and Juhola, S. (2021). Using systems thinking and causal loop diagrams to identify cascading climate change impacts on bioenergy supply systems. *Mitig. Adapt. Strateg. Glob. Change* 26, 29. doi: 10.1007/s11027-021-09967-0

Haatanen, A., Herder, d. e. n., Leskinen, M., Lindner, P., and Kurttila, M. (2014). M., and Salminen, O. (2014). Stakeholder engagement in scenario development process - Bioenergy production and biodiversity conservation in eastern Finland. *J. Environ. Manage.* 135, 45–53. doi: 10.1016/j.jenvman.2014.01.009

Hall, R., Scoones, I., and Tsikata, D. (2017). Plantations, outgrowers and commercial farming in Africa: agricultural commercialisation and implications for agrarian change. *J. Peasant Stud.* 44, 515–537. doi: 10.1080/03066150.2016.1263187

Hess, T. M., Sumberg, J., Biggs, T., Georgescu, M., Haro-Monteagudo, D., Jewitt, G., et al. (2016). A sweet deal? Sugarcane, water and agricultural transformation in Sub-Saharan Africa. *Glob. Environ. Chang.* 39, 181–194. doi: 10.1016/j.gloenvcha.2016.05.003

Hoffmann, S., Pohl, C., and Hering, J. G. (2017). Methods and procedures of transdisciplinary knowledge integration: Empirical insights from four thematic synthesis processes. *Ecol. Soci.* 22, 27. doi: 10.5751/ES-08955-220127

Horcea-Milcu, A. I., Leventon, J., and Lang, D. J. (2022). Making transdisciplinarity happen: phase 0, or before the beginning. *Environ. Sci. Policy* 136, 187–197. doi: 10.1016/j.envsci.2022.05.019

Hunsberger, C. (2010). The politics of Jatropha-based biofuels in Kenya: convergence and divergence among NGOs, donors, government officials and farmers. *J. Peasant. Stud.* 37, 939–962. doi: 10.1080/03066150.2010.512465

Inam, A., Adamowski, J., Halbe, J., and Prasher, S. (2015). Using causal loop diagrams for the initialization of stakeholder engagement in soil salinity management in agricultural watersheds in developing countries: A case study in the Rechna Doab watershed, Pakistan. *J. Environ. Manag.* 152, 251–267. doi: 10.1016/j.jenvman.2015.01.052

Jarzebski, M. P., Ahmed, A., Boafo, Y. A., Balde, B. S., Chinangwa, L., Saito, O., et al. (2020). Food security impacts of industrial crop production in sub-Saharan Africa: a systematic review of the impact mechanisms. *Food Secur.* 12, 105–135. doi: 10.1007/s12571-019-00988-x

Kates, R. W. (2011). What Kind of a Science Is Sustainability Science? *Proceed. Nat. Acad. Sci. USA.* 108, 19449–50. doi: 10.1073/pnas.1116097108

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., et al. (2001). Sustainability science. *Science* 292, 641–642. doi: 10.1126/science.1059386

Kiptop, E. (2015). Gender roles, responsibilities, and spaces. *Int. Forestry Rev.* 17, 11–21. doi: 10.1505/146554815816086426

Klerkx, L., Seuneke, P., Wolf, d. e., and Rossing, P. (2017). Replication and translation of co-innovation:the influence of institutional context in large international participatory research projects. *Land Use Policy* 61, 276–292. doi: 10.1016/j.landusepol.2016.11.027

Kok, K. P. W., Gjefsen, M. D., and Regeer, B. J. and Broerse, J. E. W. (2021). Unraveling the politics of "doing inclusion" in transdisciplinarity for sustainable transformation. *Sustain. Sci.* 16, 1811–1826. doi: 10.1007/s11625-021-01033-7

Komiyama, H., and Takeuchi, K. (2006). Sustainability science: building a new discipline. *Sustain. Sci.* 1, 1–6. doi: 10.1007/s11625-006-0007-4

Kondo, Y., Miyata, A., Ikeuchi, U., Nakahara, S., Nakashima, K. I., Onishi, H., et al. (2019). Interlinking open science and community-based participatory research for socio-environmental issues. *Curr. Opin. Environ. Sustain.* 39, 54–61. doi: 10.1016/j.cosust.2019.07.001

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., et al. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustain. Sci.* 7, 25–43. doi: 10.1007/s11625-011-0149-x

Lawrence, M. G., Williams, S., Nanz, P., and Renn, O. (2022). Characteristics, potentials, and challenges of transdisciplinary research. *One Earth* 5, 44–61. doi: 10.1016/j.oneear.2021.12.010

Leventon, J., Fleskens, L., Claringbould, H., Schwilch, G., and Hessel, R. (2016). An applied methodology for stakeholder identification in transdisciplinary research. *Sustain. Sci.* 11, 763–775. doi: 10.1007/s11625-016-0385-1

Lux, A., Schäfer, M., Bergmann, M., Jahn, T., Marg, O. Nagy, E., et al. (2019). Societal effects of transdisciplinary sustainability research—How can they

be strengthened during the research process?. *Environ. Sci. Policy* 101, 183–191. doi: 10.1016/j.envsci.2019.08.012

Maasen, S., and Dickel, S. (2019). Normative answers, epistemic questions. Updating the science-society contract, in *Handbook of Science and Public Policy*. eds D. Simon, S. Kuhlmann, J. Stamm, W. Canzler (Cheltenham: Edward Elgar), pp. 49–66 doi: 10.4337/9781784715946.00011

Marshall, F., Dolley, J., and Priya, R. (2018). Transdisciplinary research as transformative space making for sustainability: enhancing propoor transformative agency in periurban contexts. *Ecol. Soc.* 23, 8. doi: 10.5751/ES-10249-230308

Matsumoto, Y., Kasamatsu, H., and Sakakibara, M. (2021). Challenges in forming transdisciplinary communities of practice for solving environmental problems in developing countries. *World Fut.* 3, 1–20. doi: 10.1080/02604027.2021.2012878

Meadows, D. H. (2008). *Thinking in Systems.* ed. D. Wright. Vermont: Chelsea Green.

Mellor, J. W., and Malik, S. J. (2017). The impact of growth in small commercial farm productivity on rural poverty reduction. *World Dev.* 91, 1–10. doi: 10.1016/j.worlddev.2016.09.004

Minh, T. T., Cofie, O., Lefore, N., and Schmitter, P. (2020). Multi-stakeholder dialogue space on farmer-led irrigation development in Ghana: an instrument driving systemic change with private sector initiatives. *Knowl. Manag. Dev. J,* 15, 98–118.

Mobjörk, M. (2010). Consulting versus participatory transdisciplinarity: a refined classification of transdisciplinary research. *Futures* 42, 866–873. doi: 10.1016/j.futures.2010.03.003

Mudombi, S., Ochieng, C., Johnson, F. X., von Maltitz, G., Luhanga, D., Dompreh, E. B., et al. (2021). Fuelling rural development? The impact of biofuel feedstock production in southern Africa on household income and expenditures. *Energy Res. Soc. Sci.* 76, 102053. doi: 10.1016/j.erss.2021.102053

Mudombi, S., von Maltitz, G. P., Gasparatos, A., Romeu-Dalmau, C., Johnson, F. X., Jumbe, C., et al. (2018). Multi-dimensional poverty effects around operational biofuel projects in Malawi, Mozambique and Swaziland. *Biomass Bioenergy* 114, 41–54. doi: 10.1016/j.biombioe.2016.09.003

Musvoto, C., Mason, N., Jovanovic, N., Froebrich, J., Tshovhote, J., Nemakhavhani, M., et al. (2015). Applying a transdisciplinary process to define a research agenda in a smallholder irrigated farming system in South Africa. *Agric. Syst.* 137, 39–50. doi: 10.1016/j.agsy.2015.03.008

Neef, A., and Neubert, D. (2011). Stakeholder participation in agricultural research projects: a conceptual framework for reflection and decision-making. *Agricult. Human Values* 28, 179–194. doi: 10.1007/s10460-010-9272-z

Nyambane, A., Johnson, F., Romeu-Dalmau, C., Ochieng, C., Gasparatos, A., Mudombi, S., et al. (2020). "Ethanol as a clean cooking alternative in Sub-Saharan Africa: Insights from sugarcane production and ethanol adoption sites in Malawi and Mozambique," in *Sustainability Challenges in Sub-Saharan Africa II: Insights from Eastern and Southern Africa*, eds. A. Gasparatos, A. Ahmed, M. Naidoo, A. Karanja, K. Fukushi, O. Saito, K. Takeuchi (Berlin: Springer) 115–144 doi: 10.1007/978-981-15-5358-5_5

O'Donovan, C., Michalec, A., and Moon, J. R. (2022). Capabilities for transdisciplinary research, *Res. Evaluat.* 31, 145–158. doi: 10.1093/reseval/rvab038

OECD (2017). *Skills for a High Performing Civil Service*. Paris: Organisation for Economic Cooperation and Development. doi: 10.1787/9789264280724-en

Ordway, E. M., Naylor, R. L., Nkongho, R. N., et al. (2019). Oil palm expansion and deforestation in Southwest Cameroon associated with proliferation of informal mills. *Nat. Commun.* 10, 114. doi: 10.1038/s41467-018-07915-2

Ordway, E. M., Naylor, R. L., Nkongho, R. N., and Lambin, E. F. (2017). Oil palm expansion in Cameroon: Insights into sustainability opportunities and challenges in Africa. *Glob. Environ.* 47, 190–200. doi: 10.1016/j.gloenvcha.2017.10.009

Pereira, L., Hichert, T., Hamann, M., et al. (2018). Using futures methods to create transformative spaces: visions of a good Anthropocene in southern Africa. *Ecol. Soc.* 23, 119. doi: 10.5751/ES-09907-230119

Pereira, L., Kushitor, S. B., Cramer, C., Drimie, S., Isaacs, M., Malgas, R., et al. (2022). Leveraging the potential of wild food for healthy, sustainable, and equitable local food systems: learning from a transformation lab in the Western Cape region. *Sustain Sci.* doi: 10.1007/s11625-022-01182-3

Phiri, E., Bwalya, M., Froebrich, J., Mweetwa, A. M., Chishala, B. H., Meebelo, N., et al. (2020). Transdisciplinary development and adoption of irrigation innovations in Africa. Linkages to principles of caadp: a commentary. *Irrig. Drain.* 69, 148–154. doi: 10.1002/ird.2376

Pohl, C., Krütli, P., and Stauffacher, M. (2017). Ten reflective steps for rendering research societally relevant. *GAIA-Ecol. Perspect. Sci. Soc.* 26, 43–51. doi: 10.14512/gaia.26.1.10

Purwanto, A., Sušnik, J., Suryadi, F. X., and Fraiture, d. e,. C. (2019). Using group model building to develop a causal loop mapping of the water-energy-food security nexus in Karawang Regency, Indonesia. *J. Clean. Prod.*, 240, 8170. doi: 10.1016/j.jclepro.2019.118170

Reed, M. S., Hubacek, K., Bonn, A., Burt, T. P., Holden, J., Stringer, L. C., et al. (2013a). Anticipating and managing future trade-offs and complementarities between ecosystem services. *Ecol. Soc.* 18, 5. doi: 10.5751/ES-04924-180105

Reed, M. S., Kenter, J., Bonn, A., Broad, K., Burt, T. P., Fazey, I. R., et al. (2013b). Participatory scenario development for environmental management: a methodological framework illustrated with experience from the UK uplands. *J. Environ. Manage.* 128, 345–362. doi: 10.1016/j.jenvman.2013.05.016

Roland, N. (2019). *A Political Ecology of Water Conflicts in Sugarcane Areas of Swaziland*. [master's thesis]. [Kashiwa: The University of Tokyo].

Romeu-Dalmau, C. Gasparatos, A., von Maltitz, G., Graham, A., Almagro-Garcia, J., Wilebore, B., and Willis, K. J. (2018). Impacts of land use change due to biofuel crops on climate regulation services: five case studies in Malawi, Mozambique and Swaziland. *Biomass Bioenergy* 114, 30–40. doi: 10.1016/j.biombioe.2016.05.011

Romijn, H., and Heijnen, S. Rom Colthoff,J., De Jong, B., and van Eijck, J. (2014). Economic and Social sustainability performance of jatropha projects: results from field surveys in Mozambique, Tanzania and Mali. *Sustainability* 6, 6203–6235. doi: 10.3390/su6096203

Schaafsma, M., Eigenbrod, F., Gasparatos, A., Gross-Camp, N., Hutton, G., Nunan, F., et al. (2021). Trade-offs decisions in ecosystem management for poverty alleviation. *Ecol. Econ.* 187, 107103. doi: 10.1016/j.ecolecon.2021.107103

Schmitt Olabisi, L., Liverpool-Tasie, S., Rivers, L., Ligmann-Zielinska, A., Du, J., Denny, R., et al. (2018). Using participatory modeling processes to identify sources of climate risk in West Africa. *Environ. Syst. and Decis.* 38, 23–32. doi: 10.1007/s10669-017-9653-6

Schoneveld, G. C. (2014). The geographic and sectoral patterns of large-scale farmland investments in sub-Saharan Africa. *Food Policy* 48, 34–50. doi: 10.1016/j.foodpol.2014.03.007

Schut, A. G. T., and Giller, K. E. (2020). Sustainable intensification of agriculture in Africa. *Front. Agric. Sci. Eng.* 7, 371. doi: 10.15302/J-FASE-2020357

Semie, T. K., Silalertruksa,T., and Gheewala, S.H. (2019). The impact of sugarcane production on biodiversity related to land use change in Ethiopia. *Glob. Ecol. Conserv.* 18, e00650. doi: 10.1016/j.gecco.2019.e00650

Smalley, R. (2013). *Plantations, Contract Farming and Commercial Farming Areas in* Africa: A Comparative Review Rebecca Smalley Land and Agricultural Commercialisation in Africa. LACA project Working Paper series. Future Agricultures Consortium.

Stankov, I., Useche, A. F., Meisel, J. D., Montes, F., Morais, L. M., Friche, A. A. L., et al. (2021). From causal loop diagrams to future scenarios: Using the cross-impact balance method to augment understanding of urban health in Latin America. *Soc. Sci. Med.* 282, 114157. doi: 10.1016/j.socscimed.2021.114157

Sterling, E. J., Betley, E., Sigouin, A., Gomez, A., Toomey, A., Cullman, G., et al. (2017). Assessing the evidence for stakeholder engagement in biodiversity conservation. *Biol. Conserv.* 209, 159–171. doi: 10.1016/j.biocon.2017.02.008

Sterman, J. D. (2000). *Business Dynamics—Systems Thinking and Modeling for a Complex World*. Boston, MA: McGraw Hill Higher Education.

Strona, G., Stringer, S. D., Vieilledent, G., Szantoi, Z., and Garcia-Ulloa, J. and Wich, S. A. (2018). Small room for compromise between oil palm cultivation and primate conservation in Africa. *PNAS* 115, 8811–8816. doi: 10.1073/pnas.1804775115

Tantoh, H. B., McKay, T. T. J. M., Donkor, F. E., and Simatele, M. D. (2021). Gender roles, implications for water, land, and food security in a changing climate: a systematic review. *Front. Sustain. Food Syst.* 5, 707835. doi: 10.3389/fsufs.2021.707835

Thompson, M. A., Owen, S., Lindsay, J. M., Leonard, G. S., and Cronin, S. J. (2017). Scientist and stakeholder perspectives of transdisciplinary research: early attitudes, expectations, and tensions. *Environ. Sci. Policy* 74, 30–39. doi: 10.1016/j.envsci.2017.04.006

Thompson, W. J., Blaser-Hart, W. J., Dawoe, E., et al. (2022). Can sustainability certification enhance the climate resilience of smallholder farmers? The case of Ghanaian cocoa. *J. Land Use Sci.* 17, 407–428. doi: 10.1080/1747423X.2022.2097455

UNCTAD (2015). Commodities and Development Report 2015—Smallholder Farmers and Sustainable Commodity Development. United Nations Conference on Trade and Development (UNCTAD). Available online at: https://unctad.org/system/files/official-document/suc2014d5_en.pdf (accessed December 2022).

van Ewijk, E., and Ros-Tonen, M. A. F. (2021). The fruits of knowledge co-creation in agriculture and food-related multi-stakeholder platforms in sub-Saharan Africa—A systematic literature review. *Agric. Syst.* 186, 102949. doi: 10.1016/j.agsy.2020.102949

Van Vliet, J. A., Schut, A. G. T., Reidsma, P., Descheemaeker, K., Slingerland, M., Van De Ven, G. W. J., et al. (2015). De-mystifying family farming: features, diversity and trends across the globe. *Glob. Food Sec.* 5, 11–18. doi: 10.1016/j.gfs.2015.03.001

van Zwanenberg, P., Cremaschi, A., Obaya, M., Marin, A., and Lowenstein, V. (2018). Seeking unconventional alliances and bridging innovations in spaces for transformative change: the seed sector and agricultural sustainability in Argentina. *Ecol. Soc.* 23, 11. doi: 10.5751/ES-10033-230311

Veisi, H., Jackson-Smith, D., and Arrueta, L. (2022). Alignment of stakeholder and scientist understandings and expectations in a participatory modeling project. *Environ. Sci. Policy* 134, 57–66. doi: 10.1016/j.envsci.2022.04.004

Vincent, K., Conway, D., Dougill, A. J., Pardoe, J., Archer, E., Bhave, A. G., et al. (2020). Re-balancing climate services to inform climate-resilient planning—A conceptual framework and illustrations from sub-Saharan Africa. *Clim. Risk Manag.* 29, 100242. doi: 10.1016/j.crm.2020.100242

Vitale, J. (2018). *Economic Importance of Cotton in Burkina Faso: Background Paper to the UNCTAD-FAO Commodities and Development Report 2017 Commodity Markets, Economic Growth and Development*, Rome: Food and Agriculture Organization of the United Nations.

von Maltitz, G., Gasparatos, A., and Fabricius, C. (2014). The rise, decline and future resilience benefits of jatropha in southern Africa. *Sustainability* 6, 3615–3643. doi: 10.3390/su6063615

von Maltitz, G., Gasparatos, A., Fabricius, C., Morris, A., and Willis, K. (2016). Jatropha cultivation in Malawi and Mozambique: Impact on ecosystem services, local human wellbeing and poverty alleviation. *Ecol. Soc.* 21, 3. doi: 10.5751/ES-08554-210303

von Maltitz, G. P., Henley, G., Ogg, M., Samboko, P. C., Gasparatos, A., Ahmed, A., et al. (2019). Institutional arrangements of outgrower sugarcane production in southern Africa. *Dev. South. Afr.* 36, 175–197. doi: 10.1080/0376835X.2018.1527215

Webber, A. D., and Hill, C. M. (2014). Using Participatory Risk Mapping (PRM) to identify and understand people's perceptions of crop loss to animals in uganda. *PLoS ONE* 9, 2912. doi: 10.1371/journal.pone.0102912

Wollenberg, E., Edmunds, D., and Buck, L. (2000). Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests. *Landsc. Urban Plan.* 47, 65–77. doi: 10.1016/S0169-2046(99)00071-7