Bundling agri-food systems innovations for women's resilience and empowerment

Building the evidence base

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Successful outcomes for agri-food systems and the communities that rely on them are dependent on a whole range of factors and situations. Innovative technologies must align with these to stand any chance of achieving the goal of healthy, equitable, resilient and sustainable systems. These interventions can be better understood and applied using so-called 'socio-technical innovation bundles', or STIBs. This working paper looks at the experiences of women, particularly in marginalised situations, and the outcomes that are possible for them and their families. It proposes a practical framework to support researchers and others, and invites practitioners to trial this so that a much-needed evidence base can be built.

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Summary

Innovations and technologies in agri-food systems are touted as pathways to higher productivity, income, and household resilience. Such claims are most often made in the context of climate change and a growing interest in terms of gender empowerment. However, performance is determined by alignment with a wide variety of different situations. Hence successful outcomes depend on considering the situation of end-users — in turn shaped by gender, age, caste, ethnicity, class, language and culture, among others. Complex challenges and contexts require innovations and technologies aligned with both people and place.

Achieving healthy, equitable, resilient and sustainable agri-food systems will require interventions that are bundled to fully realise outcomes — so called socio-technical innovation bundles (STIBs). STIBs are a construct that bring the social and technical dimensions of an innovation process together. They can change the resources and opportunities (such as markets, finance, policy, training) available to people and other stakeholders as they interact with a given context (social norms, geography, enabling environment, and so on).

Despite the promise, there has been little research to investigate how women experiencing overlapping forms of marginalisation foster resilience, empowerment and other outcomes. Existing studies mainly focus on adoption of technologies or innovations, with little account of outcomes or impacts. Further, studies seldom explore the complementarity between the attributes and characteristics of women, technology and context, especially through an intersectional lens. This detracts from the required synergy in socio-technical interactions needed for sustainable, equitable outcomes for innovations in agri-food systems.

This study presents a practical framework to support researchers and development practitioners applying STIBs to achieve critical outcomes like empowerment and resilience. Using the realist evaluation methodology, this work analyses 12 studies that touch on technology, gender, outcomes and impacts. Among other things, the findings show empowerment or self-determination as a precondition for successful, longer-term outcomes. The work also found social capital and groups were vital enablers in accessing resources and information on innovations. Further, innovations must respond to the often different needs of men and women farmers and follow best practice in delivering support. Thus, there is a need for different technological (such as seeds, irrigation, climate information services), technical (training, extension services, and so on) and social bundles (including markets, policy, institutions) for farmers working in different contexts. But more evidence is needed to identify STIBs that work in different contexts to achieve desired outcomes.

We are looking to trial our framework with like-minded institutes and practitioners to begin to identify what works, where, and why. To start working with STIBs, implementing organisations must nurture the specific skillsets needed to develop and operationalise a practical guideline that takes a gender-lens to contextual analysis. STIBs interventions should be set within a wider set of local planning initiatives for agri-food systems and supported with robust structures for monitoring, evaluation and learning (MEL). And finally, longitudinal studies are needed to build the evidence base for STIBs to enable better outcomes for women and other groups experiencing marginalisation.

1

Agri-food systems and gender pathways

Agri-food systems (AFS) are the stakeholders and activities involved in food and non-food agricultural products from production to consumption (FAO 2022). By providing jobs, incomes and food, AFS tend to dominate rural economies in Asia, sub-Saharan Africa and Latin America. As a result, building better agri-food systems has huge transformative potential for millions of farmers and other actors who depend on them for their livelihoods. However, agri-food systems are currently not delivering desired outcomes in a sustainable or just manner (Barrett et al. 2022).

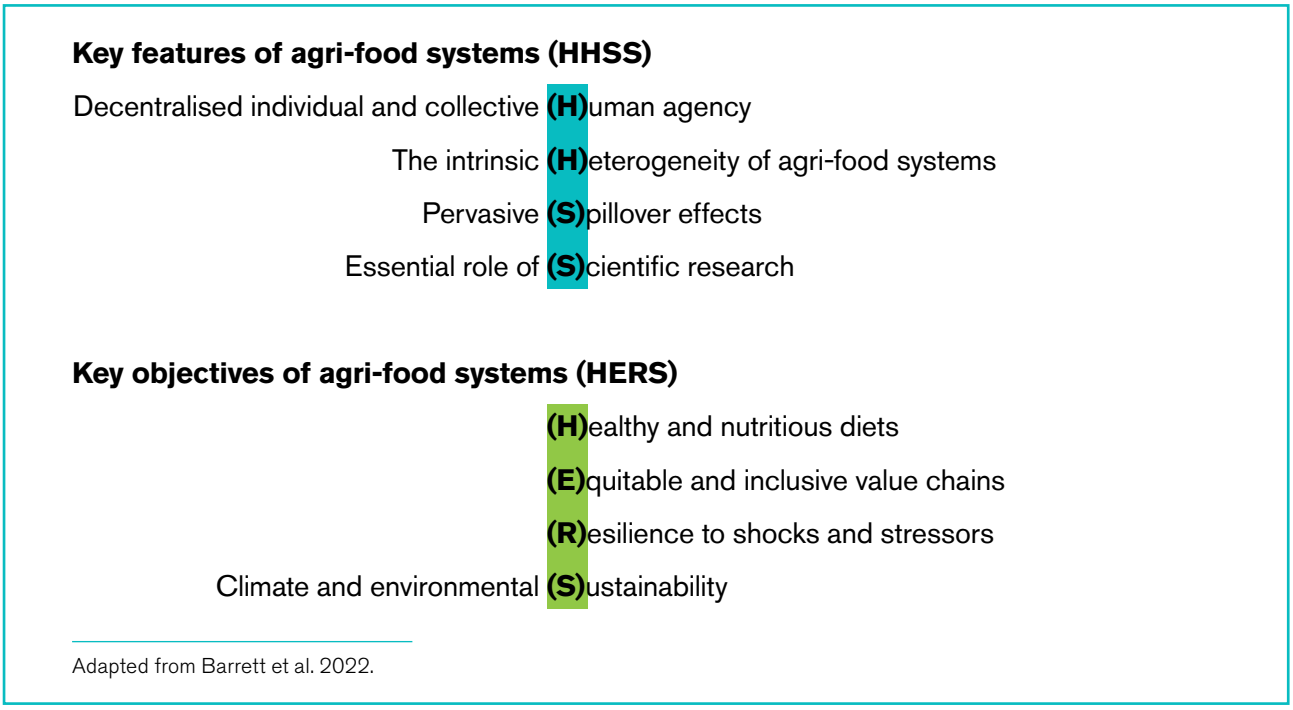
In their pivotal 2022 book 'Socio-Technical Innovation Bundles for Agri-Food Systems Transformation', Barrett et al. argue that future iterations of agri-food systems need to ensure food security and nutrition and other global objectives while addressing the triple crisis of poverty, climate and environment. They lay out four features and four objectives of agri-food systems that approaches must incorporate and strive for (Figure 1). The HHSS (pronounced 'his') are critical features of existing agri-food systems and will remain so in future versions. The HERS (pronounced 'hers') are categories of outcomes that are desirable globally to make better, more just agri-food systems. These may look slightly different across contexts. Given the interconnected nature of these issues, Barrett et al. argue that a transformation in agri-food systems must take a multi-pronged approach.

In this global context, combining technical and social innovations and technologies[1] with other enablers that can reach different outcomes has the potential to transform the climate, economic, environmental, health and social challenges in agri-food systems. These so-called 'socio-technical innovation bundles', or STIBs, are defined as a 'mix of science and technology advances, properly contextualised, combined with specific institutional or policy adaptations' (Barrett et al. 2020b). It is the process of combining different innovations and implementing them to achieve synergies to reach the desired HERS outcomes. Bundling innovations that work in a specific time and place are now trending as multi-pronged solutions for a transformative agri-food system that can have positive outcomes for humans and nature alike (Barrett et al. 2022).

Even though researchers and extension workers have tried to combine different technologies and innovations in the past, STIBs are a recent conceptual construct. But bundling and integrating activities to achieve desired development outcomes — and for systems change — dates back to the 'integrated rural development' of the 1960s, with iterations on multi-sectoral development since — for example, the 'Millenium Villages Project' (Barnett 2018). There are other niches, such as 'productive uses of energy', where evidence shows that electric appliances and equipment

[1] We take a broad view of 'innovations' and 'technologies' for this work. **Innovations** are 'doing something new and different, whether solving an old problem in a new way, addressing a new problem with a proven solution, or bringing a new solution to a new problem. Types of innovation include technological, social, policy, institutional and financial innovations'. **Technologies** are 'the application of science and knowledge to develop techniques to deliver a new product and/or service or to use a new process to deliver an established product or service' (FAO 2022).

Figure 1. Key features and objectives of agri-food systems



Adapted from Barrett et al. 2022.

powered by decentralised renewable energy systems must be deployed with a wider set of supporting functions, and where other important socio-cultural factors like gender must be integrated (Johnstone et al. 2022). Another example would be BRAC's 'Graduation' approach, which focuses on those living in extreme poverty. It bundles types of support for households, including productive assets, weekly stipends, training and healthcare, and has shown promising results for lifting households out of extreme poverty (BRAC 2019).

Despite decades of hard-earned lessons, many companies and organisations continue to focus on discrete interventions or products. They deploy technologies and innovations without linking to other important social or technical dimensions that enable wider adoption, in markets that are nascent and missing vital characteristics and support functions. End-users are still not systematically included in the design of activities or products for example.

This is particularly true of women in agri-food systems, where technologies are usually designed with men's needs and priorities in mind, which can also vary widely across socio-cultural contexts (Satyavathi 2010). This means the contexts in which women live and work are not well understood. Yet this is what dictates people's position and ability to use and benefit from innovations. Further, institutional support is often ignored, and innovations are deployed without proper policy or regulatory support.

STIBs offer a pathway that can incorporate important social innovations, while integrating other critical elements like institutes and policies, along with amplifiers of vulnerability like climate change. With that said, it must evolve further to integrate gender equality and social inclusion more comprehensively.

1.1 Barriers and opportunities for women in agri-food systems

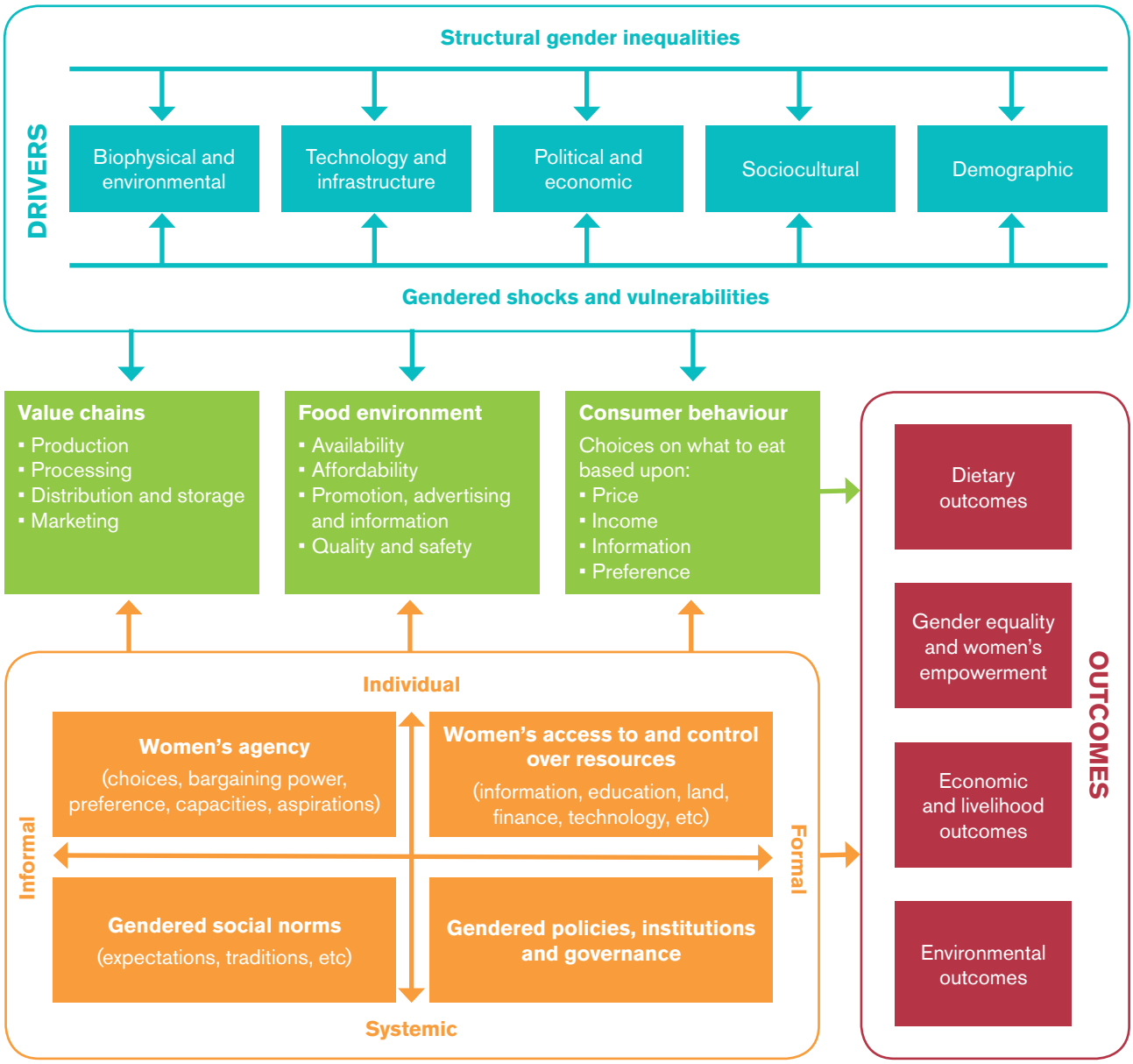
Women are critical actors in agri-food systems, constituting two-thirds (66%) of women's employment in sub-Saharan Africa and 71% in Asia (FAO 2023). Yet, due to gender norms, women typically fill spaces that men do not prioritise or want, they have limited upward mobility, and receive lower wages on average (Vepa 2005). The gender gap in access and control of resources continues to reduce the potential of achieving more sustainable and equal agri-food systems. But progress on reducing this gap has broadly been slow. Recent policy frameworks are recognising the challenges and barriers more, but do not necessarily address them (FAO 2023).

Njuki et al. (2022) framed gender as a critical aspect within agri-food systems, coursing through different elements within the system — social, political, institutional, economic and so on. Figure 2 illustrates the conceptual relationship between the different elements, and how inequalities and vulnerabilities feed into the different drivers of change, shown in teal. The area in orange shows where transformation happens at different levels (individual and systemic) as well as informal and formal ways. These two aspects then feed into the

three areas in green: value chains, food environment and consumer behaviour. Finally, both then lead to the various desired outcomes, shown in red. We describe in more detail below important gendered aspects and some barriers and opportunities that socio-cultural norms demand in different contexts.

The migration of men to urban areas over many decades has resulted in the feminisation of some rural contexts, and with it, crop and sometimes livestock production (Gartaula et al. 2010, Neog and Sahoo 2020). This may have provided some opportunities for women to participate in agricultural decision making, but the larger socio-cultural norms and expectations still hinder transformative change. Indeed, women continue to face barriers that impact their productivity and potential contribution to agri-food systems transformation. Some women in parts of India for example, tend to dominate certain spheres of agri-food systems including vegetable production, smaller livestock animals, and food processing — but many of the tasks that gender norms constrain them to are more arduous and time consuming, like weeding (Satyavathi et al. 2010). There is, however, also a huge variety of roles and tasks that women fill across different contexts. Indeed, these can vary even within countries, with socio-economic forces continuing to push and transform agri-food systems and the position of various actors within them, especially women (Patil and Babus 2018).

Figure 2. Gendered food systems



Source: Njuki et al. (2022)

Despite some advances, barriers to the effective participation of women in agri-food systems persist. An array of well-documented structural and socio-cultural obstacles mean that women in agriculture are not realising their full potential (Phiri et al. 2022). Women are often:

a) Prohibited and/or inhibited from owning productive land through legal systems and patriarchal norms (Imburgia et al. 2019, Doss et al. 2018)

b) Unable to access credit to support productive processes and business enterprises (Mwololo et al. 2022)

c) Burdened with disproportionate domestic labour and childcare responsibilities (Davison 2019)

d) Limited by poor access to education, information, and basic skills and suitable agricultural training (Collett and Gale, 2009)

e) Constrained by having relatively less power and agency on key decisions and resource allocation in the home (Crossland et al. 2021), and

f) More vulnerable to the impacts of climate change because of resource constraints (FAO, 2023)

Female-headed households tend to be at a distinct disadvantage because on average, there are fewer people within their households, which means they have access to less labour (Patil and Babus 2018). This is compounded by the need in many cases to manage the household, while also being the 'head'.

Other constraints influence women's livelihood options and choices, structuring their ability to effectively engage with rural livelihoods. For instance, legal barriers such as laws that prevent women from owning land constrain their ability to test land-based livelihood strategies such as climate-smart herding and installation of agricultural technologies (Giovarelli et al. 2013). Social and gender norms typically assign men as household heads, offering them agency to evaluate trade-offs on pivotal livelihood decisions, such as growing nutritious or cash crops (Rukmani et al. 2019). Limiting the agency of women feeds back to further disempower women, necessitating engagement with inferior and less valuable livelihoods relative to men. An important study in Tanzania sums up empowerment: "[w]omen find themselves in a double bind — possessing characteristics considered to be innate which could assist them towards empowerment and, at the same time, being disempowered by these same characteristics which the community considered possibly incompatible with 'relating to others according to appropriate gender roles'" (Galiè and Farnworth 2019). This also highlights the importance of how gender dynamics play out within and between households in communities.

1.2 Putting gender equality and social inclusion at the heart of STIBs

Changes proposed in 'Socio-Technical Innovation Bundles for Agri-Food Systems Transformation' represent an essential push towards better AFS. However, a central critique — and motivation for this review — is that equality is not yet systematically incorporated. The book calls for a transformation in AFS without adequately addressing equality. Despite centring 'human agency' in much of the narrative, the work does not explore differentiating factors that enable or prevent agency, such as gender. For example, the word 'gender' is only mentioned five times, 'women' four times, 'inclusion' seven times (with reference to social inclusion), while empowerment is not mentioned at all. In an important document that runs to 226 pages, this is a glaring omission. As a result, the acronym of 'HERS' implicitly referring to gender (and specifically in the 'equitable and inclusive value chains') for desired agri-food systems outcomes feels unsupported and unsubstantiated.

Another example to highlight would be the five farm typologies outlined in the book. They are useful in understanding general trends, but they do not consider the intra-household dynamics that families and individuals face, which, if included, could better explain the barriers and opportunities that exist. Without an applied gender or inclusion lens, the typologies do not necessarily account for the additional constraints that women and other marginalised groups must overcome to achieve comparable results to men. However, we believe that STIBs can respond, and where possible transform, power structures to deliver results for everyone.

To help fill this gap, we conducted a literature review, using a systematised sampling technique (see details in next section) to try and fill in and identify what constitutes effective STIBs that can deliver empowerment and enhance household resilience while achieving other outcomes for women — including improved nutrition, knowledge, and agricultural productivity. In Section 3, we highlight our findings from the studies we identified, touching on some of the main takeaways for each study. Based on these and a workshop with CGIAR partner organisations in Nairobi, we constructed a practical framework for practitioners to use STIBs in Section 4. Section 5 outlines in more details some of the examples and findings. Finally, we end on some recommendations for moving STIBs forward.

2 Methodology

We used a systematised sampling technique to identify literature relevant to STIBs, interrogating Google Scholar and Scopus databases using keywords with a series of 'and' 'or' search strings (Table 1). These included key terms associated with the literature on STIBs research and practices, including 'technology', 'gender', 'assets', 'control', 'empowerment', 'harvest' and 'productivity', and provided a sample of documents. 'Climate smart agriculture' was later added to the search string. Our searches were limited to English language studies.

The database searches detailed above provided approximately 583 documents for screening. The addition of the term 'climate smart agriculture' to the search string revealed a total of 613 documents and, following the removal of six duplicates, there were 607 documents for the team to review.

To narrow the search further, a simple relevance criterion was applied in abstract screening to check that articles included key elements around gender, technology and empowerment outcomes. A scoring system with scores from 0 to 5 was applied with 5 for articles that included all three elements and 0 for articles that did not mention any of the three elements.

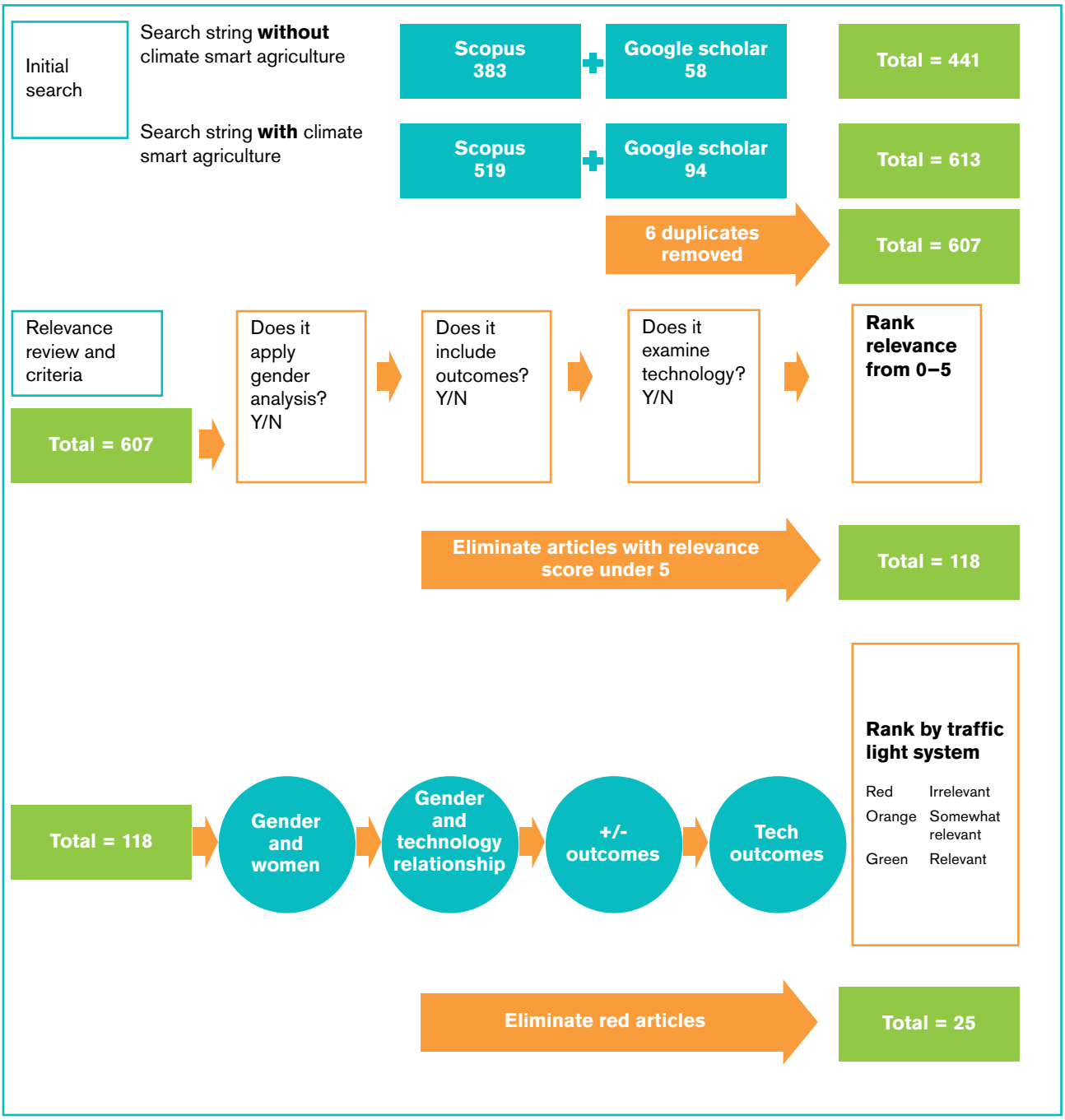
A total of 118 articles with relevance scores of 5 were moved on to full article screening. We applied the realist evaluation methodology to these articles, screening abstracts for analysis of the gendered context, mechanisms for technology adoption and resulting outcomes. A red, orange and green traffic light system was used to code and rank articles. Red codes were applied to articles of no relevance while green was coded for articles that discussed in detail all desired criteria. After red-coded articles were eliminated, we arrived at 25 articles for deeper analysis. Finally, after careful review, we excluded an additional 14 with lesser relevance to focus on 11 that showed the most promise for STIBs content.

Table 1. Keywords used

Technology	Resilien*	Gender	Empower*	Asset	Agricultur*
Agency	Voice	Soil	Fertil*	Emission	Reduc*
Mitig*	Value	Food	Security	Drudgery	Labor
Saving	Diet	Nutrition	Cost	Eff*	Crop
Income	Divers*	Knowledge	Aware*	Post	Harvest
Agricultur*	Asia	Africa	South	America	MENA
Impact	Control	Climate smart	Productiv*	Add*	Outcome

*Signifies dual or multi-directional end of word — such as Agriculture or Agricultural

Figure 3. Methodology



2.1 Realist evaluation methodology to review STIBs

The review collated the impact- and outcome-based changes achieved through the adoption and use of STIBs in different contexts. Using the realist synthesis methodology, we conceptualise the unit of analysis in terms of context, intervention (STIBs), mechanism and outcome or impact recorded within each document (Pawson et al. 2004). Here STIBs represent a change in the resources and opportunities available to people (stakeholders, actors, subjects, beneficiaries) as they interact with a given context (geography, enabling environment, social norms and so on) to cause changes in outcomes or impacts (Barrett et al. 2020a). Figure 4 provides insight into the context (C), the STIBs, and the outcomes (O) and so provides a way to establish and set out systematically what STIBs are working, where, for whom and how.

The mechanisms (M) link the context, STIBs and outcomes. The mechanisms are the thoughts, beliefs, confidence, reasoning and other cognitive triggers and processes within people's minds that are caused by receiving and engaging with STIBs. When people do this, they have to put them to work (Dalkin et al. 2015, Lemire et al. 2020). STIBs change what people can do as they engage with their context. Mechanisms fill the 'black box' between STIBs and outcomes. Without mechanisms, STIBs have no functional human element to interact with the resources and skills provided, which then go on to generate outcomes and impacts, in other words, they simply will not work if people either cannot, or will not, use them. Outcomes or impacts can be intended (according to programme theory) or unintended (effects outside programme theory), but all represent the cognitive processes around the change in resources and opportunities open to beneficiaries of STIBs.

Once each unit of realist evaluation is created through a unit of evidence (a document), the realist evaluation approach enables the organisation of multiple pieces of research into the context–STIB–mechanism–outcomes format. This approach enables systematic comparison of the same or different STIBs in similar or different contexts, and with many different outcomes possible. Various arrangements of context and mechanisms, and with varying levels of performance in terms of the same outcome, provide the detail to support the development of a broad evidence base on STIB performance.

Figure 5 shows the basic logic of using realist synthesis to systematically review literature. In this instance, the different STIBs, operating within different contexts, are being compared in terms of their performance against the same outcome.

Following the trends in the literature reviewed, the basic combination of context–STIB–mechanisms can be arranged in several ways (see Table 2). There could be a comparison of the same STIBs operating in different contexts, and on the same outcome (row 1). Similarly again, the outcomes could be different (rows 3 and 4). All this depends on the literature reviewed and the patterns that emerge from the design and findings.

Figure 4. Unit of realist evaluation: context–mechanism–outcome (C–M–O)

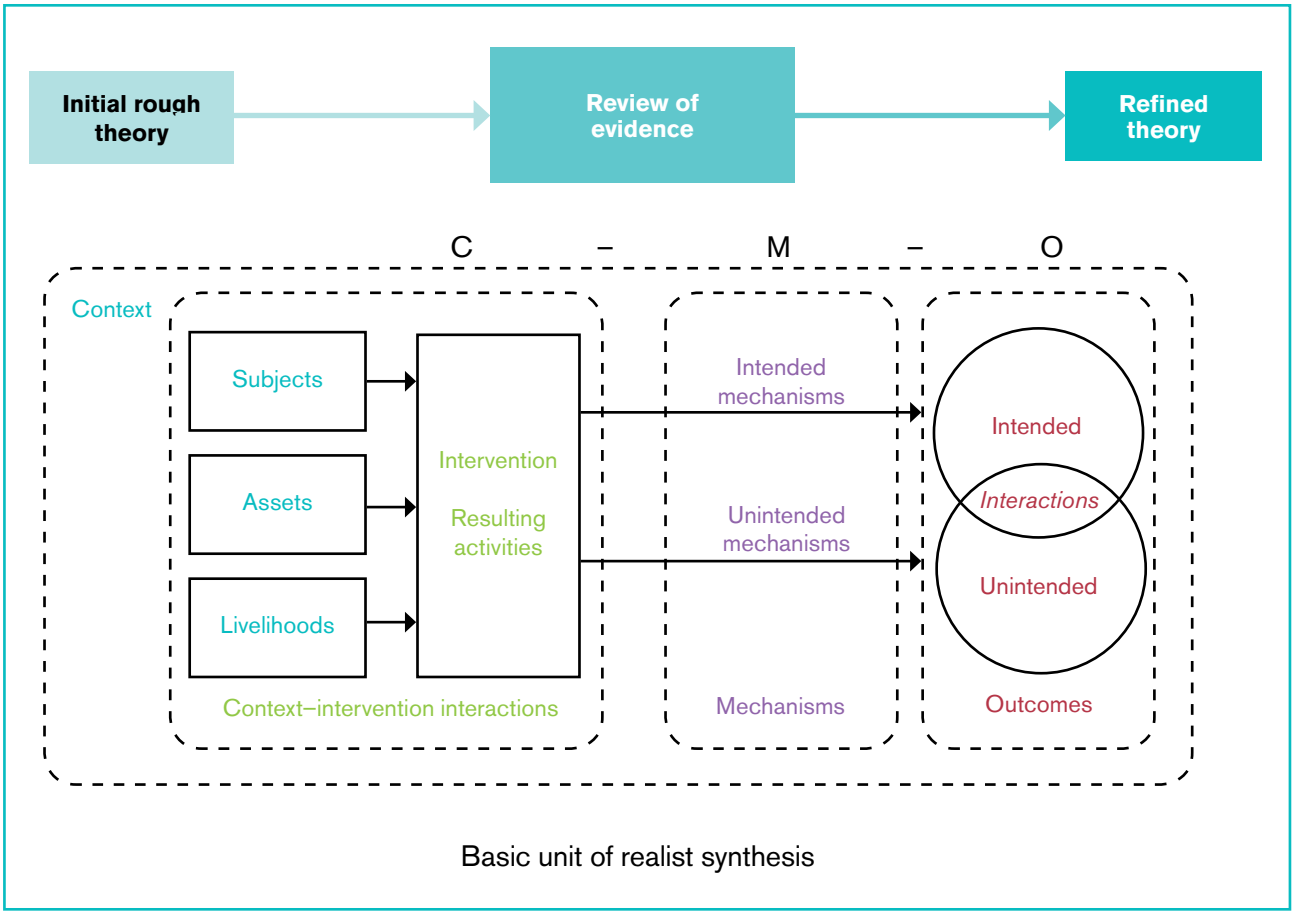


Figure 5. Different STIBs operating in different contexts, contributing to same outcomes

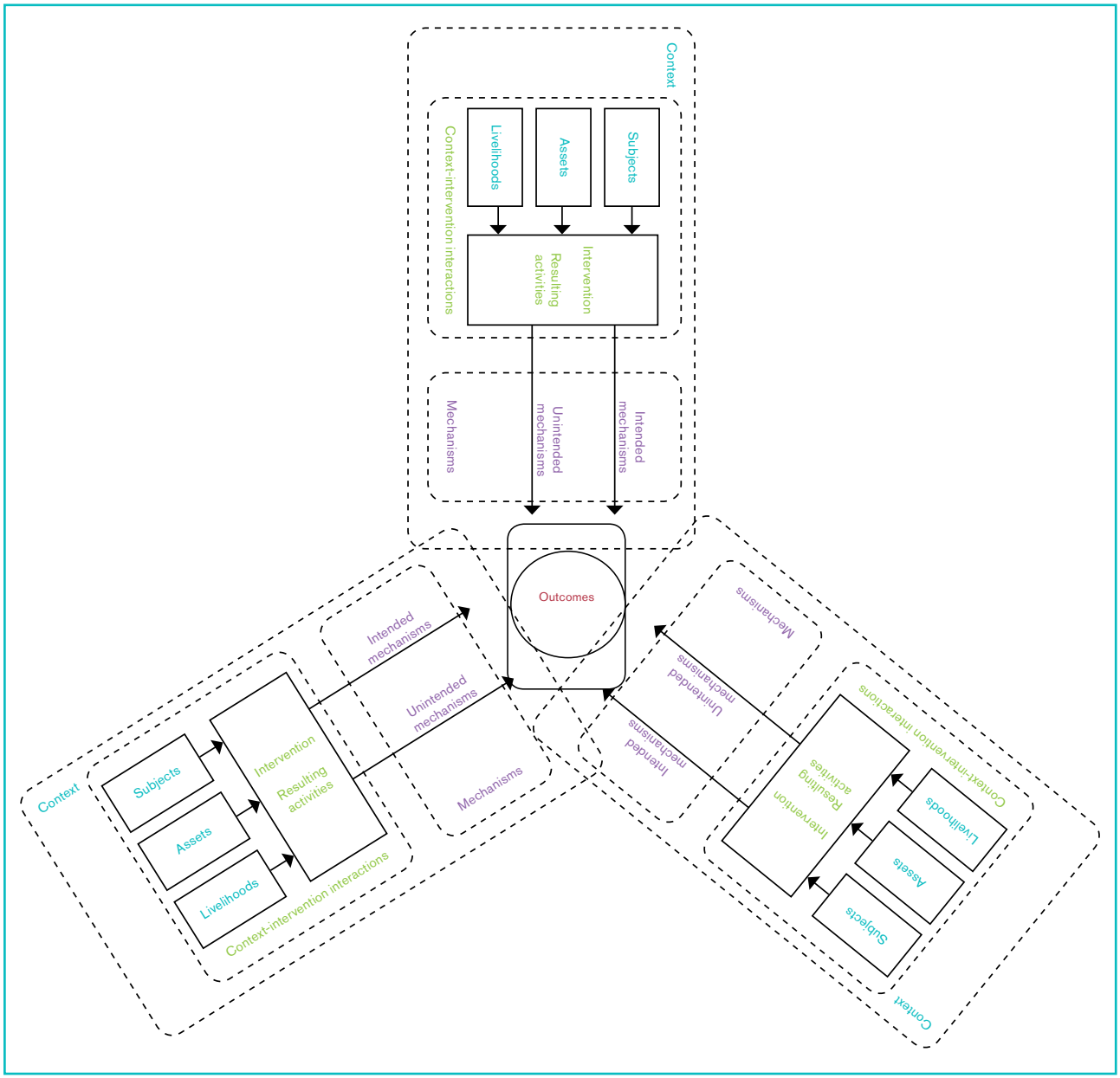


Table 2. Possible combinations of context–STIBs–mechanism–outcomes

CONTEXT	STIBS	MECHANISM	OUTCOMES
1. Different contexts	Same STIBs	Mechanism	Same outcomes
2. Same contexts	Different STIBs	Mechanism	Same outcomes
3. Same contexts	Same STIBs	Mechanism	Different outcomes
4. Different contexts	Same STIBs	Mechanism	Different outcomes

Generating variation in outcomes for realist synthesis review

Experts at CGIAR identified five categories of interest relating to STIBs: (1) technological innovation and innovation capacity, (2) climate resilience and adaptive capacity, (3) livelihoods and income resilience, (4) empowerment and (5) social innovation.

Associated with each of the categories is a series of indicators (note the same colour coding in Figures 5 and 6). These indicators are grouped according to another categorisation designed specifically for this review of empirical literature on STIBs, and in particular, their effectiveness. These are: outcomes for female farmers, access to productive resources and services, external drivers (climate, population and outside income), social and gender norms (overlapping with empowerment), and the wider enabling environment (institutional, policy, infrastructural and regulatory).

This enabled the organisation of indicators into a series of relationships which are most likely to crop up in the literature — especially in empirical literature focusing on the effectiveness and impact of STIBs. This approach was designed to identify the patterns in the literature of empirical analysis on STIBs. It potentially shows the main outcomes of focus, and their effectiveness or impact performance, while considering a range of alternative explanations.

Figure 7 is an example of the organisation of literature around the outcome of productivity. Each document within the review will have used some form of data or conceptual deliberation to make a claim about STIBs as one of the causes of the outcome or explain STIBs as interacting with other factors to influence the outcome. While this was the ambition of the work, the limited quality and quantity of evidence (especially around outcomes) in studies did not allow us to fully identify and complete the realist synthesis output. As a result, we established a simple table that highlights the selected works. As the evidence base fills out, our original ambition on the realist synthesis output may offer a useful way of establishing the linkages between studies that can strengthen future STIBs work.

2.2 Research barriers and gaps

One of the main challenges is that the body of research on agri-food systems still does not adequately or systematically address gender within studies. Despite women making up a huge proportion of agri-food system stakeholders, one study found that only 10% of reviewed interventions took gender into account (Bizikova 2020). Early contributions were more temporally sporadic, but some were aware of the gender dynamics of agricultural technology adoption (Doss 2001, Doss and Morris 2000, Doss 2002 and Udry 1996) and livestock management, marketing and retail (Aklilu et al. 2007). To date, some of the literature that does include gender remains focused on dimensions of 'lack' in terms of resources, and agency — among many other indicators of disadvantage (Huyer, 1996) — and with consistent calls for gender inclusion in technology design and adoption (Rola-Rubzen et al. 2020). Little practical and translatable guidance is available on how to translate the complex, context-specific dynamics of women's needs and attributes into a coherent framework for technology use. And there remains a dearth of evidence linked to outcomes and impacts from innovations.

The limited progress made in the field of gender and technology adoption in particular is in part attributable to the specialist skills required to collect and analyse gender-disaggregated household or individual data (Doss 2013). Gender-blind agri-food systems research has pervaded due to limited resources for the development and operationalisation of gender-disaggregated indicators, and particularly the scarcity of nuanced analyses of sex and gender (Tickamyer and Sexsmith 2019). The implication is that the research of agri-food systems is applicable primarily to the aggregated household level as the primary unit of analysis. While this does enable the assessment of attributes such as farm endowment, socio-economic status, and capacity and power in relation to other households, it does not provide insights into the intrinsic gender and power dynamics within households. If intra-household gender dynamics are not considered, endowments, power and so on are more likely to reflect the decision making and preferences of men — because of gender norms.

Further, intersectionality, or the multiple ways that people experience disadvantages through gender, age, caste, and so on, is also often overlooked in studies, more so than gender (CGIAR 2020). As a result, there is even less evidence unpacking intersectionality than gender alone. Indeed, a 2019 study found that only 243 papers out of 26,000 candidate papers from 2008 to 2019 had an equity focus, and that few looked at the reasons behind the equity problem (CGIAR 2020).

Figure 6. Categories of interest related to STIBs

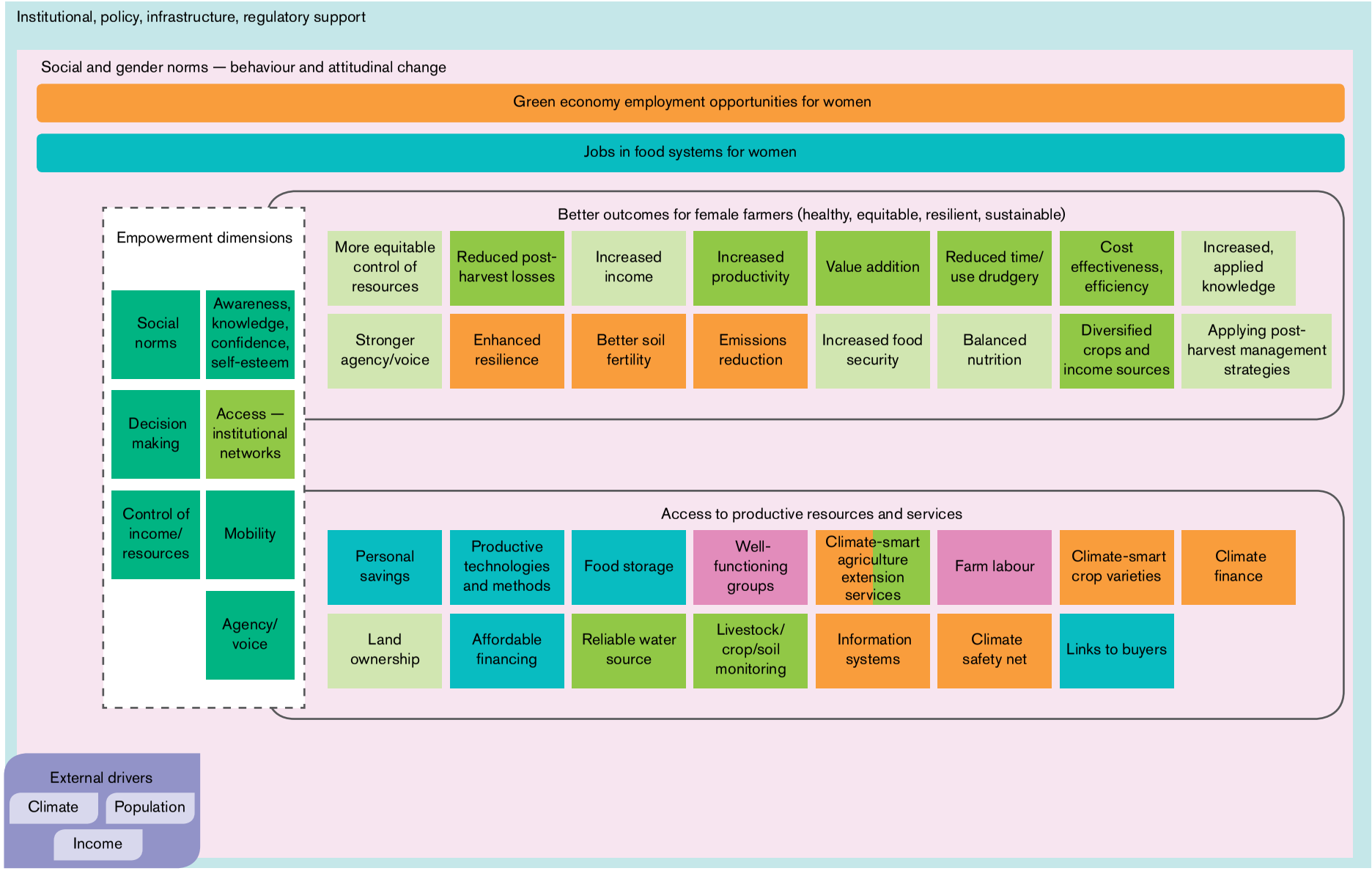
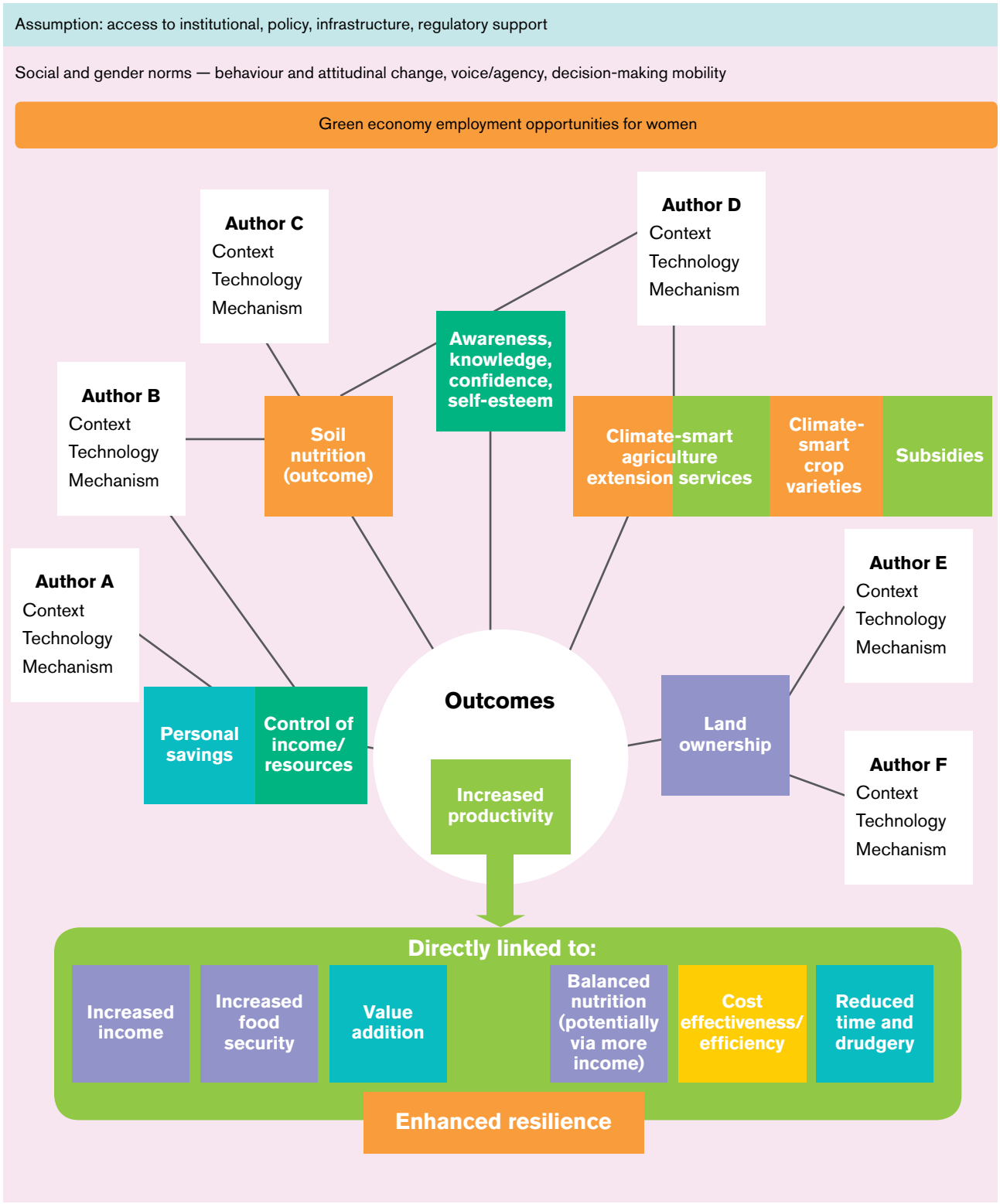


Figure 7. Realist synthesis output: factors (including STIBs) associated with or causing increased productivity



3

Evidence on bundling for women's empowerment and household resilience

The pivotal book framing and defining STIBs was published in 2022. As a result, the literature on gender, resilience and STIBs is yet to be consolidated, conceptually verified or empirically substantiated in agri-food systems. The wider body of literature in agri-food systems generally shows a series of discrete socio-cultural, technological, and other context-based drivers or interventions, but focuses less on bundles of interventions and how those bundles interact within different contexts.

Table 3 summarises 11 studies that were captured through our keyword string searches (see full methodology in Section 2). We have ordered them primarily chronologically, with a secondary order alphabetically by country. Column two highlights interventions or important contextual drivers emphasised in the various studies. Column three shows our interpretation of what we believe was the cognitive trigger, or process, that the interventions prompted (the mechanism), which enabled women to engage with the interventions and achieve the outcomes they desired. This so-called mechanism is usually not clearly defined in the studies, so the researchers had to make assumptions based on the available information.

The studies vary dramatically in structure (literature reviews, experimental studies, some observational studies) and detail, which complicates their comparison. This is not meant to be an exhaustive list of the available evidence that could support STIBs implementation but represents an initial trawling to start establishing the case for STIBs that centre gender equity and household resilience. Many of the selected studies have interesting references to other studies that may be relevant to STIBs work, but these were not included because of our methodology and project constraints.

Table 3. Identified literature that speaks to bundling interventions

LITERATURE COUNTRY, YEAR, TITLE	BUNDLED INTERVENTIONS AND/ OR CONTEXTUAL DRIVERS (planned and unplanned)	MECHANISM (our assumptions based on our readings — some explicitly mentioned)	OUTCOME(S)
Benin, 2014 Organic cotton production as an adaptation option in north-west Benin	(1) Training in organic farming (2) Opportunity to reduce input costs via organic farming avoiding expensive fertiliser and pesticide inputs (3) Delays in provision of farm inputs for conventional farming from government (4) New income without needing husband's permission (5) Organic cotton does not compete with conventional cotton ('men's crop') growing	Farmer association trains women farmers, giving them the confidence to cultivate organic cotton, along with the 'organic' price premium of 20%. Reduces costs from fertilisers and pesticides because of organic farming principles, and intrinsic motivation to have 'own' income.	Diet diversity, nutrition, food security, income
Vietnam, 2017 Incorporating gender into low-emission development: A case study from Vietnam	(1) Agricultural training — including 'alternative wetting and drying' (2) Reduction in farm input costs (3) Intermediary that can challenge deep gender norms and reduce barriers (4) Women saw trusted neighbours benefiting and attended training courses themselves (5) Information sharing through informal networks	A trusted intermediary (Women's Union) ran agricultural training courses that also challenged deep-seated gender norms, which instilled confidence in women. Other women saw their neighbours benefiting, this increased their confidence and encouraged them to sign up for the courses. This in turn improved knowledge and shifted gender norms in agriculture, which made space for women's agency. Sharing through informal networks boosted confidence.	Productivity, income, profit, household resilience
Malawi, 2018 Exploring the potential of household methodologies to strengthen gender equality and improve smallholder livelihoods: Research in Malawi in maize-based systems	(1) Implementation of Gender Action Learning Systems (GALS)	Couples (men and women) within farming households grow in understanding and confidence, shifting gender norms, behaviours and tasks within the household towards more equal, joint achievements.	Empowerment (men and women)
Zimbabwe, 2018 Women's food security and conservation farming in Zaka District, Zimbabwe	(1) Conservation agriculture training through trusted intermediary (2) Lead farmers supported with training materials and tools, and a monthly stipend (3) Women's solidarity through sharing farm labour (4) Contextual drivers — politicisation of food aid, institutions and climate impacts, migration of men	Conservation agriculture training through a trusted intermediary, combined with contextual drivers, motivated and lent confidence to women to implement conservation agriculture practices.	Food security, resilience
Tanzania, 2020 Home gardening improves dietary diversity, a cluster-randomized controlled trial among Tanzanian women	(1) Agricultural training and inputs to promote home gardens and diversifying diets — including farmer field schools (2) Nutrition and public health counselling from agricultural extension workers and community health workers (3) Peer-sharing between women in the farmer field schools	A combination of access to nutritious vegetable seeds with integrated health advice changed understanding of nutrition. Additional agricultural extension support changed know-how and practices building confidence in women to grow home gardens, while disseminating knowledge through trusted networks reinforced that confidence.	Nutrition, diet diversity, health, limited effect on food security

LITERATURE COUNTRY, YEAR, TITLE	BUNDLED INTERVENTIONS AND/ OR CONTEXTUAL DRIVERS (planned and unplanned)	MECHANISM (our assumptions based on our readings — some explicitly mentioned)	OUTCOME(S)
Guatemala, 2020 Sustainability of agro-ecological interventions in small scale farming systems in the Western Highlands of Guatemala	(1) Agricultural training including promotion of gender equity (2) Deteriorating land quality and decreasing yields (2) More women involved in promoting agro-ecological practices	Women extension officers offered training in agroecological principles, which instilled confidence in women farmers.	Productivity, food security, gender equity
Niger and Nigeria, 2020 Rural women's participation in solar-powered irrigation in Niger: lessons from Dimitra Clubs	(1) Implementation of 'Dimitra Clubs' (community groups) with a dialogical, feminist approach (2) Cash through petrol pump buy-back scheme (3) Access to solar irrigation pumps	Women's knowledge was valued through Dimitra Clubs, they feel more able to participate and craft solutions that work for them. Their solar-powered irrigation intervention gave them the confidence to be effective rice farmers.	Empowerment (women's leadership), food security, health, education
Brazil, 2021 Public policies for agricultural diversification: Implications for gender equity	(1) School feeding programme as public procurement mechanism, to buy produce from women's home gardens (2) Social movements that support agro-ecology practices and inclusion of women	Women's participation in social movements inspired greater confidence and empowerment, giving them the courage to 'convince' their husbands to establish a home garden to sell into the school feeding programme.	Empowerment, farm diversification, income
Kenya, 2021 Onto the farm, into the home: How intra-household gender dynamics shape land restoration in Eastern Kenya	(1) Training on tree planting and planting basins (2) Out-migration of men can give agency to women	An intra-household approach (engaging both men and women) to restoration can increase women's confidence and agency implementing tree planting and planting basins schemes on their farms.	Empowerment
Kenya and Burkina Faso, 2022 Home gardening in sub-Saharan Africa: A scoping review on practices and nutrition outcomes in rural Burkina Faso and Kenya	(1) Access to various farm inputs and irrigation (2) Training in home garden best practices	Access to irrigation and training on agricultural best practices instilled confidence in women to grow home gardens, which fit within women's needs and gender norm constraints.	Diet diversity, food security.
Tanzania, 2022 Community-based approaches to support the anchoring of climate-smart agriculture in Tanzania	(1) Implementation of farmer field business schools (FFBS) (2) Village savings and loans associations (VSLAs) (3) Women's empowerment	A combination of knowledge from FFBS and finance from VSLAs, alongside having other female peers to share ideas and knowledge, gives female farmers the confidence to adopt climate-smart agriculture practices.	Productivity, income, nutrition, empowerment, resilience, savings
Togo and Benin, 2023 Gender and access to complex and gender-biased agricultural technology information and knowledge: Evidence from smart-valleys in West Africa	(1) On-farm demonstrations and awareness-raising meetings (2) Women facilitators	Women facilitators coupled with practical, on-farm demonstrations can raise the confidence of women to implement new technologies.	Empowerment

The following section highlights important details and aspects from each of the selected literature, building on the details within Table 3.

Organic cotton production as an adaptation option in North-West Benin

Kloos, J and Renaud, F G (2014)

This study clearly finds that organic cotton production is a viable climate adaptation strategy for women in this part of Benin. Important cost and price considerations included the fact that organic farming has lower capital outlays and reduced dependency on external farm inputs. This was particularly important for farmers experiencing marginalisation in various forms as it means a lower barrier to entry. One important contextual motivator was being independent from government provision of farm inputs for conventional farming, which can be delayed and affect planting seasons.

The study found that conventional cotton was considered 'men's business'. Since organic cotton production was not seen as interfering or competing, gender norms 'allowed' women to cultivate it. Importantly, this also meant women had an independent income, which they invested in the household (usually needs of children) or livestock. Planting on marginal land, viable due to organic farming practices, also reduced perceptions of competition with 'men's business'. The study argues that this income, diversification and investments increased household resilience and women's empowerment.

Incorporating gender into low-emission development: a case study from Vietnam

Farnworth, C R et al. (2017)

This study states that technology and innovation deployment 'strikes at the heart of intra-household, decision-making processes around expenditure and risk'. This is a critical point for STIBs, as it highlights the role of integration and an understanding of intra-household dynamics to reduce these barriers.

It suggests that to achieve scale in 'low-emission development projects', it is important that deeply held gender structures and barriers are identified and dismantled. One avenue is to work with a trusted intermediary, in this case the national 'Women's Union' in Vietnam. This emphasises the critical need to include empowerment within bundles of socio-technical innovations, and the importance of selecting intermediaries that have existing relationships and influence with communities to unlock women's agency.

The study highlights that excluding women from extension services increased intra-household tensions, as women were expected to implement technologies that only men had been trained in. And, after years of exclusion, many women had internalised the gendered misconception that their husbands were better at learning and consequently should be the ones to participate in training — a view held by many men as well. Finally, the study highlights some of the challenges around counterintuitive interventions, as the new techniques required a reduction in farm inputs but led to increased production.

This study is one of the few to explicitly highlight the 'mechanism' that shifted: 'Working through the Women's Union on the technical benefits and co-benefits of 1M6R [rice cultivation] was a critical first step in garnering women's attention and their resolve. Bolstered in confidence, women were then able to participate actively in regular farmer association/farmer group meetings to learn more' (Farnworth et al. 2017).

Exploring the potential of household methodologies to strengthen gender equality and improve smallholder livelihoods: Research in Malawi in maize-based systems

Farnworth, C et al. (2018)

The Gender Action Learning System (GALS) is a methodology that unpacks intra-household gender relations, for example through the drawing and division of assets by control and use. This study found that households who experienced the GALS methodology had increased accumulation of assets, increased financial transparency, and consultation on expenditures in contrast to control groups without the intervention. However, men continue to be the 'final decision makers' in both groups.

This work shows the importance of understanding intra-household dynamics when designing interventions such as STIBs, and the importance of incorporating empowerment tools and methods within bundles to achieve greater gender parity in the division of household and farm labour.

Women's food security and conservation farming in Zaka District-Zimbabwe

Hove, M et al. (2018)

This study in particular shows the importance of contextual drivers that might enable or hinder STIBs — in various positive and negative ways. More erratic rainfall, deteriorating economic conditions, outmigration of men to cities, and politicisation of food aid resulted in increased motivation and space for women's agency.

This study also confirmed in Zimbabwe that women — as in many other studies — faced competing domestic

duties, which made the labour-intensive creation and application of organic fertiliser challenging for some. This again highlights the importance of considering labour requirements when designing technologies and innovations. Sharing of labour between women helped ease the burden of some conservation agriculture practices, such as establishing planting basins, but this did not extend year-round due to the differing needs and tasks throughout the year. Labour limitations also constrained women from expanding their farm plots through conservation agriculture practices like mulching.

Other barriers included absence of fencing to protect farm plots and dry spells. But those who did overcome these barriers, for example through conservation farming techniques, managed to increase their household's food security.

Home gardening improves dietary diversity, a cluster-randomized controlled trial among Tanzanian women

Blakstad, M et al. (2020)

The intervention from this work integrated health and nutrition training with agricultural trainings, suggesting the importance of bundling both to achieve diet diversity. This randomised trial claims to be the first to 'find statistically significant impacts of a home gardening programme on women's dietary diversity' — critical work with promising outcomes. It hypothesises that women changed food consumption patterns based on the dietary education they received, and an increased food budget allowed them to buy other foods that they didn't grow at home.

The study also suggests that positive externalities may exist, in that neighbouring households — not included in the interventions — may also benefit from increased dietary diversity. It posits that this could be a result of witnessing their neighbours' home gardens and implementing themselves or by receiving produce from their neighbours' gardens.

Sustainability of agroecological interventions in small scale farming systems in the Western Highlands of Guatemala

González-Esquivel, C E et al. (2020)

This study discusses gender but not to an adequately detailed level to reveal deeper insights for our purposes. It does find that some of the agroecological interventions require additional labour, which usually falls to the women in households, and that using women facilitators increases women adopting the practices.

The study cautions that even with agroecological interventions, some farms on marginal, mountainous land in Guatemala, coupled with population pressure, may need continuous external inputs like fertilisers. This can be a challenge for many women who do not have independent sources of income, and makes farming more capital intensive, which can reduce savings and thus resilience. It also highlights the importance of measuring soil quality and erosion control in future work.

Rural women's participation in solar-powered irrigation in Niger: lessons from Dimitra Clubs

Adisa, O (2020)

This study looks at Dimitra community listeners clubs in Niger and Nigeria, which use a dialogical, feminist approach to empower women: 'This feminist perspective is concerned with bringing together academic and non-academic voices and assigning equal weights to both, not privileging one over the other.' The group members discuss and solve livelihood challenges. Giving equal weight to women's voices from the community listeners clubs, the study argues, was critical in raising the confidence of women in co-designing their own solutions for solar irrigation pumps. For example, in Nigeria, women identified affordability as a major impediment. As a result, the project implemented a petrol irrigation pump buy-back scheme to allow women to afford the solar irrigation pumps.

This case study highlights the opportunity for establishing a safe space for women, where their voices are elevated to the same status as men. This would be particularly useful for implementing STIBs in societies like Niger, which has one of the highest rankings in the Gender Inequality Index.

Public policies for agricultural diversification: Implications for gender equity

Valencia, V et al. (2021)

This study is one of the few in this selection that touch on institutions and policies. It shows the opportunity that public procurement mechanisms can offer as a driver of demand for horticultural products within the government's school feeding programme — a critical opportunity for women's empowerment at scale. The programme supported diversification of farm crops and the conditions for women's empowerment, for example with agency through greater on-farm decision making. The study highlights social movements as amplifiers, supporting agroecological practices and inclusion of women. It also shows the importance of ensuring an enabling framework that, in this case, encompasses smallholder farmers and women.

Onto the farm, into the home: How intrahousehold gender dynamics shape land restoration in Eastern Kenya

Crossland, M et al. (2021)

This study looked at land restoration in Eastern Kenya, observing intra-household gender dynamics around tree planting and planting basins. It found that women typically initiate, but full adoption also requires the incorporation and confidence of men. As for intra-household dynamics, many men and women valued consultation to avoid conflict, but a significant number of men did not consult with their wives to avoid disagreement on how to spend household time and financial budgets. Regardless, the authors conclude that consultation is likely to be commonplace here, challenging the assumption that male heads of households hold all the decision-making power. Male outmigration is also flagged as a critical context driver, creating opportunity for women's agency.

Home gardening in sub-Saharan Africa: A scoping review on practices and nutrition outcomes in rural Burkina Faso and Kenya

Hansen, L-S et al. (2022)

This literature review found a select few relevant studies that show the promise of home gardens as an impact pathway for climate adaptation and improving household nutrition. However, it also found that there is a general lack of rigorous experimental study on the efficacy of home garden interventions in Burkina Faso and Kenya. This lack of evidence likely extends across many if not most contexts and is a barrier to further unpacking how they might contribute within a bundle.

The review found a mix of different interventions, such as access to various farm inputs and irrigation, but the details are inadequate for the purposes of our work in understanding how innovations can be bundled together. It does recommend women's empowerment as a critical component of any home garden intervention, including co-design of home garden interventions. It also identifies the heterogeneity of the home gardens, and the importance of understanding each community and household context as a result.

Community-based approaches to support the anchoring of climate-smart agriculture in Tanzania

Pamuk, H et al. (2022)

This work highlights an important aspect of the bundling of innovations that STIBs aim to synergise. It finds that the separate interventions of farmer field business schools (FFBS) and village savings and loans associations (VSLAs) do not necessarily deliver the desired outcomes. Rather, it is only through combining them that the innovations synergise aspects of empowerment (women's agency and leadership on the farm) with access to resources (through financing) that can enable women to adopt principles of climate-smart agriculture and achieve their desired outcomes.

Gender and access to complex and gender-biased agricultural technology information and knowledge: Evidence from smart-valleys in West Africa

Kinkingninhoun Medagbe F M et al. (2023)

This study explores the gender disparities in diffusion of knowledge and, consequently, access and uptake of technologies. Like many other studies, it reinforces the fact that women facilitators and demonstrators can effectively reduce the gender gap in technology adoption. The study found that a project in Togo that specifically targeted female farmers managed to reach significantly more women

Disparities in education levels between men and women, in addition to women being assigned highly gendered tasks during the training that they were supposed to be participating in — such as fetching water and cooking — also hindered their uptake. The work references another study in Ethiopia that found misconceptions on gender roles ('women do not devote much time to agricultural activities') when the reality is they are highly productive members of agri-food systems. These were likely to contribute to lower uptake of technologies by women.

This work emphasises the importance of wrapping empowerment and gender-lensed activities with other innovations to reduce the gender gap in uptake. The study gives specific guidance on a gender-integrated approach: 'encouraging couples to attend training events; providing guidance on intrahousehold decision-making and negotiation; facilitating discussion of gender roles; and using participatory planned comparisons that allow households to test and compare options and variations of them'.

4

A practical, gender-integrated STIBs framework

The context is central to designing and implementing STIBs that can enable gender equality and empower women, and men, to effectively engage with innovations and technologies in agri-food systems. Indeed, Barret et al. (2022), highlight the fact that agri-food systems are heterogenous — what works in one context may not work in another. Specifically, using methods such as a gender-integrated situational analysis can provide the necessary nuanced understanding of context that provides the foundation of socio-cultural and technical innovations. This means the starting point in the design of STIBs is likely to take account of different nuanced aspects of contexts that are often unique. These represent opportunities to empower by combining different dynamics of context (gender norms, economic conditions and so on) to provide the catalyst which results in the desired outcomes.

Based on these and our other findings, and together with CGIAR and other partner organisations, we designed a practical framework for STIBs. Figure 8 illustrates the framework for socio-technical bundles, which centralises context as the starting point. The logic is expressed in four steps:

(1) The importance of understanding the contextual dynamics — both within and between households — to bundle for women's (and men's) empowerment according to the specific advantages and constraints of operating within their environment, which leads to …

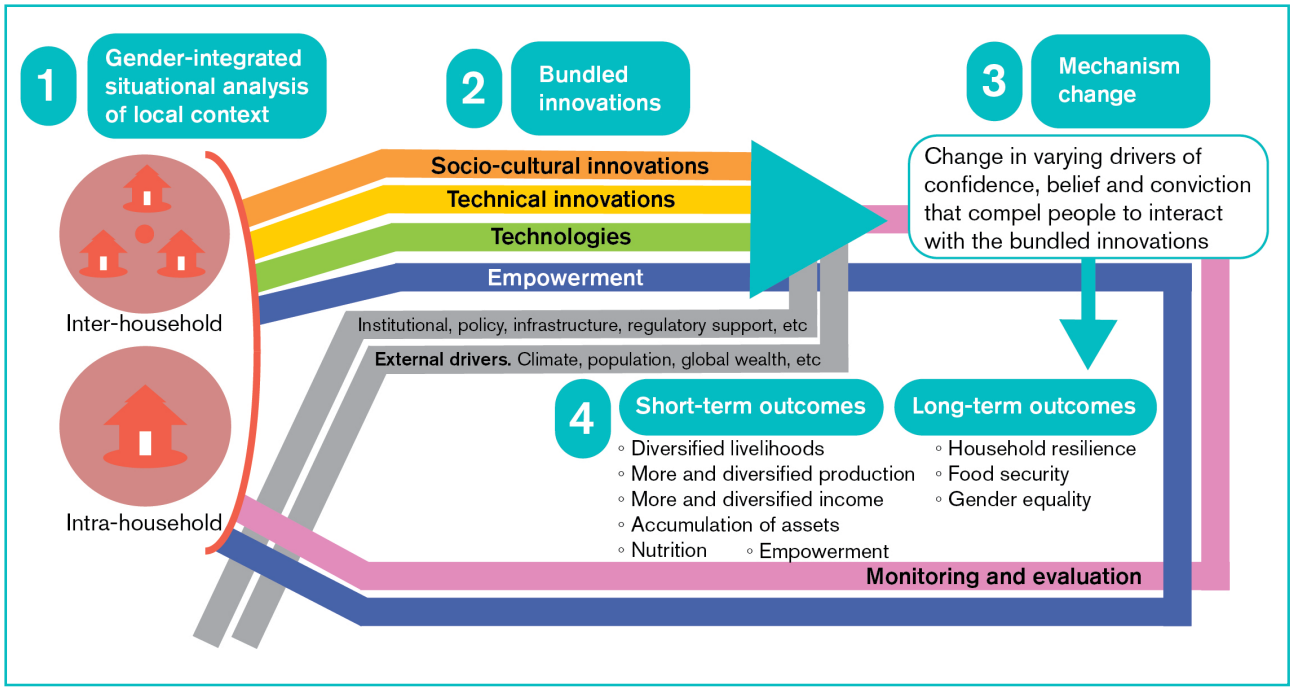
(2) Co-designing of socio-cultural, technical, and technology bundling, according to advantages and constraints revealed in Step 1. This must consider critical policy and regulatory support, which can encourage the longer-term interactions of people with STIBs. This leads to …

(3) The mechanism or the varying drivers of confidence, belief and conviction that compel empowered women (and men) to interact with the bundled innovations with assurance that such an engagement will be effective, so they can achieve …

(4) Their desired outcomes — both immediate or short term (such as income and asset holdings) or longer term (such as resilience and food security).

After Step 4, empowerment and self-determination are enhanced and nurtured, which itself feeds back to incrementally improve the power situation of women and, iteratively, better enables them to engage with existing or revised STIBs. A critical aspect is that of monitoring, evaluation and learning that can then be used for revised iterations of STIBs and applied to other contexts where relevant.

Figure 8. Practical framework for socio-technical innovation bundles



5

Deconstructing bundles: what works?

Our ambition was to uncover evidence on what different combinations of STIBs worked for women, where, why, and how? However, few studies adequately deconstructed bundles of innovations that might be needed to explain how their constituent pieces might interact with each other to show clearly what bundles work and for what outcomes.

In this section we present more in-depth insights from the review (combining the 11-study shortlist with evidence from other studies) that we think could be valuable when applying the practical gender-integrated STIBs framework from the previous section. Given the focus of our approach on gender, it is not surprising that empowerment and power dynamics runs throughout as a common and critical theme, to be considered within the designs and implementation of STIBs.

Tagged to the four steps from our framework, the sub-sections below outline the ways some of the literature has addressed key elements that collectively provide insight into using the STIBs approach to technology design and implementation. These components could be included within STIBs themselves as bundled interventions or used to support STIB implementation — we hypothesise that the sequencing will likely depend on the context and need.

5.1 Local context as the starting point

As we have already emphasised in this report, learnings from the studies highlight the fact that context is critical. There are no panacea solutions or bundles that can be applied universally. Implementing a gender-integrated situational analysis can help uncover the different dynamics at play. These dynamics within households, between households, and within local social, political and institutional structures will vary. As a result, the innovations within the bundles will differ either marginally or significantly. Further, an 'innovation' is a relative term, in that what is 'new' in one context (using our definition of innovation, see footnote 1), may be old or unworkable in another and thus not needed. Hence understanding each context should be the starting point.

5.2 Intra-household dynamics

We found that most studies focused on the household as the unit of analysis, including Barrett et al. (2022). In the context of male-headed households, focusing on the household level is more likely to favour the man's perception, preferences and needs over the woman's. As a result, we think that STIBs based at this level of analysis would skew or favour men over women. This risks not activating synergies within the household and not achieving the desired outcomes. Therefore co-designing STIBs must start at the individual level, which can reveal the relationships, power and dynamics that flow within the household. We believe that understanding these intra-household dynamics is a critical first step in designing appropriate STIBs.

Men and women together must engage with bundles. Gender norms and dynamics require the involvement of both since it is reshaping and renegotiating the relationship between the two (Scambor et al. 2014). Focusing on women's empowerment without involving men risks worse outcomes, as in Tanzania (Galièa and Farnworth 2019). Understanding who uses or has access to different assets and the breakdown of household and livelihood tasks and activities will help guide socio-technical interventions that are better suited to the constraints that men and women live by. In rural Malawi, Farnworth et al. (2018) document the relational transparency and empowerment functions of the Gender Action Learning Systems (GALS) methodology. New norms are nurtured around greater understanding and sharing of assets, resources and decision making that can result in the successful running of the household. And as stated previously, Crossland et al. (2021) found that men in male-headed households in Kenya were more likely to consult their spouses than social norms might indicate. This highlights that in at least some male-headed households, decision making may be more nuanced than what is typically assumed, with a decision-making dynamic that plays out between wives and husbands. But this would need to be interrogated to understand whose priorities and preferences ultimately prevail.

Another important note is that women and men within the same household can manifest different priorities and, as a result, different strategies for adapting to climate change. This is in response to the different pressures they may face. For example, in Benin some men focused their efforts on commercial, 'cash' crops, partly to qualify for subsidies. However, the women in the households preferred to focus on crops for household consumption to ensure food security for the family. This highlights very different priorities and the distinct pressures from gender norms that they each face, where women are expected to provide for the household, and thus focus on food security (Phiri et al. 2022). In northern Mali, some men viewed their economic migration to cities for jobs as a way to mitigate vulnerability while women saw it as a source of vulnerability, adding to their workload, and requiring them to take children out of school to replace the lost labour — too high an opportunity cost (Phiri et al. 2022). STIBs must consider and accommodate these perspectives to accurately design and apply appropriate bundles for success.

Unpacking intra-household dynamics can reveal important trends and dynamics. Power in relationships can dictate access to information and knowledge in different types of households. For instance, Nyantakyi-Frimpong (2019) found that in polygamous households in Ghana, younger wives were often excluded from information if it was delivered through senior or elderly wives. Meanwhile, male heads-of-households were more likely to share information with other male members of the household, but not women. Consequently, understanding how communication channels work in targeted communities could help make or break implemented STIBs (see next section on access to information for inter-household).

5.3 Combining different innovations into bundles

The innovations and examples below highlight different opportunities for STIBs emerging from our literature selection. They may already exist in specific contexts and can therefore be built upon immediately and incorporated as parts of STIBs to be implemented. In other contexts, it may make sense to build out functions or activities as a part of the STIB implementation. It is difficult in some examples to clearly define what is technical, what is technological, what is socio-cultural, and so on. Often, they will overlap, so we have done our best to structure them to make them as reader friendly as possible.

5.3.1 Socio-cultural innovations

We used the Cambridge Dictionary's definition of socio-cultural as 'related to the different groups of people in society and their habits, traditions, and beliefs'.[2] Most relevant for this work are social and gender norms that provide barriers or opportunities to different types of people within the varied contexts that they operate and live within.

[2] See https://dictionary.cambridge.org/dictionary/english/sociocultural

We have covered some of the specific barriers and challenges around gender in previous sections. Here we highlight some relevant examples and pathways that may be important when considering how to package STIBs considering socio-cultural elements.

Identify access and channels of information. As a result of gender norms that can, for example, constrain women's movement, many women have turned to each other to access and share vital information individually and in groups. This type of knowledge sharing can enable them to overcome structural, institutional and cultural barriers in accessing information (Niewoehner-Green et al. 2019). In practice, information sharing tends to occur along gender lines, with women sharing between women, and men sharing between men, but not always (Padmaja et al. 2006, Nyantakyi-Frimpong 2019). As seen previously in several examples in Table 3, it can also reinforce understanding and confidence, which in turn enables and sustains practices. See also examples on intra-household dynamics in the previous section regarding polygamous household information dynamics in Ghana.

Analyse how social capital and collective action function. Social capital is the value of relationships between and among people, and the broader networks of those relationships in a given community, where essential information, skills and experiences can be shared (Claridge 2004, Boxman et al. 1991). The importance of social capital was clearly evident in our shortlisted literature in Table 3. Social capital can be an essential catalyst as well as an outcome for STIBs as women draw on a range of available resources to overcome barriers for effective engagement with agri-food systems, such as control over resources and access to credit (Crossland et al. 2021, Mwololo et al. 2022). Important for STIBs is the possible cascading effect of social capital on neighbours and community members who may not be directly involved in interventions. For example, Blakstad et al. (2020) found diet diversity outcomes also reached neighbours.

To this end, women farmer cooperatives and self-help groups are associated with improved outcomes, such as food security, income, knowledge and access to finance (Bizikova et al. 2020, Bernard et al. 2008, Abate et al. 2014, Kwarteng and Sarfo-Mensah 2019). Social capital offers an enabling function for women to access resources, where they experience barriers in formal channels. For example, in the eastern Kenyan drylands, Po and Hickey (2020) found women used social capital and networks to access information and training resources for soil conservation technologies, which were unavailable to them through formal channels. In Kenya, Tanzania and Uganda, Otieno et al. (2021) found that some women favour the social interaction of farmer-to-farmer seed exchanges. Ingutia and Sumelius (2021) found in Kenya that some women farmer groups have a support function that builds social capital and empowers them to effectively participate in agricultural livelihoods and achieve crop yields which are better than those farmers not participating. While focusing on agency, Kwarteng and Sarfo-Mensah (2019) assessed the empowering role of savings groups for women in Ghana. They recorded a range of impacts, including greater confidence to speak out, improved access to credit and improved decision making around the purchase of agricultural inputs, cropping strategies, herd management and household expenditure.

Groups, both women-only and mixed gender, can offer different vital functions that are not readily available within communities. For example, Kwarteng and Sarfo-Mensah (2019) found that in Ghana, village savings and loan association groups acted as important social security for its members, providing support for one another on important occasions such as funerals and marriages, as well as for medical and other social needs. Abate et al. (2014), in their assessment of agricultural cooperatives on smallholder farmer's technical efficiency in Ethiopia, found that on average, farmers who were members of cooperatives had greater technical efficiency than non-members. Cooperatives provide easier access to productive inputs and access to training and other resources. The study provides cursory analysis from a gender perspective, but it does find that members of cooperatives are more likely to come from male-headed households.

A study focusing on rural Kenya found that women farmers benefited from being part of farmers' groups including improved crop yields. The study emphasised the importance of groups for overcoming the challenges that female farmers face in these contexts (Ingutia and Sumelius, 2021). However, a broad literature review of studies (Bizikova et al. 2020) offers a less optimistic picture. They found that group membership had a beneficial effect on different types of farmers' income, but found less evidence on increased crop yields and production quality. There is also evidence that farmers experiencing marginalisation through limited literacy, gender, education, land access and social status may need additional support before they're able to benefit from membership of farmers' organisations (Bizikova et al. 2020). Women experiencing different forms of marginalisation often do not participate in farmer groups at all as a result (Abate et al. 2014, Bernard and Spielman 2009).

In some contexts, groups could have an important enabling function for STIBs and empowerment, but not all have access to them. Other factors inhibiting access to groups include insufficient financial resources to pay group member fees and cash contributions (Bizikova et al. 2020). If a STIB seeks to reach people experiencing marginalisation, the design will need to consider these barriers and effectively manage them to ensure that those people can access and benefit from the group. This could be for example, having the STIB subsidise member fees for a period, exempting them completely, or applying an alternative accountability mechanism.

As highlighted in the previous section, Farnworth et al. (2017) showed the importance of women in Vietnam seeing their peers involved in training on new, alternative wetting and drying techniques for rice. This gave them the confidence to participate as well and helped dismantle deep-seated and negative gender stereotypes around women's abilities to partake in training. The training also used women facilitators from a national and trusted intermediary, which reinforced confidence. But this may not be a requirement nor practical in all contexts.

5.3.2 Technical innovations

Technical solutions should be designed by thinking through structural, institutional, political and economic factors (such as land tenure and gender norms) that have hitherto reduced technical interventions and livelihood options for women. Below we highlight some of the examples from the literature that may help in thinking through and co-designing STIBs.

Technical trainings are important for bundling. Common across the literature were interventions that used technical trainings. These included government programmes via extension services, and custom curriculum through local and national nongovernmental organisations and intermediaries. The training courses were usually supplemented with other support such as access to farm inputs or financing. Pamuk (2022) is clear in their view that the intervention only worked because training in climate-smart agriculture was combined with access to financing, which built the confidence of female farmers in Tanzania. Blakstad et al. (2020) similarly conclude that combinations of training in nutrition and production, combined with providing nutritious seeds, allowed women to achieve dietary diversity. Few studies offered such analysis on the bundling of activities, but building this evidence will be critical in implementing better STIBs. Kinkingninhoun (2023) does show that some women facilitators in West Africa could better empathise, understand and adapt to the unique circumstances of women, for example ensuring that training sessions fit with women's schedules, around household duties, childcare and so on.

Demonstrations and farmer field schools seem to offer particular benefits. Public and private entities set up 'farmer field schools' to demonstrate techniques, innovations and technologies to farmers. This allows them to witness, understand, assess and practice them under the guidance of experts, before returning to their own farms to implement and test. For instance, Kinkingninhoun et al. (2023) found in West Africa that women-only teams of extension agents attracted a higher proportion of women than men-only or mixed-sex teams. The study concludes that increasing the ratio of female agents could help reduce the gender disparity. This suggests that in some contexts, combining women facilitators and demonstrations can ultimately reduce gender inequality in technology, information and knowledge diffusion — an important implementation approach for STIBs. Another striking example is in Ghana, where some Muslim women, often excluded in receiving extension support, were more comfortable engaging with female extension officers (Nyantakyi-Frimpong 2019).

Co-identify differences in priorities and opportunities. Women operating, living and raising families within agri-food systems often have different requirements and preferences to men, so this needs to be taken into account when designing technical interventions (Doss 2001). Technical solutions should consider these differences when looking at opportunities available. For example, it is also important to design around the unique time-based and circumstantial constraints that women experience (Tarjem 2022). Kinkingninhoun et al. (2023) also found that women facilitators were more accommodating and understanding of these when working with women participants in West Africa. For home vegetable gardens, Hansen et al. (2022) emphasised the importance of co-designing the gardens with stakeholders, which can help increase buy-in and ensure the gardens reflect the needs of the women. The study found that the garden vegetable varieties and types varied dramatically — reflecting the availability of those types in local markets, soil type, cultural preferences, and so on.

A study in India highlights pathways for participatory learning and research projects, which emphasises the importance of including biological, social, cultural, economic and symbolic considerations. Some of these include discussions on the role of institutes, benefits of and threats to local varieties, socio-cultural value of crops, gender roles within the community, and so on (Singh et al. 2011). Women often play a major role in conserving local crop varieties and horticultural knowledge, passing it on to the next generation. For example, the same study in India highlighted women's major role as cultivators and custodians of an important local variety of rice. Male elders in the village act as mediators on price, aggregating demand within the

village and leveraging their position to ensure better prices for the female farmers. This variety is found to be more sustainable in the long run than other varieties and has become an important part of the culture. Indeed, the study recommends protecting the practices from encroachment by commercial farming (Singh et al. 2011). In this context, a STIB could consider how local gender roles can support and protect interventions like different crop varieties.

Home gardens are frequently aligned with women's unique capacities and constraints. A study in Kenya and Burkina Faso found that including women in the design of home gardens was central to adopting this time- and labour-saving technology bundle (Hansen et al. 2022).

Consider labour requirements for STIBs. Women typically have responsibility for household management as well as livelihood tasks. This makes them particularly sensitive to technical solutions that require additional time or labour. A clear example can be found with locally made, organic fertiliser, which reduces the need for and cost of synthetic fertiliser. But collecting and composting the organic material can be time consuming and labour intensive. This can pose a barrier for some women who either cannot access additional labour, or do not have the time themselves to collect and compost the materials. This is particularly the case for female-headed households. In a good example we highlighted previously, Hove et al. (2018) found that some women in Zimbabwe had limited time or resources. This made the labour-intensive creation and application of organic fertiliser challenging for some. A group of women in this study managed to come together and support each other to make organic fertiliser at different times of the year — but not year-round. This emphasises the importance of designing STIBs around labour requirements.

The example of gendered crop choices. Based on individual opportunities and limitations, men and women often express different preferences for crop varieties and traits. Crops appropriate for some women's preferences — resulting from several factors, including local gender norms — could include native varieties, climate-smart or sustainable varieties, but these will depend on local conditions. In Benin, Kloos and Renaud (2014) found that 'commercial cotton' was considered a 'men's crop'. Cultivation of organic cotton results in less cotton produced and therefore did not appeal to male farmers, who could also get access to the additional farm inputs needed for commercial production. As a result, organic cotton offered a gender-responsive solution to women, who were also usually relegated to marginal land. By working with women to become confident in growing organic cotton, they benefited from the 20% price premium, which compensated for the lower production (Kloos and Renaud 2014).

Tarjem (2022) unpacks the G+ Toolbox, a set of protocols which are useful in understanding gendered trait preferences and screening to help determine breeding priorities that are important for women.[3] Crops sometimes described as 'women's crops' will usually have lower market value and require higher amounts of labour to cultivate than so-called 'men's crops'. As a result, gender norms 'allow' women to cultivate them, so the individual's 'choice' to cultivate is not necessarily a meaningful one (Polar et al. 2021). The opposite is also true that if women become successful with a crop, there is a risk that men will try and claim that success.

Underutilised crop species or native varieties may also fall under the domain of women in some contexts. Often women tend to value the preservation and storage of seed of a number of indigenous and other crop varieties to maintain species diversity in mixed cropping systems (Rukmani et al. 2019). In the Columbian Caribbean, women grew over 70 different, staple and culturally significant crops to mitigate crop failure (Cely-Santos and Hernández-Manrique 2021). In Peru, women grow a diversity of native potatoes to protect biodiversity and achieve household food security (Molina et al. 2022).

Bundling gender-responsive technical innovations. When combined with other gender-responsive support in a single bundle, such as grants of money, inputs, equipment, and so on, there is promise of better outcomes in some contexts for female farmers. For example, in Zimbabwe, Chidakwa et al. (2020) found combining farmer training with credit, remittances, chicks and nutritional gardening enabled women to meet their need of household food security. Further, Warinda et al. (2020) found aggregating farmer training, inputs and credit allowed female farmers to effectively integrate within their agricultural production strategies. In Tanzania, Pamuk et al. (2022) demonstrated that combining farmer field schools — including topics such as crop rotation, intercropping, manure composting, mulching and soybean cultivation — with access to credit resulted in successful adoption, which led to higher incomes, and ultimately better nutrition.

In addition to gender analysis of inputs, bundling inputs with knowledge support is beneficial. A 2020 study (Blakstad et al.) shows that tailored input packages that combine giving seeds of nutritious vegetables in conjunction with health and nutrition training, result in better nutrition and health outcomes than conventional extension services, which only provided training on production. From this nascent evidence basket, we can start to see the paths that STIBs can offer when appropriately combined in local situations.

[3] For detailed explanation, see: https://www.cgiar.org/innovations/g-tools-for-gender-responsive-breeding/

5.3.3 Technology innovations and applications

Technology innovations and applications tend to favour certain interests and power holders. For example, the needs of smallholders, women and other marginalised groups are often overlooked when developing technologies and innovations — yet they are an important component of many agri-food systems (FAO 2022). Further, the outcomes and impacts of innovations and technologies can be difficult to measure. The FAO (2022) found that in agri-food systems; 'very few indicators that measure STIs (science, technologies, and innovations) can be disaggregated, again making it difficult to assess inequities'. Disaggregating indicators should be standard practice to measure and assess how innovations are being used by different types of people. Technology designed with gender equity in mind should result in similar outcomes for men and women, when considering the different trade-offs that they both experience. The same FAO report (2022) on innovation recommends understanding four key issues when designing contextualised innovations:

(1) Determine innovation maturity to solve problem

(2) Assess adoption with socio-cultural factors

(3) Determine scalability timeframe

(4) Assess transformative potential.

As previously mentioned, the studies tended to focus on technology only to the point of adoption — a major limiting factor in understanding what technologies actually work in the longer term, for which types of people.

Technology and climate information services (CIS) can be narrowly defined as information products — typically daily, weekly, monthly and especially seasonal forecasts and associated livelihood advisories. They provide climate information in a way that addresses climate risk when making livelihood decisions (Machingura et al. 2018). As such, climate information is the cornerstone of climate risk management and is the 'process for incorporating knowledge and information about climate-related events, trends, forecasts and projections into decision-making to increase or maintain benefits and reduce potential harm or losses' (Travis and Bates 2014). The objective is to factor in and evaluate climate risk, part of a broader risk management strategy for women and men working in climate-sensitive, agri-food systems.

Climate information services have been difficult for women to operationalise, but again, limited use of gender-disaggregated data makes the identification of gender-specific barriers particularly difficult (Berrang-Ford et al. 2021). When data disaggregation occurs, and problem identification is possible, research suggests women experience prohibitive gender norms around accessing climate information and acute structural barriers such as low literacy levels (Berrang-Ford et al. 2021). Gender analysis of climate information services in Ghana found that men and women differ in their access to and use of CIS primarily around access, with women less likely to own mobile phones as well as lacking funds to top-up credit. But women are more likely to incorporate CIS information into their farming practices, if they have the literacy and numeracy skills to interpret data and comprehend livelihood advisories (Partey et al. 2020). Further, research has shown that women favour particular types of climate information that meet their specific needs, such as drought forecasts and rain cessation predictions, that address their tendency to plant later than men (Tall et al. 2014). In the context of Niger, Adisa (2020) argues that proactive, timely and effective adoption of the dialogical, feminist approach strengthens women's participation in solar-powered irrigation technologies. The approach works by improving access to information for women, specifically using solar radios, and ensuring that women's voices are given equal weight to men through the dialogical, feminist approach in technology adoption and implementation decisions.

The available literature highlights evidence-based pathways to support women in accessing and using climate information. Given the restrictions for women in the use of digital and mobile technology, having access potentially reduces socio-cultural barriers associated with male-dominated, decentralised climate services and extension (Mittal 2016). In addition, in terms of use, reviews of empirical literature suggest ways of making climate information services more gender-responsive, including using women's groups as information-sharing networks, and by integrating CIS in the existing rural development programming, designed specifically to address women's resource and agency constraints (Gumucio et al. 2020).

5.4 Institutional, policy, infrastructure and regulatory support

Possibilities with public institutes and support. Local and national governments have an array of mechanisms to support the development of STIBs. These include development planning windows, regulatory support, policies and budget processes, among many others. Our review highlighted the power of government aggregation via a public procurement process, with Valencia (2021) showing how to leverage a national school feeding programme with the local procurement of food. It also detailed the role that social movements can have in supporting empowerment, and ultimately supporting women in the Brazilian context to establish more self-determination, making space for them to cultivate their own vegetable gardens. Public policy can leverage STIBs and offer opportunities and pathways for scaling them.

Extension services offer farmers critical technical support including training and advice on topics ranging from inputs to marketing — with the aim of more productive harvests for cash crops and higher income. Accessing these services may be difficult for some farmers. A survey in India found that 29% of male-headed households and only 18% of female-headed households had accessed extension services during the previous year (World Bank and IFPRI 2010). Similar statistics were found in Ethiopia. In Ghana, a survey found that 12% of male-headed households and less than 2% of female-headed households had accessed the same. Further, women from male-headed households were more likely to attend community or group meetings than the women who headed households. The study hypothesises that they have more time or attend with their spouses, but female-headed households get less access regardless (World Bank and IFPRI 2010).

These figures highlight an overall access discrepancy to extension programmes — alluding to overstretched services — but also the huge difference in access by gender. Women have much less access to these essential services in general. This should be considered when bundling activities together either through compensating through provision of direct advisory support to farmers or (less likely) advocating additional government support.

5.5 External drivers

Climate change. Women equipped to effectively support agri-food systems are central to the process of adapting to climate variability and change. Agriculture in developing countries has the highest climate sensitivity, especially in rain-fed smallholder settings (Howden et al. 2007). Intersectional disadvantages such as limited access to resources, ownership of assets and decision-making power coalesce to produce acute sensitivity and exposure to climate variability, coupled with inherently low adaptive capacity (Trisos et al. 2022). Supporting women to engage in agriculture also means more effectively improving climate resilience for women as individuals and heads of families.

5.6 Outcomes

Few studies that we reviewed from our long list of abstracts linked directly to outcomes, while most studies in our shortlist did provide specific outcomes, as presented in Table 3. From a conceptual point of view, it is useful to re-list some of the different outcomes we have already covered, all of which are closely related. For example, the four broad categories proposed by Njuki et al. (2022) from Figure 2 include: dietary outcomes, gender and equality and women's empowerment, economic and livelihood outcomes, and environmental outcomes. Similarly, our work integrated outputs and outcomes important to CGIAR (see Figure 6 for list), which are also closely linked to the HERS objectives: healthy and nutritious diets, equitable and inclusive value chains, resilience to shocks and stressors, and climate and environmental sustainability.

Empowerment came across as a strong outcome in many of the studies. Given our focus on gender, and the literature on gender focusing on different aspects of agency, including control of assets, we expected this. Other outcomes tended to focus on food security and diets, which is also reflective of how many societies see women's role in nurturing and protecting children and families. Fewer studies linked to aspects of livelihoods such as income and productivity. This could also be reflective of the constraints that women face in expanding their own sources of income or having equal say in how household income is spent.

Linking STIBs more closely to outcomes will be critical for moving the evidence base forward. This necessitates a comprehensive monitoring and evaluation of STIB interventions to try and attribute outcomes, while providing more detail in narrative studies. Some studies did not describe the intervention in detail, and many lacked supporting evidence for some claims around the mechanism change in people — many others did not

include a mechanism at all. Many of these are common flaws in evaluation studies, as White (2023) has found across global programmes. He also posits that 'most interventions don't work'. But he offers some concrete steps to move forward in a systematic way through 'Evidence Needs Assessments', which include setting up portals and accessible toolkits (White 2019). Moving towards the HERS objectives for agri-food systems necessitates better evidence that links to outcomes.

5.7 The loop of power and empowerment

Self-determination and empowerment are important concepts that have implications for everyone, but especially for women and other marginalised groups. A pivotal study highlights five important aspects of power that are relevant for framing our work, and how our practical framework might be used when considering empowerment activities.

These five different concepts show how power flows and interacts within the individual and through their relationships (Galiè a and Farnworth 2019):

1. 'Power within' — a transformation of individual consciousness which leads to a new self-confidence to act
2. 'Power with' — power that results from individuals organising and acting as a group to address common concerns
3. 'Power over' — suggests a social relation of domination or subordination between individuals
4. 'Power to' — power to bring about an outcome or resist change
5. 'Power through' — individual power won, and lost, through changes in the empowerment status of others, or through relating to others. In this process, the individual may not have acted.

In particular, the study's concept of 'power through' is relevant as an important caution of empowerment, which highlights the tension between 'gender-responsive' and 'gender-transformative' activities and programmes. In the study, some Tanzanian women explain their experiences of the process from being empowered to disempowered after they challenged gender norms via establishing independent income streams from their husbands. The husbands consequently reduced their support to the family, and some even divorced their wives, noting that their 'breadwinner' role as men had been undermined. This left the women and their families more food insecure and feeling disempowered (Galiè a and Farnworth 2019). This brings up an important ethical dimension of empowerment. If the process of empowering leads ultimately to disempowering, this is certainly not a just outcome and should be avoided. Considering 'gender-responsive' and 'gender-transformative' activities in bundles, the context will be critical in understanding potential outcomes (intended and unintended), and how best to frame empowerment approaches.

In sum, the literature provides a wide range of empirically demonstrated, individual components of STIBs that can empower women (and men) according to their unique needs and qualities. Table 1 sets out an overview of the main themes, the mechanism started by the initiatives and the gender-sensitive and/or transformative dynamic to be considered. The literature suggests ways to support women to:

a) Access resources, through social capital
b) Facilitate communication and decision making between men and women through intra-household initiatives
c) Structure more suitable and appropriate technical input design
d) Enable access to information and facilitate comprehension for women and knowledge sharing, and
e) Make training more suitable in terms of ensuring it is well aligned with women's needs and attributes.

6

Next steps towards empowerment and resilience outcomes

The literature set out in this working paper offers some examples of innovations in agri-food systems that support women and men in achieving desired outcomes. This again highlights the fact that empowerment of women and men together, for achieving gender equality, is central to effective engagement in agri-food systems. Each documented and described example offers empirical- and case-based insights. But the literature is yet to aggregate findings together on STIBs for women to accurately guide practitioners as they design and implement technologies. This aggregated perspective was illustrated within the STIBs framework. The process resulted in the following recommendations:

Recommendation 1: Trial the practical framework in the formulation of STIBs projects and programmes. The STIBs framework is an opportunity to systematically think through future projects and programmes to develop and promote agricultural technologies in terms of the characteristics and attributes of women and the contexts they live in. We recommend that the heart of the process be a gender-integrated, situational analysis that will support designers and communities to understand the context and attributes of women and men operating in agri-food systems. The results of the situational analysis will guide the plan and implementation of STIBs that women can adopt and use, and that ultimately become ongoing habits and practices. The International Food Policy Research Institute's (IFPRI) 'Reach-Benefit-Empower Framework' might be useful in building up an intersectional approach that considers various disadvantages that people experience (CGIAR 2020), in conjunction with our practical framework. Ultimately, we stress that these processes must be inclusive and co-designed with the people who will interact with the STIBs.

Recommendation 2: Develop guidelines and staff specialism in gender-integrated situational analysis. The STIBs framework identifies a gender-integrated, situational analysis as key to systematically incorporating the qualities and advantages women have with the characteristics and opportunities of the context. A situational analysis for gender-integrated STIBs requires a specialised yet lean guideline to be developed and trialled by practitioners. Further, personnel with the necessary skills and experience would be required to support the development and operationalisation of the guidelines.

Recommendation 3: Layer STIBs technologies and interventions within a wider set of local planning initiatives for agri-food systems. The STIBs framework is designed to support empowerment by designing and implementing innovative technologies to meet the differentiated needs of women and men. However due to the experimental nature of STIBs for women, there need to be risk mitigation safeguards in place to account for limited success in the early years when learning is taking place. This can be achieved in part through engaging local planning to ensure that social protection and other safety net and risk transfer programmes are available to women should they require additional support. Examples relevant to rural planning for livestock and agriculture include public works and livelihoods initiatives within the Productive Safety Net Programme in Ethiopia (Federal Democratic Republic of Ethiopia 2022) and the Mahatma Gandhi National Rural Guarantee Scheme (MGNREGS) in India (Kaur et al. 2017), as well as social cash transfer schemes with climate shock-responsive functionality, such as the Hunger Safety Net Programme (HSNP) in Kenya (NDMA 2016). Each have gender-focused, procedural and operational safeguards that support the substantive and effective engagement of women.

Recommendation 4: Develop monitoring, evaluation and learning (MEL) process for women and STIBs. The STIBs practical framework is designed to support women and men to engage with innovative technologies. As such, there is a considerable knowledge-building component to assist designers, implementers and people, particularly women, to determine what has worked, for whom, and how. A MEL system should be created that tracks key outcomes from STIBs-related projects and programmes, and which collects data on the individual as the unit of analysis. Besides gender-disaggregated data, programmes should ethically collect information where possible on other important characteristics so that an intersectional lens can move beyond binary gender norms, and into other important characteristics like age, ethnicity and so on.

Recommendation 5: Systematically develop and implement longitudinal studies to build the evidence base. This working paper highlighted a large gap in the literature when it comes to what works, where, and how for STIBs. The four recommendations above provide practical points for how to move forward with implementing STIBs. However, it will also be important to test different types of bundles in different contexts in a systematic way, to identify and build on the common threads between contexts. Donors will need to be bold in funding STIBs longitudinal research and development efforts, with long-term, multi-year timelines, to fully understand outcomes and impacts for women and gender equality, to ensure that agri-food systems of the future can be sustainable and just.

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Acronyms

AFS	Agri-food systems
CGIAR	CGIAR System Organization
CIS	Climate information services
C–M–O	Context–mechanism–outcome
FAO	Food and Agriculture Organization of the UN
FFBS	Farmer field business schools
GALS	Gender Action Learning Systems
HERS	*see Figure 1*
HHSS	*see Figure 1*
IFPRI	International Food Policy Research Institute
MEL	Monitoring, evaluation and learning
NDMA	National Drought Management Authority (Kenya)
STIBs	Socio-technical innovation bundles
VSLA	Village savings and loans association

Successful outcomes for agri-food systems and the communities that rely on them are dependent on a whole range of factors and situations. Innovative technologies must align with these to stand any chance of achieving the goal of healthy, equitable, resilient and sustainable systems. These interventions can be better understood and applied using so-called 'socio-technical innovation bundles', or STIBs. This working paper looks at the experiences of women, particularly in marginalised situations, and the outcomes that are possible for them and their families. It proposes a practical framework to support researchers and others, and invites practitioners to trial this so that a much-needed evidence base can be built.

IIED is a policy and action research organisation. We promote sustainable development to improve livelihoods and protect the environments on which these livelihoods are built. We specialise in linking local priorities to global challenges. IIED is based in London and works in Africa, Asia, Latin America, the Middle East and the Pacific, with some of the world's most vulnerable people. We work with them to strengthen their voice in the decision-making arenas that affect them — from village councils to international conventions.

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