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Research Paper

Inclusive and gender-transformative seed systems: Concepts and applications

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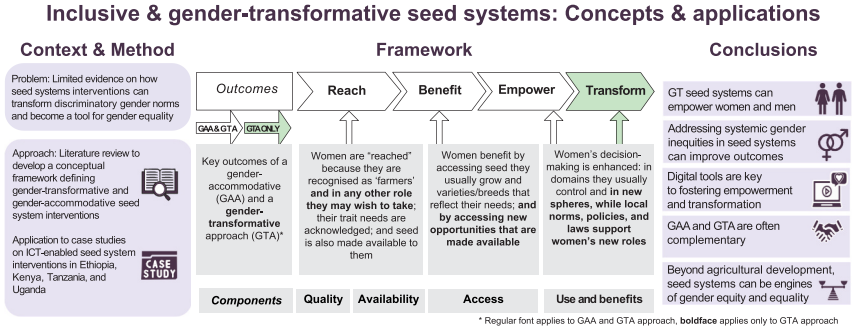
HIGHLIGHTS

- Gender transformative seed systems can create a conducive environment for women's empowerment to materialize.
- Gender equality through transformational change is necessary for effective seed systems.
- Social media can be a powerful strategy to impact social and gender norms at various levels of seed systems.
- Transformative approaches may have an empowering effect on men: less restrictive gender norms benefit everyone.
- Seed systems support livelihoods and gender equality when transformative approaches are intentionally adopted.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Seed is vital to the nutrition and livelihoods of millions of women and men small-scale farmers in low- and middle-income countries. Seed systems interventions can significantly enhance food security and nutrition by accelerating the adoption of improved varieties and the use of quality seed, which in turn increase the rate of genetic gain, productivity, and household welfare. These interventions can be particularly effective when advancing gender equality by supporting women's empowerment and addressing discriminatory gender norms. However, there is relatively little evidence on the ways in which seed systems can be an entry point for advancing gender equality by transforming discriminatory gender norms.
OBJECTIVES: We develop and illustrate a gender transformative approach applied to seed sector development. Our first objective is to provide a framework to better understand how seed systems interventions can contribute to gender equality by (1) integrating gender-accommodative and gender-transformative approaches; and (2) assessing their gendered impacts. Our second objective is to apply this framework to a particular innovation – gender messaging via information and communications technologies (ICTs) – and explore how seed system interventions can be made more gender-transformative.

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METHODS: We first reviewed the existing literature to develop a framework that defines gender-transformative and accommodative seed system interventions and their impacts. We then synthesized lessons learned from the application of this framework to case studies from Ethiopia, Kenya, Tanzania, and Uganda that used ICTs that contained gendered components.
RESULTS AND CONCLUSION: We discuss how a gender-accommodative approach aims for gender considerations to improve seed systems, while a gender-transformative approach flips the goal around by aiming at progress toward gender equality through seed systems. We find growing evidence on the potential of gender-transformative seed systems interventions to influence positively the empowerment of women and also men, and to create more conducive gender norms, as shown by three case studies on ICT enablers. These case studies also show that accommodative and transformative approaches are often complementary.
SIGNIFICANCE: We introduce research questions that research and development practitioners can ask to develop accommodative or transformative approaches in seed system interventions, and show the potential of both approaches to progress toward gender equality. The case studies indicate the feasibility of gender-transformative, ICT-enabled seed system interventions, with clear indications of the potential for low-cost adaptation at scale. However, the transformative potential of these interventions requires careful consideration of messaging content, format, and context, as well as strategic public investment and strong political will.

1. Introduction: Gender considerations in seed sector development

Seed sector development is central to local and global efforts to accelerate agricultural productivity growth and improve food and nutrition security in low- and middle-income countries (LMICs). In this study, we define seed as any propagation material used in the cultivation of crops, trees, fodder, forages, fish, and livestock. Seed is the very start of the food value chain: it provides food and sustenance, incomes and livelihoods, and the essential biodiversity that forms the basis of a healthy food system and agro-ecosystem. As such, seed is essential to the livelihoods of both women and men farmers, particularly small-scale, resource-poor farmers (Delaquis and Almekinders, 2020; McGuire and Sperling, 2011; Nabuuma et al., 2020).

Currently, however, women's ability to leverage seed to improve their households' livelihoods is limited because seed systems fail to address their needs. Generally, women are more disadvantaged than their male counterparts in several dimensions of empowerment related to agriculture, which is also referred to as a 'gender-based disadvantage' (Alkire et al., 2013; Galiè et al., 2022). Gender refers to the identities and expectations associated by society to a certain sex, which are in turn affected by power relations that intersect with other social markers (e.g. age, ethnicity), and which influence access to and control over resources and opportunities. When these identities and expectations become 'normalized' into stereotypical images of a 'woman' or 'man' (across other social markers), they can be referred to as 'gender norms'. When gender norms are not conducive to gender equality, we refer to these as 'restrictive gender norms'. These may include, for example, norms that establish that it is not appropriate for women to drive a motorbike or frequent markets.

Despite the central role of gender norms in shaping agri-food systems, gender considerations are poorly integrated into seed sector development. Yet there may be considerable variation between the priorities, preferences, and opportunities that are available to different women and men in seed systems. First, there can be differences in priority crops and breeds for women and men. For example, women in charge of the manual harvesting of crops may prefer crops with traits such as smooth stems that make manual harvesting less onerous, whereas men tasked with mechanized harvesting may prefer taller crops that are more suitable for threshers (Ceccarelli et al., 2012). Or women tasked with the daily management of livestock may prefer docile goats that are easier to manage, while men tasked with marketing the animals may prefer heavier animals that generate higher profits (Cavicchioli et al., 2023; Kariuki et al., 2021). Moreover, women may possess different types of knowledge and preferences from men on issues such as seed use, selection, and storage, based on their uses of the crop or livestock itself (Nordhagen et al., 2021; Scurrah et al., 2013; Zaremba et al., 2021). These in turn affect the traits that seed may need to have to be useful to the farmers.

These gendered dimensions of trait preferences are increasingly acknowledged in breeding programs, though still not fully mainstreamed nor fully visible in the public and commercial seed distribution channels that they utilize (Ashby and Polar, 2019; Voss et al., 2023; Ndabashinze et al., 2024). Generally speaking, these channels develop and distribute varieties and seed designed for the male farmer, typically assumed as the sole decision-maker over what crops or species to choose (McDougall et al., 2023; Murphy et al., 2020; Tufan et al., 2018). As a result, quality seed of improved varieties or breeds mainly benefit men, widening gender gaps in rural areas, and they may not be adopted when women have a say in varietal choice because traits were not selected with women's preferences in mind (Tufan et al., 2018; Polar et al., 2021).

Second, together with gendered preferences and needs, gender norms may also affect the spaces and people women and men can frequent, and therefore the channels that reach them. In many contexts, farmers, especially women, tend to rely on informal channels — highly localized social networks and kinship structures that are critical to conserving biodiversity — to source their seed (Coomes et al., 2015; McGuire and Sperling, 2016; Nkengla-Asi et al., 2020; Rietveld et al., 2023). Local gender norms generally limit women's mobility and their ability to liaise with unrelated men such as male agro-dealers or farmers, thereby restricting women's options to source seed. Yet, the informal seed channels that women use are often disconnected from breeding programs and formal seed distribution networks, thereby limiting access to seed with improved genetic or physical attributes (Kilwinger et al., 2020; Puskur et al., 2021).

Third, seed marketing and dissemination strategies are rarely geared toward women's specific knowledge, needs, and preferences (Dalton et al., 2009; Nagarajan et al., 2009). For instance, extension and advisory services can play a key role in providing farmers with access to quality seed and useful information. Given that seed is an 'experience good', such that its quality or performance cannot be evaluated until it has been used, access to information often determines a farmer's adoption of a new variety or trait. Yet, in many LMICs, women face systematically lower levels of access to extension and advisory services compared to their male counterparts (who already have limited access to formal information channels, especially in remote rural areas), thereby inhibiting access to information on crop and livestock management (Badstue et al., 2018; Kramer and Galiè, 2020). Moreover, women may have limited control over household income, and limited access to financial services such as credit or insurance, making it more difficult for them to purchase more expensive seed (Rietveld et al., 2023), posing a challenge to women's equitable and beneficial participation in seed sector development at the farm level.

Fourth, these gender-based challenges extend to the marketing node of the seed system, where women and men traders and entrepreneurs

sell seed to farmers. The abovementioned constraints to information, financial services, control over income, and decision-making power can limit women's ability to become viable seed producers, entrepreneurs, and traders (Farnworth et al., 2024a, 2024b; Galiè et al., 2017; Mason and Ricker-Gilbert, 2013; Mudege et al., 2015). Gender norms may hinder the ability of women to obtain loans for their business, drive vehicles to transport their products, or be trusted by their customers as providers of technical expertise (Mudege et al., 2018; Rietveld et al., 2023). Gender norms may also affect how (male) buyers perceive (female) seed sellers and negotiate prices, possibly to the detriment of the latter (Van Campenhout and Nabwire, 2023).

Gender-based disadvantages in seed systems can stifle the considerable potential that women have as farmers, livestock keepers, traders, and entrepreneurs, while also limiting the potential of seed systems in supporting livelihoods. Women's empowerment is considered both a means to reduce the gender-based disadvantage, and an end in itself, being inscribed in the SDGs (particularly SDG5). Most efforts toward seed sector development, including those that do consider gender, will however only engage with gender issues as a means to improve the sector. They will therefore mostly take into account existing gendered roles and preferences to develop better targeted interventions. When considering women's empowerment as an end in itself, on the other hand, more complex gender dynamics are likely to emerge, such as for example, gender norms.

Gender norms are the main obstacle to empowering women (Achandi et al., 2023). Transforming such norms is therefore necessary to create a conducive environment in which empowerment opportunities can actually benefit women. This calls for moving from approaches that do not intentionally address gender norms (referred to as gender-accommodative approaches, GAAs) to gender-transformative approaches (GTAs). GTAs are defined as approaches that aim to intentionally address restrictive gender norms, to create a conducive environment for women's empowerment and gender equality. While GTAs were introduced in the development sector a few decades ago, there is little evidence of studies that apply GTAs to seed sector development. Also, the existing literature on seed systems with a gender lens offers minimal evidence on the outcomes, impacts, or cost-effectiveness of approaches that aim to empower women or transform gender norms in the seed sector (Kramer and Trachtman, 2023). Finally, discussions and recommendations on seed systems interventions tend to focus on how to increase women's involvement in current (male-biased) systems rather than how to transform seed systems and their underlying gender relations toward more equality (see for example Puskur et al., 2021).

The aim of this paper is to stimulate research and development communities involved in seed sector development to consider: (i) the potential of seed sector interventions to catalyze transformative change toward gender equality; (ii) the likely impacts of accommodative and transformative approaches toward gender equality in seed sector outcomes; and (iii) exemplary questions and examples of engaging with GTAs and GAAs in seed sector development. To that end, we discuss the ways in which seed sector development can be leveraged to support women's empowerment with a focus on the potential of interventions in the seed sector to transform restrictive gender norms. We first present a number of gender-accommodative and gender-transformative questions that can guide planning seed sector interventions. We then discuss what impacts these approaches toward planning an intervention can have on the ground, based on the Reach-Benefit-Empower-Transform Framework proposed by Johnson et al. (2018). Finally, we present empirical evidence from three case studies, illustrating how the application of GAAs and GTAs in seed systems development can create strategic entry points to empower women and transform inequitable gender norms.

2. Methods

This study emerged out of a few targeted efforts by international agencies to consider gender equality in agricultural development in LMICs that involved the authors of this paper. These include the 2017 CGIAR Gender & Breeding Postdoctoral Fellow (PDF) Capacity Development Initiative which aimed to integrate gender experts in its breeding work (across crops, fish, and livestock); the Netherlands-CGIAR seed systems development program implemented from 2019 to 2022; and the Integrated Seed System Development-Africa (ISSD-Africa) program, which was launched in 2019 and included a research theme on gender dynamics in seed systems. The body of work that emerged from these programs (Kariuki et al., 2021; McDougall et al., 2023; Farnworth et al., 2024a, 2024b; Kramer and Trachtman, 2023) showed the potential of seed systems to support women's empowerment and perhaps even have transformative implications for gender norms (Galiè et al., 2017; Kramer and Galiè, 2020). Given the growing yet still limited evidence on the effectiveness of GTAs in agriculture, we decided to further explore the topic through expert consultations, literature reviews, and case studies, to to stimulate further discussions on this topic.

We started by listing relevant literature that contains components related to gender analysis in seed systems. Jointly reviewing the articles helped us develop an overview of what gender considerations are important in each of the key components of a seed system (Table 1). This overview was built also on our own experience and those of colleagues conducting gender research for development in seed systems. Through the literature, we identified the Reach-Benefit-Empower-Transform (Fig. 1) as a useful framework to assess how seed interventions could affect gender equality and women's empowerment. On this basis we engaged in a series of virtual and in-person discussions, partly facilitated by the international agencies listed above, in which we aimed to conceptualize how GAAs and GTAs applied to each component of a seed system may affect gender equality. Finally, we applied this framework to relevant case studies in Ethiopia, Kenya, Tanzania, and Uganda that used information and communications technologies (ICTs) with gendered components to illustrate empirically how this framework can be used to guide seed sector development. Four of the authors were involved in these case studies.

3. Conceptual framework

In this section, we introduce several conceptual framings to improve our understanding of the relationships between seed sector development and gender dynamics. We begin by defining a set of key terms and terminology used throughout this paper. We then introduce two broad approaches to addressing gender-based needs and preferences—accommodative and transformative approaches (Aregu et al., 2019; Cole et al., 2020)—and their implications for gender equity and women's empowerment. Finally, we describe the Reach-Benefit-Empower-Transform framework (Johnson et al., 2018) that can be used to assess the gendered impacts of an intervention.

3.1. Key terms and concepts

As mentioned in the introduction, gender refers to the identities and characteristics associated by society with a certain sex and which are affected by expectations also associated to other social markers (e.g. age, ethnicity). In this paper, we limit our discussion to women and men as the two main gender groups of interest, based on the extensive body of literature showing the importance of inter-gender differences between these two groups, particularly with respect to agriculture and rural livelihoods. However, we fully acknowledge that non-binary perspectives on these same topics exist, are equally valid, and require targeted research, particularly in contexts where non-binary identities are not accepted.

Gender-based identities become informal rules that communities hold about what is 'normal' for an individual of a specific sex (and age, ethnicity, or religion, among other identities) to own, do, share, say, like, and so on. These informal expectations are called 'gender norms'; they are specific in time and context, and are kept in place through both

Table 1
Key accommodative and transformative gender considerations applied in seed system interventions.

Key seed system components	Key characteristics of each component	Gender accommodative considerations in each component	Gender transformative considerations in each component
Seed quality: standard that determine the potential performance of a seed lot	Healthy seed Physiological, genetic and physical qualities Resilient to shocks	Who cultivates the chosen crop and species? What are their trait needs and preferences in the chosen crop/ species?	What seed (crop/ varieties, species/ breeds) can potentially support women's and girls' empowerment based on roles they may aspire to take in farming? What trait preferences and needs do women and men have that can help them leverage seed to achieve their aspirations?
Availability: the physical existence of enough quality seed at the right place and time from the right source	Multiplication (based on demands and needs) Delivery channels, seed sources, and storage options	Whose needs and preferences does this seed variety/ breed reflect? Who is reached by the seed? How?	What delivery system would make seed available to women and men for similar transaction costs? How can the gendered reach of delivery channels and sources be improved?
Access: ability and willingness to acquire seed (through purchase, exchange, loan and barter) and related information	Awareness Affordability Mobility Social networks	Who has access to information on available seed? Who can access and control resources needed to access the seed? Who can access the seed sources? Who has what social networks to access seed?	Under what conditions can women sustain their access to this seed?
Use and benefits: ability to decide what crops, species, varieties, or breeds to source and grow/raise, and how to use the associated benefit	Legal frameworks (global, national) Other practical constraints Access to other resources	Who (among men and among women) are likely to benefit/be negatively affected by a new seed policy or regulation?' What are enabling environment and constraints to replant or sell the seed for women and men? Who controls the resources needed to benefit from seed?	What policies and regulations need to change for women and girls to be able to use and benefit from the seed or associated opportunities? What norms need leveraging or addressing for women and girls to be able to use and benefit from the seed or associated opportunities? How does access to resources need to change for women and girls to be able to use and benefit from the seed and associated opportunities?

Source: Authors, adapted from Galiè et al. (2021) and Kilwinger et al. (2020).

informal and formal social, economic, and political mechanisms that punish those that do not conform and praise those that do. Gender norms become formally institutionalized when they shape written rules such as, for example, laws and regulations. Gender norms shape who can, for example, access and control resources and opportunities, do certain activities, take decisions, or show a dominant behavior. In agri-food systems, gender norms affect the roles women and men play in agriculture (called 'gender division of labor'), their needs, opportunities, and constraints, and also their ability to use, own, exchange, and conserve seed, which ultimately affects their ability to participate in and benefit from seed systems (Kramer and Trachtman, 2023; Marimo et al., 2021; Otieno et al., 2021; Sachs et al., 2014). The ways in which gender norms are translated into daily arrangements within households and communities are negotiated through everyday social interactions. We refer to such complex and changing relationships and interactions between and among various genders as 'gender dynamics.' In most societies and economies, restrictive gender norms and dynamics disadvantage women and girls compared to their male counterparts. This is called a 'gender-based disadvantage'.

Women's empowerment is considered key to addressing gender-based disadvantages. Women's empowerment refers to a process of change whereby women gain the capability to live the life that they value (Sen, 1990). In the context of seed sector development, supporting women's empowerment entails ensuring that women can leverage the sector to achieve their set goals on an equal basis with men. Progress toward women's empowerment, however, is hindered by the very gender norms that shape such disadvantages. In other words, restrictive gender norms are a major hindrance to women's empowerment (Achandi et al., 2023).

Traditionally, interventions that support women's empowerment have not intentionally addressed gender norms. We use gender-accommodative approaches (GAAs) as an umbrella term to refer to any method, tool, or intervention that recognizes men's and women's specific needs and realities and responds to them by developing interventions reflecting existing gender roles and responsibilities. GAAs do not intentionally challenge restrictive gender norms but work around them. While GAAs have been the main approach in gender-responsive agricultural development for decades and have been an important first step to address gender in seed sector development, as an unintended consequence, GAAs can reproduce and strengthen gender-based disadvantages. For instance, a dairy value chain intervention could train women on milk processing and men on marketing skills, to align with a given local gender norm that 'women are responsible for household chores and men for marketing, with control over the generated revenue'. If such an approach results in higher-quality dairy produce that fetches a higher market price, women may not benefit, as they are traditionally not involved in marketing and sales activities. Further, this may exclude them from marketing even more, particularly after reasserting men's role in marketing through the very training, emphasizing milk as a marketable commodity. Tavenner and Crane (2018) show that women may even lose control over milk for household consumption that they may have had before the intervention. GAA critics argue that meaningful and sustainable progress toward gender equality is only possible when formal (laws, policies, written regulations) and informal institutions (local traditions, beliefs, and norms reproduced through social interaction) are transformed (Pyburn and Hallin, 2023).

We refer to gender-transformative approaches (GTAs) as an umbrella term to include any method, tool, or intervention that aims to intentionally address the root causes of gender inequality by addressing restrictive gender norms (McDougall et al., 2023). GTAs do so, for example, by engaging communities to reflect on inequitable gender norms (e.g., "a good woman should not leave the house to go to the market"), thereby raising awareness of norms that cause harm or restrict positive developments (Badstue et al., 2020). Because gender norms influence both formal (e.g. policies, laws, and regulations) and informal (unwritten, tacit beliefs and practices) rules, GTAs engage with various

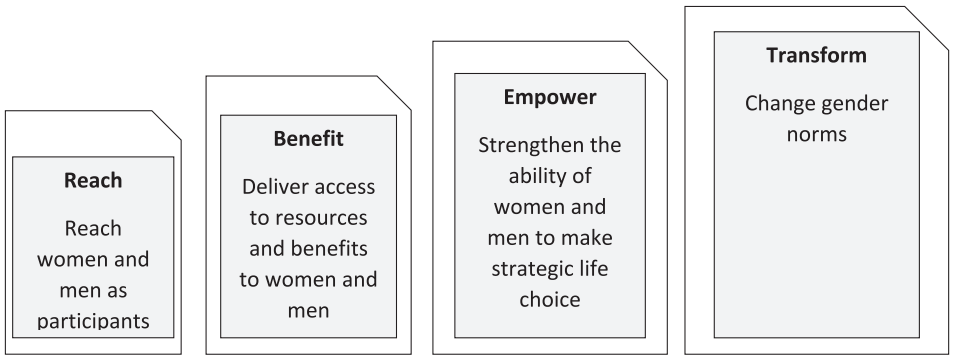

Fig. 1. The Reach-Benefit-Empower-Transform Framework.
Source: Authors, adapted and elaborated from Quisumbing et al. (2023)

levels of society that shape such rules. They therefore also address gender discrimination in formal institutions by, for example, engaging decision-makers from communities to national level, to both appreciate how policies and regulations may inadvertently disadvantage one group, and to formulate more gender-equitable rules. Supporters of GTAs argue that sustainable development toward gender equality can only be achieved when the root causes of gender discrimination – identified as restrictive gender norms – are addressed.

While the boundaries between GTAs and GAAs are clear at the level of interventions (with those aiming to change restrictive norms being considered transformative, and others accommodative) – they can be blurry in terms of their outcomes. For instance, approaches that start as accommodative may still change norms. For example, strengthening women's milk processing skills may reinforce their traditional roles, rather than supporting women's access to markets to gain an income. However, in the longer term, it may increase the visibility of women's work, because without it, men would not have dairy products to sell at the market. As a result, women could be able to claim some of the milk revenues. The norm that 'women are responsible for household chores and men for marketing, with control over the generated revenue' may start to transform. In some contexts, a GAA with the potential to slowly transform gender norms may be more appropriate than a GTA that may encounter more resistance from the community by addressing existing norms (for example, by questioning why women in that community cannot frequent the market) head on. GTAs and GAAs can be, and often are, complementary approaches to respond to gendered needs and opportunities, and progress toward gender equality (Njiru et al., 2024). Which approach to adopt needs to be decided on a case-by-case basis, and we acknowledge that, in some cases, GAAs can help take the initial step to address gender in seed sectors.

Finally, we often refer to the goal of gender analysis in seed systems as progress toward gender equality. With gender equality we refer to an ideal state where diverse women and men, boys and girls, have assets and opportunities necessary to achieve life outcomes that are of equal value, regardless of how different the life outcomes that they choose, and value are. Gender equity, on the other hand, refers to the process of ensuring that men and women have equal opportunities and outcomes by intentionally addressing and compensating for gender-based disadvantage: gender equity is a means to achieve gender equality (UNICEF, 2017).

3.2. The reach-benefit-empower-transform framework

We will use the Reach-Benefit-Empower-Transform framework (Johnson et al., 2018; Quisumbing et al., 2023) to discuss how GAAs and GTAs applied to seed sector development may affect gender equality in outcomes. This framework was developed to assess the extent to which a given program or intervention impacts its stakeholders in terms of gender equality. The four steps indicate a crescendo of progress toward gender equality to which a given project may contribute (see Fig. 1). 'Reach' entails the ability of a project to involve women and men as participants in a given activity. 'Benefit' goes beyond simply involving women and men as participants and entails also supporting them with accessing resources and benefiting from them. 'Empower' entails strengthening the ability of all, women and girls in particular, to make strategic life choices (see the definition of women's empowerment above).

Empowerment, however, is not intrinsically transformative. Progress toward empowerment can be achieved without addressing the restrictive gender norms that form the root cause of gender-based disadvantages. For example, increasing a woman's decision-making in food preparation through expanding her skills set or knowledge base (e.g., by training her on cooking practices that maintain the nutritional value of food) empowers her but does not change the restrictive gender norm that women only are caregivers and responsible for domestic chores. On the contrary, 'transform' entails changing gender norms at various societal levels to create a more conducive environment for empowerment with more equitable systems. For instance, continuing our example, 'transform' would entail questioning why women are responsible for domestic chores by themselves, and why domestic chores are not shared between women and men more equitably.

3.3. The key components of a seed system

We focus on four key components of a seed system: seed quality; seed availability; seed access; and seed use and benefits. 'Seed quality' refers to the potential of seed to perform well in terms of both its physical qualities (germination rate, purity, absence of pests and diseases) and its genetic characteristics (yield, duration, biotic and abiotic stress tolerance) for different end uses and end users (McGuire, 2001). 'Seed availability' refers to the physical existence of enough quality seed in a given place, at the right time for it to be used (Puskur et al., 2021). 'Seed access' refers to whether or not the farmer has the ability and willingness to acquire seed (through purchase, exchange, loan, and barter) and related information (see also FAO (Food and Agriculture Organization of the United Nations), 2024; Spielman and Kennedy, 2016). 'Use and benefits' refers to the ability of a farmer to decide what crops, species, varieties, or breeds to source and cultivate, and how to use the associated benefit (Puskur et al., 2021).

4. Gender accommodative and transformative research questions in seed systems

4.1. Gender-accommodative research questions

Table 1 (third column) lists research questions that are typically asked when applying GAAs. When applying a gender accommodative lens to shape a seed system intervention, the overall question that is

typically addressed is: "How can applying a gender lens improve seed systems in terms of effectiveness and equality?" When addressing the issue of *seed quality*, a key gender consideration within an accommodative approach could translate into a question such as 'who cultivates the chosen crop and species?' and 'what are their trait needs and preferences in the chosen crop/species?'. For *seed availability*, GAAs are responsive to issues such as how seeds are multiplied by women and men and why. To make seed *accessible* to both women and men, GAAs will consider under what conditions women and men can access the seed and who is likely excluded from the system and why. Finally, in the area of *use and benefits* of seed, one could ask 'what are enabling environment and constraints to replant or sell the seed for women and men?' and 'who (among men and women) is likely to benefit from a new seed policy or regulation?' (e.g., Galiè, 2013). Other social markers that intersect with gender (e.g., ethnicity, age, marital status – their importance depending on the local context) need to be considered in each of these questions (e.g., Tavenner et al., 2022).

4.2. Gender transformative research questions

The focus of GTAs is on how seed systems interventions can intentionally address the root causes of gender inequality (gender discriminating norms) embedded within the system itself and be leveraged in ways that make seed systems themselves catalyzers of transformative progress toward gender equality by establishing equitable and inclusive seed systems. In the transformative approach, gender questions applied to *seed quality* can include 'what seed (crop/varieties, species/breeds) can potentially support women's and girls' empowerment based on roles they may aspire to take in farming?' (Table 1, last column). When addressing issues of *availability*, possible questions can include 'what delivery system would make seed available to women and men for similar transaction costs?'. In terms of *access*, researchers and practitioners will want to understand 'under what conditions can women sustain their access to this seed?'. When addressing *use and benefits*, one could ask 'what needs to change for women and girls to be able to use and benefit from the seed?'

We illustrate the difference between transformative and accommodative questions using the *seed quality* component. GAAs will consider 'Who cultivates the chosen crop and species?' to diagnose who currently does what in crop and livestock farming in order to target the 'very person involved in a given crop or species cultivation activity' when improving the quality of seed. In our dairy example, if women are involved in feeding cattle and cleaning the shed and men in marketing, the intervention will involve women in identifying good forage varieties and men in identifying good breeds for the market. This approach does not question whether such division of labour is equitable or supportive of women's and men's aspirations beyond the status quo, and consequently, the intervention is likely to reproduce the (gender-discriminating) status quo: women will have a more palatable forage to continue feeding the cattle while men will make more money by selling better breeds. Clearly, the empowerment outcomes of the resulting intervention are inequitable (see also 3.1, example on GAAs).

Gender-transformative seed systems are therefore characterized by a combination of:

1. Realizing the transformative potential of diverse seed systems, taking into account, among others, the value of a commodity or how it is traditionally associated with women's and men's gendered identities.
2. Providing women with access to resources they rarely own but need for seed security (e.g., land or machinery) by catalyzing norms that enable more equitable control over these resources.
3. Enhancing women's control over and decision-making in domains that traditionally belong to men (e.g., leading a seed firm). Addressing gender inequitable norms that assign to men the role of main decision-makers, breadwinners, and leaders in the household and community.
4. Providing women with access to opportunities they are usually excluded from (e.g., pond aquaculture, starting new seed businesses, or accessing financial services); and engaging women and men in identifying and finding locally desirable ways to shift constraining norms and stereotypes embedded in these so that a conducive environment is created for women to take full advantage of these new opportunities.
5. Engaging with 'positive masculinity' and new spaces and ways of being for men beyond traditional/patriarchal gender norms (for instance, as caregivers or helpers) to create more equitable 'recognition', 'division of labor', and 'intrahousehold decision-making' that can help empower both women and men with attention to intersectionality issues.
6. Supporting recognition and acceptance by communities at various levels (for instance rural, scientific, and policy-making communities) of women and men taking unconventional gender roles (such as women recognized as seed agri-preneurs, providers of artificial insemination, chicken vendors, hatchery and nursery operators; men valued as caregivers, or 'soft' leaders).
7. Advocating and building evidence for and with formal institutions to create conditions and policies that enable and support gender transformation.
8. Diversifying methodologies for understanding seed systems and for measuring impacts such as feminist approaches and interdisciplinary research.

Answering the questions in Table 1 would guide the design of gender-accommodative or transformative interventions in seed sector development. GAAs and GTAs are complementary and while gender accommodative questions are a necessary minimum standard for gender integration in seed system development, gender transformative approaches can be adopted when there is an intentional effort to address restrictive gender norms and the expertise to do so (Njiru et al., 2024).

4.3. Outcomes of accommodative and transformative approaches in seed system interventions

In the process of identifying key questions that seed system experts may want to engage with to be more gender-responsive – which is the focus of this paper – the RBET framework could serve two purposes: First, it can be used at the very beginning of the process to help orientate the experts on whether they want to adopt an accommodative, transformative or mixed approach. Second, it can be used after the research questions to be answered have been identified, in order to assess the likely outcomes of an intervention shaped on such questions. Here, we focus on option 2. We discuss the possible outcomes of an accommodative and transformative approach applied to a seed system intervention, on its beneficiaries. When looking at seed systems that apply GAAs, we can assess how they might impact women and men seed users. Fig. 2 shows that integrating accommodative considerations in 'seed quality' and 'seed availability' will increase the chances that the seed system reaches both women and men. Ensuring gender-accommodative considerations are integrated into 'seed access' also, can improve 'reach' of seed users by enhancing their access to resources (i.e., information on good seed, and financial inclusion to improve access to quality seed). Finally, when GAAs address 'seed use and benefits' with an accommodative gender lens, they can contribute to 'decision-making', the key component of empowerment. Seed systems can contribute to

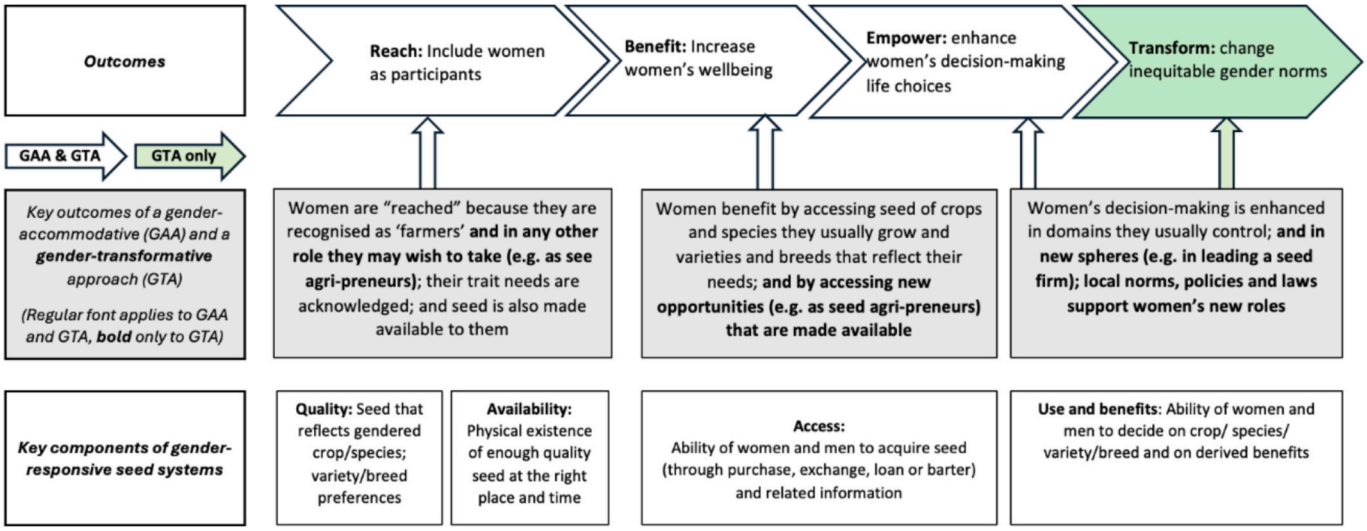

Fig. 2. The likely outcomes of gender accommodative and transformative seed system interventions.
Source: Authors

empowerment only by integrating gender considerations across all key components (Fig. 2).

Applying GTAs when intervening in seed systems likely yields additional outcomes compared to the ones obtained when adopting an accommodative approach. These additional outcomes are highlighted in bold in Fig. 2 above. Integrating transformative considerations in 'seed quality' and 'seed availability' by addressing farmers' aspirations will increase the chances that the seed system reaches both women and men, while also opening the ground for an initial transformation of 'who can conceive, be accepted and be recognized as… [any role they may aspire to take in the seed system]'. Integrating transformative considerations in 'seed access' can enhance access to resources and create new opportunities in the seed sector (e.g., access to seed of lucrative crops that are usually considered a man's domain, or accessing opportunities to sell seed as an entrepreneur); which, in turn, can also improve 'reach' of seed users. Finally, integrating transformative considerations in 'use and benefits' of an intervention can support women's decision-making in domains where they are traditionally involved in (e.g. taking decisions on planting crops they traditionally grow), and in new spheres where they aspire to have decision-making power (for example, the opportunity to lead a seed firm). A transformative approach would also address the normative context of these women to ensure that formal and informal rules do not discourage or hinder them from taking on these new roles effectively (e.g. an intervention could engage communities to ensure that they accept and support women to carry their products to the market and sell them to both women and men customers). Seed systems can contribute to transformative change only by integrating transformative considerations across all key components (Fig. 2: highlighted green).

5. Case studies applying GTAs to seed sector development

In this section, we apply the framework presented above to seed system interventions conducted in Ethiopia, Kenya, Tanzania, and Uganda, in which several authors of this article were involved. Each case illustrates elements of the gender-accommodative or gender-transformative approach and assesses impacts in the context of the Reach-Benefit-Empower-Transform framework. We explore case studies that share a common theme – the application of ICTs to seed system interventions. Although ICTs are not the main focus of this paper, we capitalize on this shared attribute of the case studies to recognize that ICTs are often viewed as a uniquely transformative means of sharing information with and among women, creating women role models where no may exist, challenging gender norms, and empowering women (Riley, 2024; Spielman et al., 2021; Aker and Mbiti, 2010).

5.1. Seed, extension, and ICTs in Ethiopia and Uganda: From accommodative to transformative approaches

We first consider two ICT-mediated scaling interventions – one in Ethiopia evaluated by Abate et al. (2023) and one in Uganda by Van Campenhout et al. (2021) – that feature aspects of seed sector development via innovative extension approaches. A key hypothesis tested in both studies was that a gendered approach to ICT-mediated extension service provision results in an observable change in farmer awareness, knowledge, adoption, and farm-level productivity improvements.

The Abate et al. (2023) study was a randomized controlled trial conducted to evaluate the impact of a large-scale video-mediated extension program that was implemented by the Government of Ethiopia and Digital Green, a social enterprise specialized in digital extension solutions for agriculture and nutrition. The study by Van Campenhout et al. (2021) was a field experiment conducted to explore a similar set of questions with a similar randomized design, although it was implemented by the researchers themselves in partnership with Viamo, a tech-driven social enterprise specializing in mobile-based information services. In both cases, the content communicated to participating farmers was a package of recommended technologies, inputs, and practices for cereal cultivation. The package revolved significantly around seed: not just blanket advice to farmers about the importance of planting improved varieties and quality seed, but also recommendations for precision seeding rates, seed spacing, row spacing, fertilizer application quantities and timing, and weeding practices, all of which were designed to ensure that farmers realized substantial gains in crop yields and revenues.

Both studies included treatment arms that specifically investigated gendered aspects of the video-mediated extension approach for these packages, as well as control groups that provided the necessary counterfactual. In doing so, they addressed the research questions noted in Table 2 by testing alternative delivery systems that seek to increase access to information for women, challenge masculine biases and norms in delivery systems, and generate benefits that accrue to women.

In Ethiopia, the study included a treatment arm to test the impact of the video-mediated approach when targeted to both female and male co-heads of household, as compared to a treatment group that targeted only the head of household (the majority of whom were male, which tends to be the norm in extension service provision in this context), and a control

group that received the standard "chalk-and-talk" extension service (again, targeted primarily to male household heads). This study addressed the accommodative question: 'who has access to information on seed and associated practices?' The Uganda study included multiple variations of this same treatment, varying who was targeted (male co-head, female co-head, or both) and who was featured in the video (male actor, female actor, or both). This study addressed the transformative questions: 'What norms need leveraging or addressing for women and girls to be able to use and benefit from the seed or associated opportunities?' Taken together, these treatments allowed for hypothesis testing on the measurable effects of increasing women's access to information and challenging biases and norms that steer extension services toward male farmers and inhibit women's participation in decision-making on crop production and management.

Results from the Ethiopia study showed positive and significant effects of the video-mediated extension approach for women in terms of increased awareness and knowledge about the recommendations in the package (Abate et al., 2023). However, no effects were observed past this point on the hypothesized impact pathway: the study found no evidence of higher rates of adoption of the recommended inputs or practices (nor higher yields) among households in which male and female co-heads were treated compared to households in which male co-heads only were treated.

Results from the Uganda study (Van Campenhout et al., 2021) went further along this pathway and were more nuanced. The study found that providing information to female co-heads (without their male counterparts) led to an increase in agricultural knowledge, decision-making, adoption of recommended inputs and practices (which also increased when information was provided to both the female and male co-heads), and yields on the fields she managed (see Lecoutere et al., 2023; Van Campenhout et al., 2023; Van Campenhout and Dey, 2023). Interestingly, the same treatment led to a reduction in unilateral decision-making by the male co-head. In unpacking the mechanisms behind these effects, they found that the informational pathways (providing information directly to women in the video) were more influential than the pathways that relied on role modelling (women seeing enterprising women farmers in the video) or influencing gender roles and norms (men viewing women as enterprising farmers in the video). In other words, the Uganda study illustrated reach (with info), benefit (support access to info), and empowerment (women have more decision-making) impacts, with additional evidence of potentially transformative changes (new seed varieties are adopted as women's role as farmers and decision-makers is acknowledged). The Ethiopian study did not go beyond the 'benefit' domain (that is, it focused on access to information).

Arguably, the main difference between these studies was their research approach. The Ethiopia study might be described as a naïve *gender-aware* study that focused on proximate measurement of reach and benefit, and that tested a single hypothesis around knowledge accumulation and decision-making that built off an early vein in the gender and agriculture literature (e.g., Doss, 2015; Palacios-López and López, 2015). The Ethiopia study effectively reads as *gender-accommodative,* offering no new insight that might push against poorly evidenced conventions suggesting that male co-heads are the only decision-makers in cereal crop production, even despite a rich literature to the contrary (Gebre et al., 2019; Mulema and Damtew, 2016). But despite its gender-accommodative design – and recognizing that the study's primary focus was the delivery mechanism and not gender – the intervention did generate gender-specific effects (increased awareness and knowledge). With a better, more gender-transformative sensitive design, it is possible that these effects could have generated adoption outcomes through, e.g., intra-household bargaining processes (Gulati et al., 2024; Van Campenhout et al., 2023).

The Uganda study, on the other hand, focused on a more complex set of gender-specific treatments and measurements that covered the entire reach-benefit-empower-transform continuum, resulting in evidence of what might be called a genuinely *gender-transformative* study. The range of hypotheses tested – intra-household information asymmetries and information hiding between spouses, intra-household bargaining, homophily and role model effects, challenges to gender norms, roles and stereotypes, and gendered response biases – offers rich insight into the mechanisms at play in video-mediated extension.

Rather than criticizing these studies for the designs they pursued, it is worth exploring the drivers of their differences. First, the Ethiopia study was conducted at the behest of partner organizations that did not explicitly prioritize gender at the time. The Uganda study, on the other hand, was conducted by the researchers themselves, providing greater freedom to operate and more opportunity to explore the gender dimensions of their intervention. Second, the Uganda study was likely powered by a more gender-intentional design process that was motivated by the research team members themselves, at least to a greater extent than the Ethiopia research team was. Third, whereas the Uganda study found immediate and significant gender effects along its impact pathway, the Ethiopia study did not, effectively shutting down further lines of inquiry and exploration.

The implications of these studies for seed sector development should be clear: there is considerable scope to design gender-transformative interventions that can not only accelerate the sustained use of improved varieties and quality seed among women farmers but can also generate observable changes in gender norms and behaviours within farm households that contribute to women's empowerment (and technology adoption). While too little may still be known about exactly what these design attributes are, there are opportunities to measure and understand the impacts of these attributes if a more gender-transformative approach is central to the design process.

5.2. GTAs for seed sector interventions around agricultural insurance and mass media in Kenya

A next application of the reach-benefit-empower-transform framework builds on Aju et al. (2022) in Kenya, where research on women's empowerment in a seed sector development project informed the design of GTAs to promote seeds of improved varieties and agricultural insurance. This study was embedded in a larger seed sector development project, "Promoted stress-tolerant varieties at scale", which had as its main objective to improve smallholder farmers' resilience and increase varietal turnover (Cecchi et al., 2019). The project aimed to achieve this by (i) increasing awareness of new drought-tolerant maize, sorghum, and green gram varieties through seed trial packs; (ii) improving the availability of these new varieties through a new business model in which so-called champion farmers, also known as village extension service providers, located in beneficiaries' villages, were enabled to sell seeds of the new varieties; and (iii) reducing the weather-related risks associated with adopting these new varieties by providing an innovative picture-based insurance solution that utilizes smartphone images to verify crop losses. These interventions were implemented by ACRE Africa and the Kenya Agriculture and Livestock Research Organization (KALRO) in seven counties spread across the western, upper eastern, and lower eastern regions of Kenya.

This case study shows that GTAs and GAAs can be complementary. The project asked transformative research questions from Table 2, such as what delivery system could make seed available to women and men at similar transaction cost (availability), and under what conditions women could sustain this access to seed (access). However, the main project aimed at being gender accommodative rather than transformative, as the main aim was to ensure that the interventions would increase the adoption of promoted varieties and insurance products among men and women farmers alike. Women's potential restrictions in mobility–increasing their transaction costs—were overcome by working through a delivery system that leverages champion farmers. Champion farmers were recruited to promote and distribute the promoted varieties and insurance products within their villages, and bring products closer

to the farmgate, thereby reducing transaction costs. The project hypothesized that due to how gender shapes social networks, female champion farmers would connect better with other female farmers than male champion farmers, and that sustained access to seed for women required a delivery system with female champion farmers. The implementing partners therefore selected relatively more female than male champion farmers. This was expected to ease access to seeds and insurance, especially for female farmers, and increase their active participation in the seed sector. Thus, while the project asked transformative research questions, it adopted accommodative interventions that did not intentionally address gender norms restricting mobility, but rather developed solutions (the champions) to work around the norm.

It was, however, also recognized that for women to truly benefit from the interventions, they would need control over the use of seeds and related products. To ask how access to resources would need to change for women to be able to use and benefit from the seed, another question listed in Table 2, the study collected data on women's and men's empowerment in an initial stage of the intervention (Cecchi et al., 2021). Using the Project-level Women's Empowerment in Agriculture Index (Pro-WEAI) (Malapit et al., 2019), at baseline, researchers in the Kenya program found a higher degree of disempowerment among women than among men farmers; with Fig. 3 showing that the main drivers of disempowerment stemmed from work-life imbalances, limited income control, perceived decision-making constraints, and a troubling acceptance of domestic violence (Cecchi et al., 2021). Researchers and implementing partners in the case study were worried that these factors would limit women's ability to take up insurance and control insurance payouts or to use and control seeds of improved varieties, and could even result in a backlash if women were to use promoted services without their husbands' approval. The team therefore decided to ask the transformative question of whether challenging existing gender norms contributing to women's disempowerment could increase women's ability to use and benefit from the seed sector interventions.

Specifically, the team harnessed the power of edutainment, a pedagogical technique merging education and entertainment. A short (24-min) TV drama, "The Wise Woman", was produced to convey messages centered on the importance of joint decision-making within households, debunking gender stereotypes that men would be more knowledgeable than women and should be the sole decision-makers in agriculture, and challenging the notion that intimate partner violence against women is acceptable, by highlighting how such violence could obstruct a conducive atmosphere for knowledge exchange within the household. The drama was produced in partnership with The Media Company, the producer of "Shamba Shape Up," a popular TV program on transforming smallholder farms that have been demonstrated to positively influence viewers' agricultural knowledge, practices, and adoption of technology (Areal et al., 2020; Clarkson et al., 2018). In this case, both research question and intervention were transformative, illustrating the difference between accommodative and transformative interventions in the seed sector.

Employing a field experiment with 1703 farmers spread across the 7 study counties, the team tested the effects of watching this drama on a range of gender outcomes. Researchers randomly assigned farmers to a control group, where a regular Shamba Shape Up episode without gender-related content was screened, and to a treatment group, where farmers watched The Wise Woman (https://shambashapeup.com/series/series-12/ep-23-shamba-shape-up-story-wise-woman/). After the screening, farmers completed an implicit gender bias test, in which they were presented with a mix of accurate and incorrect recommendations from fictional champion farmers, varying whether these champions had a male or female name. Farmers following male champion farmers' recommendations, even when inaccurate, were considered to express a male bias and vice-versa. In the control group, the researchers found a significant bias among women toward recommendations from female champions, whereas, among male respondents, they observed a bias toward the recommendations from male farmers. In other words, both men and women were biased toward the advice provided by champions of their own gender. Interestingly, in the treatment group, these gender biases disappeared, especially after having participated in a debrief session to strengthen the drama's messages and incite a dialogue with

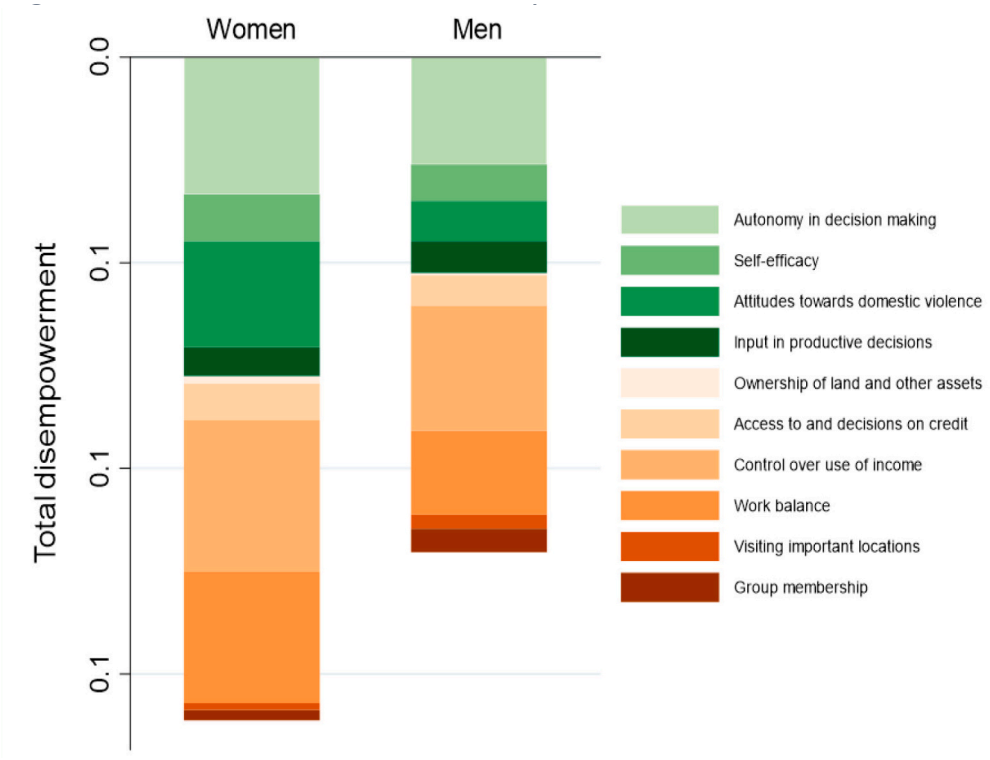

Fig. 3. Drivers of disempowerment for men and women farmers in the Kenya case study.
Source: Aju et al., 2022.

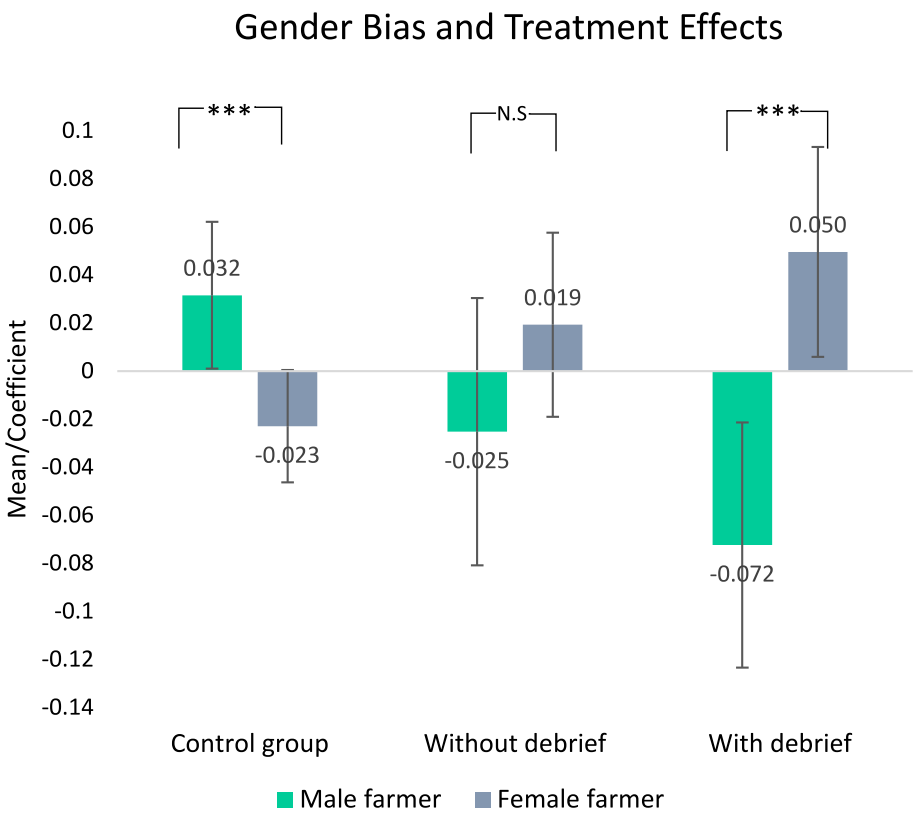

Fig. 4. Gender bias and impact of edutainment.
Source: Aju et al., 2022.

other community members who had watched the drama (see Fig. 4).

Note: Mean values are reported for the control group figure, while treatment estimates are reported for the edutainment impact (with and without debrief); * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, N·S – Not significant.

Finally, a few weeks after the experiment, the researchers assessed participant's empowerment levels by means of a follow-up Pro-WEAI survey. Edutainment had a significant positive effect on respondents' input in productive decision-making – an indicator where farmers previously exhibited low levels of empowerment – and this result was driven by wives who had not watched the drama themselves, but whose husbands had attended the screening and subsequent debrief sessions. Based on these findings, the producers of The Wise Woman decided to air the drama in one of its episodes of Shamba Shape Up, reaching millions of farmers through national TV.

In conclusion, gender biases in the seed sector significantly affect farmers' relationships, both within their households and society at large. The Kenya project tested various interventions applying a GTA approach, including a (female) champion farmer system to promote and distribute seeds, to improve the gendered reach of delivery channels, and a TV drama that challenged norms that restrict women from being able to benefit from such seed sector interventions. Given the cost-effectiveness and scalability, edutainment offers a promising mechanism to employ a gender-transformative approach to address restrictive gender norms, fostering a more inclusive and equitable seed sector.

5.3. Gender transformative approaches to the dissemination of improved chicken seed in Tanzania

The "Women in Business: Chicken Dissemination Project (WiB)" was a three-year project implemented by the International Livestock Research Institute (ILRI) in collaboration with the Tanzania Livestock Research Institute (TALIRI), AKM Glitters (a private company that produces day old chicks of the improved Kuroiler breed) and the Ministry of Livestock and Fisheries. The project was implemented in the Kilimanjaro and Lindi regions. The WiB project aimed to disseminate improved chickens of the Kuroiler breed – selected by Tanzanian farmers through a previous project – to women farmers from remote areas. Chickens in Tanzania (as in many other countries) are considered a species that is part of women's domain with strong potential to support women's empowerment (Galiè et al., 2022). However, chicken breeds that are commonly kept by rural households, have low productivity potential to enable women to generate enough eggs for nutrition security in the household, and surplus eggs and meat for sale.

Based on these premises, we assumed that chicken were a good species for WiB to support women's empowerment (first question in Table 2). We then asked the question: 'what breeds can potentially support women's empowerment?'. Based on consultations with women and men farmers we agreed that improved breeds (along with local ones) would be able to provide surplus eggs that the women could sell. When we asked the women farmers 'Under what conditions can women sustain their access to this seed?' we found that local gender norms generally discouraged women from leaving the home and from liaising with unrelated men. This meant that the women had limited access to agricultural inputs and output services, including improved breeds of chickens, animal drugs and animal health advice, and markets to sell the surplus. The women argued that engaging women's animal health service providers would support their access to improved breeds.

To respond to this need the project adopted an accommodative approach and identified interested women vets and paravets who went through a business incubation process to become 'chicken vendors' as the project called them. As the women chicken vendors established their businesses after the incubation process, they were mentored by chicken business experts also in marketing the eggs produced by the farmers. By supporting women chicken vendors, the project aimed to promote the economic empowerment of both women vendors (who sold chicken and

services) and farmers (who accessed improved breeds, had surplus eggs, and could sell them through the vendors), and to improve food and nutrition security of their households. Rather than working around the norms that women should not leave the house and deal with unrelated men, a transformative approach would have engaged with the communities to make both activities acceptable and the norms less restrictive. WiB decided that they would not intentionally address these norms (and focus on others, see below).

As the women vendors established their businesses, it became evident that gender norms were affecting their ability to perform well in the business. We asked the question: 'What norms need leveraging or addressing for women and girls to be able to use and benefit from the seed business?' Two main norms were identified as particularly disruptive: the norm that women should not be in business, which is a man's domain; and the norm that women should not earn more than their male partners. The first norm resulted in male farmers not taking the women vendors seriously, and therefore harassing them to also provide other (sexual) services. The second norm resulted in partners' hostility when the business started to be financially viable. Some partners asked the women vendors to quit the business as soon as they started making an earning (Farnworth et al., 2024a, 2024b; Omondi et al., 2025).

We asked the question: 'What enabling environment would allow women and men to use (e.g., replant) or benefit (e.g., sell) from the seed or associated opportunities?' We decided that for the women to benefit from the new chicken business the two norms above needed to be less strict. To address the two norms we involved Shujaaz, an award-winning multi-media youth platform that engages with behavior change of young people in Tanzania. In October 2021, Shujaaz partnered with WiB to design and implement a social media campaign to support the project's women vendors and also, increase the number of women confidently engaging in chicken agribusiness – by breaking down the two identified pervasive and negative gender norms that acted as a barrier to the women vendors making a decent living livelihood in chicken business.

The campaign consisted of stories shared on social media that showed successful women chicken vendors and highlighted how their 'deviant' behavior was positively impacting their lives by providing an income. They also praised men who support the women chicken vendors. These stories triggered dynamic taboo-busting conversations among young people about the benefits of women in working in agribusiness, not just to the women themselves but also to their families and the wider community. Among the young women followers of Shujaaz, their engagement with poultry farming or any form of agribusiness rose from 67 % to 74 %. For the young men, it rose from 76 % to 80 %. This showed that our messages targeted to address restrictive gender norms in poultry business indirectly encouraged both young women and men to engage in the business possibly also because of a more conducive norms environment. The project evaluation showed an increase in the empowerment of both women vendors and women farmers involved in the project.

6. Discussion

This paper aimed to discuss how GAAs and GTAs in seed sector development can improve the reach, benefits, and empowerment of women, and transform the restrictive normative environment they live in (RBET). We provided a framework that can help research-for-development and development practitioners focusing on seed sector development respond to gendered needs and opportunities, and contribute to gender equality. While we consider GAAs and GTAs to fall on a continuum of complementary approaches, both with their own benefits, a key difference between GAAs and GTAs is the latter's intentional goal of transforming restrictive gender norms. Engaging with GTAs requires the adoption of a mind frame (in both research and development) that i) identifies existing gender norms that underlie and reinforce inequality; and ii) considers aspirations that individuals may have for their own life goals, which may be curtailed by restrictive gender norms. Such analysis needs to be applied to both intra-household and community level seed management; and to policies and laws that may reproduce gender disadvantage in ways that affect the outcomes of seed sector development (such as, for example, laws and policies on land ownership that may inadvertently disadvantage women's ability to grow crops or raise livestock).

One question that arises from our framework, which contributes to a greater debate in the women's empowerment literature, is whether the transformation of restrictive gender norms is a means to improving a seed sector, achieving gender equality, or a combination of the two. We argue here, based also on the evidence from the case studies, that by addressing restrictive gender norms and the resulting gender-based disadvantage, GTAs create a conducive environment for women's empowerment to materialize, and this, in turn, is key to progress toward gender equality and essential for developing functional seed sectors. In other words, gender equality through transformational change is important for an effective seed sector; at the same time, a gender-responsive seed sector offers key opportunities to support women's empowerment and transform restrictive gender norms. In this light, it is important to note that the RBET framework—well established in the literature on women's empowerment—is important to assess an intervention's progress toward gender equality, but does not help make gender-responsive choices when designing an intervention.

In this article, we provided three case studies on seed sector interventions with different approaches to addressing gender issues. The first case study compares two projects: one engaging with a GAA and the other with a GTA in both research questions and interventions respectively. The second and third case studies show how transformative questions can be answered with both accommodative and transformative interventions. These case studies provide several key learnings. First, at the researcher level, moving toward GTAs requires researcher capacity. In the Ethiopia case, the video-mediated extension approach impacted women's awareness and knowledge of recommended practices, inputs, and technologies, but not their adoption likely because study partners were insufficiently cognizant of the gender-transformative potential that could have been introduced into the design, as was done in the Uganda case. Likewise, the Kenya case study initially adopted an accommodative approach toward designing a seed sector intervention, not realizing that the adopted approach would be insufficient to answer its transformative research questions. This eventually led the project team to implement a more transformative intervention.

Second, the three case studies show that GTAs can be a powerful strategy in impacting social and gender norms at various levels, from the individual to the wider society, as shown by our cases that adopted social media as a GTA. At an individual level, media can perform a persuasive and educational function, whereby individual consumers undergo a learning process, ultimately leading to personal values and beliefs being updated. More importantly, because social media is delivered publicly, there is a social coordination effect, because media consumers know that others in their social group are interacting with the same information, helping them to form an understanding of shared beliefs. This relates to new learning from our case studies: when does a change in behavior shown by the participants in an intervention, become a change in gender norms? Social media, with their wide reach, may support reaching the tipping point from individual change to norms change. To be most effective, however, GTAs need to assess their target level. Social media in the Tanzania project reached any young women and men who could afford to have a phone and an internet connection nation-wide. This is useful to address gender norms at a more systemic level (the national level in this case) but may not necessarily reach targeted project communities. A different GTA, for example, a community conversation, may be needed to engage directly with the project communities (see Njiru et al., 2024; Mulema et al., 2020).

Third, we show how transformative approaches may have

unexpected impacts on non-targeted norms and an empowering effect on men, highlighting how a society with less restrictive gender norms benefits everyone. By addressing gender norms around the acceptability of women in business, the Tanzania project's social media encouraged young men to engage in business with poultry, a commodity usually associated with women only. The Kenya study provides evidence that engaging men in intentional gender messaging can change outcomes for their wives, whereby researchers observed a significant increase in joint decision-making among the women who had been randomly selected to watch the gender drama with their spouses. It also illustrates the importance of engaging with masculinity and starting to change norms by targeting not only women whom we aim to empower, but also the men in relation with whom their gender roles are defined (although the project measured only individual perceptions and attitudes toward gender, and not commonly held norms). These findings confirm that GTAs are promising not only for transforming gender norms and facilitating women's empowerment but also more efficient for influencing technology adoption and behavioural change, thereby achieving greater impacts in the technical aspect of seed system transformation.

Finally, the case studies show that any intervention will have gendered impacts because there is no such thing as a gender-neutral intervention. Any intervention that excludes gender considerations will automatically support one gender group, most likely men. To facilitate gender-transformative seed sector development, strong institutional support and policy change are required. Whether to use GAAs, GTAs or a combination of both rests on a project's assessment of what approach will be most effective. A GAA only approach is less likely to move beyond reach and benefit.

7. Conclusion

In this paper, we focused on the impact of seed sector development on a continuum of progression toward gender equality, from reaching to benefiting and empowering women farmers to transforming restrictive gender norms. We mostly engaged with empowerment and transformation, which are the two types of impacts that contribute more substantially to progress toward gender equality. We engaged with the gender transformational aspects of seed systems, in particular, because despite the potential that GTAs have shown to sustainably support progress toward gender equality in agriculture, theoretical and in-field engagement with the topic in the context of seed systems has been extremely limited. To this aim, we provided both (i)a conceptual framework that showed what type of seed sector interventions may affect women and how, along the reach to transform continuum, and (ii) evidence from the application of social media for women's empowerment and gender norms transformation in four countries.

The paper discussed how gender-equitable seed systems are both a proximate outcome of equitable, improved access to and use of quality seed of improved varieties—and an end in themselves, through their positive influence on progressing toward gender equality. Seed systems themselves can be a catalyzer of progress toward gender equality when intentional transformative considerations are adopted.

CRediT authorship contribution statement

Alessandra Galiè: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Berber Kramer:** Writing – review & editing, Writing – original draft, Visualization, Funding acquisition, Formal analysis, Data curation, Conceptualization. **David J. Spielman:** Writing – review & editing, Writing – original draft, Visualization, Validation, Formal analysis, Data curation, Conceptualization. **Nozomi Kawarazuka:** Writing – review & editing, Investigation, Conceptualization. **Anne M. Rietveld:** Writing – review & editing, Conceptualization. **Stellamaris Aju:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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