Chapter 2

EXAMINING CHOICE TO ADVANCE GENDER EQUALITY IN BREEDING RESEARCH

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Breeding is a technical pillar of CGIAR research: the animal/fish breeds, and plant varieties developed are international public goods that contribute to agricultural development for low-income contexts worldwide. Gender equality and women's empowerment are critical social dimensions underpinning agricultural development in these contexts. Progressing toward gender equality in agriculture requires that women, as well as men, have equal capabilities to make decisions about agricultural innovation, and specifically technology choice. Current evidence, however, suggests the situation here is not yet equal. Nevertheless, despite ongoing inequalities, there is a dearth of literature on the connection between gender and breeding in agricultural research.

This chapter critically examines what has been done to address gender dynamics in (current) breeding structures and processes, and what more can be done so that breeding programs contribute to advancing gender equality. We are specifically concerned with **technology choices in relation to the plant variety or animal/fish breed** by resource-poor smallholders in low-income countries. The chapter explores how CGIAR and public breeding programs generate options based on user needs, preferences, and constraints, and the institutional requirements needed to develop them in such a way that they contribute to gender equality and women's empowerment.

We begin with a discussion on why gender matters for breeding. Here, we also position this chapter within a technology, society, and gender frame, and briefly look at how the incorporation of gender dimensions in breeding processes have evolved, starting with the Green Revolution.

We next introduce our conceptualization of how breeding relates to gender equality, emphasizing, in particular, technology options and the power to choose. We deepen this by presenting an impact pathway that can be used to

identify intervention and information gaps, and potential new areas of research that can foster a better understanding of the linkages and relations between breeding for agricultural development and gender equality.

We go on to review a process of incorporating gender dimensions into different stages in the breeding cycle, looking at *when* and at what stages of the breeding cycle we need to take gender into account, and *how* this can concretely be done. This allows us to delve into examples of how technology options relate to gender equality by contributing to the generation of "real choices" that fit the needs, preferences, opportunities, and constraints of men and women.

Finally, we look forward, laying out new research opportunities and challenges in advancing breeding toward gender equality. We focus specifically on how to ensure the inclusion of gender equality dimensions at the level of breeding objectives. We also further articulate how monitoring, evaluation, and learning can strengthen feedback loops in the breeding cycle, and how this can be conducive to the integration of gender dimensions.

Why gender matters in breeding

Agricultural innovations such as new crop varieties and animal/fish breeds have great potential to contribute to agricultural production and development if these innovations meet users' needs and demands. Plant and animal breeding aims to improve the genetics or traits of breeding products to produce desired characteristics with the goal of achieving food security and better livelihoods. In meeting these objectives, understanding the priorities that women and men assign to genetically determined traits becomes critical (Orr et al. 2018). A socially inclusive, and thus gender-inclusive, process in product development can enhance gender equality when women and men's voices are heard and effectively inform the breeding process.

Although there is growing recognition of the vital role women have in informal (farmer-led) breeding processes, knowledge on how and when to involve men and women farmers and how gender-responsive breeding can advance gender equality is limited. Furthermore, the pathway from biophysical research to gender equality is complex and requires careful attention to multiple factors.

In the case of breeding for agricultural development, gender-differentiated access to and control over assets and resources can influence the technology, crop, and/or variety selected for production (Njenga and Gurung 2011, Kawarazuka and Prain 2019, Olaosebikan et al. 2019). Studies on gender-differentiated trait preferences show that varietal choice is related to resources, rights, and responsibilities shared differentially by men and women who are

differently engaged in production, processing, and marketing (Fisher and Carr 2015, Christinck et al. 2017, Bentley et al. 2018, Isaacs et al. 2018, Teeken et al. 2018, Ashby and Polar 2019, Marimo et al. 2019, Olaosebikan et al. 2019). Similarly, formal and informal social structures and social relations shape men and women's innovation experiences and choices of technology (Bullock and Tegbaru 2019, Kawarazuka and Prain 2019).

In the broad context of technology and innovation in agriculture, **lower adoption of modern varieties among women producers** (Wale and Yalew 2007, Ashby and Polar 2019) emerges as a significant trend, reflecting unequal access to technology. Unequal access may imply that technology is *physically* not accessible equally. Alternatively, it may imply that the technology developed has not considered or does not respond (equally) to the needs and demands of gender-differentiated segments of the population (Mulema et al. 2019, Polar et al. 2021). This speaks to the need for institutional and structural innovations that revitalize the way new varieties are developed and disseminated for uptake, to ensure the consideration at multiple levels and stages of factors such as gender-differentiated control over assets and resources, and normative climate. Crop and animal breeding programs need to consider gender differences when setting priorities and targets for breeding, since overlooking traits important to women farmers and consumers may lead to women's disempowerment and aggravated household food insecurity and poverty (Tufan et al. 2018), thus increasing the gender gap and inequality.

Before proposing and further exploring ways to integrate gender dimensions into breeding processes and practices, we take two steps back: one step to reflect on the relationship between technology, society, and gender and a second step to briefly reflect on the history of breeding since the Green Revolution.

Framing technology, society, and gender

Technology is not neutral. For one thing, it tends to be associated with masculinity, not only in popular assumptions but also, in some cases, in academic "truths" (Gill and Grint 1995). The gendered nature of technology reflects that technology and society co-constitute one another (Bijker 1995, MacKenzie and Wajcman 2011) and co-evolve (see Chapter 10, this volume). Social and cultural factors condition ideologies, while policies shape the development and endurance of technology, and vice versa (Johnson 2010). Technologies are thus inherently political as they can be designed, consciously or unconsciously, to open certain social options and close others (MacKenzie and Wajcman 2011).

As such, in agricultural research for development, it is important that technology be framed not as an artifact, technique, system of knowledge, or expertise but rather as a sociotechnical system (Hughes 1994) produced by the interactions of the technology and society. Technology change is then one factor among many others—political, economic, cultural—in the dynamics of social change (MacKenzie and Wajcman 2011). Adopting a technology may have far more effects than are first evident. Technology matters not only physically and biologically but also to human relations and social processes. This shifts the frame of technology adoption from passive adoption by users/receivers of a technological innovation toward a more active role of users in shaping technological change (ibid.).

This shift is crucial to advancing toward gender equality. The material features of a technology are necessary but not sufficient conditions for gender-equitable relations (Johnson 2010). Two aspects required in understanding the potential contribution of technology to gender equality are (a) the features of the technology and how they may (or may not) carry a deliberate gender bias; and (b) the sociocultural context surrounding the access to and use of the technology (Gill and Grint 1995, Johnson 2010, Polar et al. 2017).

The philosophical and actual separation between women and technology in western culture is linked to changes that took place during the Industrial Revolution. The separation of public and private spheres and the move toward factories for manufacturing resulted in a gendered division of labor that fostered male dominance of technology (Gill and Grint 1995). Similarly, the Green Revolution marks a breaking point between women and technology resulting from a drive toward specialization in agricultural production.

Toward gender integration in breeding processes

Between the 1950s and the late 1960s, when food shortage was one of the world's major challenges, the Green Revolution endeavors, advanced by Norman Borlaug, leveraged agricultural research and technology to increase productivity in the developing world (Hazell 2009). The introduction of packages of new high-yielding plant varieties with improved practices, fertilizers, and other improved inputs was crucial to increase food production in many countries (Farmer 1986, Zaidi et al. 2019).

Decades after Borlaug won the Nobel Peace Prize as the "Father of the Green Revolution," credited with saving over a billion people from starvation, breeding programs continue to increase smallholder farmers' yields, reduce pesticide use, improve nutrition and health, and contribute to poverty reduction (Qaim et al. 2007, Osei et al. 2014) through new varieties and animal breeds. However,

the drive to reach the maximum number of farmers and generate the greatest production improvements has also led to lack of attention to the diversity of needs, challenges, and preferences differentially faced by men and women. Furthermore, although many studies show the positive contribution of breeding for agricultural development, there is a gap in knowledge on the outcomes or impact of the new technologies on women and gender equality.

Male and female farmers in marginal ecologies have not benefited from the outstanding yield increases that Green Revolution endeavors obtained in environments that are naturally favorable or that can be made favorable profitably by using inputs (Ceccarelli et al. 1996). Consequently, adoption of new crop varieties by resource-poor farmers has been limited. To enhance the adoption of breeding products developed by breeding programs with social welfare and development goals, a key consideration in product design and advancement is the potential impact of a new breeding product on the welfare of end users. The drive toward more "client-focused" breeding processes has grown and evolved over the past decades (Ashby 1996, Persley and Anthony 2017, Ragot et al. 2018).

Unequal power relations and differentiated roles and/or control over assets and resources imply that men and women engage in agriculture with different means of production and face different constraints. As a result, women frequently develop different strategies for farming than men, based on systematic differences in their rights, opportunities, and resource endowments (Ashby and Polar 2019, Olaosebikan et al. 2019). Whenever poor men and women on small farms produce for direct household consumption as well as for the market, gender inequalities often translate into gender disparities in the adoption of new technologies (Peterman et al. 2014, Fisher and Carr 2015, Mehar et al. 2017). These adoption disparities are aggravated when technologies are developed to address "common denominator" traits such as yield or disease resistance (Teeken et al. 2018) and not necessarily gender-differentiated needs and preferences.

Because of this, we argue that it is necessary to deliberately address gender dimensions in the development of new technologies, including new varieties and animal breeds, to level the playing field toward gender equality among women and men belonging to different age and ethnic groups. This involves providing farmers with **real technology choices** that better address their needs, preferences, and constraints (Polar et al. 2021). With new technological advances in breeding such as genomic selection and high throughput processing, there are also more opportunities for breeding to expand the range of traits prioritized and to tailor new products to specific end-user preferences. This

opens the door to the formulation of breeding objectives that actively integrate gender considerations (Ashby and Polar 2019) that advance breeding endeavors beyond the Green Revolution by developing new crop varieties and animal breeds that foster inclusion, equality, and sustainability.

How do technology options relate to gender equality?

The power to choose!

Gender inequality relates directly to power. One aspect of power is the ability to make choices (Kabeer 2005). Women and men may not have the same possibilities to make choices, and gender-related disparities often intensify the effects of poverty, creating cycles of greater inequality. Individual preferences are an important dimension of choice;[1] they are not so much features of individuals but rather also reflect internalized inequalities from the wider social context (Kabeer 2002). Moreover, individual preferences also embody the extent to which individuals seek to challenge such societal inequalities.

People are not free when they cannot make choices about their lives (Sen 1994, 2004). The power to make such choices refers to human agency, which creates new possibilities and actions (Rowlands 1997), but also to social structures (Akram 2010) that enable or restrain choices and choice-making. Empowerment relates to the existence of real choices, the exercise of choice, and the outcomes that result from the process (Kabeer 1999, Alsop et al. 2006).

For there to be "real choices," two basic conditions need to be met (Kabeer 2005):

> *There must be alternatives to choose from that make meaningful choices possible.*
>
> *Alternatives must not only exist but they must also be seen to exist.*

Both the existence of choice and users' perception of its existence stem directly from the relationship between individuals and society, or human agency and social structures (Akram 2013). Human agency and social structures are assumed as interdependent processes that shape the way culture,

1 Collective and individual choice-making are both part of human agency. However, for the purpose of exemplifying the existence of real choices, this chapter addresses only individual aspects of choice-making.

institutions and values, norms, beliefs, and behaviors of humans co-evolve (Musolf 2003).

While issues of human agency and social structures have multiple dimensions, we are interested in how they are at play in the existence and perception of practical interests and choice **related to the adoption of a new plant variety or animal/fish breed**. We are looking at the breeding processes and structures involved in the generation of options (plant varieties or animal breeds) that do respond to the needs, preferences/priorities, and constraints facing men and women. This calls for a dualistic perspective: (a) the identification of gender-differentiated needs, priorities, and constraints related to plant varieties and animal breeds; and (b) the institutional and organizational frameworks of breeding that enable or restrain the generation of options for meaningful choice-making. We consider these two issues across the different stages of breeding that we discuss further below.

There is a growing body of research and insights on the needs, priorities, and constraints facing men and women, but only just emerging are examples of how this information is and can be incorporated meaningfully into breeding programs. Decisions made by breeders about which traits to incorporate in a new plant variety or animal breed often involve tradeoffs about whose preferences among different end users are prioritized (Ragot et al. 2018, Tufan et al. 2018, Polar et al. 2021).

For technology users, gender inequalities in the availability of options for meaningful choice-making occur when (a) breeding programs do not develop products with traits that women value positively, whether or not men producers also value those traits; or (b) the new breeding products incorporate traits that men producers value highly but that are detrimental to women. The latter is the case, for example, when the new, higher-yielding variety increases women's unpaid labor in threshing or requires the use of inputs of unequal access for women. The integration of gender dimensions in breeding hence entails both "doing good" and "doing no harm."

A prospective impact pathway linking breeding and gender equality

Gender equality refers to equal rights, responsibilities, and opportunities of women and men, implying that the interests, needs, and priorities of both are taken into consideration (Fredman et al. 2015; see also Chapter 1, this volume). Advancing toward gender equality and women's empowerment requires transformative shifts, integrated approaches, and new solutions through innovations in policies, management, finance, science, and technology (Waezi 2017). It

is increasingly clear that science and technology can create new, unforeseen problems and that they may not benefit all equally (UN Women, 2019)—but can also create new opportunities if purposefully approached.

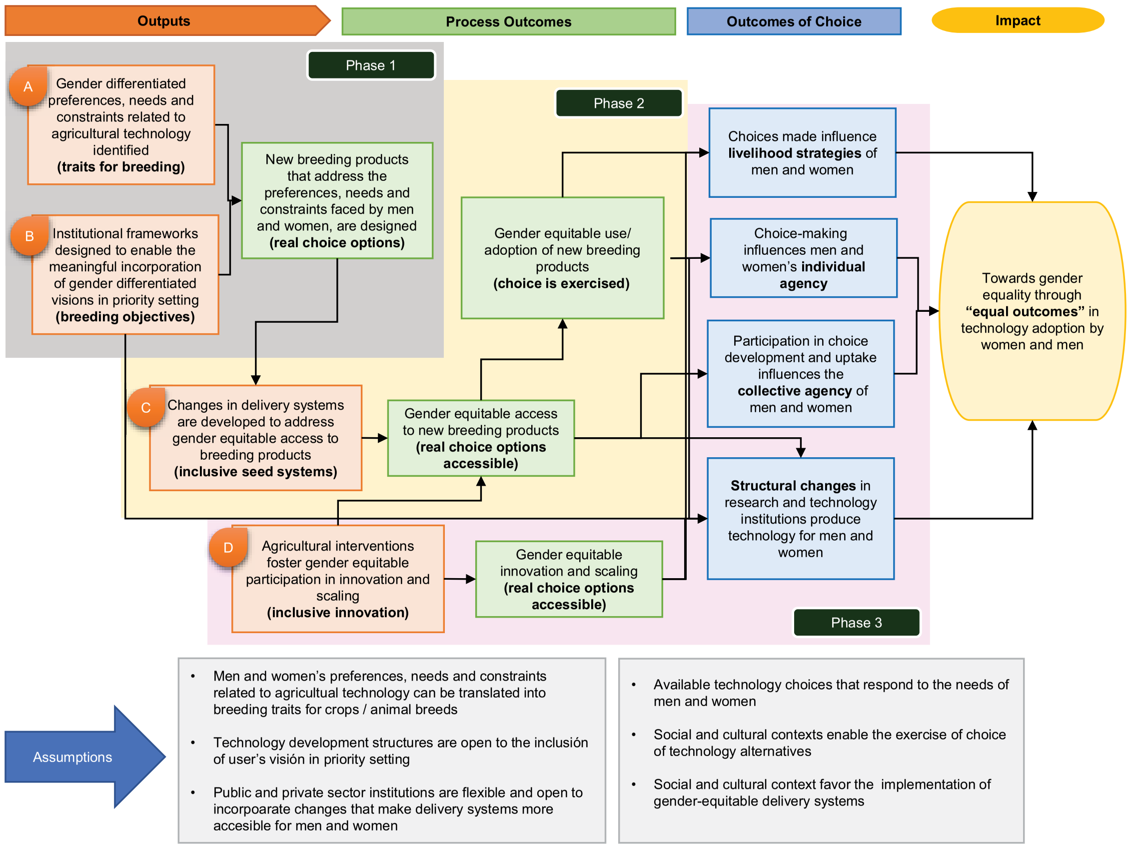
In this definition of gender equality, the elements for biophysical research and breeding for agricultural development are providing and ensuring that the interests, needs, and priorities of both women and men are taken into account when setting priorities and targets for breeding. Based on these premises, Figure 2.1 presents an impact pathway describing the prospective changes expected from setting breeding priorities toward gender equality, including a summary of intermediate steps. Innovations in science and technology that disrupt "business as usual" are increasingly being recognized as preconditions (Waezi 2017) in the path toward gender equality. The process described in Figure 2.1 presents a disruption of business as usual by changing traditional technology development structures (breeding programs) through institutional innovations that incorporate gender analysis to set breeding objectives that contribute to equality in opportunities.

This proposed impact pathway focuses only on interventions based on formal breeding systems. While there may be multiple mechanisms to achieve gender equality that do not necessarily address formal structures of technology development and breeding, the pathway presented below describes the steps from breeding processes and products to socioeconomic change and gender equality. The simplified logic holds a series of assumptions, mainly associated with social and behavioral change, that are fundamental to equality outcomes.

The impact pathway presented in Figure 2.1 is subdivided into three phases. Each phase has specific outputs and outcomes; the three are linked to each other sequentially but with some degree of overlap. Within and between phases there are a number of important assumptions that need to be intentionally addressed to make sure they are actually in place in reality. For example, the first assumption will require a great deal of biophysical research to translate the basic components of preferred traits (for example taste, smell, other traits) in terms of genes, heritability, and breeding potential. A second assumption is the need for flexible structures that enable an inclusion of users' vision in priority-setting. Other assumptions also are not automatic and require an intentional approach to ensure they are in place.

Phase 1 includes the first steps of the breeding cycle. Gender in this phase may be included in multiple ways and through different tools and mechanisms. Essentially, the expected outputs are:

FIGURE 2.1 Impact pathway from breeding for development to gender equality



Source: Developed by the authors.

(A) Identify the preferences, needs, and constraints related to agricultural technology from the experiences of men and women; and
(B) Design institutional frameworks to enable meaningful incorporation of gender-differentiated visions in priority-setting for breeding objectives.

The process outcome of this intervention is the existence of **"real choice options"** in the form of new breeding products that respond to the preferences, needs, and constraints facing men and women.

Phase 2 deals more with the delivery system. Once **"real choice options"** exist, men and women must be able to access them equitably. This requires:

(C) The development of changes in delivery systems to address gender-equitable access to breeding products (Inclusive seed systems).

The design of such delivery systems will probably require multiple approaches and specific tools that may go beyond the scope of agriculture. The process outcome of more inclusive seed systems would be equitable access to new breeding products by men and women, meaning essentially the **accessibility of real choices** and potentially the **exercise of choice** in the form of use and adoption of new breeding products.

Phase 3 reaches out to a broader context of agricultural development and social change. This requires:

Gender-responsive and transformative interventions that (D) foster gender-equitable participation in innovation and scaling.

The outcome of this process is also the accessibility of real choices through behavioral change. However, the stronger emphasis on inclusive innovation and behavioral change, and the prior outcomes of Phases 1 and 2, can contribute to empowerment, through outcomes related to choice-making. These outcomes are changes in individual agency, collective agency, livelihood strategies, and social and institutional structures.

The final expected impact of this three-phased pathway is progress toward gender equality through equal outcomes. It is important to highlight that, as the pathway advances, the outcomes are influenced by an increasing number of variables and actors and thus may yield results that deviate from what is expected. This process is non-linear: it comprises a thick interconnected network of variables that may require multiple feedback loops.

In the next section, we take an in-depth look at Phase 1 of the impact pathway. That means we focus on outputs (A) and (B) in the impact pathway.

We explore in more detail the changes in the breeding process, both methodological and institutional, that need to be made in the breeding research process to generate **real choice options** for men and women. In this, we keep in mind that technologies have a political dimension, and how this can and must be addressed as early as the design phase.

Inclusion of gender considerations in the breeding cycle

In assessing the place of gender considerations in critical breeding decisions, two aspects need to be considered:

When, along the breeding decision process, is gender a consideration?

How are gender-differentiated needs, preferences, and constraints incorporated and what does this imply for institutional/organizational structures?

This section presents some of the products from the CGIAR Gender and Breeding Initiative (GBI), which focused on these two aspects.

GBI emerged from the conclusions of a workshop held in Nairobi in late 2016, with the objective of bringing together plant and animal breeders, and social scientists to develop a strategy for gender-responsive breeding. GBI started in 2017 through a one-year grant from CGIAR System Management Office, coordinated by the CGIAR Research Program on Roots, Tubers and Bananas. In order to enhance the inclusion of gender considerations in breeding programs, GBI identified seven critical decision points along the breeding process where gender must be included (Ashby et al. 2018). Based on these decision points, a set of questions were developed to trace activities and information needed to make decisions, including also the expected results. Table 2.1 presents a summary of the questions formulated in the "decision checklist."

The first four decision points seek to incorporate gender in **customer segmentation and targeting,** and in the definition of the **product profile or package of traits** for the target group of customers, considering also the breeding feasibility of these traits. Decision point 5 takes place iteratively during breeding and early testing. Decision points 6 and 7 are part of the product delivery process.

Using the guiding questions of these decision points, Figure 2.2 presents a simplified breeding cycle overlaid with concrete INTERVENTIONS and expected OUTPUTS. The checklist can be used at any stage in the breeding program but is likely to be most effective if used during the early stages, when decisions are made about whom to target and what desired package of traits is

TABLE 2.1 Guiding questions in the "decision checklist for gender-responsive breeding"

Point	Questions that guide actions and decisions	Focus area
1	Who are the potential customers when gender is considered?	Segmenting and targeting
2	What customers to target? What is the justification for targeting one segment of the user population versus another, considering differences in gender equality?	
3	Which trait preferences could the program potentially breed for? Which existing or new-bred plant or animal traits could potentially satisfy some aspects of identified demand?	Understanding trait preferences
4	What product meets the needs of a gendered target customer? What product can feasibly be developed to meet the priority demand of the most important customer group?	Changing priority-setting
5	How is the program going to breed for the traits needed to reach the gender-responsive product profile? Is new variation needed to meet the specifications of the product profile?	
6	How will selection of bred genotypes meet the specifications of the gender-responsive product profile?	Testing and selection
7	What gendered constraints should be included in the design of delivery systems for the breeding products?	

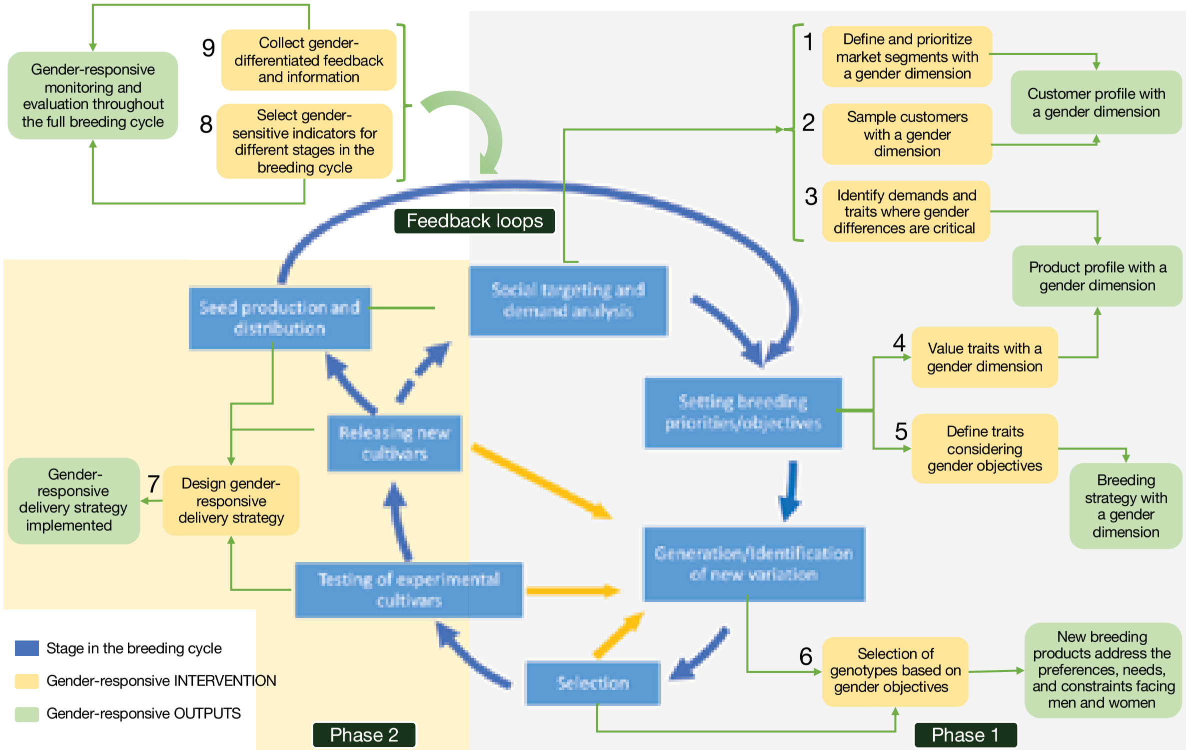
Source: Adapted from Ashby et al. (2018).

to be prioritized. Therefore, we take a much closer look at the decision points in Phase 1 by discussing four areas: (a) segmenting and targeting, (b) understanding trait preferences, (c) changing priority-setting, and (d) selection and testing. For each of these areas, we discuss ways to integrate gender dimensions, and share concrete examples of how that has been done.

Segmenting and gender targeting when breeding for the poor

A first challenge for the incorporation of gender considerations in public sector breeding programs is a methodological one. For public breeding programs focused on breeding for the urban and rural poor, gendered dimensions of demand and market signals are often obscured or not readily discerned (Orr et al. 2018). The challenge is compounded by the fact that, unlike private entities,

FIGURE 2.2 Gender-related interventions and outputs along the breeding cycle



Source: Developed by the authors as a representation of how "Decision Points" (Asby et al. 2018) integrate with the Breeding Cycle.

public breeding programs, especially programs for resource-poor farmers, do not have the wherewithal to conduct extensive market research to understand their clients, and to assess and evaluate the findings of the research to redevelop the program (ibid.).

One source of information for segmenting and targeting is data from extension services, participatory plant breeding, and, to some extent, household surveys. However, in terms of indicating market demand accurately, micro-level data collected from trials and local extension services are often ineffective in reflecting gendered demand for varieties because they frequently represent narrow, self-selected groups of informants, presenting a problem for generalizing results (Orr et al. 2018). Large datasets, on the other hand, often obscure the social context and rarely reflect reliable information on gender dimensions that affect breeding choices. Most breeding programs, to date, rely on geographic data, mapping out breeding demand in relation to production constraints, without including and understanding demography, and the social characteristics of the client groups. Weak segmentation and targeting that does not include gender analysis can affect the feasibility and adaptability of the breeding lines and products.

An alternative approach to bridge existing data limitations is to combine information around agro-physiological variables with multidisciplinary large-scale datasets—such Living Standards Measurement Study–Integrated Surveys on Agriculture, the Women's Empowerment Assessment Index, and Demographic and Health Surveys—that contain information on consumer preferences and gender in decision-making. This was done for cassava in Nigeria (Orr et al. 2018), where a segmenting and targeting exercise predominantly reflected farm-level data. Segmenting and targeting for other actors in the value chain, however, remains a challenge.

Segmenting and targeting are often implicit in the organization of priorities of breeding programs (defining consumers and producers at various stages of the value chain). Choice of market segment is often made based on agro-ecological markers set out by national datasets with little or no inclusion of consumer preferences, and without gender differences flagged. Outstanding examples that challenge this trend are the cases of market beans in East Africa (Katungi et al. 2018a), cassava adoption in Nigeria (Olaosebikan et al. 2018), and *ololili* forage systems in Tanzania (Galiè et al. 2018). These cases have considered gender differentiation in targeting, and the results have influenced other stages of the breeding cycle.

In the case of market beans in East Africa, the International Center for Tropical Agriculture conducted different studies, including household surveys,

choice experiments, and participatory varietal selection, to gather socioeconomic data from male and female respondents. Results revealed that farmers' preferences for bean traits were influenced by landholding size, age, household size, sex, and wealth of the household (Katungi et al. 2018b). These are variables that also influence technology adoption. An important finding was that traits cannot be labeled as men or women's, since often both prefer the same traits but with varying intensity or for different reasons.

The above study also revealed a shared preference for reduced cooking time, and this trait was further explored in a complementary market study with consumers, which revealed the significance of selling precooked beans, given the lower cost per person of boiling beans and the fundamental importance of color for buyers (Aseete et al. 2018).

These findings have two significant implications for setting breeding objectives: (a) if precooking beans is a viable marketing option, fast cooking may not need to be included in the package of traits for biofortified beans; and (b) if color is a main driver for buyers, this trait should be included in the development of new breeding products.

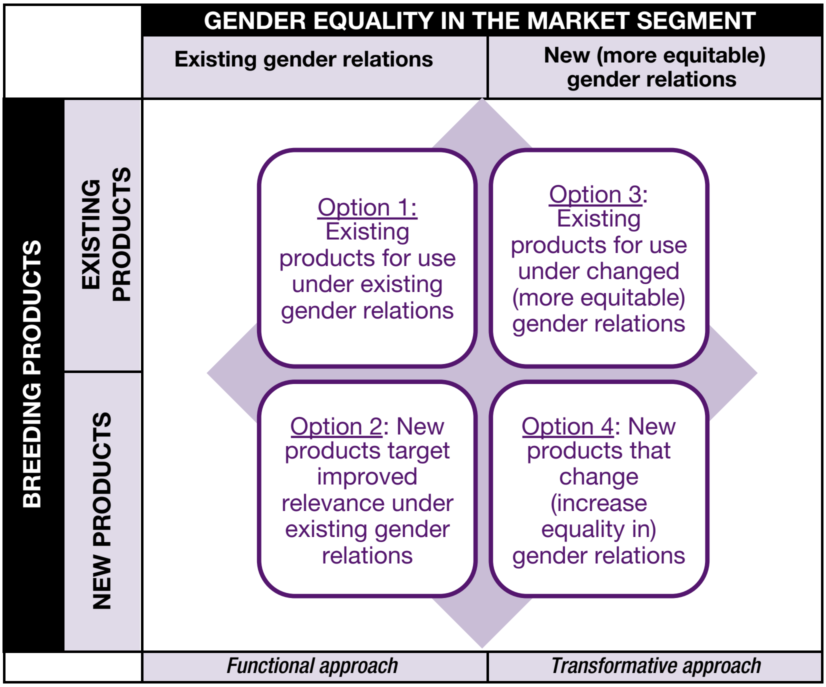
Incorporating gender into social targeting can take a functional or transformative approach, especially when formulating breeding objectives (Orr et al. 2018, 2).[2] Figure 2.3 depicts four different options in deciding on what market segment to target, taking gender into account. The approach taken to incorporating gender into targeting will determine gender equality outcomes. On the other hand, both functional and transformative approaches to targeting have the potential to influence breeding product and program design, thus supporting the generation of **real choice options** for women as a basic step toward empowerment and gender equality.

Understanding gender dynamics in trait preferences: simplifying a complex picture

Historically, decision-making in breeding programs has been economic, focusing on the value of a preference linked to the genetic gain of a specified trait (Hazel et al. 1994, Mehar et al. 2019). With the twofold incentive of more inclusive agricultural research for development and increased adoption of breeding products, the opportunity to incorporate potential users' preferences

2 "A functional approach takes gender differences among small producers into account only when the delivery of relevant breeding products to both men and women users is essential for achieving desired levels of adoption and impact" (Orr et al. 2018).

FIGURE 2.3 Decisions that incorporate gender into targeting through a functional or transformative approach to gender equality



Source: Orr et al. (2018).

has gained traction in recent years. A critical foundation for this is clear and accurate data regarding women and men clients' preferences.

To this end, CGIAR carried out a series of foundational literature reviews and empirical research studies to systematically assess knowledge regarding gender differentiation in trait preferences, with the aim of identifying options for breeding programs to better address gender-specific needs (Christinck et al. 2017, Ramasawmy et al. 2018, Mehar et al. 2019, Mulema et al. 2019, Murphy et al. 2020). Overall, the studies highlighted that gendered trait preference information was relatively scarce and reliable methods were still a work in progress in public sector agricultural research for development in the Global South.

A multiorganization, multicommodity initiative with post-doctoral researchers to unpack methodological challenges and opportunities related to gender analysis in trait preferences surfaced several methodological challenges that need further work. These challenges include accurate assessment when there are notable differences between what people mean, what they say, and

what they do (for example what they actually purchase as opposed to what they say they purchase); and the challenge of translating information about preferences into traits that are potentially actionable by breeding programs. The latter also involves sifting through preferences to determine which can be included in a breeding program versus those that can be addressed through the development of best management practices and extension (see Mehar et al. 2019).

To understand gender dimensions in trait preferences it is important to look at how these latter reflect underlying gender differences in assets, markets, information, and risk, and the ways institutions and policies condition these. Unpacking the links between trait preferences, social differences, and gender asset inequalities can provide indications as to the expected potential impact of a breeding product. For example, a participatory breeding program in Mali identified that women expressed preferences for varieties tolerant to low soil fertility. Further analysis reflected underlying structures of gender inequality in land rights, land access, and access to inputs for soil fertility (Rattunde et al. 2018). Although challenging and changing gender norms and access to land would be an ideal intervention, it may be outside the sphere of control of agricultural researchers working on breeding. In this case, breeders proactively acted to decrease gender inequality by developing varieties with improved tolerance to low phosphorus, which were particularly beneficial for women producers (Ashby 2018).

Similarly, the study of trait preferences with the *ololili*[3] in Tanzania showed that men gave higher importance to livestock fattening whereas women gave higher importance to milk production and this reflected unequal asset distribution: men own the animal while women control other assets like milk production (Galiè 2013). In this situation, breeders can actively make a choice to support gender equality through breeding for a composite of traits that benefit both men and women.

In relation to livestock, the African Chicken Genetic Gains Project tested different strains of chickens to improve their performance under different agroecologies in Africa. At its onset, the project assessed the traits preferred by men and women chicken farmers from more than 3,500 households through a baseline survey in Ethiopia. Following this, a qualitative study was conducted to triangulate the results. Although men and women showed similar preferences for physical traits, the reasoning behind these preferences differed. Male

3 *Ololili* is a traditional dry season forage reserve maintained by Tanzania's pastoral Maasai communities to feed their animals. In this system, a portion of land is fenced to let the natural pasture grow during the wet season.

respondents focused on the productivity, health, and marketing of chickens while women elicited behavior and consumption traits as well (Mulema 2018, Ramasawmy et al. 2018).

Although the project has not gone through the entire breeding and dissemination process, the results will guide breeders as to which traits to integrate into the second phase of the breeding program, and how to involve men and women in the selection, testing, and delivery of preferred chickens. The project aims at setting up a Long-Term Chicken Genetic Gains Program for sub-Saharan Africa, to produce chicken breeds that are more relevant for women and their households, providing options for different contexts.

An often-observed trait preference of women and food-insecure producers is for early-maturing varieties, despite the tradeoff of lower productivity. This may be because women and the poor are often land-scarce and cash-poor and face food insecurity, trying to meet household subsistence food needs year-round. Early-maturing varieties are one way to manage asset scarcity early in the growing season. Dependence on rain, vulnerability to climatic risks, availability of labor, and priorities in time allocation may also be factors affecting women and men differently and influence the preference for early-maturing varieties. Going beyond trait preferences as such—and into the underlying factors that shape them—can help breeders **set breeding priorities** that more effectively address the needs of the target population (Ashby 2018, Weltzien et al. 2019, Mudege et al. 2020) to provide them with **real choice options**.

Changes in how breeding priorities are set

Before the formalization and specialization of breeding programs, both men and women farmers, depending on their role in seed management and status, were involved in breeding. This included selection of naturally emerging crosses (Mokuwa et al. 2014), testing, cross-breeding, conducting varietal trials across seasons from material sourced from neighbors and those in their social circles, and evaluating the merits and demerits of these varieties in their specific sites (Farnworth and Jiggins 2003). With formal (current) breeding, processes, and decision-making largely shifted to breeding scientists, in terms of managing and controlling the gene flow and deciding what genetic qualities should be valued and for what markets, the operational implications of the differentiated roles of men and women have often been unwittingly ignored (ibid.). Nevertheless, some initiatives have targeted a bridging process to incorporate user perspectives, and more specifically, gender perspectives in breeding objectives.

An early example of changes in breeding priorities, influenced by gender-differentiated information and/or preferences, is the case of bean breeders in Colombia during the 1980s. Inspired by new evidence from participatory research, breeders learned about the multiple uses of beans in households and the key role of women in making the choice on what varieties to grow. As a result, breeders' fields kept varieties that they would not otherwise have selected (Ashby 1990). Nearly 40 years later, bean breeding teams in Africa are using segmentation and targeting tools and techniques combined with thorough socioeconomic analysis to make more fundamental decisions to consistently incorporate gender considerations in breeding priorities (Nchanji 2018).

At the turn of the century, the Green Revolution breeding paradigm began to shift toward more participatory breeding schemes. Animal and plant breeders started to acknowledge the need for gender analysis in breeding (Ceccarelli et al. 2007, Christinck et al. 2017, Katungi et al. 2018a). The barley breeding program in Syria is an example of an intervention that decided to carry out participatory diagnosis early in the design of new breeding products. This allowed a focus on the strategic needs of women for income-generating opportunities and the co-development of new varieties with women producers to expand their participation in seed marketing (Galiè et al. 2018).

The case of cassava in Nigeria is a more recent example of changes in the operational structure of breeding programs and how they set priorities to include gender considerations. Cassava in Nigeria is a major smallholder crop primarily for local processing and home consumption. Trait preference studies on cassava underscored the extent to which food product quality and processing traits were more important for women, including ease of peeling and swelling ability in *gari* and *fufu*[4] (Bentley et al. 2017, Olaosebikan et al. 2018). These findings, and additional gender and monitoring information, have led the breeding unit to (a) include a focus on women farmers and processors; (b) integrate social science and food science as breeding team competencies; and (c) include information on social and food quality variables for decision-making processes.

This example is critical to understand two important aspects in addressing gender in breeding to advance toward gender equality. The first aspect is that of tools, methods, and procedures that enable a better understanding of the interplay between traits and gender. Such an understanding can drive concrete actions and suggestions that can be addressed through breeding. The second aspect is the incorporation of these suggestions and the traits selected through

4 *Gari* and *fufu* are traditional West African foods based on flour made from cassava roots.

deliberate attention to gender. Important here is that the incorporation of gender dimensions is not by chance, or the result of fleeting opportunities, but rather a consequence of formal and systematic processes embedded in breeding structures.

Selection and testing experimental cultivars and new animal breeds

Improving access to and adoption of improved crop varieties and livestock breeds that are adapted to specific environmental conditions is an important approach to increasing production, productivity, and food and nutrition security. However, improving access is a challenge that requires rethinking approaches to mechanisms and market systems that can advance access to new breeding material. Conventional breeding programs that focus narrowly on high input use to minimize environmental risks have limited success. Environmental variations at both the landscape and the field level, limited access to resources by smallholder farmers, poor infrastructure, poor governance, and limited risk mitigation measures further hinder the success of conventional breeding (Charles et al. 2010). Social structures, including gender norms and gender division of labor, that inform farmer selection criteria are often unknown to the breeders or not part of breeders' standards for selection (Mulatu and Zelleke 2002).

Most experiences of gender integration in breeding are related to the later stages of breeding decision-making, with women involved in evaluating advanced material or released varieties and in their distribution. Mother and baby trials, participatory varietal selection, and other participatory research appraisal tools are frequently used to conduct evaluations and extract information to refine breeding products and enhance gender responsiveness in delivery mechanisms.

In response to low rates of adoption of improved released cultivars in rain-fed rice environments in eastern India, a participatory plant breeding project was implemented in the late 1990s. Male and female farmers in the drought-/submergence-prone villages agreed that grain yield and crop duration were the most important traits when choosing varieties for upland and low-lying areas. However, women gave more importance to traits related to tasks that they conducted, such as weed competitiveness and post-harvest qualities (ease of de-husking and threshing, high milling recovery, and suitability for different food preparations, for example puffed rice).

This led to the program revising the methods for evaluating rice varieties on farmers' fields. Farmers' selection criteria were included in rice varietal selection

(mother trials) and farmers were also included in the early evaluation of new rice lines under their own management (baby trials). The women were able to select lines with good eating qualities and suitable for making other rice products. The approach described in the rice case contributed to equitable access to cultivars with traits that responded to the general needs of men and women (Paris et al. 2008). It is during the evaluation processes of this later stage that valuable information is generated to support further changes in earlier stages of the breeding cycle.

These experiences have contributed to growing recognition that gender analysis is not something that should come at the end of the research process, essentially to enhance adoption of the new breeding products generated with so-called "gender-neutral" objectives. The findings support the need to develop feedback loops to learn from experiences of early and late testing of material, in a way that these can feed into developing gender equality objectives in early stages of the (next) breeding process. Developing effective feedback loops requires systematically and cyclically incorporating gender equality concerns throughout the different stages of the breeding cycle. The continuous monitoring and evaluation of outputs and outcomes is essential to enhance learning and to redirect the process toward the desired outcomes.

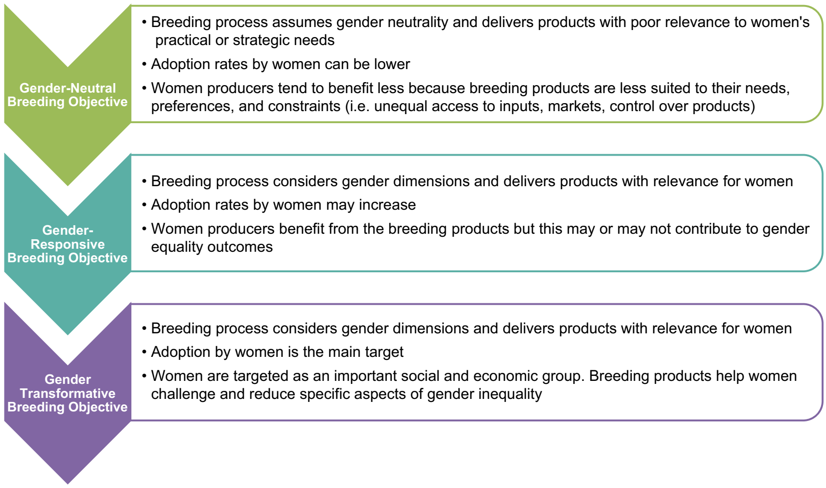
Toward a next generation agenda for gender research and breeding-related development outcomes

The incorporation of gender in breeding processes has gained attention from biophysical researchers over time, mainly as an opportunity to tackle low adoption rates of new breeding products. However, it is important to point out that higher adoption rates do not necessarily mean progress toward gender equality. Outputs and outcomes achieved are determined by the objectives set in breeding priorities. The three possible outcomes of a breeding process depend on the objectives pursued and the measurement indicators established. Figure 2.4 describes these.

A gender and breeding research agenda should carefully articulate gender objectives in breeding to advance toward gender equality. The big question is: **How do we ensure gender equality objectives are incorporated at the level of breeding objectives?**

Taking this question to heart, with differentiated objectives as a starting point, a future-oriented research agenda that builds on the existing and emerging gender and breeding work can be envisioned. Such a research agenda includes both methodological and institutional innovations. Further **methodological** innovation is needed for segmentation, targeting, trait identification, and breeding selection procedures at each stage, and gender-inclusive product

FIGURE 2.4 **Process and outcomes of different gender objectives in breeding**



Source: Orr et al. (2018).

evaluation. Innovative mixed methods approaches and big data need to be further used and adapted to integrate data from gender relations and the underlying factors that shape preferences, needs, and constraints.

New tools and methods, at all stages of the breeding cycle, should include in their design a prospective analysis of positive or negative effects of the new breeding products vis-à-vis gender equality. They can build on emerging insights into the usefulness of taking a gender relations perspective and looking at the underlying factors of gender differences and disparities. These tools will need to collect data *from* women and men, and *on* women and men, to shed light on gender dynamics and the underlying factors that shape them. In order to formally incorporate the use of new methodological innovations in a systematic and consistent way across breeding programs, **institutional** innovations will also be needed. The CGIAR Excellence in Breeding Platform, currently working to change the breeding mindset toward interdisciplinary and client-oriented breeding, offers great potential to formally incorporate gender dimensions across the breeding process.

At this point, we want to focus our attention on a third core element of the future research agenda: the key role that **monitoring, evaluation and learning** can play in advancing gender equality through breeding. Evaluation and learning are central in the complex scenario of understanding the potential and actual contribution of technology development to gender equality.

Monitoring and evaluation plays a key role in strengthening the impact pathway, presented in Figure 2.1, and the possible outputs aligned with the breeding cycle, presented in Figure 2.2. These provide a robust starting point for further monitoring, evaluation and learning innovations that can play a critical role in assessing and strengthening contributions toward gender equality. This section presents specific suggestions for evaluation and learning loops in four specific areas: (a) segmentation, targeting, and the definition of trait preferences; (b) changing breeding priorities; (c) selection and testing of experimental cultivars; and (d) creating a new network of feedback loops.

Evaluation and learning in segmentation, targeting, and the definition of trait preferences

Research should focus on **understanding when, where, and why gender relations and inequalities influence beneficiary or user groups**. At this early stage, it is also important to anticipate how design decisions may affect and be influenced by gender-differentiated constraints and access to resources and opportunities (Ashby et al. 2018). This will enable the breeding program to better understand the gender dimensions in each social segment the program decides to target, and in relation to the potential package of traits. The final outcome of Stage "0" should be the definition of a product profile that holds breeding objectives (Kotch n.d.) to benefit specific beneficiary groups taking into account gender differences.

As discussed in earlier sections, there are concrete examples of incorporating gender dimensions at the stage of product design (Paris 2001, in Farnworth and Jiggins 2003, Ceccarelli et al. 2007, Galiè 2013, Nchanji 2018). However, all cases have used different approaches and methods, and have collected information on different variables. Looking ahead, it is important to formally incorporate a systematic and replicable process of data collection, aggregation, and analysis in existing breeding structures.

Evaluation and learning in changing breeding priorities

Experiences with participatory plant breeding demonstrate that engaging farmers in the breeding process and in early testing can yield positive results, both in terms of breeding products with traits that are useful for women and men and for achieving women's empowerment (Galiè 2013, Nchanji 2018). In Rwanda, women were identified as bean experts to work with breeders for better cultivars—a revolutionary move in a patriarchal context (Nchanji 2018). Participatory plant breeding emerged as a means of decentralizing breeding processes, increasing the responsiveness of breeding processes to the gender

roles of men and women, yielding empowering outcomes for women (Galiè et al. 2018). While multiple factors contributed to the successful integration of gender, an element emerging as a common denominator is that the breeding objectives were set and defined by the **end users**, therefore generating **real choice options**.

Looking ahead, the challenge is to replicate the success of these cases in defining breeding objectives that respond to the needs, preferences, and constraints of both men and women, and that promote structural changes that allow breeding to produce real choice options. This should be accompanied by a thorough assessment of the social and economic impact of breeding in terms of gender equality, creating and dynamically incorporating feedback loops across different stages of the breeding cycle to enhance the learning process.

Evaluation and learning in selections and testing of breeding material

An essential component for incorporating gender equality dimensions in the selection and testing of breeding material is the definition and implementation of evaluation criteria with, and for, gender-differentiated target segments of the population. Experience includes tools such as participatory varietal selection (Agboh-Noameshie et al. 2013, Misiko 2013, Mudege et al. 2015, 2017), mother and baby trials (Paris et al. 2008), and other participatory research appraisal tools for evaluation (Paris et al. 2008, Misiko 2013, Mudege et al. 2017) applied to intentionally capture gender-differentiated perceptions.

For the most part, gender has been considered only at the later stages of breeding, with women involved in evaluating advanced material or released varieties, and in their distribution. Insufficient consideration of gender-responsive or gender transformative dimensions in data collection processes over varietal adoption and impact is reflected in inadequately described product profiles (Thiele et al. 2020), and this makes the creation of feedback loops a real challenge. Lessons need to be harvested to make it possible to develop and institutionalize feedback loops, which can contribute to breeding priorities that promote equality of opportunity in accessing meaningful technology options for choice-making.

Evaluation and learning: creating a network of feedback loops

Gender dimensions and equality are rarely identified as a priority consideration in breeding decisions at the beginning of a process (Ashby 2018). Interestingly, however, learning loops and feedback emerging from the inclusion of gender dimensions in the later stages of the process prompt breeders to reconsider the

gender analysis upstream. An outstanding example of this is in sorghum in Mali, where a fundamental shift in product definition occurred in response to research on gender undertaken during the testing of experimental varieties. The program found that, while sorghum is locally considered a "man's crop", women also grow it for their own specific uses. This led to a rethink of the product profile and acknowledgment that gender dimensions must be included at earlier stages (ibid.).

Stakeholder consultations and socioeconomic surveys are critical to integrate gender into decision-making. Examples from programs like the *ololili* forage system in Tanzania and Matooke in Uganda have successfully integrated insights from gender-responsive methods, complementing meaningful qualitative research with surveys. A more nuanced approach should (a) integrate gender considerations in mixed methods and large datasets; (b) use gender-disaggregated data with reference to socioeconomic indicators; and (c) not rely solely on "women's participation" in activities, but more on their specific roles. This will shape a more disciplined, less anecdotal approach that can be formally institutionalized.

Moreover, some programs, as with groundnuts in Malawi and barley in Syria, have proactively sought to alter procedures to suit the convenience of women participating in various consultations. Examples from some of these programs have evolved to transform the composition of breeding research teams, with the inclusion of seed system actors, gender and social scientists, and traders, in addition to breeders. They thus systematically embedded these actors in the breeding decision-making process (Ashby and Polar 2019). Others, like the Maize program in Africa, have seen the inclusion of manuals for gender-responsive breeding (Mulema 2018, Adam et al. 2019) for a more thorough institutionalization of approaches.

Over the years, the formal inclusion of gender analysis in breeding has been attempted across CGIAR institutions and in many national agricultural research and extension system networks (Farnworth and Jiggins 2003), as well as through initiatives like GREAT[5], which focused specifically on integrating gender into the biophysical sciences. Breeding programs have evolved in terms of changing some protocols and considerations as to how they evaluate demand. However, with few exceptions, gender analysis in breeding is still at a formative stage, evolving "from ad hoc discovery of gender-differentiated traits" but more

5 Gender-Responsive Researchers Equipped for Agricultural Transformation (GREAT) is a Gates Foundation–funded five-year collaboration between Cornell University, in the United States, and Makerere University (www.greatagriculture.org).

often benefiting from lessons encountered at the later stages of the breeding process (Ashby 2018).

The objective ahead is to identify and institutionalize systematic entry points to create feedback loops linking gender analysis into the procedures, protocols, and practices of the breeding cycle and breeding structures. While current market trends visualize breeding as a pipeline, to foster learning and benefit from feedback loops, the process needs to be internalized as a cycle. Feedback should be formally established through a definition of entry points (moments and frequency of data analysis). While the specific moments of critical analysis have been identified (see Table 2.1 on the decision checklist and Figure 2.2 on the breeding cycle entry points), the iterative generation of data and their collective analysis as part of the breeding process are yet to be tested, moving from ad hoc processes to systematic, replicable, and cyclical ones. This type of analysis will provide evidence to support further institutional innovations and structural change to advance toward engendering breeding processes that disrupt the status quo and create equal opportunities for men and women to benefit from agricultural science and technology development.

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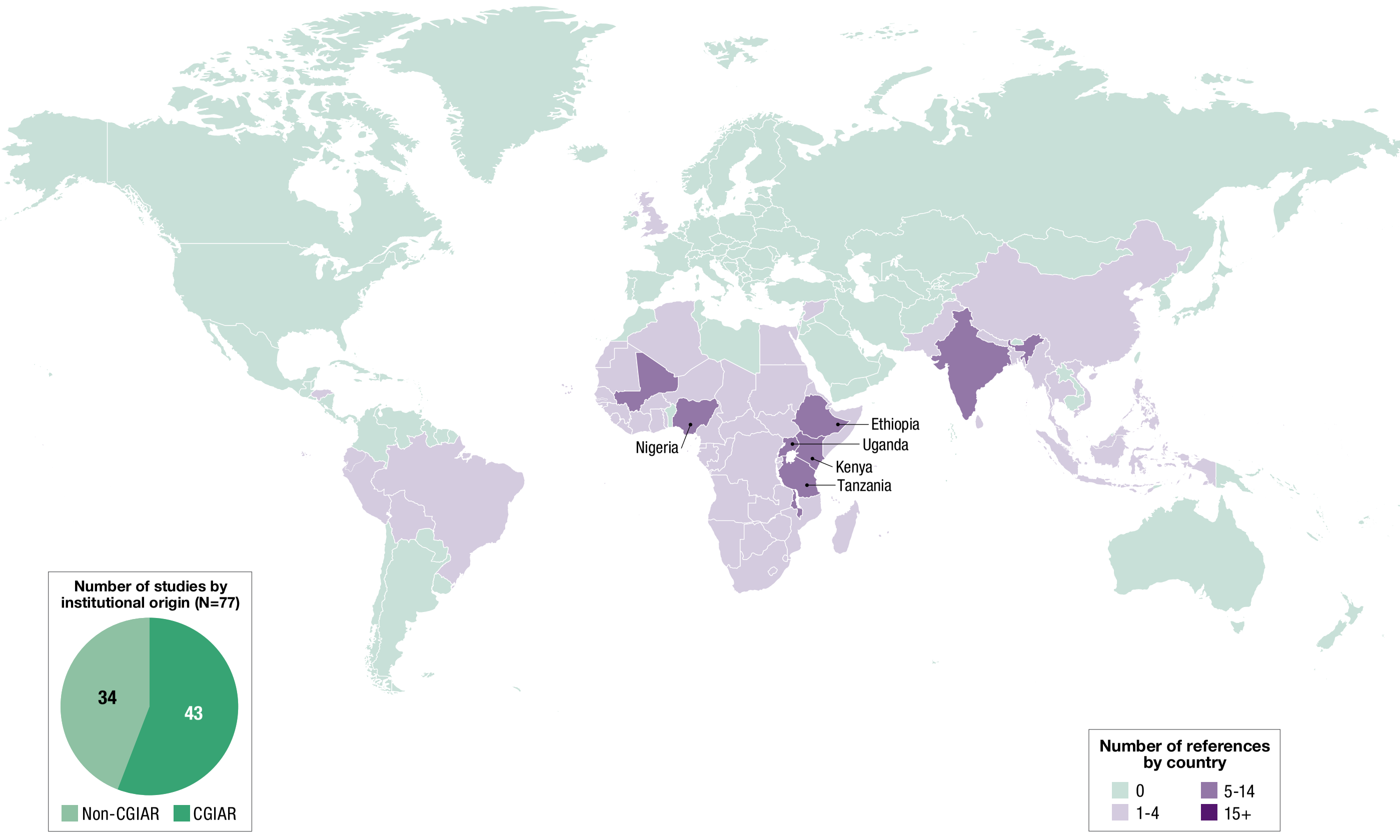
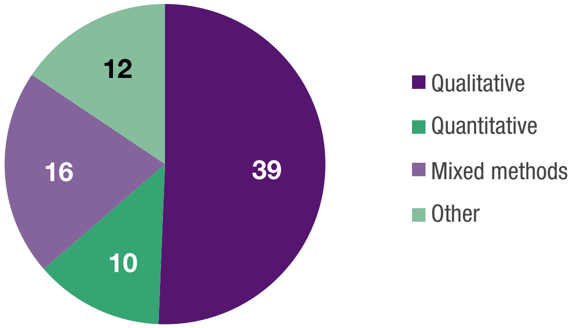
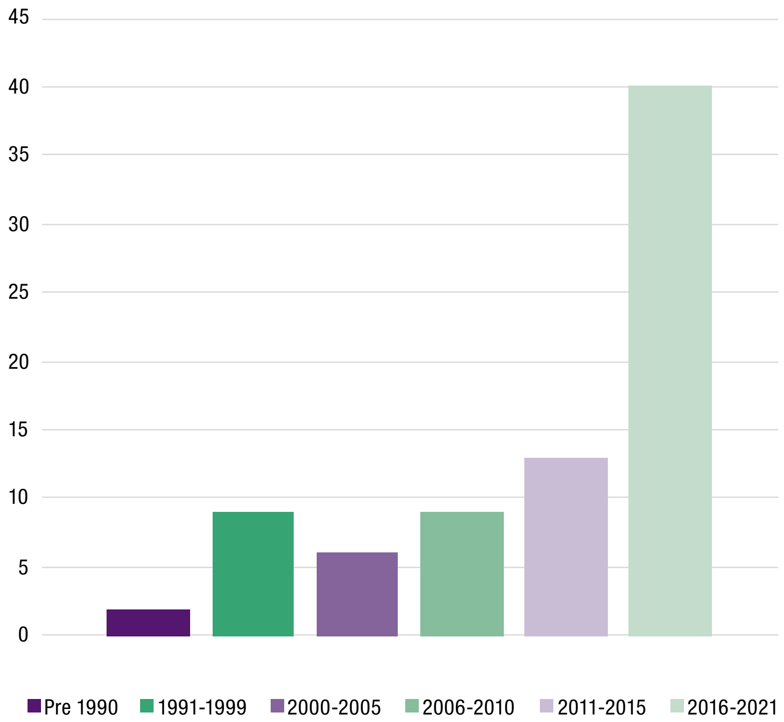
Geography of study sites for publications cited in Chapter 2



Number of cited studies by research methodology (N=77)



Timeline of cited studies (N=77)



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