

WOMEN FARMERS, AGRICULTURAL EXTENSION AND ACCESS TO IMPROVED CROP GENETIC TECHNOLOGIES: A REVIEW

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ABSTRACT

Women play a vital role in agriculture through crop production, seed selection, livestock management, post-harvest activities, household nutrition and conservation of plant genetic resources. However, women farmers often face gender-based constraints in accessing land, credit, markets, agricultural extension, information, quality seed and improved crop technologies. Improved crop genetic technologies, including high-yielding, disease- and pest-resistant, drought- and heat-tolerant, early-maturing and nutritionally enhanced varieties, can contribute significantly to productivity, food security, income generation and climate resilience. Nevertheless, technological availability alone does not guarantee adoption or benefits among women farmers. Access to information, financial resources, inputs, markets and household decision-making strongly influences technology uptake. Gender-responsive agricultural extension can help overcome these barriers by linking women farmers with researchers, breeders, seed producers, input suppliers and markets. Approaches such as participatory varietal selection, farmer field schools, women extension workers, self-help groups, community seed systems, farmer-to-farmer learning and digital advisory services can strengthen women's participation in agricultural innovation. This review highlights the need to recognize women as active partners in crop breeding, varietal evaluation, seed production, technology dissemination and agricultural decision-making. Integrating gender-responsive extension, marketing and seed systems with improved crop genetic technologies can promote more inclusive, productive, resilient and sustainable agricultural development.

KEYWORDS: Women farmers, agricultural extension, gender-responsive extension, and women empowerment

1. INTRODUCTION

Agriculture continues to be one of the key sectors of livelihood in developing nations especially for rural families that rely on agricultural farming, animal rearing, horticulture and forestry for their income and food. In agriculture, women have a great role to play through diverse tasks like seed selection, nursery growing, planting, transplanting, weed removal, harvesting, threshing, drying, storing, processing and marketing. Women's role is equally significant in growing crops which are grown mainly for home consumption. Despite the realization of women's contributions to agriculture production, this has not always been coupled with equal provision of productive means and technologies in agriculture.

The concept of the farmer has traditionally been associated with the male head of the household in many agricultural programmes. As a consequence, agricultural research and extension systems have frequently approached men as the primary users of new agricultural technologies, while women's agricultural activities have remained less visible. This situation is particularly important in relation to improved crop genetic technologies because access to improved seed and planting material is strongly influenced by information, institutional participation, purchasing power, access to markets and decision-making authority. A woman may actively participate in crop production but may not independently decide which variety is cultivated, where seed is purchased, how much seed is purchased or how the resulting income is used, (Achandi et al., 2018).

Improved crop varieties are among the most widely disseminated agricultural technologies. Plant breeding programmes have produced varieties with higher yield potential, improved resistance to diseases and insect pests, tolerance to drought, heat, salinity and flooding, early maturity, improved nutritional characteristics and better processing or storage qualities. Such technologies are increasingly important in the context of climate change,

population growth, natural-resource degradation and increasing demand for nutritious food. Nevertheless, genetic improvement alone cannot generate its intended benefits unless improved seed reaches farmers and farmers have the resources and knowledge necessary to use it effectively, (Doss, 2018).

The process of technology adoption is therefore influenced by a complex interaction between technological characteristics and socioeconomic conditions. Doss and Morris demonstrated that differences in adoption of improved maize technology cannot necessarily be explained by gender alone because unequal access to complementary resources such as land, labour and extension services can substantially influence technology adoption. This observation is important because it shifts the discussion from the question of whether women are willing to adopt improved technologies toward the more fundamental question of whether women have equal opportunities to access and use them, (Doss, 2000).

Agricultural extension and advisory services occupy a critical position within this system. Extension can provide information regarding improved varieties, production practices, seed sources, pest and disease management, climate adaptation and market opportunities. Extension can also create a feedback mechanism through which farmers communicate their needs and preferences to researchers and breeders. When women are directly incorporated into extension programmes, they can contribute information about crop traits, processing requirements, household consumption, labour demands and local production constraints that may otherwise remain poorly represented in breeding programmes, (Alkire et al., 2013).

The increasing emphasis on gender-responsive agriculture has therefore created an important opportunity to connect crop genetic improvement with inclusive agricultural extension. Instead of considering women merely as recipients of technologies developed elsewhere, contemporary approaches increasingly emphasize their participation as knowledge holders, evaluators, producers, entrepreneurs and co-designers of agricultural innovation. The present review examines these interrelationships and discusses pathways through which agricultural extension can improve women's access to improved crop genetic technologies, (FAO, 2023).

2. The Role of Women Farmers in the Agricultural System

Women farmers cannot be considered a homogeneous group as there are differences in the agricultural roles performed by women depending on geographic location, crops, farming systems, size of landholding, household structure, socio-economic status, education, age and access to institutional resources. In some production systems, women participate in labor intensive work like transplanting, weeding, harvesting and processing crops; while in other production systems, women operate on their own farms, livestock enterprises, horticulture units and small agricultural firms. Thus, "women farmers" refer to a very diverse group with varying technological needs and differing control over agriculture related resources, (Doss, 2018).

The role of women is evident in the operations of seed selection and use of crops. Women can be involved in selecting seeds from the last harvests, selecting the best performing crops, separating the seeds, drying the seeds, storage of planting material and selection of varieties suitable for domestic consumption. In many traditional agricultural systems, women also have good knowledge about the taste, cooking quality, storability and nutrition content of various crop varieties. This kind of information is very useful for improving crops as yield alone is not the only performance trait of varieties, (FAO, 2026).

Women play an equally important role in providing household food security. Women's participation in decision-making about crop diversification, food preparation at home and food distribution implies that they may have a different assessment of improved crops compared to farmers whose focus is on yield potential for the market. Thus, if the variety has high potential in terms of yield for the market, but needs more time for cooking, has bad taste or requires additional labour for processing, then it will not be preferred. Likewise, if the variety has good nutritional qualities, but looks and cooks differently from the locally preferred food, then its adoption may be limited, (Doss et al., 2014).

Thus, it is necessary to note that the efficiency of crop varieties should be evaluated in terms not only of biological yield. Farmers evaluate varieties based on agronomical, economical, nutritional, cultural and labour qualities of varieties. Since women usually are responsible for certain aspects, their participation in technology evaluation becomes important.

3. Gender Disparity in Access to Agricultural Resources

Access to improved agricultural technologies depends highly on the access to other resources. Seeds cannot be considered separately from land, irrigation facilities, fertilizers, credit, labour, equipment, markets and agricultural knowledge. When women have less control over these resources, their ability to benefit from improved crop genetics may also be restricted, (Hidrobo et al., 2024).

Access to land is especially significant. In many agricultural societies, ownership or control over land is a condition necessary to be eligible for agricultural programs and institutional and government subsidies. Women might farm land that belongs to their household or family without being owners or having the right to take independent decisions. Thus, agricultural institutions, which consider land ownership in selecting beneficiaries, might unintentionally ignore women engaged in agriculture, (Adekola et al., 2026).

Finances are another crucial component. The use of improved seeds, particularly hybrid seeds or special climate-resistant varieties, might be associated with higher costs in comparison with locally saved seeds. Thus, women with poor access to credit or own income might be unable to afford improved seeds although they understand that such seeds will bring more benefits. Poor access to credit might limit their capacity to buy fertilizer, irrigation and pest control products that are needed to achieve higher yields from new seeds, (Abebe, 2017).

Labor availability is as crucial a component as well. New improved technologies may be productive but they might change labor needs in cultivation, harvest, or processing of agricultural products. Many women combine their engagement in agriculture with household chores and childrearing responsibilities. Consequently, a technology that increases production while increasing women's labour burden may not necessarily improve their overall welfare. Agricultural extension must therefore consider the complete resource environment within which women make technology decisions. Providing information without addressing the associated constraints may produce limited results, (FAO, 2026).

Table 1. Conceptual relationship between women farmers, extension and improved genetic technologies

Stage	Conventional approach	Gender-responsive approach
Breeding	Researcher-defined traits	Participatory identification of women's and men's trait preferences
Testing	Research-station evaluation	On-farm evaluation involving women
Extension	Male household head targeted	Women and men directly targeted
Demonstration	General farmer demonstration	Women-inclusive demonstrations
Seed supply	Commercial/official channels	Formal + community + women-led channels
Training	Fixed location/time	Flexible, accessible training
Digital advisory	Generic messages	Gender- and context-responsive messages
Adoption	Individual household decision	Individual and intra-household decision analysis
Impact	Yield and income	Yield + income + labour + nutrition + agency
Feedback	Researcher-to-farmer	Two-way farmer–extension–breeder feedback

4. Agricultural Extension and Its Changing Nature

For a long time, extension has been defined as a means for transfer of agricultural technology and knowledge from agricultural research institutions to farmers. Extension in modern times is not as narrowly defined as the earlier definition. Modern day extension has come to be recognized as a knowledge and innovation system involving farmers, research, universities, government ministries, private organizations, non-governmental organizations, farmer groups and markets, (Barbercheck, 2020).

This change is especially important for women farmers. The technology transfer model will usually treat the male member of the family as the farmer while communication is conducted via meetings that women are not able to attend. The knowledge system model acknowledges different types of agricultural actors and seeks to establish appropriate communication linkages with each one of them, (Jiggins et al., 1997).

There are various ways in which extension can help women gain access to genetically improved crops. This includes increasing awareness of newly introduced varieties, providing information on their agronomic characteristics, seed sources, conducting demonstrations, participatory varietal selection, linking up farmers with seed providers and farmer feedback to breeders

Gender-responsive extension therefore requires more than simply increasing the number of women attending training programmes. It requires redesigning extension institutions so that women are recognized as agricultural clients and active participants in agricultural innovation, (Mishra et al., 2024).

5. Gender-Sensitive Agricultural Extension

Gender-sensitive extension is an approach where the varying requirements, responsibilities, constraints, choices and possibilities of women and men are systematically taken into account in the design, implementation and evaluation of advisory services. The goal is not necessarily to have completely different advisory service systems for women and men but rather to make sure that the services are accessible and relevant to both sexes, (Jafry and Sulaiman, 2013).

One key step here is to recognize women as farmers while designing programmes. Sex-disaggregated data on participation, technology awareness and adoption, training attendance, advisory services etc. need to be collected by extensionists. Without these data, gender-related differences can remain unseen in household-level data.

It is equally important to consider timing and location of the advisory activities. Women with significant household responsibilities might not be able to participate in training activities held in the busiest periods of their household and farming activity. Decentralized trainings and demonstrations can help here (Galiè, et al., 2025). In addition to that, the communication approach used needs to be carefully designed. Practical demonstration, visual communication, use of the language of the farmers, mobile advisory services and farmer-to-farmer learning can complement the traditional training style. Where literacy levels are low, visual and practical methods can be particularly useful, (Diaz, and Najjar, 2019).

Women extension agents can also play an important role, especially in communities where social norms limit interaction between women farmers and male extension workers. However, increasing the number of women

extension workers should be accompanied by institutional support, training, mobility facilities, safety and opportunities for professional advancement, (Jarial and Sachan, 2021).

6. Access to Improved Crop Genetic Technologies

Improved crop genetic technologies constitute one of the key products from agricultural research. Traditional breeding, hybrid breeding, participatory breeding, molecular breeding, and genomic breeding have increased the capacity of scientists to produce varieties suitable for particular production conditions and farmer needs, (Paris et al., 2008).

Improved varieties can be superior in terms of productivity, time of maturity, resistance to disease and pest, stress tolerance, nutrition quality, processing traits, or market price. However, the presence of an improved variety does not necessarily lead to farmer adoption, (Ragasa et al., 2013).

The first prerequisite is awareness. Without knowing about a variety, farmers cannot assess its worth. The second prerequisite is the availability of seed. Although farmers may be aware of a variety, adoption might be still low due to the absence of seed in the locality, high price, or poor quality. The third prerequisite is technical knowledge. It requires farmers to know how to manage a particular variety. Finally, the fourth prerequisite is the availability of complementary inputs and market. Women could face difficulties in all these steps. Agricultural extension becomes the linking bridge between crop improvement and farmer adoption, (Nyberg et al., 2025).

Table 2. Potential roles of women in crop genetic technology systems

Role	Major activities
Knowledge holder	Local varietal identification and seed knowledge
Variety evaluator	Participatory varietal selection
Seed producer	Seed multiplication and quality management
Seed entrepreneur	Community seed enterprise
Extension participant	Farmer field schools and demonstrations
Technology disseminator	Farmer-to-farmer communication
Consumer evaluator	Taste, cooking and processing assessment
Decision-maker	Variety and seed selection
Breeding partner	Identification of preferred traits
Community leader	SHG/FPO/cooperative-based innovation

7. Gender Aspects of Variety Selection

The variety selection process involves many criteria and dimensions. The farmers will not consider only the yield when selecting varieties. Maturity period, pest and disease tolerance, stress resistance, grain and fruit quality, economic value and labour input will also be considered.

The women might have specific knowledge in relation to attributes which relate to household consumption and processing. In vegetable crops, the involvement of women during harvesting, grading, processing and consumption of the products may reveal traits which are underrepresented in the breeding programme. In the cereals and pulses, attributes related to preparation time, taste, storability and nutritional values will be considered, (Tufan et al., 2018).

This does not necessarily imply that women will have specific preferences whereas men will have other preferences. On the contrary, gender roles and responsibilities might reveal differences between women and men in relation to crop performance attributes. What is needed is an empirical assessment of these preferences. Participatory breeding and varietal selection offer good opportunities for such evaluation. Women farmers can test the varieties in their real environment and give comments on their agronomic and household attributes.

8. Participatory Variety Selection and Women Farmers

The process of participatory variety selection offers a chance for farmers to participate in the evaluation of improved breeding materials and varieties. In other words, rather than being tested in experimental farms run by researchers, varieties are evaluated in farms managed by farmers. It is especially important to involve women because farmers evaluate varieties based on criteria not measured by breeders. These may include cooking properties, difficulty in processing, labour requirements during harvesting, storability and many other factors, (Dar et al., 2020).

Participatory research conducted in eastern Uttar Pradesh has illustrated the importance of women farmers' involvement in rice breeding and variety evaluation. This may make breeding programmes more relevant because it will ensure the establishment of communication channel between farmers and researchers.

But the usefulness of participatory research is not confined to variety selection. Involving women farmers in participatory research increases their confidence in the technologies, makes them aware of variety features and provides them with opportunities to interact with extension personnel and other farmers. In this sense, a participatory approach turns women farmers into participants of innovation process rather than passive receivers, (Dar et al., 2026).

9. Women and Seed Systems

Seed systems will influence the actual availability of improved varieties to farmers. Seed systems may be formal systems consisting of seed companies in the public sector, private sector, research organizations and certified seed

systems, or informal systems consisting of farmers saving seeds, exchanging planting materials and producing community seeds. Women can take part in both seed systems. They can save household seeds, exchange planting materials, produce community seeds and form small seed companies. Participation of women in these systems might be especially critical when it comes to crops where local exchanges are an important channel of seed acquisition, (Hossain et al., 2024).

Women's self-help groups might serve as an institutional structure to organize seed production, storage, distribution and marketing. Collective efforts of women can help them to overcome transaction costs related to small seed companies. Recent experience from India shows that women community institutions are capable of helping to disseminate and adopt improved rice and wheat varieties. This experience is important as it proves that women are able to act not just as receivers but also as intermediaries in seed systems, (Suri and Gartaula, 2023). However, women-led seed systems require technical training, access to foundation or breeder seed, quality-control mechanisms, storage facilities, market connections and institutional support. Without these components, community seed initiatives may remain small-scale and difficult to sustain.

10. Self-help groups as agricultural extension platforms for women

Self-help groups have been identified as an important institution that women in rural areas in India use. While most of the SHGs had originally been founded on savings and credit, their institution allows for possibilities of agricultural training, joint procurement of inputs, seed production, enterprise and market linkage. Some of the constraints that individual women farmers face could be reduced by creating an environment of a group. Training can be undertaken jointly, information can be shared, and experiences regarding new varieties can be exchanged. A member of an SHG who has adopted a new variety of seeds can share practical information with others and thereby help them adopt new technologies quickly, (Raghunathan et al., 2019).

Demonstrations of improved varieties can be conducted within the self-help group. This could prove particularly useful because women will be able to assess the performance of crops rather than relying on information conveyed through extension messages alone. However, when self-help groups are used as platforms for agricultural technology transfer, care must be taken not to impose additional duties on women who already have considerable agricultural work to do. There should be clear benefits from group activities, (Nichols, 2021).

11. Women as Seed Entrepreneurs

Inclusion of women in seed production is an area that presents a significant possibility of combining the empowerment of women with technology transfer. Community-based seed production could lead to local employment as well as increased availability of improved varieties.

Seed entrepreneurs among women could be involved in seed multiplication, cleaning, sorting, packing, storage and marketing locally. Technical assistance from extension services on variety purity, seed quality, isolation needs, crop management and storage would be essential. This kind of enterprise would not only enhance distribution of improved varieties but also allow them to reach the end users who could be living in rural and inaccessible locations where commercial seed enterprises would not consider it cost-effective to distribute their products, (Puskur, et al., 2021).

Nonetheless, the promotion of seed entrepreneurship should be done only when a thorough market analysis is done first. The enterprise needs consistent demand, technical support, quality control and access to markets. Women need to control the income derived from the seed enterprise for this kind of program to have any meaningful contribution towards women empowerment, (Nuruzzaman, Islam, et al., 2023).

12. Digital Extension and Women Farmers

Advances in technology have opened up new avenues for digital extension in agriculture. The mobile phones, smartphones, messaging systems, agricultural apps, webinars and interactive voice response systems are all tools that can help disseminate information about agriculture quickly and efficiently and at low costs.

The digital extension system can prove especially useful when it comes to disseminating information about superior seeds since the farmers will not have to visit any extension offices for information related to varietal characters, seed sources, sowing times and production practices. Yet, the digital divide is one major problem. Women may lack access to smartphones, Internet connectivity, digital payments and agricultural apps (Lecoutere, et al., 2020). In many families, the women may have access to a single shared phone with little autonomy over its usage. Digital literacy levels may also vary greatly. Hence, the digital extension system needs to be used alongside the personal one. A combination of the two can include digital messages, village demonstrations, women extension officers, SHGs and farmer field schools.

13. Women Extension Workers

Women extension workers can contribute significantly to improving communication between extension systems and women farmers. In some rural communities, women may be more comfortable discussing agricultural, household and nutritional concerns with female extension personnel, (Saha et al., 2026).

Women extension agents can organize women-focused demonstrations, facilitate SHG meetings, support participatory varietal selection and identify constraints affecting women farmers. They can also act as institutional bridges between women's organizations and research institutions. Nevertheless, women extension personnel may themselves face institutional constraints, including limited transportation, inadequate field support, heavy workloads and insufficient opportunities for training or promotion. Gender-responsive extension therefore requires changes not only in farmer-level programmes but also within extension organizations, (Gezahay, et al., 2025).

14. Climate-Resilient Crop Genetic Technologies and Women

Climate change is increasing the importance of genetic technologies that improve crop adaptation to environmental stresses. Drought-tolerant, heat-tolerant, flood-tolerant, salinity-tolerant, disease-resistant and early-maturing varieties can help farmers reduce production risk. Women farmers may face particular constraints in accessing climate-resilient varieties because adaptation often requires financial resources, extension information and access to seed markets. If women have limited control over these resources, they may be less able to experiment with unfamiliar varieties.

Extension can reduce this uncertainty by demonstrating the performance of climate-resilient varieties under local conditions. Participatory trials can allow women to compare varieties and identify those that fit their production systems, (Muttappagol et al., 2025).

Climate-resilient breeding should also incorporate women's perceptions of risk. For example, a variety that matures earlier may help households avoid periods of food shortage, while a variety requiring less labour may be valuable where women face severe labour constraints, (Sadhukhan, 2025).

15. Nutrient-Dense Crops and Women

Another field in which gender considerations come into play in relation to crop genetics is that of nutrient-dense crops and biofortification. Women have an interest in household nutrition decisions, and thus women's tastes may influence the cultivation of nutritionally improved varieties. The fact that a variety is nutritionally improved does not guarantee that the variety will be adopted by farmers just because of the presence of the nutrients. Other factors may include taste, color, cooking time, and marketability, (Beal et al., 2024).

Women could contribute to the selection of biofortified varieties by participating in extension activities and demonstrations through which the nutritional benefits are explained, but at the same time the crops can be assessed against the criteria of local food preferences. The adoption of nutritional technologies would thus be encouraged.

16. Agricultural Extension as a Link Between Breeders and Women Farmers

One of the most important functions of extension in relation to genetic technologies is the creation of a feedback loop between farmers and breeders.

The traditional model can be represented as:

Researcher → Variety → Extension → Farmer

A more inclusive innovation model is:

Researcher ↔ Breeder ↔ Extension ↔ Women farmers ↔ Seed system ↔ Market

In the second model, women provide information that influences future breeding objectives. Extension personnel collect farmer feedback, breeders use this information to modify selection criteria, and seed systems respond to farmer demand.

Such feedback is particularly important for traits that are difficult to measure in conventional research trials. Cooking quality, processing labour, household acceptance and market preferences may only become evident when varieties are evaluated by farmers.

17. Women's Decision-Making and Technology Adoption

Technology adoption should not be interpreted simply as a household decision. Agricultural households may contain multiple decision-makers whose preferences differ according to their responsibilities and control over resources. A woman may decide which seed to save but another household member may decide which variety to purchase. A woman may manage a crop but have limited authority over marketing. Similarly, women may participate extensively in production but receive limited control over the resulting income, (Venkatesh et al., 2000).

Consequently, studies of agricultural technology should measure women's participation in decision-making rather than only recording whether a household adopted a variety. Important dimensions include women's involvement in selecting varieties, purchasing seed, deciding planting area, determining production practices, selling produce and controlling agricultural income, (Bendell et al., 2020).

18. Technology Access to Technology Agency

Access vs. Agency is a critical concept in gender-sensitive agricultural development, since while the former implies the capability of a person to get/operate a resource, the latter implies the right to make important decisions regarding this resource, (Cornelio, et al., 2022). In other words, a woman could have access to improved seeds, but she cannot decide if these seeds would be used; similarly, she could be involved in extension activities but lack any control over the resources required for the implementation of the advice. As such, in the future researches one should consider the following pattern:

Information access → seed access → technology adoption → decision making → control over the outcomes → empowerment

Women's Empowerment in Agriculture Index, among others, offers an effective way of assessing women's involvement in agricultural decisions, resource ownership, income management, leadership, and time allocation.

19. Intersectionality Among Women Farmers

Gender cannot be treated in isolation. Women farmers are diverse depending on their caste, socio-economic class, land ownership, age, education, marital status, place, institutional connections and many more factors.

For instance, there will be a difference between a woman from a family that owns no land and another woman who farms on five hectares of land. Another example is a young woman having access to a smartphone and another woman having poor digital skills.

There is therefore need for future extension and breeding projects to avoid treating women as one homogenous group of beneficiaries. Interventions should recognize different groups of women and their individual constraints.

20. Major Obstacles to Women's Access to Genetic Improvement Technologies

These obstacles facing women are interrelated rather than independent. Poor land tenure can limit access to credit which in turn limits access to seeds which further limits experiments and extension access which ultimately limits decision making.

Social norms can further restrict women's mobility and participation in public agricultural programmes. Time poverty can reduce their ability to attend training. Limited digital access can restrict participation in online advisory services. Weak institutional representation can prevent women's preferences from reaching breeders and policymakers.

Table-3: Major Constraints Affecting Women's Access to Improved Genetic Technologies

Dimension	Major constraint	Consequence
Information	Limited direct extension contact	Low varietal awareness
Institutional	Male-oriented farmer identification	Women excluded from programmes
Economic	Limited credit and savings	Lower seed purchase
Land	Limited land ownership/control	Reduced decision-making
Labour	High domestic and agricultural workload	Low training participation
Mobility	Restrictions on movement	Reduced market and extension access
Seed system	Limited local availability	Low adoption despite awareness
Technology design	Insufficient attention to women's traits	Poor varietal fit
Social networks	Limited institutional participation	Reduced information diffusion
Digital	Limited phone/internet access	Digital exclusion
Decision-making	Limited household bargaining power	Reduced control over varietal choice
Market	Weak market information	Lower incentive for commercial varieties

Therefore, interventions that address only one constraint may have limited impact. A comprehensive approach needs to integrate extension, seed access, finance, collective action and women's decision-making.

Table-4: Major barriers include:

Barrier	Effect on women farmers	Implication for genetic technology
Limited mobility	Reduced participation in distant training	Lower awareness of improved varieties
Male-oriented extension	Women receive information indirectly	Reduced capacity for independent varietal decisions
Limited land ownership	Women may not be recognized as clients	Reduced access to formal programmes
Time poverty	Difficulty attending fixed-time training	Lower exposure to new technologies
Limited credit	Reduced ability to purchase seed and inputs	Lower experimentation and adoption
Weak market access	Uncertainty about returns	Reduced incentive to adopt market-oriented varieties
Limited digital access	Unequal access to digital advisories	Digital divide
Weak social networks	Fewer opportunities to exchange information	Slower diffusion of new varieties
Cultural norms	Restricted interaction with male extension personnel	Limited direct advisory contact
Limited female extension staff	Communication and institutional barriers	Lower participation by women

A recent systematic review of agricultural extension for female smallholders found that the literature identifies barriers such as lack of time, restricted mobility and limited information and ICT access. It also emphasizes that merely providing technology is insufficient when household decision-making structures continue to limit women's control over it, (Nyberg et al., 2025).

21. Integrated Gender–Extension–Seed–Breeding Framework

An integrated framework can be developed to explain how gender-responsive agricultural innovation may operate. The first stage involves gender diagnosis, in which researchers identify the agricultural responsibilities and constraints of women and men. The second stage involves trait identification, where farmers participate in defining the characteristics they require from new varieties. The third stage involves participatory breeding and varietal selection, where women participate in testing breeding materials. The fourth stage involves gender-responsive extension, through which information is disseminated using accessible communication channels. The fifth stage involves inclusive seed systems, ensuring that quality seed is locally available. The sixth stage involves adoption and management, where farmers use the technology under their production conditions. The final stage involves impact assessment, including productivity, income, nutrition, labour, resilience and empowerment. This framework can be represented as:

Gender diagnosis
↓
Women's trait preferences
↓
Participatory breeding and varietal evaluation
↓
Gender-responsive extension
↓
Women-inclusive seed systems
↓
Access and experimentation
↓
Adoption and continued use
↓
Productivity + income + food security + nutrition + resilience
↓
Women's agency and empowerment
↓
Farmer feedback to breeders and extension

22. Evidence from India

India is one of the best places to explore the issue of women farmers and extension and improved crop varieties due to a well-developed system of self-help groups, Krishi Vigyan Kendras, agricultural universities, state agricultural departments, farmer producer organizations and other community institutions.

Self-help groups for women have evolved from savings and credit to livelihood development and agriculture. These organizations already have an established social structure, which can serve as an existing basis for the work of extension institutions in providing training and collective use of technology.

It has been shown by the evidence from Uttar Pradesh that women's self-help groups can contribute to greater access to and adoption of improved rice and wheat varieties. Likewise, the study on the wheat seed system in Bihar highlighted the importance of increased awareness of the role of women farmers and ways of taking their feedback into account during seed provision.

This suggests that gender-specific programs related to seeds and extension can be incorporated into the existing rural organizations rather than establishing any new ones. Nevertheless, further research is needed in order to investigate the sustainability and scalability of these practices. Success in pilots may not necessarily guarantee success

23. Future Research Priorities

Further research needs to focus on multidisciplinary research combining crop breeding, agricultural extension, gender analysis, and seed systems. The crop breeder needs to interact with gender researchers and agricultural extension from the very beginning of technological innovation rather than focusing on gender dimensions while disseminating innovations.

Participatory research needs to be extended where women take part in determining desired trait, assessing breeding lines and variety trials. Further research is needed to determine women's varietal preferences based on socio-economic factors, farming systems and agro-ecologies.

Extension research needs to be carried out to assess the relative impact of women extension workers, self-help groups, farmer field schools, mobile advisories, community demonstrations and farmer-to-farmer technologies. Future research must not focus merely on the extent of knowledge transfer and adoption but also changes in women's decision-making, income, labor burden and resource control. Research is needed on community-based seed enterprises run by women whether they are able to ensure sustainable access to quality and resilient seeds along with income generation.

Table 3. Priority indicators for future research

Dimension	Suggested indicators
Extension access	Number and frequency of extension contacts
Information	Awareness of improved varieties
Seed access	Distance, price, availability and source
Adoption	Area/share planted with improved variety
Continued use	Adoption over multiple seasons
Decision-making	Women's participation in varietal decisions
Agency	Control over seed and crop-related decisions
Economic outcomes	Yield, gross return, net return
Labour	Women's labour hours and drudgery
Nutrition	Household dietary and crop-use outcomes
Resilience	Performance under climate stress

Collective action	SHG/FPO/seed-group participation
Digital inclusion	Phone ownership, literacy and platform use
Empowerment	WEAI-related indicators

24. CONCLUSION

The women farmers play a significant role in the process of agricultural production and rural innovation, but at the same time their contribution has not been complemented by equal access to agricultural extension, improved seed, productive resources and decision making. The advances in technologies aimed at genetic improvements have huge potential in increasing productivity, providing better food security, reducing the risks related to the adverse effects of climate change, and building up rural livelihoods. However, these benefits can only be achieved when farmers are able to access information about new technologies, have access to quality seed, mobilize complementary inputs and make technology-related decisions. Agricultural extension is a vital element in the process of crop improvement and farmers' activities. Gender-aware agricultural extension services would help women become more familiar with the new varieties of seeds, to take part in demonstration trials and participatory varietal selection, connect women farmers with seed providers and provide feedback from the side of farmers to the side of breeders. Research needs to cover economic, technical and institutional indicators.

The evidence also demonstrates the importance of moving beyond a simple understanding of women as beneficiaries. Women can act as farmers, technology evaluators, seed producers, entrepreneurs, extension partners, knowledge holders and participants in crop-breeding decisions. Their knowledge concerning processing, nutrition, labour requirements, household consumption and local adaptation can improve the relevance of crop genetic technologies. The future of gender-responsive crop improvement should therefore be based on an integrated relationship between breeding, extension and seed systems. Improved varieties should be developed with consideration of the needs and preferences of diverse women and men farmers; extension systems should ensure that women receive information directly; seed systems should make improved varieties physically and economically accessible; and impact assessment should measure not only adoption and yield but also women's agency, workload, income, nutrition and resilience. In this context, the central objective should not simply be to increase the number of women adopting improved crop varieties. The broader objective is to create an agricultural innovation system in which women have meaningful opportunities to access, evaluate, select, use, produce, disseminate and influence the development of improved crop genetic technologies. Such an approach can contribute to more inclusive agricultural development, strengthen the efficiency of extension and seed systems, and improve the social and economic relevance of crop improvement programmes.

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