Received: 2 May 2024 | Revised: 29 May 2025 | Accepted: 12 June 2025
DOI: 10.1002/ppp3.70070

RESEARCH ARTICLE

Plants People Planet PPP Open Access

Know your men and women farmers: Ensuring host farmers in participatory trials represent heterogeneity within the target environment

Jill E. Cairns[1] | Mainassara Zaman-Allah[1] | Frédéric Baudron[1,2,3] | Rachel C. Voss[4] | Kirsty L. Hassall[5,6] | Michael Euler[7] | Emily Amondo[4] | Paswel P. Marenya[4] | Boddupalli M. Prasanna[4]

[1]International Maize and Wheat Improvement Center (CIMMYT), Harare, Zimbabwe
[2]CIRAD, UPR AIDA, Montpellier, France
[3]AIDA, CIRAD, Université de Montpellier, Montpellier, France
[4]CIMMYT, Nairobi, Kenya
[5]Rothamsted Research, Harpenden, UK
[6]University of Warwick, Warwick, UK
[7]CIMMYT, Addis Ababa, Ethiopia

Correspondence
Jill E. Cairns, International Maize and Wheat Improvement Center (CIMMYT), Harare, Zimbabwe.
Email: j.cairns@cgiar.org

Funding information
Bill and Melinda Gates Foundation, Grant/Award Number: INV-003439; Biotechnology and Biological Sciences Research Council, Grant/Award Number: GB-GOV-13-FUND-GCRF-BB_T009047_1

Societal Impact Statement
Gender responsive and more socially inclusive breeding strategies are needed to ensure new crop varieties, which offer greater yields in an increasingly variable climate, meet the needs of a diverse range of smallholder farmers. Participatory varietal selection actively involves farmers in testing and selecting new varieties at the end of the breeding process. We evaluated the inclusivity of a participatory maize breeding program in Zimbabwe. Our analysis found that setting targets for women farmer participation ensured adequate representation, but participatory research should move beyond simple targets and ensure the inclusion of different types of women and men farmers.

Summary

- There is growing interest in participatory varietal selection and gender-responsive breeding in research and development initiatives. On-farm testing is increasingly used to ensure that new varieties perform within the target environments. However, there are few established approaches for selecting host women and men farmers who reflect the diversity of the overall target population of smallholder farmers. This study sought to evaluate ex-post if recruited farmers within a participatory breeding network in Zimbabwe were representative of the surveyed population and pilot an approach to developing comprehensive farm typologies to ensure more gender-responsive and socially inclusive breeding.
- A sample of over 2,000 randomly selected women and men farmers, including those hosting breeding trials, were surveyed. A typology was constructed to group farms with similar characteristics associated with household demographics, maize production and resource endowments. This facilitated the subsample of trial-hosting farmers characteristics to be compared with the broader typology.

Disclaimer: The New Phytologist Foundation remains neutral with regard to jurisdictional claims in maps and in any institutional affiliations.

- The distribution of farm types selected by extension agents to host trials closely reflected the distribution of farm types within the surveyed population. Two farm types associated with women household heads and three types associated with men-headed households were identified, highlighting the heterogeneity within these groups. Other important factors of differentiation included farm assets, livestock ownership and maize production features.
- Sampling strategies that explicitly incorporate agronomic and socio-economic diversity within the target population should be used in the selection of host women and men farmers for participatory research to ensure appropriate gender and social inclusion.

KEYWORDS
farm typology, gender-responsive breeding, intersectionality, participatory research, participatory varietal selection, smallholder farmers, social inclusion, women-headed households

1 | INTRODUCTION

Women and men farmers are increasingly involved in the final stage of crop breeding pipelines to validate the performance of new varieties within the context of their own environment (Bruno et al., 2018; de Sousa et al., 2024; Katuuramu et al., 2020; Madu et al., 2024; Obunyali et al., 2019; Setimela et al., 2017, 2018; Voss et al., 2025; Worku et al., 2020). Smallholder farmers are highly diverse in terms of resource endowments and access, preferences, aspirations and constraints, even within a community (Crossa et al., 2002; Doss, 2001). It is therefore essential that on-farm testing strategies adequately capture the social heterogeneity of smallholders within the target population of environments to ensure that crop breeding is responsive to diverse farmers' needs. Failure to do so could result in the under-, or overrepresentation of a subset of farmers (Crossa et al., 2002) and, ultimately, the development of varieties poorly suited to the needs, constraints and priorities of certain subgroups of the rural population.

Of special concern are women and resource-poor farmers who are sometimes under-represented in breeding trials without direct procedures to target them, contributing to gender blindness in breeding programs (Ashby, 2024; Freeman, 2001; Rohrbach, 2001; Snapp, 2002). For this reason, on-farm testing approaches increasingly set targets for women farmers' participation as trial hosts or deliberately elicit varietal preferences of women visiting trials (Voss, Cairns, et al., 2023). However, gender is one axis of social difference that impacts agricultural production, crop varietal choice and end uses (Bacud et al., 2024; Bullock & Crane, 2021; Elias et al., 2018; Harcourt, 2016; Madu et al., 2024; Yami et al., 2024). Social differences including marital status, age, education level, ethnicity, wealth, access to capital and in- and output markets, as well as livelihood orientation, are affecting factors that influence the adoption of agricultural innovations (Ruzzante et al., 2021; Schulz & Börner, 2022) and farm productivity (Acevedo et al., 2020; Chikowo et al., 2014; Christinck et al., 2017; Weltzien et al., 2019). Setting targets for women's participation is therefore an important first step in a more gender and socially inclusive breeding strategy, but should not be seen as an end goal; rather, it opens opportunities for including intersecting social dimensions with gender.

Methodologies to select women and men farmers in participatory research to test agricultural technologies are often not reported (Laajaj et al., 2020). A meta-analysis of agronomic on-farm trials in sub-Saharan Africa (SSA) found only 26% of studies provided information on the criteria used to select host farmers (Kool et al., 2020). Criteria were either bio-physical or socio-economic, with few studies using both. In breeding-related studies, the proportion of women participating in varietal or trait evaluations is often reported, but rarely the number of women household heads or plot managers hosting trials (Setimela et al., 2017; Bruno et al., 2018; Worku et al., 2020; de Sousa et al., 2021; Moyo et al., 2021; Collinson et al., 2022; Gesesse et al., 2023). This may constitute a shortcoming in the design of on-farm testing as the gender of the household and plot manager can be directly related to the household's choice of crop variety (Smale & Olwande, 2014; Cairns et al., 2022). In southern Africa, the selection of trial-hosting women and men farmers has primarily been under the purview of extension agents (Collinson et al., 2022; Madu et al., 2024; de Roo et al., 2017; Setimela et al., 2017, 2018). Historically, extension agents preferentially selected farmers in easy-to-access locations, with higher yields and better agronomic management (de Roo et al., 2017). To overcome this, there has been increasing training of extension agents around the importance of farm and farmer heterogeneity in on-farm varietal evaluations, including greater inclusion of women plot managers (Hamadziripi et al., 2024; Voss, Cairns, et al., 2023).

Smallholder farmers' characterization has been conducted in various studies using different approaches suited to the specific purpose. Farm typologies are often used to handle the heterogeneity of smallholder farming systems by grouping farms of similar characteristics (Alvarez et al., 2018; Hammond et al., 2020). Typologies have been extensively used in sustainable intensification research in southern Africa to understand the adoption of climate-smart agriculture practices (Makate et al., 2018; Mujeyi et al., 2020), gradients of soil fertility (Masvaya et al., 2010; Mtambanengwe & Mapfumo, 2005; Zingore et al., 2007), use of organic amendments (Rufino et al., 2011), crop residue uses and trade-offs in smallholder crop-livestock systems (Baudron et al., 2014; Baudron, Homann-Kee Tui, et al., 2024; Rusinamhodzi et al., 2015), adoption of practices to enhance soil fertility (Bellon et al., 1999) and farming system trajectories (Baudron et al., 2011). These typologies were primarily constructed with variables associated with resource endowment (for example, farm size, number of cattle, ownership of key farming equipment, ability to afford hired farm labour and quantity of mineral fertilizer used). Hassall et al. (2023) proposed a methodology for typology construction that is more flexible in terms of the types of variables that can be included, variable weighting and the specific features a typology might represent. If typology development involved more socio-demographic variables, farm types could be used to select host women and men farmers for participatory on-farm research. This could ensure adequate representation of diverse farming households (Baudron, Cairns, et al., 2024) and, retrospectively, quantify farm heterogeneity within current on-farm phenotyping networks (Crossa et al., 2002).

Participatory varietal selection is used by the International Maize and Wheat Improvement Center (CIMMYT) maize breeding pipelines in southern Africa to develop stress-tolerant varieties with farmer-preferred traits. The first four stages of selection are conducted in experimental research stations, with the final stage of selection conducted in farmers' fields (Prasanna et al., 2022). Farmers' preferences and candidate hybrid yields on women- and men-managed plots are used in the final advancement decision of hybrids to release for commercialization. There has been a significant effort to increase farmers' participation in the evaluation of candidate hybrids and prioritise their feedback in advancement decisions. The number of women and men farmers evaluating candidate hybrids has increased from just 40 farmers in 2010 (Setimela et al., 2017) to several hundred per pipeline in 2024.

It is essential that on-farm testing itself (not just product evaluations) reflects the real-world conditions within diverse farming households. In plant breeding, the effectiveness of the selection environment is a function of the heritability of traits under selection within that environment and the genetic correlation between performance in the selection environment and performance in the target population of environments (Atlin et al., 2001; Werner et al., 2025). Farms as the selection environment within participatory breeding approaches must therefore be representative of the larger target population of environments (Witcombe et al., 2005). Recognizing both the heterogeneity of smallholder farmers and that host farmers - as the selection environment - will ultimately dictate the performance of new maize hybrids within the target population of environments, maize participatory breeding strategies in southern Africa have endeavored to ensure host women and men farmers are representative of the wider population within the target user market segment. Extension agents have received annual training to sensitize them on the need to select a diverse range of farms, with emphasis placed on the inclusion of women and resource-constrained farmers. Training primarily consisted of discussing in depth the rational for selecting different types of farmers based on gender, asset and resource endowments and average maize production and providing feedback on the previous year's trials. The latter was included to reinforce that the trials were not demonstrations, and high-yielding trials (relative to the wider community) did not meet the overall breeding objectives. Training also focused on the need for trials to be conducted under farmers' own management practices to ensure they were reflective of farmers' own real-world conditions.

The primary aim of this study was to evaluate ex-post whether trial-hosting women and men farmers within a participatory maize breeding network in southern Africa were representative of the surveyed population they were selected to represent. A secondary aim was to pilot an inclusive approach to guide the recruitment of on-farm trial hosts within participatory breeding, using maize trials by the CIMMYT in Zimbabwe as a case study.

2 | METHODS

2.1 | Study area and sampling strategy

Five of Zimbabwe's 10 provinces (Mashonaland West, Midlands, Mashonaland East, Manicaland and Masvingo) were included in this study. These five provinces are part of the CIMMYT's maize on-farm testing network in Zimbabwe and were selected based on bio-physical criteria, primarily frequency of drought stress and total seasonal rainfall. High rainfall areas (relative to the national level) are not targeted in CIMMYT's maize testing network. Zimbabwe is sub-divided into five natural regions, with natural region 1 experiencing the highest annual rainfall (>1,000 mm per annum) and region 5 experiencing the lowest annual rainfall (<50 mm per annum).

Each province is divided into administrative districts. Eighteen districts across the five provinces included in this study were randomly selected. The majority of the 18 districts sampled in this study were in natural regions 3 (500–800 mm per annum) and 4 (450–650 mm per annum), while four districts were classified as natural region 2 (700–1,050 mm per annum) (Moyo, 2000). Maize is the predominant crop in all the selected provinces, grown by over 80% of households (ZimVac, 2022). The average maize production per household was estimated at 524 kg per household in Mashonaland West (natural regions 2 and 3), 295 kg per household in Midlands (natural regions 3, 4 and 5), 230 kg per household in Mashonaland East (naturals regions 1, 2 and 3), 162 kg's per household in Manicaland (natural regions 1 to 5) and 141 kg in Masvingo (natural regions 3, 4 and 5) (ZimVac, 2022).

Within each district, up to 15 wards were chosen based on population size, primarily under the guidance of the District Agricultural Extension Officer (DAEO), considering previous experience of working with extension agents within a ward. A total of 2,346 smallholder farms were randomly sampled across the wards, with the number of women and men farmers per ward proportional to the population size (Figure 1). Village heads have a registry of all households within their

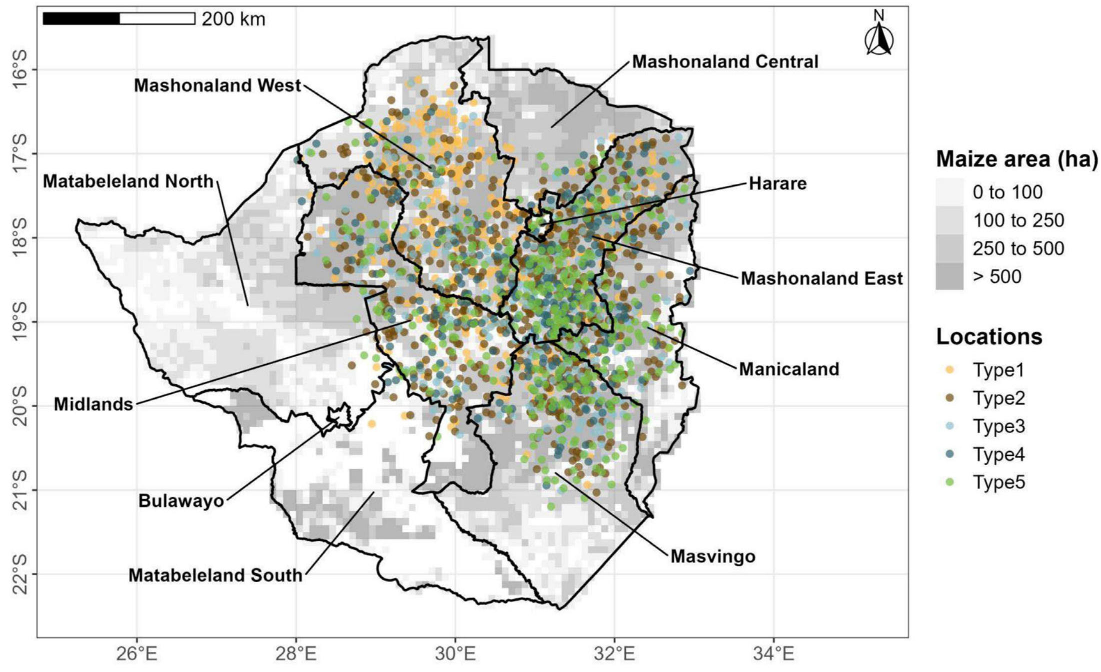

FIGURE 1 Location of the 2,040 farming households interviewed during the survey in Zimbabwe. The colour is related to the farm type to which each household was subsequently allocated. Data points are jittered to highlight the extent of the survey and reduce overlap between points and do not accurately represent the geo-spatial locations. Type 1 farms were average male-headed households, Type 2 farms were average female-headed households, Type 3 farms were resource-constrained female-headed households, Type 4 farms were relatively prosperous households and Type 5 farms were primarily off-farm households.

communities. Extension agents engaged with village heads and randomly selected smallholder farmers from household registries in each village. Large-scale commercial farmers were excluded in this survey as they fall beyond the remit of extension agents. The number of wards per district where the survey was conducted, and the number of women- and men-headed farm households interviewed within each ward is summarized in Table 1. Women-headed households included *de jure*, where there was no men head of households, and de facto, where the husband works outside the farming household and is absent (and thus the wife was interviewed as de facto household head). The age of the plot manager was not captured in households. In each of the 18 districts, household heads were interviewed by 10 to 15 trained agricultural extension agents using a structured questionnaire, which was implemented using the KoboCollect software between September to November 2021. The questionnaire included sections on the household's maize production over the past two years, input use for crop production, and crop agronomic management, farm and livestock assets, as well as household demographics. CIMMYT internal ethics review board provided ethics approval (IREC 2024.005).

To identify differences between host women and men farmers and the surveyed population, and between women- and men-headed households, the following analyses were conducted. For categorical data, a chi-square test of independence was used. For continuous data, a one-way ANOVA was used. Highly skewed data was log-transformed (with appropriate offset where required) prior to analysis. Both analyses were conducted using functions available in the stats package of R version 4.2.2 (R Core Team, 2024).

2.2 | Developing farm typologies

On-farm testing is an integral part of CIMMYT's maize breeding program. The aim is to identify improved genetics for smallholders' unique management, environment, household use and market conditions (in case of high rate of self-sufficiency) and at harnessing farmers' knowledge. This testing is critical as it supports the selection of candidate varieties which are announced for release to partners for commercialization. The on-farm evaluation of maize varieties considers both their agronomic performance and farmers' preferences, often related to maize production orientation, resource endowment, production and household use (and aspirations of individual smallholder farmers). The relevance of this evaluation depends on how representative the testing network is of the heterogeneity within smallholder farmers in the target population of environments. A typology was therefore constructed to summarize such diversity within the random sample of farms into a small number of distinct farm types.

Guided by relevant literature, a total of 17 variables describing the structure and the function of the farms were selected from the survey as potential explanatory variables for farm heterogeneity in terms of socio-demographics, farm and livestock endowments, as well as maize production system features (Figure 2). These variables are known to have high variability in smallholder farming systems in Zimbabwe and to impact maize productivity. They included gender of the household head, which has previously been shown to be a factor associated with technology adoption and overall household income

TABLE 1 Summary of the number of wards and farms in each district that were included in the survey.

					Household head		Women-headed households	
Province	District	Natural region	Wards	Number of farms	Men	Women	de facto	*de jure*
Manicaland	Buhera	3, 4	7	153	72 (47)	81 (53)	40	41
	Mutare	3, 4	7	122	91 (75)	31 (25)	5	26
Mashonaland East	Hwedza	2, 3	7	109	63 (58)	46 (42)	13	33
	Marondera	2	11	179	137 (77)	42 (23)	6	36
	Mutoko	3, 4	5	125	89 (71)	36 (29)	12	24
	Seke	2	8	109	80 (73)	29 (27)	10	19
Mashonaland West	Chegutu	2	6	119	86 (72)	33 (28)	13	20
	Hurungwe	3, 4	7	139	110 (79)	29 (21)	9	20
	Kariba	3, 4	4	61	50 (82)	11 (18)	2	9
	Makonde	2, 3	8	111	85 (77)	26 (23)	6	20
	Mhondoro Ngezi	2	15	235	162 (69)	73 (31)	34	39
	Murehwa	2, 3	6	111	59 (53)	52 (47)	19	33
Masvingo	Bikita	3, 4	8	110	76 (69)	34 (31)	8	26
	Gutu	3	7	112	90 (80)	22 (20)	4	18
	Zaka	3, 4	7	106	69 (65)	37 (35)	14	23
Midlands	Chikomba	3	6	137	80 (58)	57 (42)	17	40
	Gokwe south	3, 4	8	115	79 (69)	36 (31)	3	33
	Gweru	3	12	191	129 (68)	62 (32)	27	35

Note: Within women-headed households, the number of de facto and *de jure* women-headed households is also presented. Numbers in parenthesis are the percentage of men and women-headed households within each district.

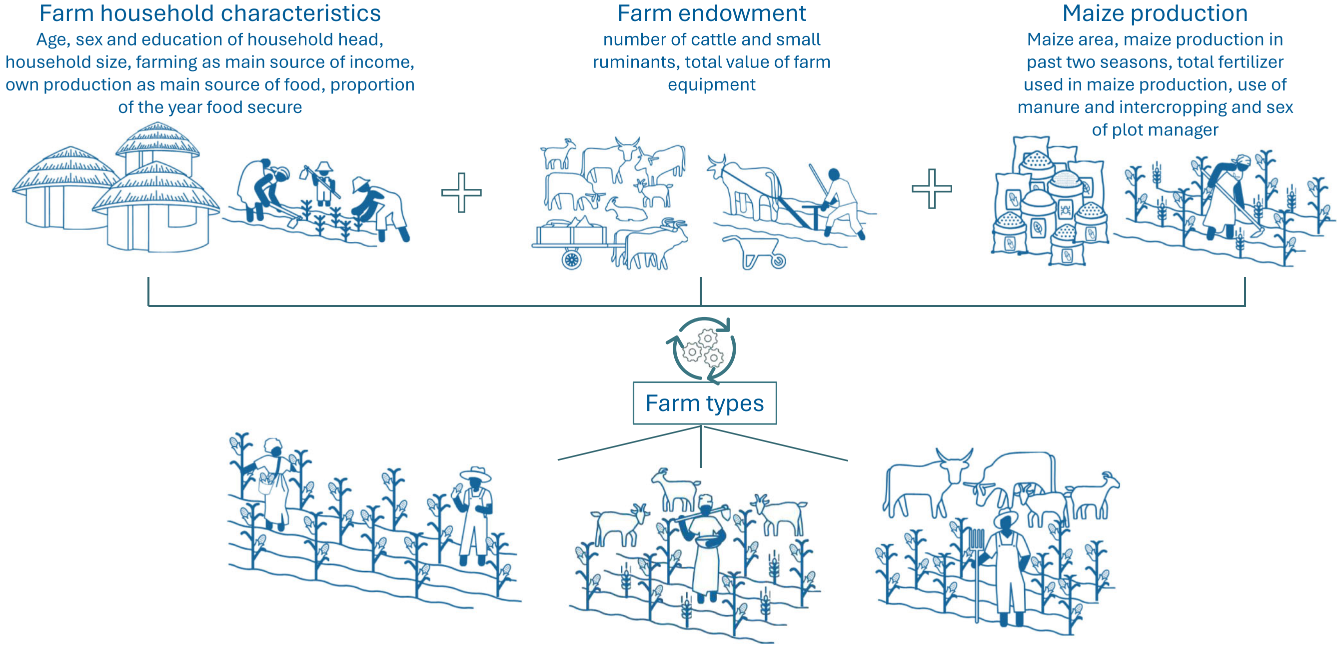

FIGURE 2 Conceptual framework used in the study to identify maize farm types in Zimbabwe. Farm types were delineated by 1) farm household characteristics, including main household demographics, significance of farming as income source, subsistence orientation and asset ownership 2) livestock and farm endowments, capturing herd sizes of large and small ruminants, as well as 3) maize production features, including area under maize production, sex of the plot manager, total household maize production and level of input use. Past studies have shown that smallholder farms in Zimbabwe differ significantly across these basic features and that these influence maize productivity.

(Dassanayake et al., 2015; Etienne et al., 2019; Ruzzante et al., 2021), area under maize production (Etienne et al., 2019), ownership of assets (Etienne et al., 2019) and ownership of livestock (Mtapuri, 2011). Only farms with no missing values for all 17 variables were included in the typology construction, leaving a total of 2,040 observations. Missing data was a result of a question not being answered by the survey participant during survey deployment. Structural continuous variables included the age of the household head, household size, gender ownership of assets and livestock (cattle and small ruminants). The value of farming equipment was calculated using an average 2021 farm-gate prices for ploughs (95 USD), cultivators (130 USD), scotch carts (500 USD), wheelbarrows (55 USD) and knapsack sprayers (30 USD). Structural binary variables included the gender of household head and primary manager of maize plots, and the level of education of the head of the household (primary school or less, or above primary school). Functional continuous variables included total maize production over the past three years, maize area in 2020, total fertilizer use and proportion of the year the household was food secure. Binary functional variables included the use of intercrops and manure (yes or no), farming as the main source of income (yes or no) and own production as the primary source of food (yes or no).

A typology was constructed using the methodology developed by Hassall et al. (2023). Highly skewed continuous variables were first log-transformed (with appropriate offset where necessary) to provide more symmetric distributions for the value of farming equipment, total maize production over the past two years, maize area and total fertilizer use. A scaled Euclidean distance was used to calculate the dissimilarity between continuous variables (using the Gower distance with the vegan R package), and the simple matching coefficient distance was used to calculate the dissimilarity between binary variables (using the dist. binary function of the ade4 R package) (Oksanen et al., 2022). Equal category weighting was applied to the functional and structural variables, but binary functional and structural variables were downweighted to limit their influence on the resulting typologies. Categorical variables can have a strong influence in determining distinct groupings. This is an artefact of the discrete nature of the data and not a feature we wished to perpetuate, but rather ensure binary variables could be included alongside continuous variables. Thus, an iterative process was used to identify the factor by which binary variables should be downweighted (Dray & Dufour, 2007). A random forest was used to assess the importance of different variables in the separation of the resulting types. When a factor of two was used, most binary variables had the largest decrease in Gini index (Figure S1). Using a factor of four resulted in a more homogeneous mixing of binary and continuous variables in terms of the mean decrease in Gini index, and this weighting was used in the final typology. A principal coordinates analysis was applied to the generalized distance matrix with six dimensions retained to feed into a hierarchical clustering with complete linkage. From the resulting dendrogram, five types were identified. To quantify dissimilarity between each farm type, the Euclidean distance between cluster centroids was calculated.

2.3 | Farmer selection for hosting on-farm trials

Within the sample used in this study to develop farm typologies, 191 farmers hosted CIMMYT's stage 5 on-farm trials for one breeding pipeline across the same 18 districts. The total number of host women and men farmers recruited was partially a function of seed and available resources. However, there has been a significant effort to increase farmers participation in the evaluation of new candidate hybrids and incorporate their feedback into the selection process. These women and men farmers were selected by agricultural extension agents, with no input or validation by CIMMYT, to host on-farm trials across the same 18 districts. Extension agents received training prior to farmer selection, highlighting the need to target a diverse range of women and men farmers and ensure the inclusion of both women-headed households and women plot managers. These women and men farmers were included in the survey (which was conducted the subsequent year) to construct the typology.

3 | RESULTS

3.1 | Selected host farmers were generally representative of the surveyed population

Household characteristics of all surveyed participants (excluding host farmers) and host farmers are presented in Table 2. Approximately 32% of households were women-headed. The average age of the household head was 54.9 years within the surveyed population and 55.8 years for the subsample of host farmers, with an average family size of 6.1 in the surveyed population and 6.3 for host farmers. Sixty-six percent of heads of households within the surveyed population had an education higher than primary level. Within the surveyed population, the average farm owned 5.3 cattle, 5.1 small ruminants and agricultural equipment worth 513.2 USD. Within host farmers, the average farm owned 5.1 cattle, 4.1 small ruminants and agricultural equipment worth 598.5 USD. The average area under maize production was 1.80 ha for the surveyed population and 2.00 ha for host farmers. Host farmers produced significantly more maize (2,742.99 kg) than the surveyed population (2,105.5 kg) ($P < 0.01$). This difference was not related to hosting breeding trials as maize production was for the season prior to hosting trials. There was no significant difference between host farmers and the surveyed population in maize production in the previous year. Within the surveyed population, an average of 373.8 kg fertilizer was used for maize production, while for host farmers an average of 364.0 kg fertilizer was used for maize production. Approximately one-third of households within the surveyed population practiced intercropping within their maize fields, compared to 41% of host farmers ($P < 0.05$). Fifty-seven percent of households within the surveyed population applied manure in their maize fields, compared to 71% of host farmers ($P < 0.001$). Farming was the main source of food for over 90% of households within the surveyed population and host

TABLE 2 Summary of key characteristics of farms within the surveyed population (excluding trial hosting farmers) and trial hosting farmers. All presented values are means (with standard deviation in brackets) or percentages. The statistical test used to evaluate the difference between farmers within the wider survyed population and trial hosting farmers is presented.

Characteristic	Surveyed population (excluding host farmers)	Host farmers	p-value	Test	X^2 value	F-value
Number of farms	1846	191				
Women-headed households (%)	31.7	32.5	0.999	Chi-squared	8.096e-30	
Women plot manager (%)	27.5	32.5	0.403	Chi-squared	0.701	
Age of the head of the household	54.9 (13.7)	55.8 (12.4)	0.335	ANOVA		0.93
Household head education above primary (%)	66.0	71.6	0.063	Chi-squared	3.445	
Family size	6.1 (3.5)	6.3 (3.5)	0.406	ANOVA		0.692
Equipment value (USD)	513.2 (461.6)	598.5 (569.1)	0.089	ANOVA		2.894
Cattle (n)	5.1 (8.1)	5.3 (9.7)	0.506	ANOVA		0.443
Small ruminants (n)	5.1 (12.6)	4.1 (5.0)	0.857	ANOVA		0.032
Maize area (ha)	1.80 (9.2)	2.00 (5.0)	0.579	ANOVA		0.308
Maize production (kg)	2103.2 (5,749.3)	2,742.9 (4,721.3)	0.007	ANOVA		0.579
Maize production previous year (kg)	2,105.5 (5,695.4)	2,154.1 (1,053.1)	0.579	ANOVA		0.308
Quantity of fertilizer used for maize (kg)	373.8 (744.4)	364.0 (540.6)	0.849	ANOVA		0.036
Using intercropping (%)	32.1	41	0.027	Chi-squared	4.896	
Using manure (%)	57.2	71	0.001	Chi-squared	11.427	
Proportion of the year being food secured	0.7 (0.3)	0.7 (0.3)	0.047	ANOVA		3.956
Farming as the main source of food (%)	93.0	94	0.445	Chi-squared	0.583	
Farming as the main source of income (%)	63.5	73	0.013	Chi-squared	6.109	

farmers, however only the main source of income for 63% of households within the surveyed population compared to 73% of households within host farmers ($P < 0.05$).

3.2 | Significant variation was observed between and within gender-disaggregated groups

In general, differences between farms with women and men heads of household were the same within the surveyed population and for host farmers (Table 3). Significantly fewer women heads of households had an education above primary level compared to men-headed households (surveyed population, $P < 0.001$; host farmer $P < 0.05$). Women-headed households had significantly fewer agricultural assets compared to men-headed households. Within the surveyed population, the value of agricultural equipment owned was significantly lower in women-headed households compared to men-headed households ($P < 0.001$). Furthermore, women-headed households owned significantly less cattle ($P < 0.001$) and small ruminants ($P < 0.001$) than men-headed households. Similarly, among host farmers, the value of agricultural equipment owned was 41% less in women-headed households compared to men-headed households ($P < 0.01$). In addition, women-headed households owned 55% less cattle ($P < 0.01$) and 47% less small ruminants ($P < 0.001$) than men-headed households. The area under maize production was 35% lower in women-headed households compared to men-headed households within the surveyed population ($P < 0.001$) and 57% lower for host farmers ($P < 0.001$). Maize production in women-headed households was significantly lower compared to male-headed households over two consecutive years in both the surveyed population and host farmers. While women heads of households were significantly older than men heads of households within the surveyed population ($P < 0.01$), there was no significant difference in age between women and men heads of households hosting trials. Similarly, there was no significant difference in the use of intercropping between women- or men-headed households hosting trials but within the surveyed population 40% of women-headed households intercropped maize compared to 29% of men-headed households ($P < 0.01$).

While there was significant variation between genders at both the household and plot manager level, there was also large variation within women-headed households, and women-managed plots (Figure 3). For example, 37% of women-headed households had more equipment than the average men-headed household. While 36% of households with women maize plot managers had more equipment than the average household with men plot managers. Similarly, 20% of women-headed households owned more cows than men-headed households. Thirty-seven percent of women-headed households had equipment of more value than the average men-headed household. While 36% of households with women maize plot managers had equipment of more value than the average

TABLE 3 Summary of women and men-headed households within recruited host farmers and the surveyed population. All presented values are means (with standard deviations in brackets) or percentages. The ANOVA and chi-squared test statistics are provided in Table S2.

	Survey population				Host farmers			
Characteristic	Women-headed	Men-headed	p-value	Test	Women-headed	Men-headed	p-value	Test
Number of farms	584	1,262			60	131		
Women plot manager (%)	66.8	9.7		Chi-squared	68.3	3.8		Chi-squared
Age of the head of the household	56.1	54.3	0.009	ANOVA	56.3	55.7	0.786	ANOVA
Household head education above primary (%)	50.3	72.2	2.2e-16	Chi-squared	61.7	77.1	0.042	Chi-squared
Family size	5.1	6.5	2.2e-16	ANOVA	5.2	6.8	0.002	ANOVA
Equipment value (USD)	387.0	558.4	<2e-16	ANOVA	409.6	691.4	0.001	ANOVA
Cattle (n)	3.6	5.7	6.32e-8	ANOVA	2.9	6.5	0.004	ANOVA
Small ruminants (n)	3.9	5.7	0.001	ANOVA	2.6	4.9	0.001	ANOVA
Maize area (ha)	1.32	2.03	<2e-16	ANOVA	1.06	2.44	0.003	ANOVA
Maize production (kg)	1813.1	3188.7	<2e-16	ANOVA	1616.2	3268.3	0.003	ANOVA
Maize production previous year (kg)	1545.5	2364.6	0.007	ANOVA	1018.3	2686.5	0.021	ANOVA
Quantity of fertilizer used for maize (kg)	290.3	413.9	0.001	ANOVA	305.7	390.3	0.382	ANOVA
Using intercropping (%)	39.8	28.8	0.00165	Chi-squared	48.3	36.6	0.090	Chi-squared
Using manure (%)	56.8	57.4	0.8734	Chi-squared	63.3	73.3	0.221	Chi-squared
Proportion of the year being food secured	0.6	0.7	0.000265	ANOVA	0.6	0.7	0.033	ANOVA
Farming as the main source of food (%)	92.0	93.5	0.264	Chi-squared	95.0	94.7		Chi-squared
Farming as the main source of income (%)	57.2	65.9	0.002	Chi-squared	81.7	68.7	0.090	Chi-squared

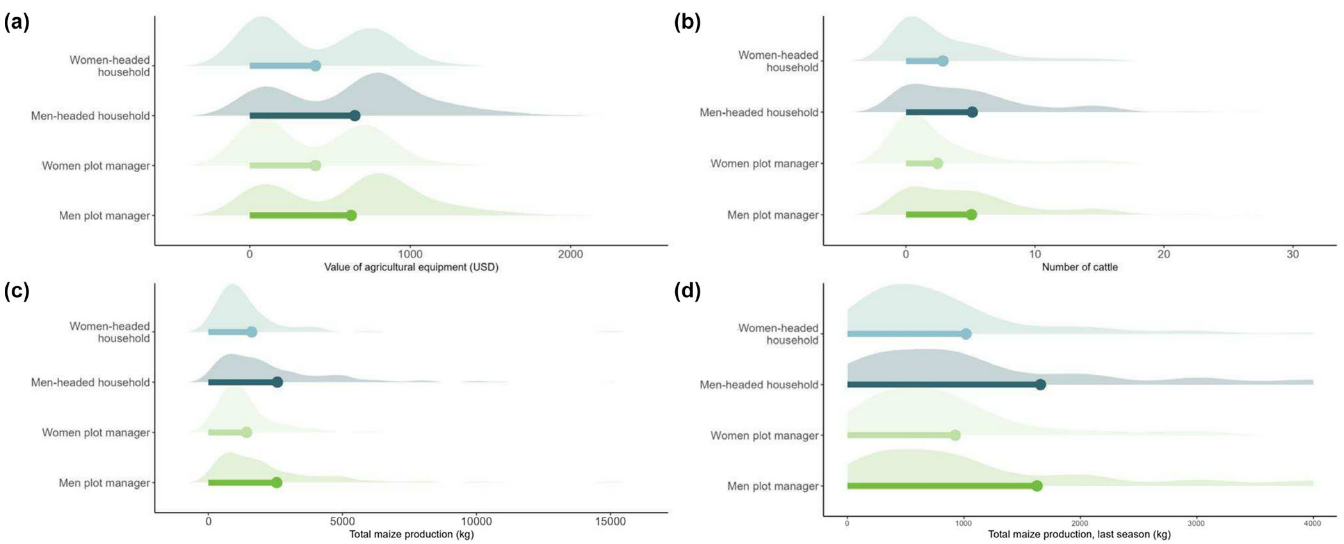

FIGURE 3 Average (a) value of agricultural equipment, (b) number of cattle, (c) total maize production and d) total maize production in the previous season disaggregated by sex of household head and plot manager. Density plots show the distribution of values for each variable. Variables presented were the most important continuous attributes distinguishing farm types.

household with men plot managers. Similarly, 20% of women-headed households owned more cows than the average number of cows owned by men-headed households.

3.3 | Agricultural assets and gender of household heads were the most segregating variables of the typology

From the typology of 2,040 farms, five farm types were identified using hierarchical clustering and k-means (Figure 4; Table 4). Farm types corresponded to decreasing capital (equipment value and cattle) and maize production. The most important variables distinguishing between farm types identified with a classification random forest were value of agricultural equipment, gender of household head, number of cattle and total maize production (Figure 5). The largest cluster was for Type 2 farms (accounting for 34% of farms), with a relatively even distribution of the proportion of farms in the four other farm types (14–19%). In general, farm types were relatively well distributed across provinces (Figure 1), except Mashonaland West province, which had relatively higher proportion of Types 1 and 2 farms.

Type 1 farms (384 farms, 19%) were predominantly men-headed households with men plot managers and a large family size as depicted in Figures 6 and 7, and Table 4. This farm type was relatively resource-endowed and commercially orientated. The area under maize production was larger than any other farm type, with many cattle and small ruminants. Intercropping was practiced by only 2.3% of farms in this group. The level of farm mechanization was relatively high with over 80% of farms owning at least one plough, cultivator, scotch cart, wheelbarrow and knapsack sprayer. Almost 50% of farms owned two or more ploughs in this farm type.

Type 2 farms (700 farms, 34%) were classified as predominantly men-headed households with men plot managers. Only 4% of farms within this cluster were women-headed, and these were predominantly de facto (Table S1). Ninety percent of Type 2 farms owned a plough (with almost 20% of farms owning more than one plough), while 68% of farms owned a scotch cart.

Farms clustered in Type 3 (302 farms, 15%) and Type 4 (282 farms, 14%) were both predominantly *de jure* women-headed households. Both farm types had household heads with relatively limited formal education, particularly Type 4 with 24% of household heads having an education beyond primary level. Types 3 and 4 farms differed in herd size of cattle and small ruminants, area under maize production, farm assets, maize production, use of manure and fertilizer use. Type 3 farms had a higher number of cattle, and the proportion of farms applying manure to their maize fields in this farm type was similarly high (83% of farms). Type 4 farms were associated with a very small number of cows and thus, limited use of manure within maize production. However, the use of intercropping was highest within this farm type, with over 91% of farms practicing intercropping (compared to 59% of Type 3 farms). For Type 3, over 80% of farms owned a plough and wheelbarrow, and over 60% owned a scotch cart. Only one-third of Type 4 farms owned a plough, while only 20% owned a scotch cart. Interestingly, although TType 3 and 4 farms had predominantly women heads of households (90% and 72%, respectively), farms that were men-headed had a very low proportion of household heads achieving education beyond primary level (23 and 16%, respectively). Similarly, the proportion of households for whom farming was the major source of income was lower in men-headed households relative to women-headed households in both Type 3 and 4 farms.

Type 5 farms (372 farms, 18%) were predominantly men-headed with men plot managers. This farm type had the highest proportion (92%) of household heads with an education higher than primary

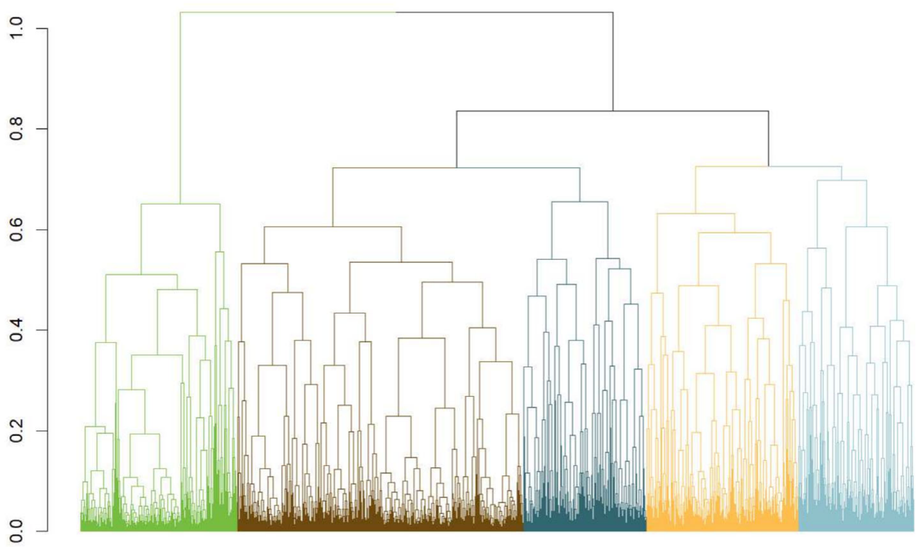

FIGURE 4 Dendrogram representing the hierarchical agglomerative clustering using complete linkage method (five clusters were identified), and representation of the five farm types identified. Type 1 farms were average male-headed households, Type 2 farms were average female-headed households, Type 3 farms were resource-constrained female-headed households, Type 4 farms were relatively prosperous households and type 5 farms were primarily off-farm households.

TABLE 4 Characteristics of five delineated farm types via household survey data (n = 2040). All presented values are means (with standard deviation in brackets) or percentages.

	Farm type				
Characteristic	**1**	**2**	**3**	**4**	**5**
Number of farms	384	700	302	282	372
Age of the head of the household	55.2 (12.5)	55.6 (13.6)	59.0 (12.2)	59.2 (14.6)	46.8 (11.8)
Women-headed households (%)	11	4.4	90	72	27
Women plot manager (%)	15	2.1	79	63	20
Education of the head of the household higher than primary (%)	8	71	40	24	92
Family size	7.6 (4.6)	6.3 (3.2)	5.5 (3.7)	4.9 (2.7)	5.6 (2.6)
Equipment value (USD)	876.4 (369.5)	623.8 (489.4)	538.3 (363.2)	200.3 (271.6)	146.7 (216.1)
Cattle (n)	12.0 (12.4)	5.1 (5.6)	5.4 (7.9)	0.9 (2.0)	0.8 (1.8)
Small ruminants (n)	10.2 (24.4)	4.8 (5.8)	5.0 (6.4)	2.6 (12.3)	2.2 (3.7)
Total area cropped to maize (ha)	6.1 (20.6)	1.4 (1.2)	1.5 (2.8)	0.7 (0.6)	0.7 (0.4)
Total maize production (kg)	20,791.5 (126,239.2)	2,295.9 (4,302.2)	1,893.8 (2,824.3)	785.7 (759.0)	700.6 (983.3)
Total maize production previous year (kg)	13,410.1 (101,028.6)	1,450.7 (1,923.3)	1,507.0 (3,432.0)	490.1 (507.2)	397.8 (432.8)
Total fertilizer used on maize (kg)	1,146.8 (3,171.6)	334.0 (522.7)	379.3 (1,356.6)	145.8 (109.6)	140.7 (111.0)
Using intercropping (%)	2.3	38	36	51	38
Using manure (%)	55	64	81	29	57
Proportion of the year being food secured	0.8 (0.3)	0.7 (0.3)	0.7 (0.3)	0.5 (0.3)	0.5 (0.3)
Own production as the main source of food (%)	96	96	93	93	84
Farming as the main source of income (%)	91	74	66	60	20

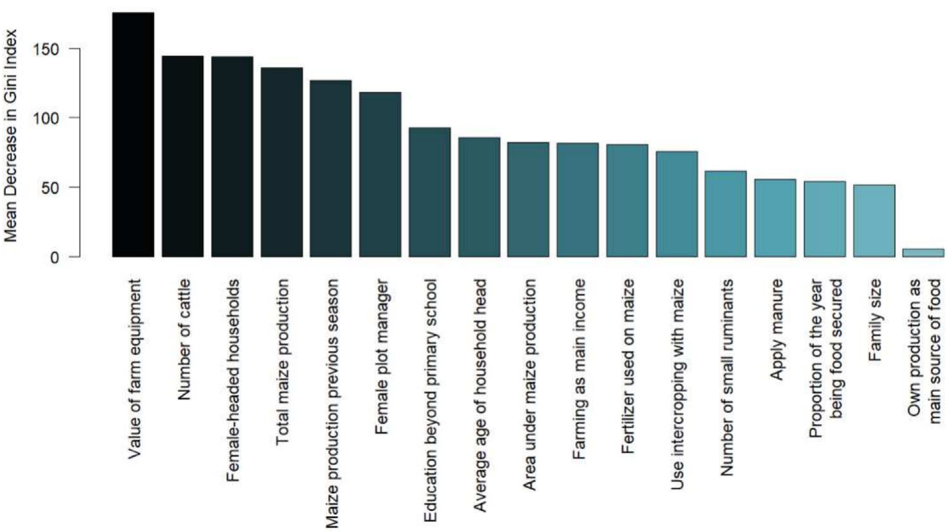

FIGURE 5 Importance plot of farm characteristics used to delineate farm types. The classification tree was trained on the data from the 2,040 farms. Shown are the mean decreases in Gini index as a result from a random forest of the associated typologies.

school. Type 5 farms were primarily off-farm households, with few cattle and small ruminants and a small area under maize production. This farm type had a very low level of farm assets, with only 13% of farms owning a scotch cart and 4% owning a cultivator.

A distance matrix was used to quantify dissimilarity between the five clusters (Table 5). Type 1 and 3 farms were the closest and Type 3 and 5 farms were the furthest apart. While Type 3 and 4 farms were predominantly households headed by women, however, the relative distance between 3 and 4 was 1.7 times greater than the one between 1 and 3.

3.4 | *Proportion of farm types within host farmers reflected the surveyed population*

The relative proportion of each farm type within the network of on-farm trial hosts closely reflected the distribution of farm types within the study area (Table 6). The largest farm type was Type 2. This farm type also accounted for the largest proportion of farms hosting trials (38%). The distribution of the other farm types hosting trials was relatively equally distributed, although Type 5 had a slightly lower

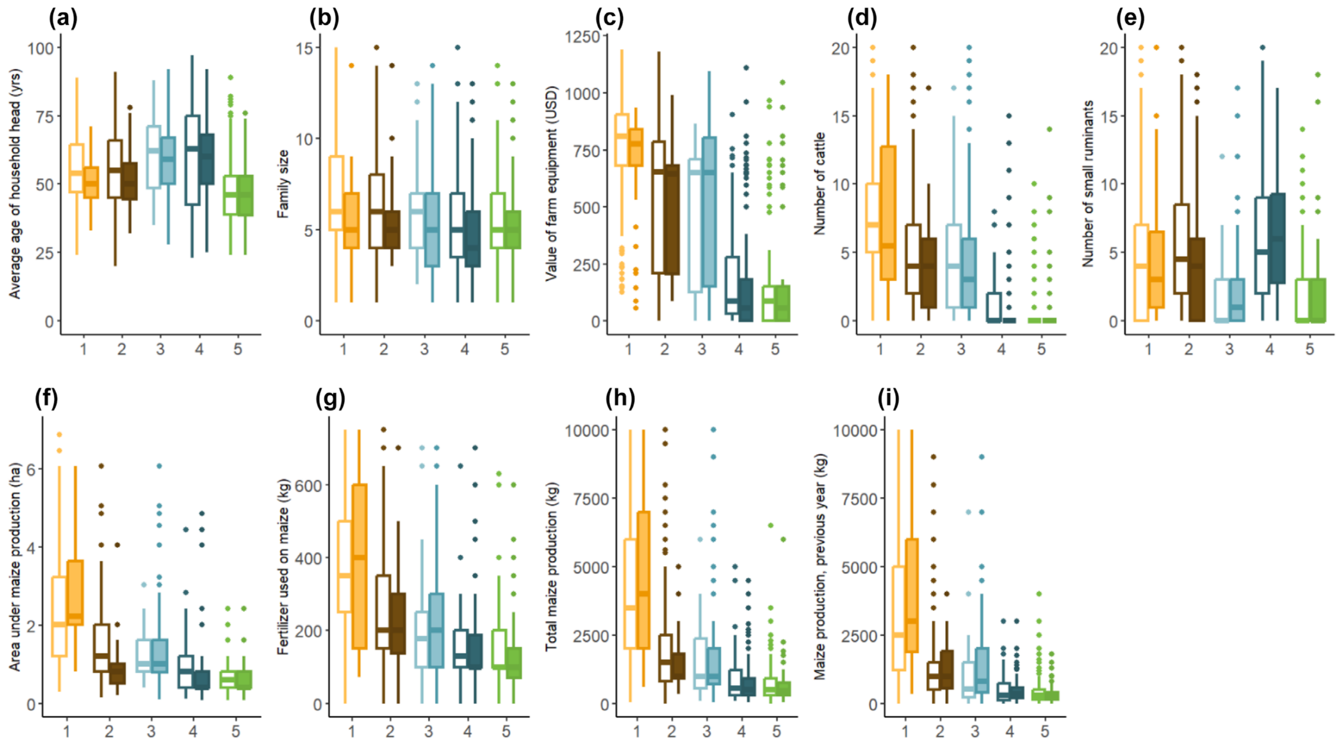

FIGURE 6 Boxplots of structural (a–e) and functional (f–i) continuous variables used to construct a typology of 2,040 farm households in Zimbabwe. For each farm type continuous variables are disaggregated by sex with solid bars representing women-headed households and outline only bars representing men-headed households. Type 1 farms were average male-headed households, Type 2 farms were average female-headed households, Type 3 farms were resource-constrained female-headed households, Type 4 farms were relatively prosperous households and Type 5 farms were primarily off-farm households.

representation. Almost 70% of trials were hosted by men-headed households (Table 5). *De jure* women-headed households accounted for 58% of all women-headed households hosting trials compared to 42% de facto women-headed households (Table S2).

4 | DISCUSSION

Our study reiterates the heterogeneity of smallholder maize women and men farmers in terms of socio-demographic features, asset and resource endowments and production orientation. The selection of representative trial hosting women and men farmers is critical to ensure new varieties are responsive to a diverse range of farmers' needs (Voss, Cairns, et al., 2023) and bias that limits their scalability is not introduced during testing (Laajaj et al., 2020). Earlier studies have shown host farmers can be more prosperous and better educated than the wider community they are purported to represent (de Roo et al., 2017; Laajaj et al., 2020), leading in particular to the underrepresentation of women farmers (Freeman, 2001; Snapp, 2002; van Etten et al., 2018).

The delineation of farm types in this study further indicates that women and men farmers recruited to host trials were generally representative of the surveyed population, with the distribution of farm types within host women and men farmers closely reflecting the distribution within the surveyed population. This suggests that, with the purview to sample diversity based on their knowledge of the communities they serve, extension agents in this study recruited women and men farmers that, in general, accurately reflected the heterogeneity of the surveyed population. Encouragingly, there was no significant difference in the proportion of women-headed households between host farmers and the surveyed population, confirming the value of setting gender-based targets for host farmer selection to meet basic gender-inclusivity requirements (de Sousa et al., 2021; Hamadziripi et al., 2024; Mancini et al., 2017; Ssali et al., 2023). There were also no significant differences in indicators of agricultural resource endowments (agricultural equipment and livestock) between host women and men farmers and the surveyed population. However, maize production among host women and men farmers was almost 20% higher than the surveyed population, although this difference may be related, in part, to the inclusion of more farms for which farming was the primary source of income and the slight under-representation of farm type 5 in the on-farm trial network relative to the surveyed population. Type 5 farms were the least involved in agricultural activities (and produced less maize), which likely accounts, at least in part, for their relatively lower inclusion.

There were significant gender-based differences in resource endowments and maize production characteristics at the household head (and plot manager) level. These differences highlight the importance of ensuring (and reporting) women's participation, however, this gender dichotomous categorization overlooks heterogeneity within

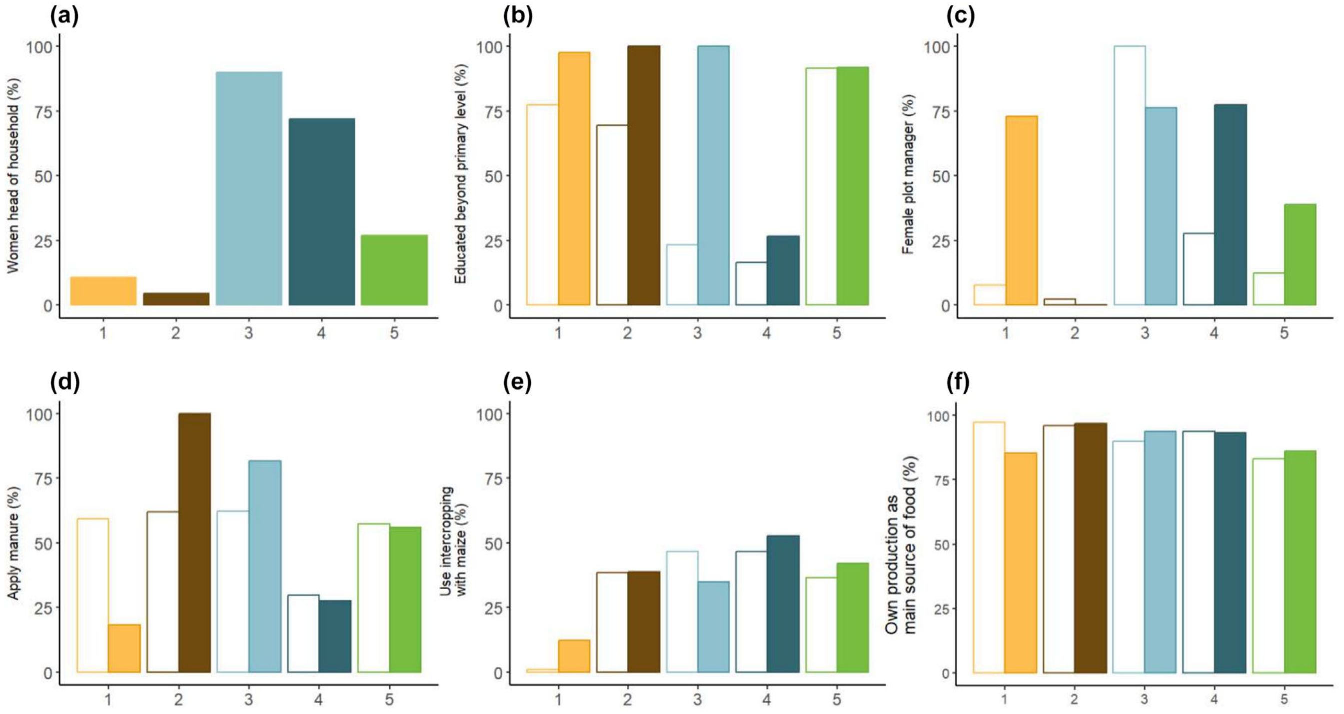

FIGURE 7 Proportions of each farm type with selected characteristics used as structural (a–c) and functional (d–g) binary variables in the typology. For each farm type (with the exception of the proportion of women-headed households), binary variables are disaggregated by sex with solid bars representing women-headed households and outline only bars representing men-headed households. Farm types were delineated from a typology of 2,040 farm households in Zimbabwe. Type 1 farms were average male-headed households, Type 2 farms were average female-headed households, Type 3 farms were resource-constrained female-headed households, Type 4 farms were relatively prosperous households and Type 5 farms were primarily off-farm households.

TABLE 5 Distance matrix between the cluster centroids of each farm type. Type 1 farms were average male-headed households, Type 2 farms were average female-headed households, Type 3 farms were resource-constrained female-headed households, Type 4 farms were relatively prosperous households and Type 5 farms were primarily off-farm households.

	Farm type 1	Farm type 2	Farm type 3	Farm type 4	Farm type 5
Farm type 1	-				
Farm type 2	0.35	-			
Farm type 3	0.24	0.35	-		
Farm type 4	0.39	0.41	0.42	-	
Farm type 5	0.34	0.44	0.45	0.31	-

TABLE 6 Number of farms within each farm type and corresponding number of farms hosting trials by farm type. Type 1 farms were average male-headed households, Type 2 farms were average female-headed households, Type 3 farms were resource-constrained female-headed households, Type 4 farms were relatively prosperous households and Type 5 farms were primarily off-farm households.

	Farms in typology construction		Farms hosting on trials	
Farm type	Number	Percentage (%)	Number	Percentage (%)
1	384	19	39	21
2	700	34	70	38
3	302	15	26	14
4	282	14	26	14
5	372	18	25	13

each group (Bacud et al., 2024; Teeken et al., 2021). Gender is only one social factor influencing farm production and varietal preferences (Bacud et al., 2024; Colfer et al., 2018; Teeken et al., 2021), and this was underlined by the large variation between women and men *and* within genders in this study. The delineation of farm types incorporating key variables associated with maize production identified two farm types that were associated with women heads of households (Types 3 and 4) and three types with men heads of households (Types 1, 2 and

5). Critically, Type 1 and 3 farms were found to be more similar than Type 3 and 4 farms, reiterating heterogeneity *within* gender-disaggregated groups in Zimbabwe. Type 3 farms were wealthier than Type 4 farms, with more farm equipment and larger livestock herds (cattle and small ruminants). Type 3 farms had a larger area under maize production and produced almost three times as much maize as Type 4 farms. Type 4 farms applied less fertilizer and manure, the latter probably a function of smaller herd size. The use of intercropping was more prevalent in Type 4 farms. Furthermore, men-headed households within Type 4 farms had a very low proportion of women plot managers. These two distinct types of women-headed households in rural Zimbabwe thus differed in terms of opportunities and constraints. One implication is that nuanced priorities, preferences and opportunities of diverse women-headed and men-headed household farm types is lost when the gender of the household head is the sole factor used to differentiate trial participants to satisfy social inclusion criteria.

This study highlighted the relevance of collaborating with local stakeholders and leveraging local expert knowledge in selecting farms for participatory research (Manners et al., 2025). However, this experience may not be universal as local intermediaries sometimes exclude underrepresented social groups from activities like trials (Falconnier, 2016; Lund & Saito-Jensen, 2013). A more nuanced and contextualized approach, recognizing intersectionality, could help ensure the systematic recruitment of different groups of women and men farmers. Previously recognizing the importance of sociodemographic features on production and farmer preferences, Mancini et al. (2017) ensured a balance of gender, age and wealth between recruited host farmers, although no details were provided on the methodology used to ensure this balance. Nanyonjo et al. (2024) selected host farmers for cassava on-farm trials in Uganda by weighting on gender, age and market orientation. In the present study, farm types were delineated *ex post* to evaluate if host women and men farmers were representative of the surveyed population, but this approach could be used *ex ante* to guide the recruitment of host women and men farmers, guided by the proportion of each farm type in the surveyed population. Deliberately increasing the representation of certain farm types might be desirable in some cases. In this study, for example, the number of farmers from Type 3 and 4 farms could be increased to ensure greater representation of women-headed households. The delineation of a typology, with the inclusion of gender-based variables, could also facilitate farmer selection to move beyond a one-dimensional gender approach to operationalize a more multi-dimensional approach. Within each farm type, gender-disaggregated targets can also be included at the plot manager level; gender differentiation at the household head level unintentionally neglects the knowledge and preferences of women farmers living in households headed by men.

Although typology delineation presents a useful tool for the recruitment of representative on-farm trial hosts, it is important to recognize that farming systems are very dynamic, particularly within regions of high climatic variability. As such, surveys may need to be conducted every year or two to delineate farm types (Baudron, Cairns, et al., 2024). In this study, recruited host women and men farmers accounted for less than 10% of the total farmers surveyed. Given budget is always a constraint of breeding programs in the Global South, further research is required to understand the minimum number of women and men farmers that could be surveyed to construct a typology to select the required number of host women and men farmers, but it is likely to be significantly less than used in this study. Key variables distinguishing between farm types are also likely to change across crops and geographies. The use of a classification random forest helped identify the most discriminating variables in this study, and this approach could be applied to guide the identification of key variables in other agro-ecologies and for other objectives.

There are some limitations to this study, including simplified definitions for some variables that may in reality be complex. In the construction of the typology, for example, the gender of the plot manager was determined as binary (women or other), which excluded the possibility of joint management. The household head and plot manager were also identified by a single member of the household (primarily the household head), although research points to gendered differences in the perception of intrahousehold decision making around crop management (Acosta et al., 2020; Doss et al., 2020; Van Campenhout et al., 2023). The identification of plot managers in this study also assumed the person(s) retained control over all aspects of management, although joint management is common in some areas, and different management activities for a single plot may involve different individuals (Voss, Gitonga, et al., 2023). Perhaps as a function of these factors, the proportion of men plot managers within men-headed households was higher than found in previous research in Zimbabwe (Cairns et al., 2022). Additionally, typologies essentially aim to provide a one-dimensional, discrete representation of a multi-dimensional continuum. The construction of typologies can be subject to many sources of bias, both implicit and explicit. A particular weakness when combining both continuous and binary variables is the domination binary variables can have in determining the resulting clusters. While the methodology applied in this study down-weighted binary variables, this choice is still subjective. Finally, all extension agents in this study had received prior training on ensuring diversity within host farmer selection, which may have contributed to the alignment between host farmer characteristics and the surveyed population. However, there was no control group to understand the variation in host women and men farmers who would have been selected without training. This, therefore, limits the ability to quantify the benefits of training extension agents on farmer selection compared to selection without training.

This study responds to concerns that lower adoption of new crop varieties by farmers is associated, in part, with breeding programs not adequately addressing the needs and priorities of different groups of farmers, particularly resource poor and women farmers (Cullen et al., 2023; Teeken et al., 2021; Voss et al., 2021). A recent survey of breeding professionals revealed one-third of biophysical scientists did not perceive value in the inputs of social scientists within breeding programs (Rice et al., 2024). This study highlights a clear entry point where social science perspectives can contribute towards breeding efforts. The incorporation of social considerations into product design and testing strategies is important to ensure breeding programs do not unintentionally leave behind a socially vulnerable sub-group of beneficiaries (Cullen et al., 2023; Hellin et al., 2024; McGuire et al., 2022). The delineation of farm types allows farmer preference evaluations to acknowledge this heterogeneity and examine variation across farm types, which may provide more clarity around differing variety preferences than studies of gender and maize have provided so far (Voss et al., 2021). The delineation of farm types could also further understand the type of women and men farmers that are adopting improved maize varieties and accrued benefits (Thuijsman et al., 2022). This approach could also offer opportunities for more inclusive trait prioritization approaches in the refinement of target product profiles and a more holistic understanding of how dimensions of production and consumption shape market segments for new varieties— including gender-based differences in preferences (Ragot et al., 2018). This study's findings indicate that proxies of wealth may be particularly relevant in identifying maize market segments, although many other factors such as farmer aspirations and intended end-uses of maize may also be relevant.

5 | CONCLUSIONS

There is currently a resurgence in on-farm participatory research for crop improvement in sub-Saharan Africa (van Etten et al., 2023). This aligns in part with concerns that breeding programs are not adequately focused on the diverse needs and constraints of heterogeneous populations of farmers, including the unique experiences of women farmers (Doss, 2001; Voss, Cairns, et al., 2023; Weltzien et al., 2019). Retrospectively validating host farmer selection based on sensitization of extension agents to the requirements of a participatory maize breeding program in southern Africa confirmed minimal elite capture and unconscious bias in the selection of women and men farmers. This study also reiterates that women-headed households and men-headed households cannot be treated as being homogeneous, and gender-responsive participatory research should strive to include different types of women and men farmers rather than setting targets for the participation of women plot managers or household heads. Finally, these findings support increased focus on wider market segmentation and attention to variables and dimensions including and intersecting with gender, that shape farm productivity and farmer choices. In this sense, it aligns with the growing focus on intersectionality in agricultural development (Bacud et al., 2024; Bullock & Crane, 2021; Elias et al., 2018; Harcourt, 2016; Nanyonjo et al., 2024).

These findings have implications for how research institutions and seed companies conceptualize and operationalize research with women and men farmers. Increased focus on gender in recent decades has helped open the door to considering farmer diversity, but this dichotomy has ultimately limited our understanding of that diversity and requires further exploration of the intersecting dimensions with gender. Farm typologies are a concrete way to operationalize intersectionality and acknowledge intersecting dimensions that impact farmer experiences. With participatory plant breeding and participatory varietal selection, they have the potential to enable better understanding of the "customer base" and support deliberate market segmentation to ensure new varieties are meeting the needs of all farmers.

AUTHOR CONTRIBUTIONS

The study was conceptualized by J.E.C., F. B and M.Z.A. M.Z.A. led the farm surveys. J.E.C., F.B. and K.L.H. primarily undertook data analysis. J.E.C., F.B. and R.C.V wrote the first draft of the manuscript. All authors contributed to manuscript revision.

ACKNOWLEDGEMENTS

This study was supported through the Bill & Melinda Gates Foundation, FFAR and USAID funded project "Accelerating Genetic Gains" (INV-003439), the Bill & Melinda Gates Foundation funded projects "FarmSelect" (INV-046703) and "1000FARMS" (INV-031561) and the UK Global Challenges Research Fund administered by the Biotechnology and Biological Sciences Research Council project "Addressing malnutrition with biofortified maize in Zimbabwe: from crop management to policy and consumers" (IATI Identifier: GB-GOV-13-FUND–GCRF-BB_T009047_1) and the CGIAR Accelerated Breeding Initiative. We are grateful to the extension agents who conducted the survey and assisted in on-farm trials, the households who gave their time to answer our survey and the farmers who hosted on-farm trials. We gratefully acknowledge the advice of Dr Chloe McLaren and of the two anonymous reviewers.

CONFLICT OF INTEREST STATEMENT

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

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on CIMMYT Dataverse (https://data.cimmyt.org/). No personally identifiable information is included in this dataset.

ETHICS STATEMENT

Our research was deemed low risk and approval was granted by the CIMMYT internal ethics review committee (IREC). IREC complies with standards setup with CIMMYT internal policies, applicable legal framework and requirements from Funders. Prior informed consent was sought by local representatives, ensuring survey participants understood the purpose of the study, participation was voluntary, raw survey data would not be shared, they had the right to refuse participation, and participation could be stopped at any time.

ORCID

Jill E. Cairns https://orcid.org/0000-0002-2735-3485
Mainassara Zaman-Allah https://orcid.org/0000-0002-8120-5125
Frédéric Baudron https://orcid.org/0000-0002-5648-2083
Rachel C. Voss https://orcid.org/0000-0002-0890-830X
Kirsty L. Hassall https://orcid.org/0000-0003-0033-1136

Michael Euler https://orcid.org/0000-0003-3697-8177
Emily Amondo https://orcid.org/0000-0002-1781-0443
Paswel P. Marenya https://orcid.org/0000-0003-2496-2303
Boddupalli M. Prasanna https://orcid.org/0000-0002-5761-2273

REFERENCES

Acevedo, M., Pixley, K., Zinyengere, N., Meng, S., Tufan, H., Cichy, K., Bizikova, L., Isaacs, K., Ghezzi-Kopel, K., & Porciello, J. (2020). A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. *Nature Plants*, *6*, 1231–1241. https://doi.org/10.1038/s41477-020-00783-z

Acosta, M., van Wessel, M., Bommel, S., Ampaire, E. L., Twyman, J., Jassogne, L., & Feindt, P. H. (2020). What does it mean to make a 'joint' decision? Unpacking intra-household decision making in agriculture: Implications for policy and practice. *The Journal of Development Studies*, *56*(6), 1210–1229. https://doi.org/10.1080/00220388.2019.1650169

Alvarez, S., Timler, C. J., Michalscheck, M., Paas, W., Descheemaeker, K., Tittonell, P., Andersson, J. A., & Groot, J. C. J. (2018). Capturing farm diversity with hypothesis-based typologies: An innovative methodological framework for farming system typology development. *PLoS ONE*, *13*, e0194757. https://doi.org/10.1371/journal.pone.0194757

Ashby, J. A. (2024). What Happened to Gender-Intentional Participatory Research in Agriculture? In J. Njuki, H. A. Tufan, V. Polar, H. Campos, & M. Morgan-Bell (Eds.), *Gender, power and politics in agriculture revisiting theory and practice* (pp. 51–70). Springer.

Atlin, G. N., Cooper, M., & Bjørnstad, Å. (2001). A comparison of formal and participatory breeding approaches using selection theory. *Euphytica*, *122*, 463–475. https://doi.org/10.1023/A:1017557307800

Bacud, E. S. T., Gerullis, M. K., Puskur, R., & Heckelei, T. (2024). Looking at gender is not enough--how diversity of farmer's marginalization relates to variety preferences. *Food Policy*, *124*, 102616. https://doi.org/10.1016/j.foodpol.2024.102616

Baudron, F., Cairns, J. E., Haefele, S. M., Hassall, K. L., Ndhlela, T., Nyagumbo, I., Manzeke-Kangara, G., & Joy, E. J. M. (2024). Projecting the contribution of pro-vitamin a maize biofortification and other nutrition interventions to the nutritional adequacy and cost of diets in rural Zimbabwe. *Journal of Nutrition*, *154*(6), 1815–1826. https://doi.org/10.1016/j.tjnut.2024.04.009

Baudron, F., Corbeels, M., Andersson, J. A., Sibanda, M., & Giller, K. E. (2011). Delineating the drivers of waning wildlife habitat: The predominance of cotton farming on the fringe of protected areas in the mid-Zambezi Valley, Zimbabwe. *Biological Conservation*, *144*(5), 1481–1493. https://doi.org/10.1016/j.biocon.2011.01.017

Baudron, F., Homann-Kee Tui, S., Silva, J. V., Chakoma, I., Matangi, D., Nyagumbo, I., & Dube, S. (2024). Tailoring interventions through a combination of statistical typology and frontier analysis: A study of mixed crop-livestock farms in semi-arid Zimbabwe. *Experimental Agriculture*, *60*, e23, 1-24. https://doi.org/10.1017/S0014479724000176

Baudron, F., Jaleta, M., Okitoi, O., & Tegegn, A. (2014). Conservation agriculture in African mixed crop-livestock systems: Expanding the niche. *Agriculture, Ecosystems & Environment*, *187*, 171–182. https://doi.org/10.1016/j.agee.2013.08.020

Bellon, M. R., Gambara, P., Gatsi, T., Machemedze, T. E., Maminimini, O., & Waddington, S. R. (1999). *Farmers' taxonomies as a participatory diagnostic tool: Soil fertility management in Chihota, Zimbabwe*. CIMMYT economics working paper no.13. CIMMYT.

Bruno, A., Katungi, E., Stanley, N. T., Clare, M., Maxwell, M. G., Paul, G., Patrick, R., & Richard, E. (2018). Participatory farmers' selection of common bean varieties (*Phaseolus vulgaris* L.) under different production constraints. *Plant Breeding*, *137*(3), 283–289. https://doi.org/10.1111/pbr.12594

Bullock, R., & Crane, T. (2021). Young women's and men's opportunity spaces in dairy intensification in Kenya. *Rural Sociology*, *86*(4), 777–808. https://doi.org/10.1111/ruso.12385

Cairns, J. E., Baudron, F., Hassall, K. L., Ndhlela, T., Nyagumbo, I., McGrath, S. P., & Haefele, S. M. (2022). Revisiting strategies to incorporate gender-responsiveness into maize breeding in southern Africa. *Outlook on Agriculture*, *51*(2), 178–186. https://doi.org/10.1177/00307270211045410

Chikowo, R., Zingore, S., Snapp, S., & Johnston, A. (2014). Farm typologies, soil fertility variability and nutrient management in smallholder farming in sub-Saharan Africa. *Nutrient Cycling in Agroecosystems*, *100*, 1–18. https://doi.org/10.1007/s10705-014-9632-y

Christinck, A., Weltzien, E., & Rattunde, F. (2017). *Gender differentiation of farmer preferences for varietal traits in crop improvement: Evidence and issues*. Working paper #2. CGIAR gender and agriculture research network; CGIAR system management office. International Center for Tropical Agriculture (CIAT).

Colfer, C. J. P., Basnett, B. S., & Ihalainen, M. (2018). *Making sense of 'intersectionality': A manual for lovers of people and forests*. Occasional Paper 184. CIFOR.

Collinson, S., Hamadzipiri, E., De Groote, H., Ndegwa, M., Cairns, J. E., Albertsen, M., Ligeyo, D., Mashingaidze, K., & Olsen, M. (2022). Incorporating male sterility increases hybrid maize yield in low input African farming systems. *Communications Biology*, *5*, 729. https://doi.org/10.1038/s42003-022-03680-7

Crossa, J., Bellon, M. R., & Franco, J. (2002). A quantitative method for classifying farmers using socioeconomic variables. In M. R. Bellon & J. Reeves (Eds.), *Quantitative analysis of data from participatory methods in plant breeding* (pp. 117–127). CIMMYT.

Cullen, B., Snyder, K. A., Rubin, D., & Tufan, H. A. (2023). They think we are delaying their outputs'. The challenges of interdisciplinary research: Understanding power dynamics between social and biophysical scientists in international crop breeding teams. *Frontiers in Sustainable Food Systems*, *7*, 1250709. https://doi.org/10.3389/fsufs.2023.1250709

Dassanayake, W., Luckert, M. K., & Mohapatra, S. (2015). Heterogeneity of household structures and income: Evidence from Zimbabwe and South Africa. *Journal of Policy Modeling*, *37*(4), 668–692. https://doi.org/10.1016/j.jpolmod.2014.11.005

Doss, C. R. (2001). Designing agricultural technology for African women farmers: Lessons from 25 years of experience. *World Development*, *29*(12), 2075–2092. https://doi.org/10.1016/S0305-750X(01)00088-2

Doss, C. R., Kieran, C., & Kilic, T. (2020). Measuring ownership, control, and use of assets. *Feminist Economics*, *26*(3), 144–168. https://doi.org/10.1080/13545701.2019.1681591

Dray, S., & Dufour, A. (2007). The ade4 package: Implementing the duality diagram for ecologists. *Journal of Statistical Software*, *22*(4), 1–20. https://doi.org/10.18637/jss.v022.i04

Elias, M., Mudege, N., Lopez, D. E., Najjar, D., Kandiwa, V., Luis, J., Yila, J., Tegbaru, A., Ibrahim, G., Badstue, L., Njuguna-Mungai, E., & Bentaibi, A. (2018). Gendered aspirations and occupations among rural youth, in agriculture and beyond: A cross-regional prescriptive. *Journal of Gender, Agriculture and Food Security*, *3*, 82–107.

Etienne, X. L., Ferrara, G., & Mugabe, D. (2019). How efficient is maize production among smallholder farmers in Zimbabwe? A comparison of semiparametric and parametric frontier efficiency analyses. *Economic Analysis*, *51*(26), 2855–2871. https://doi.org/10.1080/00036846.2018.1558363

van Etten, J., Beza, E., Calderer, L., van Duijvendijk, K., Fadda, C., Fantahun, B., Kidane, Y. G., van de Gevel, J., Gupta, A., & Mengistu, D. K. (2018). First experiences with a novel farmer citizen science approach: Crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (tricot). *Experimental Agricultural*, *55*(S1), 275–296. https://doi.org/10.1017/S0014479716000739

van Etten, J., de Sousa, K., Cairns, J. E., Dell'Acqua, M., Fadda, C., Guereña, D., van Heerwaarden, J., Assefa, T., Manners, R., Müller, A., Pèd, M. E., Polar, V., Ramirez-Villega, J., Solbergb, S. Ø., Teeken, B., & Tufan, H. A. (2023). Data-driven approaches can harness crop diversity to address heterogeneous needs for breeding products. *Proceedings of the National Academy of Sciences*, *120*, 2205771120. https://doi.org/10.1073/pnas.2205771120

Falconnier, G. N. (2016). *Trajectories of agricultural change in southern Mali*. Wageningen University.

Freeman, H. A. (2001). *Comparison of farmer-participatory research methodologies: Case studies in Malawi and Zimbabwe*. Working Paper Series no. 10. PO Box 39063. Socioeconomics and Policy Program, International Crops Research Institute for the Semi-Arid Tropics. 28 pp

Gesesse, C. A., Nigir, B., de Sousa, K., Gianfranceschi, L., Gallo, G. R., Poland, J., Kidane, Y. G., Desta, E. A., Fadda, C., Pè, M. E., & Dell'Acqua, M. (2023). Genomics-driven breeding for local adaptation of durum wheat is enhanced by farmers' traditional knowledge. *Proceedings of the National Academy of Sciences of the United States of America*, *120*, e2205774119. https://doi.org/10.1073/pnas.2205774119

Hamadziripi, E. T., Collinson, S., Voss, R. C., Baudron, F., Labuschagne, M. T., Franke, A. C., Zaman-Allah, M., Olsen, M. S., Burgueño, J., & Cairns, J. E. (2024). Validating a novel genetic technology for hybrid maize seed production under management practices associated with resource-poor farmers in Zimbabwe. *Plants, People, Planet*, *7*, 801–815. https://doi.org/10.1002/PPP3.10590

Hammond, J., Rosenblum, N., Breseman, D., Gorman, L., Manners, R., van Wijk, M. T., Sibomana, M., Remans, R., Vanlauwe, B., & Schut, M. (2020). Towards actionable farm typologies: Scaling adoption of agricultural inputs in Rwanda. *Agricultural Systems*, *183*, 102857. https://doi.org/10.1016/j.agsy.2020.102857

Harcourt, W. (2016). Gender dilemmas in international development studies. *European Journal of Development Research*, *28*, 167–174. https://doi.org/10.1057/ejdr.2016.6

Hassall, K. L., Baudron, F., MacLaren, C., Cairns, J. E., Ndhlela, T., McGrath, S., Nyagumbo, I., & Haefele, S. (2023). Construction of a generalised farm typology to aid selection, targeting and scaling of onfarm research. *Computers and Electronics in Agriculture*, *212*, 108074. https://doi.org/10.1016/j.compag.2023.108074

Hellin, J., Fisher, E., & Bonatti, M. (2024). Transforming agricultural research and development systems to meet 21st century needs for climate action. *Frontiers in Sustainable Food Systems*, *8*, 1398079. https://doi.org/10.3389/fsufs.2024.1398079

Katuuramu, D. N., Luyima, G. B., Nkalubo, S. T., Wiesinger, J. A., Kelly, J. D., & Cichy, K. A. (2020). On-farm multi-location evaluation of genotype by environment interactions for seed yield and cooking time in common bean. *Scientific Reports*, *10*, 3628. https://doi.org/10.1038/s41598-020-60087-2

Kool, H., Andersson, J. A., & Giller, K. E. (2020). Reproducibility and external validity of on-farm experimental research in Africa. *Experimental Agriculture*, *56*(4), 587–607. https://doi.org/10.1017/S0014479720000174

Laajaj, R., Macours, K., Masso, C., Thuita, M., & Vanlauwe, B. (2020). Reconciling yield gains in agronomic trials with returns under African smallholder conditions. *Scientific Reports*, *10*, 14286. https://doi.org/10.1038/s41598-020-71155-y

Lund, J. F., & Saito-Jensen, M. (2013). Revisiting the issue of elite capture in participatory initiatives. *World Development*, *46*, 104–112. https://doi.org/10.1016/j.worlddev.2013.01.028

Madu, T., Onwuka, S., Nwafor, S., Ejechi, M., Ofoeze, M., Onyemauwa, N., Ukeje, B., Eluagu, C., Olaosebikan, O., & Okoye, B. (2024). Gender-inclusive consumer studies improve cassava breeding in Nigeria. *Frontiers in Sociology*, *9*, 1224504. https://doi.org/10.3389/fsoc.2024.1224504

Makate, C., Makate, M., & Mango, N. (2018). Farm household typology and adoption of climate- smart agriculture practices in smallholder farming systems of southern Africa. *African Journal of Science, Technology, Innovation and Development*, *10*(4), 421–439. https://doi.org/10.1080/20421338.2018.1471027

Mancini, C., Kidane, Y. G., Mengistu, D. K., Melfa and Workaye Farmer Community, Pè, M. E., Fadda, C., & Dell'Acqua, M. (2017). Joining smallholder farmers' traditional knowledge with metric traits to select better varieties of Ethiopian wheat. *Scientific Reports*, *7*, 9120. https://doi.org/10.1038/s41598-017-07628-4

Manners, R., Hammond, J., Umugabe, D. R., Sibomana, M., & Schut, M. (2025). A farm typology development cycle: From empirical development through validation, to large-scale organisational deployment. *Agricultural Systems*, *224*, 104250. https://doi.org/10.1016/j.agsy.2024.104250

Masvaya, E. N., Nyamangara, J., Nyawasha, R. W., Zingore, S., Delve, R. J., & Giller, K. E. (2010). Effect of farmer management strategies on spatial variability of soil fertility and crop nutrient uptake in contrasting agro-ecological zones in Zimbabwe. *Nutrient Cycling in Agroecosystems*, *88*, 111–120. https://doi.org/10.1007/s10705-009-9262-y

McGuire, E., Rietveld, A. M., Crump, A., & Leeuwis, C. (2022). Anticipating gender impacts in scaling innovations for agriculture: Insights from the literature. *World Development Perspectives*, *25*, 100386. https://doi.org/10.1016/j.wdp.2021.100386

Moyo, S. (Ed.). (2000). *Zimbabwe environmental dilemma: Balancing resource inequities*. Zimbabwe Environmental Research Organization. 161 pp.

Moyo, M., Ssali, R., Namanda, S., Nakitto, M., Dery, E. K., Akansake, D., Adjebeng-Danquah, J., van Etten, J., de Sousa, K., Lindqvist-Kreuze, H., Carey, E., & Muzhingi, T. (2021). Consumer preference testing of boiled sweetpotato using crowdsourced citizen science in Ghana and Uganda. *Frontiers in Sustainable Food Systems*, *5*, 620363. https://doi.org/10.3389/fsufs.2021.620363

Mtambanengwe, F., & Mapfumo, P. (2005). Organic matter management as an underlying cause for soil fertility gradients on smallholder farms in Zimbabwe. *Nutrient Cycling in Agroecosystems*, *73*, 227–243. https://doi.org/10.1007/s10705-005-2652-x

Mtapuri, O. (2011). Developing an asset threshold using the consensual approach: Results from Mashonaland West, Zimbabwe. *Journal of International Development*, *23*(1), 29–41. https://doi.org/10.1002/jid.1605

Mujeyi, A., Mudhara, M., & Mutenje, M. J. (2020). Adoption patterns of climate-smart agriculture in integrated crop-livestock smallholder farming systems of Zimbabwe. *Climate and Development*, *14*(5), 399–408. https://doi.org/10.1080/17565529.2021.1930507

Nanyonjo, A. R., Angudubo, S., Iragaba, P., Brown, D., Nuwamanya, E., Esuma, W., Ozimati, A., Wembabazi, E., Kanaabi, M., Muhumuza, N., Bayiyana, I., van Etten, J., de Sousa, K., Tufan, H., & Kawuki, R. S. (2024). On-farm evaluation of cassava clones using the triadic comparison of technology options approach. *Crop Science*, *64*(5), 2679–2697. https://doi.org/10.1002/csc2.21293

Obunyali, C., Karanja, J., Oikeh, S., Omanya, G., Mugo, S., Beyene, Y., & Oniang'o, R. (2019). On-farm performance and farmer-preferred traits evaluation of drought TEGO-climate-smart maize hybrids in Kenya. *Agronomy Journal*, *11*(6), 2754–2768. https://doi.org/10.2134/agronj2019.08.0600

Oksanen, J., Simpson, G., Blanchet, F., Kindt, R., Legendre, P., Minchin, P., O'Hara, R., Solymos, P., Stevens, M., Szoecs, E., Wagner, H., Barbour, M., Bedward, M., Bolker, B., Borcard, D., Carvalho, G., Chirico, M., De Caceres, M., Durand, S., Evangelista, H., FitzJohn, R., Friendly, M., Furneaux, B., Hannigan, G., Hill, M., Lahti, L., McGlinn, D., Ouellette, M., Ribeiro Cunha, E., Smith, T., Stier, A., Ter Braak, C., Weedon, J. (2022). Vegan: Community ecology package. R package version 2.6–4. https://CRAN.R-project.org/package=vegan

Prasanna, B. M., Burgueño, J., Beyene, Y., Makumbi, D., Asea, G., Woyengo, V., Tarekegne, A., Magorokosho, C., Wegary, D., Ndhlela, T., Zaman-Allah, M., Matova, P. M., Mwansa, K., Mashingaidze, K., Fato, P., Teklewold, A., Vivek, B. S., Zaidi, P. H., Vinayan, M. T., … Cairns, J. E. (2022). Genetic trends in CIMMYT'S tropical maize breeding pipelines. *Scientific Reports*, *12*, 20110. https://doi.org/10.1038/s41598-022-24536-4

R Core Team. (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/

Ragot, M., Bonierbale, M., & Weltzien, E. (2018). *From market demand to breeding decisions: A framework. CGIAR gender and breeding initiative working paper 2*. CGIAR Gender and Breeding Initiative. https://hdl.handle.net/10568/91275

Rice, B., Kramer, B., & Trachtman, C. (2024). *Barriers to using market intelligence in plant breeding: Evidence from a survey of breeding professionals*. Market Intelligence Brief Series 18. CGIAR.

Rohrbach, D. (2001). Targeting of women farmers. In S. J. Twomlow & B. Ncube (Eds.), *2001. Improving soil management options for women farmers in Malawi and Zimbabwe: Proceedings of a collaborators' workshop on the DFID-supported project "will women farmers invest in improving their soil fertility management? Participatory experimentation in a risky environment"*, 13–15 September 2000, ICRISAT-Bulawayo, Zimbabwe. P O Box 776 (pp. 112–114). International Crops Research Institute for the Semi-Arid Tropics. http://oar.icrisat.org/1101/1/RA_00369.pdf

de Roo, N., Andersson, J. A., & Krupnick, T. J. (2017). On-farm trials for development impact? The organisation of research and the scaling of agricultural technologies. *Exploratory Agricultural*, *55*(2), 163–184. https://doi.org/10.1017/S0014479717000382

Rufino, M. C., Dury, J., Tittonell, P., van Wijk, M. T., Herrero, M., Zingore, S., Mapfumo, P., & Giller, K. E. (2011). Competing use of organic resources, village-level interactions between farm types and climate variability in a communal area of NE Zimbabwe. *Agricultural Systems*, *104*(2), 175–190. https://doi.org/10.1016/j.agsy.2010.06.001

Rusinamhodzi, L., van Wijk, M. T., Corbeels, M., Rufino, M. C., & Giller, K. E. (2015). Maize crop residue uses and trade-offs on smallholder crop-livestock farms in Zimbabwe: Economic implications of intensification. *Agriculture, Ecosystems & Environment*, *214*, 31–45. https://doi.org/10.1016/j.agee.2015.08.012

Ruzzante, S., Labarta, R., & Bilton, A. (2021). Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. *World Development*, *146*, 105599. https://doi.org/10.1016/j.worlddev.2021.105599

Schulz, D., & Börner, J. (2022). Innovation context and technology traits explain heterogeneity across studies of agricultural technology adoption: A meta-analysis. *Journal of Agricultural Economics*, *74*(2), 570–590. https://doi.org/10.1111/1477-9552.12521

Setimela, P. S., Magorokosho, C., Lunduka, R., Gasura, E., Makumbi, D., Tarekegne, A., Cairns, J. E., Ndhela, T., Erenstein, O., & Mwangi, W. (2017). On-farm yield gains with stress tolerant maize in eastern and southern Africa. *Agronomy Journal*, *109*(2), 406–417. https://doi.org/10.2134/agronj2015.0540

Setimela, P., Zaman-Allah, M. A., Gasura, E., Cairns, J. E., Thierfelder, C., & Prasanna, B. M. (2018). When the going gets tough: Performance of stress tolerant maize under conservation agriculture during the 2015/16 El Nino season in southern Africa. *Agricultural Water Management*, *268*, 79–89. https://doi.org/10.1016/j.agee.2018.09.006

Smale, M., & Olwande, J. (2014). Demand for maize hybrids and hybrid change on smallholder farms in Kenya. *Agricultural Economics*, *45*(4), 409–420. https://doi.org/10.1111/agec.12095

Snapp, S. S. (2002). Quantifying farmer evaluation of technologies: The mother and baby trial design. In M. R. Bellon & J. Reeves (Eds.), *Quantitative analysis of data from participatory methods in plant breeding* (pp. 9–17). CIMMYT.

de Sousa, K., van Etten, J., Manners, R., Abidin, E., Abdulmalik, R. O., Abolore, B., Acheremu, S., Angudubo, K., Aguilar, A., Arnaud, E., Babu, A., Barrios, M., Benavente, E., Boukar, O., Cairns, J. E., Carey, E., Daudi, H., Dawud, M., Edughaen, G., … Zaman-Allah, M. (2024). The tricot approach: An agile framework for decentralized on-farm testing supported by citizen science. A retrospective. *Agronomy for Sustainable Development*, *44*, 8. https://doi.org/10.1007/s13593-023-00937-1

de Sousa, K., van Etten, J., Poland, J., Fadda, C., Jannink, J.-L., Kidane, Y. G., Lakew, B. F., Mengistu, D. K., Pè, M. E., Solberg, S. Ø., & Dell'Acqua, M. (2021). Data-driven decentralized breeding increases prediction accuracy in a challenging crop production environment. *Communications Biology*, *4*, 944. https://doi.org/10.1038/s42003-021-02463-w

Ssali, R. T., Mayanja, S., Nakitto, M., Mwende, J., Tinyiro, S. E., Bayiyana, I., Okello, J., Forsythe, L., Magala, D., Yada, B., Mwanga, R. O. M., & Polar, V. (2023). Gender mainstreaming in sweetpotato breeding in Uganda: A case study. *Frontiers in Sociology*, *8*, 1233102. https://doi.org/10.3389/fsoc.2023.1233102

Teeken, B., Garner, E., Agbona, A., Balogun, I., Olaosebikan, O., Bello, A., Madu, T., Okoye, B., Egesi, C., Kulakow, P., & Tufan, H. A. (2021). Beyond "women's traits": Exploring how gender, social difference, and household characteristics influence trait preferences. *Frontiers in Sustainable Food Systems*, *5*, 740926. https://doi.org/10.3389/fsufs.2021.74092

Thuijsman, E. S., den Braber, H. J., Andersson, J. A., Descheemaeker, K., Baudron, F., López-Ridaura, S., Vanlauwe, B., & Giller, K. E. (2022). Indifferent to difference? Understanding the unequal impacts of farming technologies among smallholders. A review. *Agronomy for Sustainable Development*, *42*, 41. https://doi.org/10.1007/s13593-022-00768-6

Van Campenhout, B., Lecoutere, E., & Spielman, D. J. (2023). Hiding or pleasing: Spousal disagreement among Ugandan maize farmers. *The Journal of Development Studies*, *59*(1), 39–57. https://doi.org/10.1080/00220388.2022.2113065

Voss, R. C., Cairns, J. E., Olsen, M. S., Muteti, F. N., Magambo, G., Hamadziripi, E., Ligeyo, D., Mashingaidze, K., Collinson, S., & Woyengo, V. (2023). Bringing gender into conventional maize breeding in Africa: Lessons from the seed production Technology for Africa project. *Frontiers in Sociology*, *8*, 1254595. https://doi.org/10.3389/fsoc.2023.1254595

Voss, R. C., de Sousa, K., N'Danikou, S., Shango, A., Aglinglo, L. A., Laporte, M.-A., Legba, E. C., Houdegbe, A. C., dit Youssouf Diarra, D., Dolo, A., Sidibe, A., Ouedraogo, C. O., Coulibaly, H., Achigan-Dako, E. G., Kileo, A., Malulu, D., Matumbo, Z., Dinssa, F., van Heerwaarden, J., … van Zonneveld, M. (2025). Citizen science informs demand-driven breeding of opportunity crops. *Plants, People, Planet*. https://doi.org/10.1002/ppp3.70035

Voss, R. C., Donovan, J., Rutsaert, P., & Cairns, J. E. (2021). Gender inclusivity through maize breeding in Africa: A review of the issues and options for future engagement. *Outlook on Agriculture*, *50*(4), 392–405. https://doi.org/10.1177/00307270211058208

Voss, R. C., Gitonga, Z. M., Donovan, J., Garcia-Medina, M., & Muindi, P. (2023). Can I speak to the manager? The gender dynamics of decision-making in Kenyan maize plots. *Agriculture and Human Values*, *41*, 205–224. https://doi.org/10.1007/s10460-023-10484-w

Weltzien, E., Rattunde, F., Christinck, A., Isaacs, K., & Ashby, J. (2019). Gender and farmer preferences for varietal traits. *Plant Breeding Reviews*, *43*, 243–278. https://doi.org/10.1002/9781119616801.ch7

Werner, C., Zaman-Allah, M., Mamo, T. A., Cairns, J. E., & Atlin, G. N. (2025). Accelerating genetic gain through early-stage on-farm sparse testing. *Trends in Plant Science*, *30*(1), 17–20. https://doi.org/10.1016/j.tplants.2024.10.010

Witcombe, J. R., Joshi, K. D., Gyawali, S., Musa, A. M., Johansen, C., Virk, D. S., & Sthapit, B. R. (2005). Participatory plant breeding is better described as highly client-oriented plant breeding. I. Four indicators of client-orientation in plant breeding. *Experimental Agriculture*, *41*(3), 299–319. https://doi.org/10.1017/S0014479705002656

Worku, M., De Groote, H., Munyua, B., Makumbi, D., Owino, F., Crossa, J., Beyene, Y., Mugo, S., Jumbo, M., Asea, G., Mutinda, C., Kwemoi, D. B., Woyengo, V., Olsen, M., & Prasanna, B. M. (2020). On-farm performance and farmers' participatory assessment of new stress-tolerant maize hybrids in eastern Africa. *Field Crops Research*, *246*, 107693. https://doi.org/10.1016/j.fcr.2019.107693

Yami, M., Cavicchioli, M., Cole, S. M., Wossen, T., & Abdoulaye, T. (2024). Why contexts matter for gender equal outcomes in research-based plant breeding: The case of maize in Nigeria. *Economic Botany*, *78*, 445–464. https://doi.org/10.1007/s12231-024-09616-y

ZimVAC. 2022 Zimbabwe vulnerability assessment committee 2020 rural livelihoods assessment report Food and Nutrition Council

Zingore, S., Murwira, H. K., Delve, J. R., & Giller, K. E. (2007). Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrient balances on smallholder farms in Zimbabwe. *Agriculture, Ecosystems and Environment*, *119*(1–2), 112–126. https://doi.org/10.1016/j.agee.2006.06.019

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Cairns, J. E., Zaman-Allah, M., Baudron, F., Voss, R. C., Hassall, K. L., Euler, M., Amondo, E., Marenya, P. P., & Prasanna, B. M. (2025). Know your men and women farmers: Ensuring host farmers in participatory trials represent heterogeneity within the target environment. *Plants, People, Planet*, 1–18. https://doi.org/10.1002/ppp3.70070