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Bridging Yield Gaps and Accelerating Adoption: Cluster-Based Scaling of Hybrid Maize Variety in Ethiopia

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Abstract

As Ethiopia's most widely cultivated and consumed cereal crop, maize is fundamental to national food security and the economic well-being of millions of smallholder farmers. However, fragmented landholdings and limited access to improved technologies often constrain agricultural productivity. To address this, a cluster-based demonstration of the newly released Ilu (BH549) improved maize variety was conducted to evaluate its performance and stimulate adoption in the high-potential maize-producing areas of western and southwestern Ethiopia. The study was implemented during the (2022–2023) main cropping seasons across three zones (Jimma, East Wollega, and West Shewa) of the Oromia Region, encompassing four districts and four kebeles. It involved 97 farm households (12.4% female-headed) and covered 40 hectares of land, with the primary objective of creating awareness and demand for the variety among farmers and seed enterprises. Data collection integrated quantitative yield measurements and qualitative farmer feedback. Yield gap analysis revealed a substantial difference: demonstration plots using the recommended package yielded 8.42 t ha⁻¹ per hectare (t ha⁻¹), compared to 4.64 (t/ha⁻¹) from farmers' existing practices. This resulted in an extension gap of 3.79(t ha⁻¹), a technology gap of 2.58 (t ha⁻¹), and a technology index of 23.47%. The findings show that the cluster demonstration approach effectively showcases the superior yield potential of the Ilu variety. We recommend scaling this approach across similar agro-ecologies, supported by seed multiplication, input access, and extension services to maximize adoption and contribute to national food security.

Keywords: Yield gap, Demonstration, Technology, Cluster farming, Extension

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Introduction

Maize (*Zea mays*) is one of the world's most widely cultivated cereal crops and the second most widely produced cereal globally, playing a multifaceted role in agri-food systems while contributing significantly to food and nutrition security (Grote et al., 2021; Poole et al., 2021). Across Africa, maize is a crucial crop for millions of smallholder farmers, serving as both a primary food staple and a source of livelihood (Shirko et al., 2023). Cluster farming is a

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strategic approach to organizing small and marginal farmers to achieve economies of scale in production and marketing. It allows small-scale farmers to pool their resources, share costs of agricultural research, technology, and essential supplies, and negotiate better prices for bulk purchases (Endalew et al., 2024). This collaboration fosters a knowledge-sharing environment, enabling farmers to specialize in specific crops or tasks, become experts in their respective areas, and share their expertise with others. By operating as a cluster, farmers gain a stronger voice in the marketplace, leverage their combined production to negotiate better deals with buyers, and develop a shared brand identity.

Cluster farming also addresses limited market access and financial inclusion, making it a vital investment in food security and production optimization. Government bodies and development organizations support producer clusters. We seek to analyze the relationship between farmer organizations and these clusters in terms of their perceptions of farming risks and the implementation of agricultural technologies and practices aimed at reducing perceived production risks. Since the 1950s, Ethiopia has maintained sustained investment in boosting maize production and productivity, yielding measurable results: national average yields doubled from 1.9 t ha⁻¹ in 1995 to 3.99 t ha⁻¹ in 2022, while total production rose from 3.9 million to 9.5 million t ha⁻¹s over the past decade (Abate et al., 2015; Van Dijk et al., 2020). These improvements stem from expanded cultivated area, advances in genetic improvement, strengthened extension services, and increased access to improved varieties and fertilizers. Despite this progress, Ethiopia possesses significant untapped maize production potential, as evidenced by the persistent yield gap revealed in 2022 data: while research stations achieve an average of 10 t ha⁻¹s per hectare and managed farmer fields yield 7.8 t ha⁻¹s per hectare, the national average stands at just 4.17 t ha⁻¹s per hectare (Asfaw et al., 2024; Bedasa et al., 2025).

This substantial gap reflects repeated challenges, including biotic and abiotic stresses such as frequent drought, declining soil fertility, disease pressure, insect pests, and weed competition, compounded by socioeconomic and systemic constraints including limited input use, poor seed quality, inadequate credit facilities, weak research-extension-farmer linkages, and sub-optimal agronomic practices (Zerssa et al., 2021). The Bako National Maize Research Center (BNMRC) of the Ethiopian Institute of Agricultural Research (EIAR) has responded to these challenges through sustained breeding efforts, releasing sixty-four improved maize varieties between 1972 and 2020, including twenty-one hybrids and five open-pollinated varieties adapted to diverse agro-ecologies (Engida et al., 2024). Among promising new releases, the Ilu hybrid variety has demonstrated exceptional potential, with on-station yields reaching 8.0- 12.0 (t ha⁻¹) and field performance ranging from 7.45 to 8.0 (t ha⁻¹) under farmer-managed conditions. (Worku et al., 2020). However, translating this genetic potential into widespread productivity gains requires deliberate scaling strategies that move beyond small research plots to reach millions of smallholder farmers who depend on maize for their livelihoods. This imperative has catalyzed the adoption of cluster-based demonstration and commercialization approaches, which have shown significant impacts on crop productivity, market engagement, income generation, and poverty reduction (Louhichi et al., 2019; Endalew et al., 2024). Cluster farming facilitates knowledge dissemination, collective action, reduced transaction costs, and improved access to credit and quality inputs, and the spread of technological and managerial

innovations through vertical and horizontal coordination among participants and supporting organizations (Bizikova et al., 2020, Hussien and Geleta, 2021, Muddassir et al., 2016b).

This study was undertaken to demonstrate, evaluate, and scale up the improved Ilu maize hybrid through large-scale agricultural commercialization clusters across multiple districts in Ethiopia. By assessing its performance under diverse farmer-managed conditions, the study aimed to accelerate farmer adoption, bridge productivity gaps, and enhance maize production through technology dissemination and best-practice sharing. The findings provide empirical evidence to inform extension strategies and policy interventions that support the transition from subsistence-oriented to commercially viable maize production, thereby contributing to national food security and improved smallholder livelihoods.

Methods and Materials

Study Areas, Duration, and Site Selection

This large-scale demonstration and evaluation of the Ilu maize hybrid was conducted over two years (2022–2023) in purposively selected, high-potential maize production areas across western and southwestern Ethiopia (Oromia Region). The selection of districts (woredas) and villages (kebeles) prioritized regions with high maize production potential and logistical feasibility for consistent field monitoring.

In collaboration with district agricultural experts and local Development Agents (DAs), four kebeles were identified across three administrative zones: Omo Gurude (Gomma district, Jimma Zone), Boneya Molo (Wayu Tuka district, East Wollega Zone), Oda Gibe (Bako Tibe district, West Shewa Zone), and Goba Washamo (Ilu Galan district, West Shewa Zone). Within these kebeles, site selection was further refined with DAs, based on the availability of contiguous land plots (minimum 0.25 hectares per participant) and farmers' expressed interest in engaging in cluster-based demonstration farming. Table 1 summarizes the key geographic and demographic characteristics of the four study sites.

Table 1: *Geographic and demographic characteristics of the study sites*

Zone	Woreda (District)	Kebele (Village)	Geographic Coordinates	Altitude (m.a.s.l.)	Avg. Annual Rainfall	Primary Crops
Jimma	Goma	Omo Gurude	7°49'59.99"N, 36°39'59.99"E	1,900 – 2,100	1,700 – 2,100 mm	Maize, coffee, teff, sorghum
East Wollega	Wayu-Tuka	Boneya Molo	9°09'60.00"N, 36°44'59.99"E	1,300 – 3,140	Not specified	Maize, teff, hot pepper, sorghum
West Shewa	Bako Tibe	Oda Gibe	9°00'0.00"N, 37°09'60.00"E	1,650 – 2,800	1,250 – 1,560 mm	Maize, teff, hot pepper
West Shewa	Ilu Galan	Goba Washamo	8°44'59.99"N, 38°19'60.00"E	1,600 – 1,900	1,200 – 1,700 mm	Maize, teff, millet

These sites represent important maize-growing agro-ecologies across the region. The Jimma Zone is characterized by high rainfall and a dense population exceeding 3.6 million, while the East Wollega and West Shewa zones are central to national maize production, with the selected

woredas featuring significant rural populations engaged in agriculture (CSA, 2021; 2023). This geographic diversity ensures that the findings are relevant across a broad range of conditions typical for maize cultivation in the region. Figure 1 shows a map of the study areas.

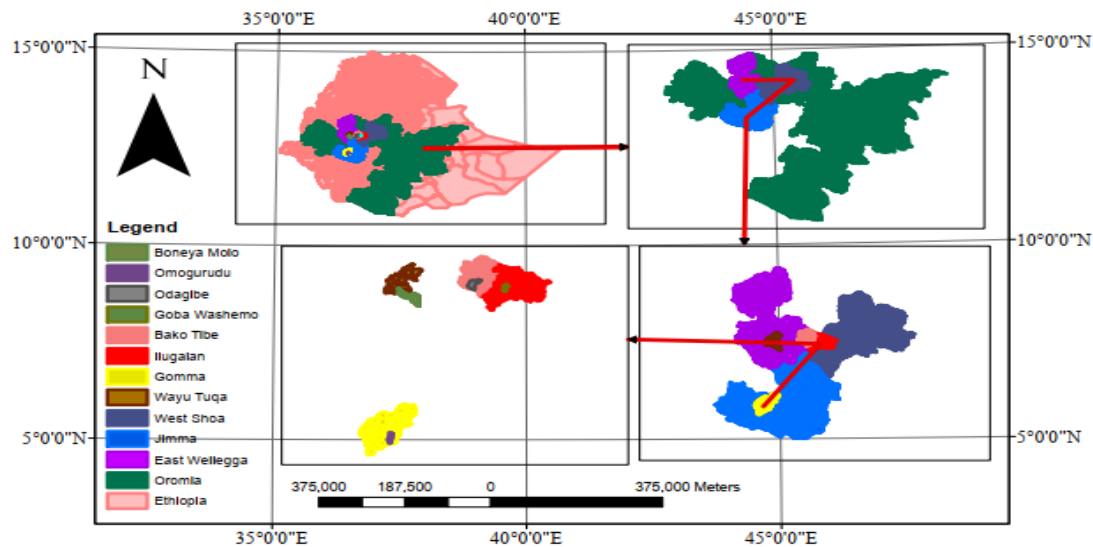


Figure 1: Map of the study areas

Study Areas, Duration, and Participant Selection

This study was conducted over two years (2022 and 2023) in three maize-producing zones of the Oromia region: Jimma, East Wollega, and West Shoa. We selected specific districts and kebeles within these zones using purposive sampling. The selection criteria prioritized areas with high maize production potential and logistical feasibility for consistent field monitoring and follow-up activities. In collaboration with district agricultural experts, the following kebeles were identified: Omo Gurude (Gomma district, Jimma Zone), Boneya Molo (Wayu Tuka district, East Wollega Zone), Oda Gibe (Bako Tibe district, West Shoa Zone), and Goba Washemo (Ilugalan district, West Shoa Zone). Site selection within these kebeles was conducted jointly with local Development Agents (DAs), based on the availability of contiguous land plots (minimum 0.25 hectares per participant) and farmers' expressed interest in engaging in cluster-based demonstration farming.

Capacity Building and Training

To ensure proper implementation, a multidisciplinary research team conducted integrated theoretical and practical training sessions for host farmers, development Agents, and district-level subject-matter specialists (SMS).

Table 2: Training of Participants

	Woredas	Kebeles	Participants							
			Farmers		Development agents		District experts		Total	
			Male	Female	Male	Female	Male	Female	Male	Female
1	Goma	Omo Gurude	28	2	1	1	3	1	32	4
2	Wayu Tuka	Boneya Mole	17	3	2	0	5	1	24	4
3	Bako Tibe	Oda Gibe	21	4	2	1	4	2	27	7

4	Ilu Galan	Goba Washamo	19	2	1	0	3	0	23	2
Total			85	11	6	2	15	4	106	17

Source: own survey (2023)

The curriculum covered core principles of improved maize cultivation, including site selection, land preparation, planting techniques, and crop management. After this training and site preparation, 97 farmer households (85 male-headed and 12 female-headed) were purposively selected to participate in the large-scale demonstration (LSD) of the Ilu maize hybrid during the subsequent 2022 and 2023 production cycles. Table 2 details the distribution of training participants across all stakeholder categories.

Technical Implementation and Agronomic Practices

The LSD utilized the Ilu hybrid maize variety with the full recommended production package. The Bako National Maize Research program and the participating farmers supplied all essential inputs through a collaboration. For the 40 hectares covered over the two years, a total of 40 quintals of seed of improved Ilu variety, 40 quintals of NPSB fertilizer, and 100 quintals of urea were distributed.

A participatory and shared-responsibility framework guided all activities, from planning through harvest. Researchers, extension personnel, district agricultural officers, and farmers collaborated with clearly assigned roles. This collaboration included input cost-sharing, coordinated field management, and regular follow-up by multidisciplinary teams.

Planting Protocol: Land preparation involved two plowing operations before sowing and a final preparation at sowing time. Planting used a spacing of 0.8 meters between rows and 0.4 meters within rows, with two seeds per hole to achieve the optimal plant population. We used a seed rate of 25 kg ha⁻¹.

Fertilizer Management: The recommended fertilizer application rate was 100 kg ha⁻¹ of NPS and 250 kg ha⁻¹ of urea.

Table 3: Land covered, inputs distributed, and participant farmers

Years	Inputs distributed (qt)			Area covered (ha.)	Participant farmers		
	NPS	Urea	Seed		Male	Female	Total
2021/2	30	75	7.5	30	67	9	76
2022/3	10	25	2.5	10	18	3	21
Total	40	100	10	40	85	12	97

Source: own survey (2023)

The full dose of NPS was applied uniformly at sowing. Urea was applied in two split doses: the first half (125 25 kg ha⁻¹) at 30-45 days after planting (the knee-height stage), and the second half (125 25 kg ha⁻¹) at 60-70 days after planting. All agronomic practices followed the recommended guidelines.

Data Collection and Analytical Framework

This study utilized a mixed-methods approach, integrating both primary and secondary data. Primary data included quantitative metrics such as crop yield performance and basic participant demographics (e.g., age, sex). Qualitative data included farmer feedback and perceptions gathered through participatory methods. To establish a baseline for comparison, secondary data

from regional agricultural surveys (Ethiopian Statistical Service (ESS)) were employed as a local check, as the demonstration plots did not include a contemporaneous control plot.

Yield Estimation Methodology

A standardized sampling protocol was used to estimate yield accurately. Each participant's plot was stratified into high-, medium-, and low-performing areas based on visual crop assessment. From these strata, 5-6 representative quadrats (each 5m x 5m) were randomly selected per farmer using a lottery method. All maize plants within a quadrat were harvested, and the total cob weight was recorded.

Grain yield was calculated based on kernel weight, adjusted to a standard moisture content of 12.5% using the established formula (Muddassir et al., 2016a):

$$\text{GY (t ha}^{-1}\text{/hec)} = \frac{[\text{Grain Weight (kg)} \times 10 \times (100 - \text{MC \%}) / (100 - 12.5)]}{\text{Plot Area (m}^2\text{)}} \dots (1)$$

Whereas:

- GY = Grain Yield in t ha⁻¹s per hectare
- MC = Measured Moisture Content in percentage
- Plot Area = Harvested quadrat area in square meters

Technology Performance and Gap Analysis

Yield data were further analyzed to evaluate the performance and adoption potential of the demonstrated technology Ilu against both theoretical potential and existing farmer practice. This was achieved through a series of gap analyses, as defined below:-

$$\text{Technology Gap (t/ha)} = \text{Potential Yield} - \text{Demonstration Yield} \dots (2)$$

Technology Gap: The difference between the potential yield (attainable under optimal research conditions) and the actual demonstration yield. This gap indicates the yield lost due to real-world field constraints.

Extension Gap: The difference between the demonstration yield and the prevailing average farmer yield. This gap represents the immediate benefit achievable through adopting the demonstrated package.

$$\text{Extension Gap (t/ha)} = \text{Demonstration Yield} - \text{Farmer Practice Yield} \dots (3)$$

Technology Index: A percentage expressing the Technology Gap relative to the Potential Yield. A lower index signifies higher feasibility and better adaptability of the technology to local farmer conditions.

$$\text{Technology Index (\%)} = \left[\frac{\text{potential yield} - \text{demonstration yield}}{\text{Potential yield}} \right] \times 100 \dots (4)$$

Percentage Yield Increase: The relative improvement offered by the new technology over conventional practices.

$$\text{Yield Increase (\%)} = \left[\frac{\text{Demonstration Yield} - \text{Farmer Practice Yield}}{\text{Farmer Practice Yield}} \right] \times 100 \text{----- (5)}$$

This analytical framework allows for a nuanced interpretation of the results, distinguishing between the technology's maximum potential, its practical performance in demonstrations, and its tangible advantage over current practices.

Findings

Descriptive Explanation of the Participants

A total of 97 farm households participated, of which 12.4% of the participating households were female-headed. Regarding their age, the participants in the LSD were found in different age groups. Table 4 shows the sex category and the minimum and maximum age of the participants.

Table 4: Sex and age of participant farmers

Locations	Sex				Age(#)				
	Male		Female		Mea n	SD	SE	t	Sig.(2- tailed)
	Freq.	%	Freq	%					
Boneya Mole (N=20)	17	85	3	15	28.2	10.6	4.47	-19.3***	0.002
Oda Gibe (N=26)	23	88.5	3	11.5	38.2	8.5	3.64	11.2**	0.004
Omo Gurude(N=30)	28	93.3	2	6.7	48.5	7.8	2.75	17.1***	0.000
Goba Washroom(N=21)	17	80.9	4	19	34	7.3	2.64	-15.8***	0.000

Source: Own computation (2023)

Yield Performance of Ilu Hybrid Maize

The demonstration of the Ilu hybrid maize variety, coupled with its full recommended production package, resulted in higher grain yields across all demonstration sites. The mean yields, as presented in Figure 1, confirm the positive impact of the large-scale demonstration (LSD) approach with improved technologies compared to prevailing local practices.

As illustrated in Figure 1, site-specific mean grain yields were 8.74 t ha⁻¹ at Boneya Mole, 8.69 t ha⁻¹ at Oda Gibe, 8.78 t ha⁻¹ at Omo Gurude, and 7.87 t ha⁻¹ at Goba Washamo. This spatial analysis reveals a notable yield gradient, with Boneya Mole recording the highest mean yield and Goba Washamo the lowest. The yield ranges further elucidate this variability: Boneya Mole (6.8 – 10.4 t ha⁻¹), Oda Gibe (6.8 – 10.8 t ha⁻¹), Omo Gurude (6.4 – 10.0 t ha⁻¹), and Goba Washamo (6.35 – 8.96 t ha⁻¹).

The recorded yields substantially exceeded regional productivity benchmarks. A comparative analysis with 2022 Existing Survey System (ESS) data, shown in Figure 2, demonstrates that the LSD approach provided a considerable yield advantage. This marked increase confirms that the integrated package of improved hybrid seed and better crop management practices can optimize productivity in the target agro-ecologies. The observed variation between sites suggests the influence of localized factors such as soil fertility, microclimate, or farmer management practices, which warrants further investigation to refine recommendations for maximum impact.

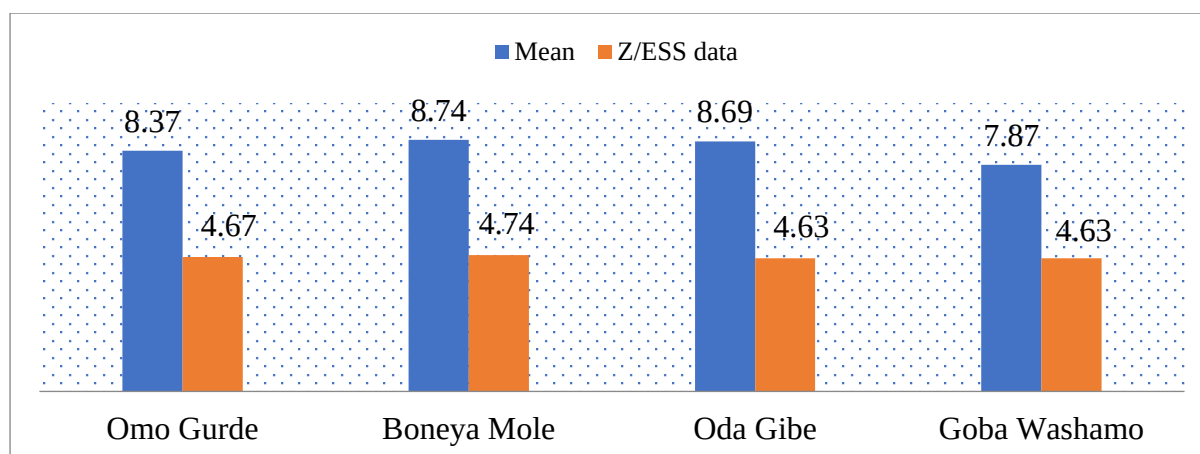


Figure 2: Productivity of the Ilu compared to Ethiopian Statistical Service data of 2022 (t ha⁻¹)

Results of Technology Gap, Extension Gap, and Technology Index

Analysis of grain yield gaps provided critical insights into the effectiveness of the large-scale demonstration and the potential for productivity improvement. The yield gap assessment compared the performance of the Ilu variety under full recommended management with both the variety's potential yield and farmers' conventional practices.

Overall Yield Advantage

The Ilu variety demonstrated exceptional performance, achieving a mean grain yield of 8.42 t ha⁻¹ across all demonstration sites (Table 5), representing an 81.4% increase over the average yield from farmers' practices (4.64 t ha⁻¹) as reported by CSA (2022). This substantial yield advantage underscores the potential benefits/effectiveness of combining improved genetics with optimal management practices. The superior performance of demonstration plots is directly attributable to the systematic application of recommended agronomic practices, including optimal sowing dates, precise fertilizer application rates and timing, and integrated pest management (Yadav et al., 2016).

Technology Gap

The technology gap is defined as the difference between the variety's potential yield (11.0 t ha⁻¹ under research station conditions) and the yield achieved in demonstration plots, which averaged 2.58 t ha⁻¹ across locations. Site-specific technology gaps were 2.63 t ha⁻¹ per t ha⁻¹ at Goma, 2.26 t ha⁻¹ per t ha⁻¹ at Wayu Tuka, 2.31 t ha⁻¹ per t ha⁻¹ at Bako Tibe, and 3.13 t ha⁻¹ per t ha⁻¹ at Ilu Galan (Table 5).

These gaps reflect location-specific factors, including environmental heterogeneity, variability in management intensity, and inherent differences in soil fertility status (Mukherjee, 2003). The narrower technology gap at Wayu Tuka (2.26 t ha⁻¹ per t ha⁻¹) suggests more favorable growing conditions or more precise implementation, while the wider gap at Ilu Galan (3.13 t ha⁻¹ per t ha⁻¹) indicates greater constraints to achieving full genetic potential.

Extension Gap

The extension gap, representing the difference between demonstration plot yields and farmers' conventional practice yields, ranged from 3.24 to 4.70 t ha⁻¹ per t ha⁻¹ across locations, with a

mean of 3.79 t ha^{-1} per t ha^{-1} . This substantial gap quantifies the productivity forgone due to continued use of traditional practices and limited adoption of improved technologies. This gap is particularly concerning because it represents immediately achievable yield gains through technology transfer. The wide extension gap strongly indicates inadequate farmer knowledge and limited exposure to improved production technologies for the new variety. This finding corroborates earlier work by Kumar and Hiremath (2015), who documented similar extension gaps in technology dissemination programs and emphasized the critical role of strengthened extension services in bridging this divide.

Technology Index

The technology index measures the feasibility of technology transfer by expressing the technology gap as a percentage of potential yield, averaging 23.5% across demonstration sites. Location-specific values ranged from 20.5% at Boneya Mole (Wayu Tuka) to 28.4% at Goba Washamo (Ilu Galan). The technology index serves as a practical indicator of technology adaptability: lower values signify greater feasibility of adoption under farmers' conditions [20]. The relatively low index at Boneya Mole (20.5%) suggests that the Ilu variety and its associated management package are highly adaptable to local conditions. In comparison, the higher index at Goba Washamo (28.4%) indicates greater challenges to technology transfer that may require location-specific adaptation or additional support. Table 5: The technology gap between varieties.

Table 5: Yield gap of large-scale demonstration

Kebeles	Woredas	Area (ha)	Potential yield (t ha ⁻¹)	LSD yield (t ha ⁻¹)	Farmers' practice (t ha ⁻¹)	% increase over farmers practice	Yield gap among production		
							Technology (t ha ⁻¹)	Extension (t ha ⁻¹)	Technology Index (%)
Boneya mole	Wayu Tuka	10	11	8.74	4.67	87.2	2.26	3.98	20.5
Oda Gibe	Bako Tibe	10	11	8.69	4.64	87.4	2.31	4.7	20.9
Omo Gurude	Goma	10	11	8.37	4.62	81.3	2.63	3.69	23.9
Goba Washamo	Ilu Gala	10	11	7.87	4.64	69.6	3.13	3.24	28.4
Mean				8.42	4.64	81.4	2.58	3.79	23.5

Implications for Extension Programming

The substantial gaps between demonstration yields and farmers' practice yields, reflected in both the extension gap and technology index, have important implications for agricultural extension strategy. These gaps cannot be attributed solely to technological factors; rather, they signal the need to fundamentally reorient extension methodologies (Chaudhary et al., 2012). The persistence of wide gaps suggests that conventional extension approaches, often characterized by limited farmer engagement, inadequate follow-up, and weak linkages between research and farming communities, cannot catalyze widespread technology adoption. Closing these gaps requires more intensive, participatory extension approaches that address not only technical knowledge but also input access, risk perception, and institutional constraints that shape farmer decision-making.

Farmer Perceptions of Ilu Variety Performance

During field day evaluations, participating farmers provided detailed observations on the agronomic and utilization attributes of the Ilu variety. Their collective assessment highlighted several distinctive characteristics:

Germination and Early Establishment

Farmers consistently noted the variety's excellent germination capacity and robust performance across diverse micro-environments within the demonstration sites. The vigorous early vegetative growth, characterized by dark green leaf coloration, was particularly appreciated as an indicator of plant health and potential productivity.

Stand Characteristics and Crop Architecture

The variety exhibited an outstanding physical stand with remarkable uniformity throughout the growing period. Farmers observed consistent plant height, synchronized flowering, and uniform cob formation, which facilitate field management and harvesting operations. The excellent husk cover, completely enclosing the cob tips, was identified as a valuable trait for protecting grain from pest damage and weather-related deterioration.

Cob and Grain Attributes

The Ilu variety produced full-length cobs with complete tip coverage, providing effective protection against field pests, birds, and moisture damage. Farmers particularly valued the sensory qualities of green maize, describing it as sweet and palatable, an important attribute for household consumption and local marketing.

Multi-Purpose Utility

Beyond grain production, farmers recognized the variety's additional livelihood benefits. The tillers and suckers were noted as valuable supplementary feed for livestock, while the robust stalks provided quality firewood, addressing multiple household needs from a single crop.

Farmers' Perspectives on the Cluster-Based Demonstration Approach

Participating farmers offered valuable reflections on the cluster-based demonstration approach, revealing important insights for scaling agricultural technologies. Their collective experience highlighted several distinct benefits of the cluster approach that extend beyond individual plot-level advantages (Degefu et al., 2025).

Collective Resource Mobilization

Clustering enabled farmers to pool resources for tractor hiring, significantly reducing individual costs and facilitating timely land preparation. This collective action mechanism proved particularly valuable for smallholders with limited individual access to mechanization. As documented in northern Ghana, collective business models for agricultural mechanization succeed when characterized by high cooperation, good relationships among members, and shared financial contributions (Ansah et al., 2024). Ethiopian farmers' experiences with the Ilu demonstration mirror these findings, confirming that group cohesion and mutual support underpin successful collective action.

Peer Learning and Social Dynamics

The spatial concentration of demonstration plots created healthy competition among participating farmers, motivating improved management practices and fostering knowledge exchange. Farmers observed Ilu maize performance and learned from neighbors' practices, accelerating technology diffusion within communities. This observation aligns with rigorous evidence from Tanzania demonstrating that peer-to-peer learning through farmer discussion groups significantly increases adoption of complex agricultural practices. Farmers participating in group discussions were 18 percentage points more likely to adopt intercropping and 15 percentage points more likely to produce organic fertilizer than those receiving information through one-way communication (Lasdun et al., 2025). The social dynamics observed in the Ilu demonstration confirm that interactive peer learning is more powerful than passive information delivery.

Enhanced Input Access

The cluster approach facilitated collective applications for credit and input procurement, overcoming individual constraints related to collateral requirements and transaction costs. This collective bargaining power improved farmers' access to quality inputs at favorable terms. Recent research from Ethiopia confirms that cluster farming participants achieve significantly higher technical efficiency scores (0.14 mean difference) and better food security outcomes compared to non-participants, largely due to improved resource access and information exchange (Degefu et al., 2025). Similarly, evidence from Northwestern Ethiopia demonstrates that cluster farming participants earned an average of 1,106 USD annually from crop sales compared to 731 USD for non-participants, with participant households commercializing 50% of their production versus 36% for non-participants (Gidelew et al., 2025). These findings underscore the economic significance of collective action mechanisms.

Stakeholder Validation and Institutional Perspectives

District agricultural experts validated farmers' observations and confirmed the Ilu variety's superior yield potential and the effectiveness of the improved management package. They observed that farmers who followed the recommended agronomic practices, including optimal planting dates, appropriate fertilizer application, and timely crop management, achieved substantial productivity gains compared with conventional practices. The experts emphasized that adherence to recommended agronomic calendars and management protocols was instrumental in optimizing crop performance across the demonstration sites. They also recommended sustained collaboration between district agricultural offices and research institutions, particularly the Bako National Maize Research Center (BNMRC), to continue promoting the variety, provide technical backstopping, address emerging production challenges, and strengthen technology dissemination. They further recommended integrating the cluster-based demonstration approach into regular extension programming to accelerate technology diffusion and achieve wider adoption. These observations align with evidence that effective extension systems require strong research–extension–farmer linkages and embedded advisory services (Waiswa et al., 2026; Degefu et al., 2025).

Participatory Evaluation and Field Days

Farmers and Experts Evaluation

The participatory evaluation unequivocally confirmed the Ilu variety's outstanding performance across multiple criteria: visual appeal, stand establishment, uniformity, pest tolerance, and overall productivity. The successful implementation of large-scale demonstrations across all districts demonstrates the feasibility of cluster-based approaches for technology dissemination. Farmers' enthusiastic reception and detailed observations provide strong evidence of the variety's suitability for smallholder farming systems and its potential for widespread adoption. Integrating quantitative yield data with qualitative farmer feedback provides a comprehensive evidence base for scaling decisions and extension programming. Chaudhary et al. (2012) emphasize that participatory validation is essential to ensure promoted technologies align with farmers' preferences and local conditions, thereby increasing adoption likelihood and development impact. Farmers have extensive knowledge; however, they lack control treatments for comparison or the statistical tools to test their hypotheses. Their perceptions of the demonstrated variety were based on criteria they defined themselves. Farmers have extensive farming experience and indigenous knowledge for evaluating new varieties. Based on their observations of the cultivated hybrid, the farmers and experts provided their respective insights. Table 6 below summarizes these perspectives from all locations.

Table 6: *Farmers' perceptions across locations*

S/N	Attributes	Scale ((%)					Mean	SD	Rank
		Very Poor	Poor	Fair	Good	Very good			
1	Uniformity in germination	12.3	19.8	22.2	23.5	22.2	3.09	1.325	8
2	Number of kernels per cob	12.3	27.2	18.5	23.5	18.5	3.19	1.276	4
3	High yielder	11.1	21	21	22.2	24.7	3.28	1.344	1
4	Tip coverage of the cob	9.9	21	23.5	21	21	3.19	1.295	5
5	Tolerance to fall armyworms	12.3	23.5	24.7	21	18.5	3.10	1.300	7
6	Resistance to lodging	16	18.5	19.8	23.5	22.2	3.17	1.395	6
7	Having double cob	9.9	25.9	17.3	29.6	17.3	3.23	1.335	3
8	Hugeness of steam/stalk	17.3	30.9	25.9	16	9.9	2.70	1.219	10
9	Plant height	24.7	17.3	22.2	19.8	16	2.85	1.415	9
10	Day to maturity	13.6	17.3	22.2	23.5	23.5	3.26	1.358	2

N = (67 males, 30 females). Rating scale (1-5), where Very poor=1, Poor=2, Fair=3, Good=4 and very good=5

Field Days

Field days were also conducted in all woredas where the demonstrations were undertaken. Farmers, experts, and stakeholders from collaborating institutions were invited to the large-scale demonstration to evaluate the intervention's overall successes and challenges.

A total of 97 participants attended the field days, including farmers (67 male and 14 female), researchers (2), agricultural experts (5), development agents (3), and representatives of other partners (6).

Policy Implications and Required Interventions

The concerns raised by seed enterprises indicate a critical bottleneck in the seed value chain: the gap between varietal development and the seed production needed to scale up for widespread farmer access. To fully harness the potential of the Ilu variety and similar single-cross hybrids, a comprehensive, deliberate policy framework is needed to bolster seed multiplication capacity. This requires moving beyond ad hoc solutions to a systemic strategy that integrates multiple, reinforcing interventions. Such a strategy should include establishing strategic seed reserves to buffer against supply shocks and meet peak demand, complemented by contract grower schemes that formally link enterprises with specialized multipliers to expand production areas.

Furthermore, mitigating the inherent risks of specialized seed production through targeted credit and insurance mechanisms is essential to encourage grower participation, while public-private partnerships can effectively link research capabilities with commercial distribution networks to accelerate scaling. Translating proven productivity gains into widespread agricultural transformation requires cohesive government action that spans from high-level federal policy to grassroots implementation support. Without an integrated approach, the benefits of this initiative risk remaining confined to a limited group of beneficiary farmers and failing to achieve the intended large-scale impact. The core challenge lies not in demonstrating the technology's effectiveness, but in creating a functional input supply system that makes it reliably accessible. Chaudhary et al. (2012) strongly support this view, arguing that successful technology transfer depends on both effective demonstration and robust input supply chains that enable farmers to procure recommended technologies when and where they are needed.

Realizing the full impact of the Ilu variety requires deliberate policy interventions including strategic seed multiplication services, contract grower schemes, credit and insurance mechanisms for seed multipliers, and continued public-private collaboration. Without such interventions, the promising productivity gains demonstrated through this initiative risk remaining confined to a small group of beneficiary farmers rather than achieving widespread impact. As adoption studies consistently show, technology transfer success depends not only on demonstration effectiveness but also on functional input supply systems that enable farmers to access recommended technologies when and where needed (Lasdun et al., 2025; Waiswa et al., 2026).

Conclusion

The present study found that cultivating a newly released Ilu hybrid maize variety with improved technologies is more productive, with grain yield increasing by an average of up to 81.36% over farmers' practices. The findings also showed gaps among the technology, extension, and technology index. The mean results were 2.58 t.h-1, 3.79 t.h-1, and 23.47% for the technology gap, extension gap, and technology index, respectively. The findings show that appropriate use of production technologies through large-scale demonstration reduced the technological gap to a considerable extent, increasing productivity. The results showed wide technological and extension gaps between research recommendations and traditional farmer practices. These results apply to maize demonstration and production packages in general. In

addition, farmers showed greater interest and are committed to cultivating the variety. The larger extension gap indicated a strong need to motivate farmers to adopt improved technologies over local practices. In addition, there is a strong need to increase farmers' awareness and train them through various extension strategies to adopt improved technologies over their local practices. There is also a need to reverse this wide extension gap among farmers through various means to promote the adoption of improved agricultural production technologies. The study also recommended that extension agents should be involved in providing advisory services for farm households and that the application of agricultural technologies in farmers' fields should give priority to organizing cluster-based demonstrations on large-scale approaches for harnessing the productivity of maize hybrids and ensuring the rapid spread of flagship technologies developed by the Agricultural Research System.

References

- Abate, T., Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., et al. (2015). Factors that transformed maize productivity in Ethiopia. *Food Security*, 7, 965–981.
- Ansah, I. G. K., Kotu, B. H., Boyubie, B. E., & Bonney, J. E. (2024). Enhancing smallholder maize shelling mechanization through the collective business model: The case of Northern Ghana. *Frontiers in Sustainable Food Systems*, 7, Article 1228382.
- Asfaw, D. M., Asnakew, Y. W., Sendkie, F. B., Abdulkadr, A. A., Mekonnen, B. A., Tiruneh, H. D., et al. (2024). Analysis of constraints and opportunities in maize production and marketing in Ethiopia. *Heliyon*, 10, Article e39606.
- Bedasa, Y., Gemechu, A., & Bedemo, A. (2025). Integration of resources, management, and technology: Closing the maize yield gap for food security in Ethiopia. *Cogent Food & Agriculture*, 11, Article 2569983.
- Bizikova, L., Jungcurt, S., McDougal, K., & Tyler, S. (2020). How can agricultural interventions enhance contribution to food security and SDG 2.1? *Global Food Security*, 26, Article 100450.
- Chaudhary, D., Kumar, A., Langyan, S., Mandhania, S., Srivasta, P., & Kumar, R. S. (2012). *Maize as fodder? An alternative approach*.
- Degefu, S., Habtamu, M., Andualem, H., Sileshi, M., Ogeto, M. A., & Bacsı, Z. (2025). Impact of cluster farming on technical efficiency and food security among smallholder wheat producers in Southeastern Ethiopia. *Discover Food*, 5, Article 129.
- Endalew, B., Elias, A., & Yasunobu, K. (2024). Impact of cluster farming on smallholder farmers' teff commercialization in Ethiopia. *CABI Agriculture and Bioscience*, 5, Article 18.
- Engida, B., Mekonnen, G., Garoma, B., Yadesa, L., Guben, B., Chalchisa, D., et al. (2024). Registering a new provitamin A-rich maize variety named 'BHA5211' for cultivation in Ethiopia. *18*, 89–96.

- Gidelew, G. E., Alemu, B. A., & Kassie, K. E. (2025). The crop commercialization impact of cluster farming initiative in Northwestern Ethiopia. *Frontiers in Sustainable Food Systems*, 9.
- Grote, U., Fasse, A., Nguyen, T. T., & Erenstein, O. (2021). Food security and the dynamics of wheat and maize value chains in Africa and Asia. *Frontiers in Sustainable Food Systems*, 4, Article 617009.
- Hussen, C. H., & Geleta, F. T. (2021). Factors affecting smallholder farmers' participations in cluster crop production: Evidence from selected districts of West Shewa Zone, Oromia National Regional State, Ethiopia. *Sarhad Journal of Agriculture*, 37.
- Kumar, R., & Hiremath, S. (2015). Residual effects of maize hybrids, plant population and fertility levels on performance of chickpea in maize–chickpea cropping sequence. *Karnataka Journal of Agricultural Sciences*, 28, 482–485.
- Lasdun, V., Harou, A. P., Magomba, C., & Guereña, D. (2025). Peer learning and technology adoption in a digital farmer-to-farmer network. *Journal of Development Economics*, 176, Article 103496.
- Louhichi, K., Temursho, U., Liesbeth, C., & Gomez y Paloma, S. (2019). *Upscaling the productivity performance of the Agricultural Commercialization Cluster Initiative in Ethiopia*.
- Muddassir, M., Jalip, M. W., Noor, M. A., Zia, M. A., Aldosri, F. O., Zuhaibe, A.-u.-H., et al. (2016). Farmers' perception of factors hampering maize yield in rain-fed region of Pind Dadan Khan, Pakistan. *Journal of Agricultural Extension*, 20, 1–15.
- Poole, N., Donovan, J., & Erenstein, O. (2021). Viewpoint: Agri-nutrition research: Revisiting the contribution of maize and wheat to human nutrition and health. *Food Policy*, 100, Article 101976.
- Shirko, A., Gechere, G., Asale, A., Mekonnen, A., Recha, J., Betemariam, E., et al. (2023). Determinants of maize farmers' market participation in Southern Ethiopia: Emphasis on demographic, socioeconomic and institutional factors. *Cogent Food & Agriculture*, 9.
- Van Dijk, M., Morley, T., van Loon, M., Reidsma, P., Tesfaye, K., & van Ittersum, M. K. (2020). Reducing the maize yield gap in Ethiopia: Decomposition and policy simulation. *Agricultural Systems*, 183, Article 102828.
- Waiswa, D., Muriithi, B. W., Murage, A. W., Ireri, D. M., Maina, F., & Yavuz, F. (2026). Adoption and dis-adoption of push–pull technology in East Africa: Evidence from survival analysis and machine learning. *Crop Protection*, 202, Article 107500.
- Worku, A., Agegn, B., Bitew, Y., Chakelie, G., & Mekonnen, M. (2020). Response of maize (*Zea mays* L.) to nitrogen and planting density in Jabitahinan district, Western Amhara region. *Cogent Food & Agriculture*, 6, Article 1770405.

- Yadav, O. P., Prasanna, B. M., Yadava, P., Jat, S. L., Kumar, D., Dhillon, B. S., et al. (2016). Doubling maize (*Zea mays*) production of India by 2025—Challenges and opportunities. *Indian Journal of Agricultural Sciences*, 86, 427–434.
- Zerssa, G., Feyssa, D., Kim, D.-G., & Eichler-Löbermann, B. (2021). Challenges of smallholder farming in Ethiopia and opportunities by adopting climate-smart agriculture. *Agriculture*, 11(3), Article 192.