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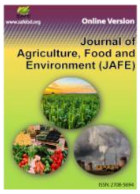

Research Article

Profitability analysis of bread wheat technology demonstration on lime-treated soils using a cluster approach in selected areas of the east Gojjam zone, northwestern Ethiopia

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A B S T R A C T

Access to improved varieties and soil acidity problems are the growing and significant hindering factors for the production and productivity of wheat in Ethiopia. The activity was conducted to enhance farmers' awareness, knowledge and skills on wheat production under lime treated soils and improve the household's income and accessibility for improved technologies in the study areas. Aneded, Awabel, Basoliben, Debre Elias and Gozamin districts were selected purposively based on wheat production potential and the prevalence of soil acidity. Both quantitative and qualitative data were collected using appropriate data collection tools. A total of 712 smallholder farmers participated and 10 wheat clusters were formed. The data were collected from the cluster farming participants the smallholder farmers. Simple descriptive and inferential analysis methods were deployed. The study revealed that producing wheat under lime treated soils through a cluster approach has a significant yield advantage over the traditional production system. Additionally, the profitability analysis results revealed that the marginal rate of return and marginal net benefit from wheat production under lime treated soils were significantly high over three consecutive years. Therefore, the demonstration of improved wheat variety under lime treated soils using cluster approach should be encouraged and scaled up to reach more smallholder farmers in unaddressed areas with similar climatic condition across the country to boost production and productivity, increase household income and reduce food insecurity among smallholder farmers.

INTRODUCTION

Wheat is one of the most important staple food crops in the world with a production of 770.88 million tons in 220.76 million hectares. Africa produces more than 29 million tons in 9.64 million hectares of land. Similarly, Sub-Saharan Africa (SSA) countries produce more than 10 million tons from approximately 30.00 million hectares of land. Ethiopia is one of the most wheat producer of the SSA countries followed by South Africa, Sudan, Kenya, Tanzania, Nigeria, Zimbabwe and Zambia in descending order (FAOSTAT, 2022). This shows Ethiopia is the largest producer of wheat in area production (1.95 million hectares) followed by South Africa (0.52 million hectares) (FAOSTAT, 2022, CSS, 2022).

The majority of the Ethiopian farm households depend on wheat for home consumption and marketing purposes. In addition to its grain, wheat straw serves as an important feed for livestock (CSS, 2022) and is also used for thatching roofs and bedding. Despite the crop's tremendous importance, its production faces immense constraints related to yield potential and industrial quality. The average yield of wheat in Ethiopia is very low compared with wheat growing countries in the world. The average wheat productivity of Ethiopia (3.13 tons per hectare) has been far from the world average productivity (3.69 tons per hectare) by 17.89 percent (FAOSTAT, 2022; CSS, 2022).

Wheat is the third widely grown crop in Ethiopia, following tef (*Eragrostis tef*) and maize (*Zea mays*) in terms of production volume and area coverage. Accordingly, Arsi, Bale, Shewa, Illubabor, West Harereghe, Sidamo, Tigray, North Gondar and Gojjam are found the major producers in Ethiopia (CSS, 2022; Holden *et al.*, 2004). It contributed nearly 20 percent of grain production among the total cereal output (CSA, 2021; CSS, 2022). Moreover, Ethiopia has shown relative improvements in area coverage and production of wheat capture the policy makers' and governments' insights. The growth of the cultivated land coverage and productivity of wheat has been promising of what it could have been with more focused on extension efforts.

However, wheat productivity is suffering from the abiotic and biotic factors that lead to low productivity. The soil acidity (Gurmessa, 2021; Elias *et al.*, 2017; Carmies Filho *et al.*, 2017), limited access to improved seed, the prevalence of pests and diseases, poor post-harvest handling, low soil fertility, rainfall variability and so on are the major factors for low productivity of crops, especially wheat. Among these, soil acidity is the major hindering factor of production and productivity of wheat and the important nutrients in the soils are not readably available for plant germination and field performances (Palansooriya *et al.*, 2020; Gruhn *et al.*, 2000). In the long run, the frequent application of inorganic fertilizers (ammonia and sulfur), monoculture practices, high rainfall patterns and removal of crop residues are significant causes of soil acidity (Gurmessa, 2021). Therefore, soil acidity problems need to be solved by using different amelioration mechanisms. Among soil acidity management practices, liming is one of the primary interventions to rehabilitate acid soils (Golla, 2019; Elias *et al.*, 2017; Carmies Filho *et al.*, 2017). To address these issues, the wheat improvement program was started a long time ago and various improved varieties have been developed and released with the merits of high grain yield and disease resistance compared with the farmers' cultivars. Additionally, many management practices have been developed and provide agricultural agronomic recommendations to enhance the production and productivity of wheat.

Cognizant of this fact, there was a practice of intensifying efforts to demonstrate promising agricultural technologies to many farmers in sustainable ways (Pretty *et al.*, 2011). Among the practices, the cluster-based demonstrations of improved technologies help the farmers to have a chance to enhance their productivity and be involved in market participation to meet their household needs (Joffre and Klerkx, 2019; Altieri *et al.*, 2012).

To address the aforementioned issues, it is essential to improve access to high yielding varieties, as well as to enhance the availability of quality seeds. Demonstrating wheat varieties under lime treated soils through cluster farming approach is a core initiative of this activity. Therefore, this research activity aims to raise awareness about acid soil management using limestone; enhance the knowledge and technical skills of smallholder farmers and improve production and productivity of wheat technologies within the study areas.

MATERIALS AND METHODS

Description of the study areas

East Gojjam zone is one of the administrative zones of Amhara's national regional state which is located in Northwestern part of Ethiopia. Geographically, it is located between 11° 13′ 54.246″ N 9° 50′ 19″ to latitudes and 37° 51′ 0.665″ to 37° 42′ 3.87″ E longitudes (Simegnew *et al.*, 2022). The zone is bordered to the north by the North Gojjam and South Gondar zones, to the south by the Oromia region, to the East by the South Wello zone and to the west by the West Gojjam zone. It is organized with 18 districts and four urban administrations. Its total area is estimated to be 1,460 km^2 which is equivalent to 1.46 million hectares. The zone covers different topographic features with altitudes ranging from 800-4200 metre above sea level (masl). Based on these topographic diffrences, the zone traditionally comprises four main agroclimatic zones: warm semiarid (*kolla*) (5.45%), cold subhumid (*woyina dega*) (80.55%), cool and humid (*dega*) (11.90%) and cold and moist (*wurch*) (2.1%). The average annual rainfall is primarily unimodal varying from 900 to 1,800 mm, while the annual average temprature ranges from 7.5°C to 27°C. Accordingly, the major soil types in order of importance include vertisols, red and gray soils. The farming system in the zone is characterized by a mixed farming approach, integrating both crop and livestock. Land use and cover patterns vary, with approximately 45% of the total land clasified as arable and an additional 8% designated as irrigable, suitable for irrigated farmig. The remaining 47% of the land is allottaed for forests, grazing areas, barren land and water bodies (Setotaw *et al.*, 2020).

The zone has significant potential for crop prodcution, with a marketable surplus for local and national urban markets. Consequently, crereals, pulses, oil seeds, vegetables and fruis are the most important crops grown in the area. Among the cereals, wheat ranks as the third most important crop interms of production and area coverage, following tef, and maize (CSS, 2022).

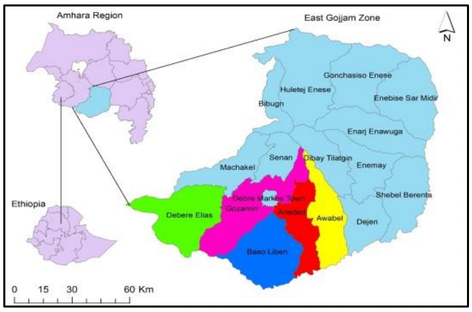

Figure 1. Map of study areas

Site and farmers selection

The activity was conducted in five districts of the East Gojjam zone that are recognized as potential wheat producers with suitable agroecological conditions for wheat production. These districts—Aneded, Awabel, Gozamin, Basoliben and Debre Elias (Fig. 1)—were selected in close collaboration with zone agriculture experts, based on criteria such as production potential, the existence of acid soil problems, accessibility of all-weather roads and farmers' willingness to participate in the cluster-based demonstration of wheat variety under lime treated soils. Additionally, the site and participant farmers were selected through collaboration and consultation with respective district experts and *kebele* [1]development agents, respectively. Accordingly, a total of ten clusters were formed in the selected districts.

Materials and implementation modality

Improved wheat variety (variety name *kakaba*) with lime (a chemical used to treat soil acidity) were used as input for cluster-based demonstration. Both seed and lime were supplied and transported by the Debre Markos Agricultural Research Center to the smallholder farmers hosting the demonstrations. Subsequently, the demonstration clusters and beneficiary farmers were identified and then the improved wheat seed and the lime were disseminated to the respective cluster sites. Furthermore, the research center offers smallholder farmers the opportunity to utilize the supplied seed at no cost, facilitating access to improved varieties on a revolving basis.

However, the supply of fertilizers and various types of pesticides—herbicides, fungicides and insecticides—was facilitated by the respective district offices of agriculture. The host farmers purchased the required fertilizer and pesticides and used them based on the respective area recommendations. The seed and fertilizer rates were applied based on the respective district's wheat production package recommendations. The lime was applied one month prior to planting, following the recommendations of the Ethiopian Institute of Agricultural Research, at a full dose averaging 2.0 tons per hectare.

Furthermore, at the beginning of the site and farmers selection process, a multidisciplinary team comprising researchers, experts and stakeholders was established. This team was responsible for providing training, evaluating and monitoring the field performance and farmers participation, as well as organizing learning and experience sharing events.

The training was conducted for largescale demonstration host farmers, experts, development agents and other stakeholders on the implementation modalities of cluster farming, crop production, acid soil management, crop protection, and post-harvest handling by a multidisciplinary team of the researchers. At various stages of crop growth, farmers' field days and exchange visits were organized in collaboration with stakeholders at kebele, districts, zonal, regional and national levels to raise awareness about the wheat production technologies. The demonstration of wheat cultivation under lime-treated soils provided an opportunity for experience sharing among host and invited farmers, development agents, experts (Siyum *et al.*, 2022). Participants in the field day events included hosts and non-host farmers, youth groups, experts, higher officials and others. Farmers' perceptions and experts' feedback regarding the technologies were collected using checklists.

Method of data collection

Both quantitative and qualitative data were used for the analysis. The quantitative data included yield measurements, the number of participants (farmers, experts, DAs and other stakeholders) in the learning platforms (such as training sessions, field days and exchange visits), the quantities of seed and lime distributed, the number of host farmers, area coverage of the clusters, the amounts of fertilizer and pesticides used and the economic returns from the demonstration. These data were collected through semi-structured interview schedules. Qualitative data regarding farmers' perceptions and the feedback from experts and stakeholders were gathered through focus group discussions (FGDs), key informant interviews (KIIs) and field observations.

Method of data analysis

The quantitative data were analyzed using simple descriptive statistics and inferential statistics specifically t-tests and ANOVA, with SPSS Version 22.0. The yield advantage of the improved varieties over the existing farmers' practices was computed using the following formula.

$$\text{Yield advantage (\%)} = \frac{\textit{yield of wheat with lime} - \textit{yield of wheat with out lime}}{\textit{yield of wheat with out lime}} \text{ X } 100 \ldots (1)$$

To evaluate the adequacy of transferring wheat production with lime and the provision of extension services in the study areas, the technological gap, extension gap and technology index were consistently computed. The technological gap, extension gap and technology index were calculated using the following formulas, as suggested by Yadava *et al.* (2004) and Samui *et al.* (2000).

Technology gap = Potential yield – demonstration yield ………….………………………....…..…… (2)

Extension gap = Demonstration yield – Yield under existing practice …………….……......…….... (3)

$$\text{Technology index} = \frac{\text{potential yield} - \text{demonstration yield}}{\text{potential yield}} \text{ x } 100 \ldots\ldots (4)$$

The qualitative data were also analyzed through thematic analysis and narrative methods. The economic return and profitability of the cluster-based large-scale demonstration of improved wheat varieties were analyzed using partial budget and breakeven analysis methods. The data was presented in frequency, percentage, mean and standard deviation values as well as t-test and f- test values. Finally, the analyzed data through simple descriptive statistics and inferential statistics were visualized and presented in tables, figures, and graphs.

RESULTS AND DISCUSSION

Participant farmers, input utilization and area coverage

The activity was conducted over three consecutive years in five selected districts of the East Gojjam zone. During this period, the cluster farming production demonstration involved the formation of 10 clusters, covering a total of 495.55 hectares and engaging 712 smallholder farming households (670 male and 42 female household heads). Essential agricultural inputs including fertilizer, lime and seed were provided based on are-recommendations. Over the three years, the center distributed approximately 68.88 tons of seed and 640.80 tons of agricultural lime to address soil acidity problems of the study areas (Table 1).

[1] Kebele is the smallest administrative units in Ethiopia.

Table 1. Area coverage, input utilization and demonstration host farmers

Years of production	No. of cluster	Area (Ha)	Agricultural inputs (tons)				Number of participant farmers		
			Seed	Lime	Fertilizer				
					NPSB	Urea	Male	Female	Total
2020/21	4	170.00	25.58	344.00	36.00	40.33	289	22	311
2021/22	4	189.25	28.45	174.00	31.11	25.69	238	10	248
2022/23	2	136.30	14.85	122.80	19.64	16.42	143	10	153
Total	10	495.55	68.88	640.80	86.74	82.26	670	42	712

Source: own computation from the survey data (2021-2023)

Capacity building through training and field day

Training was provided to participant farmers, development agents, zone and district experts and other stakeholders after the formation of the clusters. Figure 2 shows that in the implementation years, theoretical and practical training was given for 258 participants. The training was focused on the concept of cluster farming, the implantation modality of the clusters, the role and responsibility of active participates, wheat varieties, crop protection, field management practices, lime application methods, post-harvest handling mechanisms and the importance of data. This implies that the success story of the large-scale demonstration began with the initial efforts of raising awareness and forming clusters.

Field day learning platforms were organized at national, regional, zonal, district and kebele levels, with invitations extended guests ranging from federal to district-level officials, community leaders, religious and cluster leaders. These events aimed to raise broader awareness of bread wheat production and farm management practices. As a result, participants included both host and non-host farmers, development agents, experts, and other stakeholders. During these events, the field performance of the technologies was evaluated, and farmers' perceptions as well as experts` feedback were collected for further analysis.

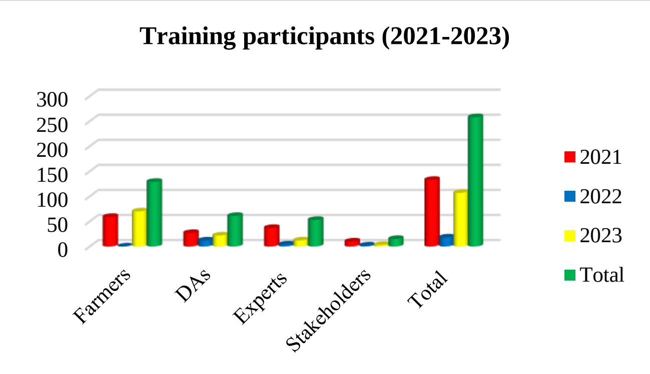

Figure 2. Training participants within three years

Thus, Table 2 shows that a total of 4,571 farmers participated in organized field day learning platforms. Not surprisingly, 87.57% of the participants are smallholder farmers, as they are primary clients of the agricultural research center. This indicates that the field day events successfully raised awareness among more than four thousand smallholder farmers and improving their knowledge and skills in wheat production through the application of limestone to amend soil acidity. As noted, soil acidity is a significant challenge and one of the primary factors hindering cereal crop production in the study areas (Setotaw *et al.*, 2020; Getachew *et al.*, 2019). Prior to these efforts, farmers in the region struggle to produce wheat sufficiently and effectively due to soil acidity problems.

Table 2. Field day participants (2021-2023)

Field day participants	Production year						Total	
	2020/21		2021/22		2022/23			
	Male	Female	Male	Female	Male	Female	Male	Female
Farmers	1256	171	1427	148	884	117	3567	436
DAs	42	16	58	25	38	18	138	59
Experts	80	9	89	13	61	17	230	39
Stakeholders	25	2	27	14	27	7	79	23
Sub total	1403	198	1601	200	1010	159	4014	557
Grand total	1601		1801		1169		4571	

Source: own computation (2021-2023)

The smallholder farmers participating in the clusters mentioned that before the intervention, they mainly produced lupin, a crop resistant to soil acidity. However, lupin had low productivity and limited market demand, making it an unattractive option for farmers in the study areas. This finding aligns with previous studies by Asmamaw *et al.* (2020) and Abate *et al.* (2017), which showed that significant areas of barley fields in the region had been replaced by oat and white lupin due to similar constraints. Additionally, the focus group discussion participants stated that an integrated demonstration of wheat variety with lime treatment using cluster farming has had several benefits. It has led to increased wheat production and productivity, improved household income, mitigated the impact of soil acidity, and enhanced farmers` awareness, knowledge and skills. Furthermore, the approach has facilitated better access to agricultural extension services and reduced the reliance on inorganic fertilizers. Therefore, cluster-based large-scale demonstrations of improved agricultural technologies combined with appropriate management practices have proven to be highly beneficial in addressing these challenges and promoting sustainable farming.

Yield performance of wheat

The yield data were collected from the participants of the large-scale demonstration of wheat under lime treated soils across the study areas. The minimum and maximum yield was recorded in 2023 which is 1.12 and 6.90 tons ha^{-1} (Table 3), respectively. This showed that there is a huge yield achievement difference between participant farmers across the cropping years. There is a mean yield difference between farmers expected during the implementation of largescale demonstration through cluster approaches (Anduamlak *et al.*, 2022). As a result, this difference could be attributed to variations in land preparation, weed management, crop protection and crop harvesting practices among the participant farmers. Differences in the adoption and execution of these critical agricultural practices likely influenced the overall productivity with better-managed fields demonstrating higher yields. This study showed that the three-year combined analysis of the mean productivity of the wheat was 3.89 tons ha^{-1}. Accordingly, the mean productivity of wheat in the clusters was 3.87, 3.77, and 4.13

tons per hectare in the first, second, and third production years, respectively (Table 3). The result clearly showed that the positive effect of a large-scale demonstration of wheat under lime treated soils over the existing farmers practices' (growing wheat without lime) in enhancing wheat yield in the study areas. The average productivity of the wheat grown under lime-treated soils through cluster farming approach showed yield stability and consistency across the years, indicating that this intervention can reliably improve wheat production. This suggests that lime application significantly addresses soil acidity problems, leading to better plant performance and overall productivity in the long term.

Table 3. Wheat productivity, technology and extension gaps

Production Year	N	Mean	Min.	Max.	St. Dev	Technology gap (kg/ha)	Extension gap (kg/ha)	Technology index (%)
2020/21	311	3.87	1.92	6.00	0.7050	1.13	0.77	22.60
2021/22	248	3.77	2.04	6.00	0.6473	1.23	0.66	24.60
2022/23	153	4.13	1.12	6.90	0.9565	0.87	1.00	27.40
Total	712	3.89	1.12	6.90	0.7587	1.11	0.78	22.20

Source: own computation from the survey data (2021-2023)

Moreover, the result of the study exhibited that the minimum and maximum technology gap were recorded in 2022/23 and 2020/21, which were 0.78 and 1.23 tons ha^{-1}. The technology gap result designates that there was a notable disparity among farmers in terms of application of agricultural inputs, pest and disease control methods and agronomic management practices. Besides, the difference could be attributed to unreliable rainfall distribution and temperature, and the occurrence of pests and diseases in the study areas. The lowest and highest extension gaps were also observed in 2021/22 and 2022/23 in the demonstration of wheat under lime treated soils, respectively. Similarly, the average extension gap under a three-year cluster-based demonstration of wheat with lime was 0.78 tons ha^{-1} (Table 3). This result exhibits the need to create awareness and enhance the knowledge and technical skills of the smallholder farmers in various improved varieties of wheat and management practices to narrow the gaps in the study areas. The overall mean technology index of the wheat variety demonstration was 22.20% over three years (Table 3). The smallest value of the technology index indicates the feasibility of the adoption of large-scale demonstration of wheat variety under lime-treated soils through cluster farming approaches. In other words, the smallest technology index value validates that the adoption of the improved wheat technology by smallholder farmers is enhanced whereas the reverse is true. Generally, the technology index result indicates that a wide gap between technological advances and the adoption rate of cluster-based production of wheat on farmers` farmland.

The ANOVA analysis result showed a statistically significant mean yield difference between the cropping years (F, 11.301, P<0.0001) (Table 4). This observed difference in yield could be attributed to various factors including rainfall distribution, variations in farmers' field management practices, the application of recommended agricultural inputs (such as lime, fertilizer, seed and pesticides), as well as the impact of climate change on the study area over the years. These factors may have contributed to the fluctuations in wheat productivity observed during the large-scale demonstration under lime-treated soils.

Table 4. ANOVA table

ANOVA					
Average yield (ton/ha)					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.645	2	6.323	11.301	0.000
Within Groups	396.675	709	0.559		
Total	409.321	711			

Source: own computation from the survey data (2021-2023)

The combined analysis of the three-year yield data revealed that the smallholder farmers have been achieving yields within the range of 1.12 to 6.90 tons per hectare. This exhibits that the farmers who thoroughly managed their farm fields and applied all recommended agricultural inputs according to the area-specific guidelines achieved the highest grain yields. In contrast, those who did not properly manage their farm fields or failed to apply the necessary inputs obtained lower yields. This result emphasizes the importance of following proper agronomic practices and utilizing recommended inputs to maximize wheat productivity under lime-treated soils. Consistently, the t-test was also conducted to know the mean yield difference between the smallholder farmers within and across cropping years. Thus, the one simple t-test result revealed that there was statistical mean yield difference between farmers within the year and across the year (t=136.97; P<0.0001) (Table 5). For instance, the 2020/21 cropping season results showed that there was a significant mean yield difference between farmers (t=96.906, P<0.0001). This mean yield difference could be caused by the disparity of the smallholder farmers' capability of using extension pieces of advice, applying pests and disease control methods, improved agronomic practices, postharvest handling mechanisms and limited follow-up of the extension agents.

Table 5. *t-test* analysis

Test Value = 0						
Crop year	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
2021	96.906	310	0.000	3.87423	3.7956	3.9529
2022	91.775	247	0.000	3.77249	3.6915	3.8535
2023	53.467	152	0.000	4.13468	3.9819	4.2875
Total	136.970	711	0.000	3.89476	3.8389	3.9506

Source: own computation from the survey data (2021-2023)

Yield comparison

It is understandable, the East Gojjam zone has immense potential for cereal crop production, particularly for wheat. However, despite its suitability for wheat cultivation, several key challenges have been limiting the productivity of the regions` smallholder farmers. Soil acidity, in particular, is a significant constraint that reduces the availability of essential nutrients, thus hindering the growth and yield of wheat. Additionally, limited access to improved agricultural technologies including high-quality seed further exacerbates the problems, preventing farmers from achieving their full production potential. Addressing these issues through interventions such as lime application and access to improved seed varieties is critical for boosting wheat production in the area (Setotaw *et al*., 2020). Therefore, this activity was conducted to demonstrate the production of wheat with an integration of improved variety with acid soil management practice.

The average productivity of farmers' practices in the first, second, and third years of production was 3.10, 3.11 and 3.13 tons per hectare (CSA, 2021; CSS, 2022) while the productivity of demonstration of wheat through cluster is 3.87, 3.77 and 3.43 tons ha^{-1} in three production years, respectively. In the three consecutive years, t*he* demonstration of clusters result showed 24.84%, 21.22%, and 31.95% yield increment from the existing farmers' practices of wheat production, respectively (Fig. 3). This aligns with the findings of Getachew *et al.* (2019) who reported that the application of lime at rates ranging from 2.0 to 2.2 tons per hectare for soil amendments among smallholder farmers resulted in yield improvements between 0.9 and 1.60 tons per hectare. This implies that lime application alone cab boost wheat yields by approximately 40% to 70%. The yield gap between farmers` traditional practices and the intervention demonstrates that using improved wheat varieties on lime-treated soils through the cluster farming approach significantly enhances productivity in the study areas. The yield gap analysis further highlights that the cluster-based large-scale demonstration consistently achieved higher yields compared to smallholder farmers` traditional practices and the national average wheat productivity.

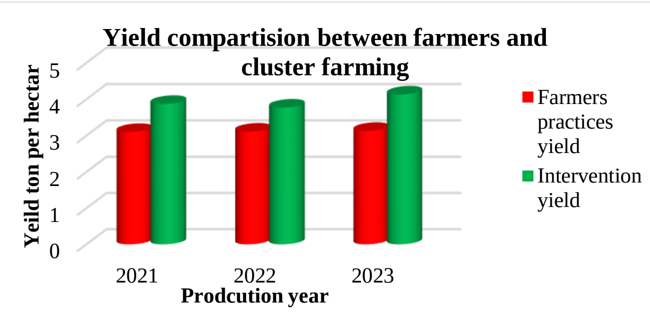

Figure 3. Yield comparison between farmers practices and cluster approach

Profitability and breakeven analysis

The partial budget analysis was used to evaluate the economic advantage of large-scale demonstration over the farmers' practices. At the household level, several factors of production need to be considered to evaluate the profitability of crop production. Among these factors, a unit prices of lime, transportation and application stages, expected yield increases and expected years of enhanced productivity are the major limiting factors of benefits of wheat production (Getachew *et al*., 2019). These factors could be affecting the net benefit as well as the marginal net benefit of wheat production under lime-treated soils. Therefore, the profitability analysis revealed that the smallholder farmers who used lime had a significant yield advantage over those producing wheat without lime. The cost of the planting materials was taking the higher share from the total variable cost of production of wheat in the study areas. This indicates wheat production under smallholder farmers incurred a high cost for purchasing and facilitating agricultural inputs. However, the gross benefit of wheat production using the cluster approach showed an increasing trend over the three years of production. According to Table 6, the cluster farming approach achieved marginal net benefits of 18,937.45 ETB, 19,496.79 ETB, and 42,085.17 ETB per hectare in the first, second, and third years, respectively. Similarly, the highest marginal rate of return (1,120%) was recorded in the 2023 cropping year which compared with the first and second years of large-scale demonstration through a cluster approach. This indicates that wheat production under lime-treated soils through a cluster approach not only had a yield advantage but also achieved better net benefits compared to traditional farmers` practices across the three production years. This study harmonized with a study done by Getachew *et al*, (2019) which revealed that wheat production using lime resulted in estimated gross and net benefits of 7,524.00 ETB and 2,324.00 ETB per hectare, respectively. This implies using lime for soil amendments in wheat production is generally profitable, providing participants with both higher yields and improved prices. Likewise, the study done by Abera *et al*. (2019) results revealed that by producing rice in the Fogera plan, the smallholder farmers earned a total revenue of ETB 33,156.43 by incurring a total of ETB 16,737.65 per hectare for the cost of rice production. Generally, the demonstration of wheat under lime-treated soils through a cluster approach has significant national economic implications. It presents the potential to enhance wheat production on a large-scale contributing to food security, reducing wheat imports, and potentially increasing exports, which could lead to the generation of foreign currency for the country.

Table 6. Partial budget and breakeven analysis

Items	Production Year					
	2020/21		2021/22		2022/23	
	No lime	Lime used	No lime	Lime used	No lime	Lime used
Mean grain yield (ton/ha)	3.10	3.87	3.11	3.77	3.13	4.13
Output price per ton (ETB)	26,976.00	26,976.00	32,730.00	32,730.00	45,843.00	45,843.00
Gross income (ETB)	83,490.72	104,397.12	101,790.30	123,392.10	143,488.59	189,331.59
Average seed cost	1,917.63	1,917.63	3,127.60	3,127.60	3,759.90	3,759.90

Items	Production Year					
	2020/21		2021/22		2022/23	
	No lime	Lime used	No lime	Lime used	No lime	Lime used
Average NPSB fertilizer cost	1,749.04	1,749.04	1,976.44	1,976.44	5,454.72	5,454.72
Average urea fertilizer cost	1,761.51	1,761.51	1,559.00	1,559.00	4,671.05	4,671.05
Average lime cost	-	1,486.68	-	1,594.91	-	1,987.78
Average pesticide cost	519.66	519.66	971.46	971.46	1,116.77	1,116.77
Average lime application cost	-	482.28	-	510.10	-	770.05
Average labor cost for cultural practices	4,642.33	4,642.33	6,795.51	6,795.51	8,544.32	9,544.32
Total operating cost (TVC)	10,590.04	12,558.99	14,430.01	16,535.02	23,755.39	27,513.22
Net income	72,900.68	91,838.13	87,360.29	106,857.08	119,733.20	161,818.37
Marginal cost	1,968.95		2,105.01		3,757.83	
Marginal net income	18,937.45		19,496.79		42,085.17	
MRR (%)	962		926		1,120	
Breakeven analysis						
Breakeven price per ton	3,416.14	3,245.22	4,639.87	4,385.95	7,589.58	6,661.80
Breakeven yield ton per ha	0.39	0.47	0.44	0.51	0.52	0.60
Yield to breakeven yield ratio	789.66%	831.25%	705.41%	746.25%	604.03%	688.15%

Source: own computation from survey data (2021-2023)

In 2020/21: The average net benefit and the marginal net income of growing wheat under lime treated soils were ETB 92,838.13 and 18,937.45, respectively. The first-year profitability analysis revealed that taking into account lime and its application costs, the benefit of lime application for soil acidity treatment on wheat demonstration through cluster approach is nearly 26.00% that of wheat production without lime. The marginal rate of return (MRR) showed that for one unit cost invested for inputs like improved seed, lime, fertilizer, pesticides and agronomic management practices for wheat production the farmers received ETB 9.62.

In 2021/22: The marginal net benefit and net income of growing wheat under lime treated acid soils were ETB 19,496.79 and 106,857.08, respectively. The second-year profitability analysis revealed that the net benefit of application of lime for acid soil treatment by taking into account lime and its application costs is 22.23% with that of wheat production without lime. As a result, the MRR from the large-scale demonstration of wheat under treated acid soils indicated that for every unit of Ethiopian Birr invested in production and cultural practices, smallholder farmers received ETB 9.26 in return. This highlights the economic viability and profitability of using lime to treat soil acidity in wheat production.

Similarly, in 2022/23: The profitability analysis also showed taking into account the cost of acid soil treatment with lime and its application, the net benefit is more than 35.15% that of wheat production without lime. The MRR indicated that a unit of cost investment on inputs and agronomic management practices for wheat production obtained 10.20 units of as benefit (Table 6). Generally, the profitability of wheat production under lime treated acid soil could have high values of net benefits per hectare. This result corroborated with study done by Asmamaw *et al*. (2020) reported that producing wheat under limed condition through cluster approach has high net benefit that accounts 48,106.75 birrs per hectare.

The breakeven analysis was deployed to know the minimum level of grain yield and price that the smallholder farmers will not experience gain or loss. Therefore, the breakeven yield per hectare was found to be 0.47 tons whereas the breakeven price per ton was ETB 3,245.22 per ton in 2020/21 production year. This result shows that the sale of 0.47 tons of wheat covers the production costs (seed, fertilizer, lime, pesticides and labor costs) without any losses. In simpler words, the breakeven analysis of wheat production under lime-treated soils over three years showed that smallholder farmers were able to cover their production costs and make a profit. For example, in the first production year, selling wheat at ETB 3,245 per ton was sufficient to cover the production cost. In the second year, the breakeven price per ton was ETB 4,385.95 per ton, with a breakeven yield of 0.51 tons per hectare. In the third year, a breakeven price of ETB 6,661.80 per ton and a yield of 0.60 tons per hectare covered the production costs (Table 6). This means that in each of the three years, farmers were able to sell their wheat at prices and yields that ensured they did not incur losses. The consistent profitability from participating in wheat production under lime-treated soils using a cluster approach shows that this method has significant economic benefits for smallholder farmers. Overall, the approach proves to be economically advantageous, helping to increase wheat yield and boost income.

Consequently, the overall profitability analysis result of the wheat production under lime treated soils through a cluster farming is a profitable enterprise in the three consecutive production years. This result is in line with a study done by Abera *et al*. (2019). The smallholder farmers producing lowland rice in the Fogera district exercised no gain and loss that has been dropping the yield and unit price by 2.06 tons ha^{-1} and ETB 4,660.00 per ton and they were able to resist the loss.

CONCLUSION AND RECOMMENDATIONS

Access to improved wheat varieties and acid soil problems is a growing and significant problem in Ethiopia in general and in the East Gojjam zone in particular. The result of these findings revealed that the cluster based large-scale demonstration of wheat under lime treated soil has better yield over the farmers' practices along with the three cropping years. Thus, producing improved wheat variety under lime treated soils could increase grain yield by 24.84%, 21.22% and 31.95% compared with that of farmers' practices, respectively over three years. This implies that the mean yield of wheat production in clusters showed that there was a yield stability and consistency across the years. The overall mean technology index was observed 22.20% in cluster-based large-scale demonstration of wheat technology over three-years. This indicates the need to create awareness and improve useability of improved agricultural inputs in an integrated way to enhance the knowledge and technical skills of smallholder farmers and eventually ensure the adoption feasibility of wheat variety under lime treated soil through cluster farming approaches. Therefore, the government must work on and strengthen the distribution of lime and accessibility of improved agricultural technologies in the East Gojjam zone which has a favorable environment for crop production in Ethiopia.

Moreover, the study findings revealed that the gross benefit and net income of wheat production under the cluster approach showed a positive and increasing trend over three consecutive years. The profitability analysis from the 2020/21 to 2022/23 production years indicates that the net benefit of applying lime for acid soil treatment—taking into account lime and application costs—was 25.98%, 22.23% and 35.15% higher compared to producing wheat without lime during the respective years. This implies that growing wheat under lime-treated soils has a clear yield and economic return advantage over wheat production without lime treatment. Consequently, it can be concluded that cultivating wheat under lime-treated soils through the cluster farming approach not only improves the yield and net return for smallholder farmers but also significantly reduces the technology and extension gapsin the region. The positive impact of this intervention shows great promise for enhancing the productivity and profitability of wheat cultivation in areas facing soil acidity challenges. Therefore, it is recommended that the demonstration and scaling-up of improved wheat varieties under lime-treated soils using the cluster approach should be actively encouraged. Expanding this model to reach more smallholder farmers in areas with similar climatic conditions across the country could boost overall production and productivity, increase household income and reduce food insecurity among smallholder farmers. This strategy holds the potential for national-level impact on agricultural sustainability and economic growth.

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