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RESEARCH ARTICLE

Key Determinants Shaping Farmers' Satisfaction with Site-Specific Fertilizer Recommendations (SSFR) in Ethiopia

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ABSTRACT

This study assessed farmers' satisfaction with site-specific fertilizer recommendations (SSFR) and identified key determinants influencing their satisfaction in Ethiopia. Data from 202 households, selected through stratified random sampling, was analyzed using Principal Component Analysis (PCA) and Ordered Probit Model. Results show that 58.4% of farmers were satisfied with the quantity, while 56.9% were satisfied with the timing of fertilizer application in the study areas. Strong satisfaction was reported by 37.6% for recommended fertilizer rates and 39.6% for timing, with minimal (4%) dissatisfaction. Partnerships between the Ministry of Agriculture (MoA), LERSHA, and Digital Green reveals varying satisfaction level had varied satisfaction rates, with MoA leading at 44.6%, compared to LERSHA's 24.8% and Digital Green's 30.7%. The study identified key factors that affect satisfaction, including, education level, farm size, availability and affordability of SSF recommendations, the quality of information on planting time, information on land preparation, use of SMS for SSFR dissemination, recommendation of

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SSFR using cluster approach and livestock size. Higher education levels and larger farms are linked to better SSFR application. Participation in cluster recommendation units fosters collective learning and enhances satisfaction, while access to affordable and timely SSF recommendation improves implementation and crop yields. Short Message Services (SMS) communication has proven effective in engaging farmer and enhancing satisfaction. As Ethiopia continues to work towards agricultural modernization and sustainability, addressing these factors will be vital for promoting the use of site-specific fertilizers (SSF) across Ethiopia's diverse farming landscapes.

Keywords: Factor Analysis; Farmers' Satisfaction; Probit Model; Site-Specific Fertilizer

1. Introduction

Soil fertility plays a crucial role in improving crop production by providing essential nutrients for plant growth [1]. In Ethiopia, farmers grapple with challenges such as soil erosion, nutrient depletion, and low organic matter levels, which significantly impact crop yields [2, 3]. The use of inorganic and organic fertilizers can effectively enhance soil fertility and increase crop output in Ethiopia [4]. Although the use of inorganic fertilizers in Ethiopia is a relatively recent development compared to that in other African countries, it gained traction in the mid-20th century as part of the country's initiatives to improve agricultural productivity [5]. The government of Ethiopia introduced several initiatives to promote the utilization of inorganic fertilizers as a strategy to tackle food security issues and enhance crop yields [6–9]. These strategies included subsidies, extension services and educational program aimed at creating awareness among farmers about the advantages of incorporating inorganic fertilizers into their farming practices [10, 11].

Despite these interventions, the widespread adoption of inorganic fertilizers in Ethiopia has encountered obstacles such as restricted access to inputs in isolated rural areas, financial constraints for small-scale farmers, and apprehensions regarding the long-term impacts on soil health and the environment [12, 13]. Despite these challenges, the adoption of fertilizers in Ethiopia is gradually increasing and contributing to increased agricultural productivity and food security in the country. In Ethiopia, the history of fertilizer recommendation has evolved in response to changing agricultural practices and the need to improve crop productivity [8, 13, 14].

Initially, fertilizer recommendations were constrained by limited awareness, availability, knowledge and technology [15]. This resulted in uniform fertilizer recommendations across a specific area, without considering variations in soil fertility or crop requirements [16]. This approach was common in the past due to limited resources, infrastructure, and technical knowledge. However, blanket fertilizer recommendations are gradually being replaced by more precise and site-specific recommendations tailored to the needs of different crops and communities. This shift is driven by the recognition that soil fertility varies widely across Ethiopia, and applying fertilizers indiscriminately may not be productive, cost-effective or environmentally sustainable. By moving toward more targeted and tailored fertilizer recommendations, Ethiopian farmers can optimize the use of fertilizers, improve crop yields, and minimize adverse environmental impacts. This approach helps ensure that resources are used more efficiently, leading to better agricultural productivity and long-term sustainability in the country. Hence, over the years, the government and various organizations have worked to develop fertilizer recommendations tailored to different crops and regions in Ethiopia [16]. These recommendations take into account weather, soil types, crop nutrient requirements, and local farming practices. An interesting example, in this case, is the work by the Alliance of Bioversity International and CIAT (the Alliance) and its partners which developed a decision support tool for site-specific fertilizer recommendations (SSFR) for wheat growing areas of Ethiopia [16, 17]. The data-driven agroadvisory tool is called NextGen Agroadvisory [18] and integrates crop response to input application, environmental co-variates and climate data in a machine learning algorithm to develop contextualized advisory that also responds to upcoming seasons. Working in partnership with governmental bodies, non-profit developmental organizations and private entities such as the Ministry of Agriculture, Digital Green, and LERSHA, the Alliance piloted SSFR across different wheat-growing districts in Ethiopia [17]. The SSFR included recommendations on the type, timing and quantity of inorganic and organic input applications. Additionally, the SSFR provides agro-climate advisory to guide the optimal time of sowing and specific information on pest management for farmers [17]. After successful validation, the advisory has been piloted across the country since 2022 with Digital Green and other partners. Farmer group discussions, bureau of agriculture experts and socio-economic survey results have shown that the SSFR has out-performed the local farmers' practices as well as the blanket recommendation [19]. The objective of this paper was to assess the satisfaction level of farmers with the SSFR and understand the influencing factors that affect farmers' satisfaction. A survey tool was developed for this study, aiming to measure the satisfaction levels of a specific group regarding a product, service, or experience and to identify key factors influencing their satisfaction [9, 20, 21]. The analysis results can help pinpoint areas for improvement, monitor changes in satisfaction over time, identify key factors affecting farmers' satisfaction, and support strategic decision-making [22, 23].

2. Methodology

2.1. Development of Site-Specific Fertilizer Recommendation (SSFR)

In Ethiopia, the process, as illustrated in Figure 1, consists of five main components: data ecosystem, analysis and modeling, fertilizer advisory generation, dissemination of site-specific fertilizer recommendations (SSFR), and validation and feedback. The process began by collecting and consolidating data, including legacy crop response to fertilizer data, recent farm trial data, and geospatial data (such as soils, topography, climate) corresponding to the sites with available crop response data. During the analysis and modeling phase, a data-driven approach was employed, where a machine learning-based predictive model was developed to generate location-specific fertilizer recommendation (LSFR) rates for wheat in Ethiopia, incorporating crop response data and co-variates [16]. The SSFR was validated on 300 farmer fields in 2021 [17]. Validation results showed that LSFR substantially increased wheat grain and straw yields, enhanced nutrient and water use efficiency, and improved farmers' return on fertilizer investment [17]. Building on the success of the validation phase and local farmer interest, the Alliance of Bioversity and CIAT, in collaboration with partners (MoA, Digital Green, and LERSHA), agreed to pilot the SSFR advisory in wheat-intensive regions. These pilot trials were conducted in 10 districts across three regions (**Figure 1**), selected based on partner agreements and local interest in applying the advisory on their farms [24].

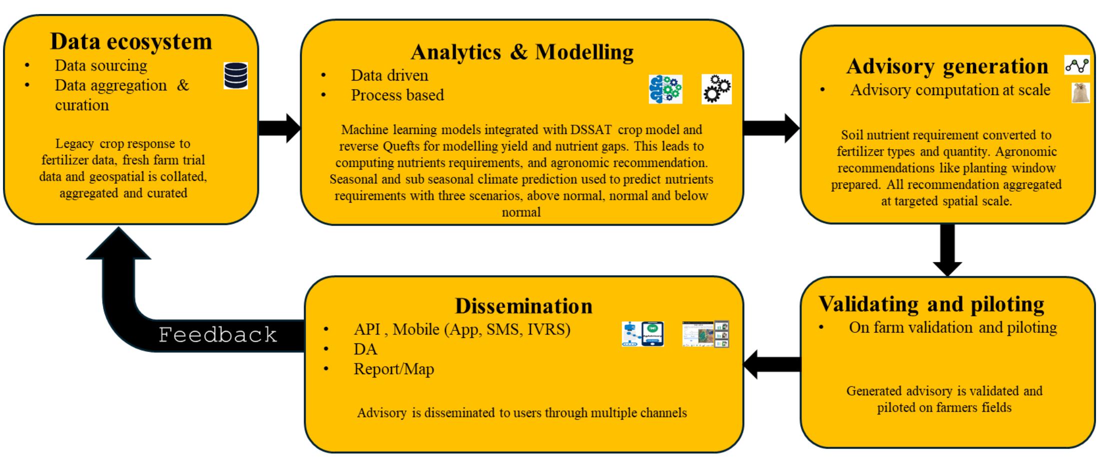

Figure 1. Flow chart for the development of Site-Specific Fertilizer Recommendation. (Source: Authors' formulation).

2.2. Research Sites, Data Sources and Data Collection

A survey on farmers' satisfaction with SSFR and factors affecting their satisfaction was conducted in 10 districts of Ethiopia (**Figure 2**) where Digital Green, Green agro-solution (LERSHA) and Ministry of Agriculture (MoA) pilot scaling of the advisory. These districts were predominantly wheat-growing areas and found in three regional states of the country including the Oromia region (Munessa, Kore, Gadab Asasa, Hittosa, Digalu Tijo), Central Ethiopia region (Lemo, Sodo, Doyogena) and Amhara region (Moretina Jiru). This satisfaction assessment survey was conducted among farmers who received training on SSFRs and implemented SSFRs.

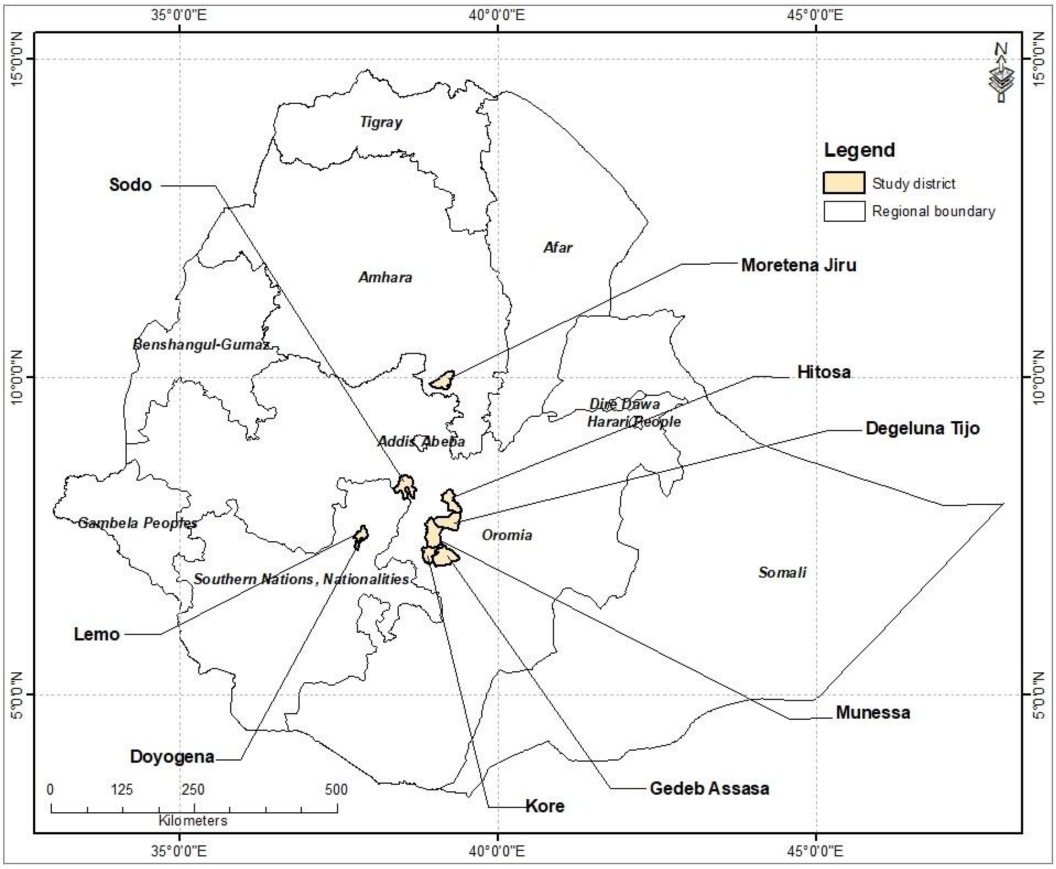

Figure 2. The study districts in Ethiopia.

The study was conducted in 10 districts where the pilot implementation of site-specific fertilizer recommendations (SSFR) took place. These pilot districts were selected based on their predominantly wheat-based cropping systems, the potential for wheat production, the broader suitability for SSFR implementation, and the active involvement of partner organizations. Likewise, pilot kebeles were chosen in consultation with the Ministry of Agriculture (MoA), Digital Green, and LERSHA development agents, considering SSFR implementation performance and wheat production potential. In total, 202 farmers were selected from the 10 districts using a proportional random sampling (stratified random sampling) approach and were interviewed. As a result, 202 households were drawn from the districts of Munessa, Kore, Sodo, Lemo, Goba, Doyogena, Gadab-Asasa, Hetosa, Digalu Tijo, and Moretna Jiru (**Table 1**).

The sample size for each district was determined based on the proportion of households that received SSFR within each district. Following Krejcie and Morgan's (1970) formula, a systematic random sampling method was used to select 202 respondents from the 11 districts. Household interviews served as the primary data source for this study. Data collection took place in 2023, using a structured questionnaire created via the online data collection platform Kobo[25]. The survey was conducted in November when wheat fields had reached a maturity stage suitable for comparing the Site-Specific Fertilizer Recommendations (SSFRs) against local practices. Training sessions—both virtual and face-to-face—were held for enumerators and Development Agents (DAs). Trained enumerators conducted interviews with the selected farmers, under the supervision of Digital Green and LERSHA development agents. The assessment measured satisfaction levels among beneficiaries and experts regarding the performance and applicability of the site-specific fertilizer recommendations.

Table 1. Distribution of sample households by districts.

Implementing Partners	Districts	Sample Farmers
Digital Green	Munessa	20
	Kore	22
	Goba	20
MoA	Sodo	20
	Lemo	20
	Doyogena	50
LERSHA	Gadab Asasa	10
	Hetosa	10
	Digalu Tijo	10
	Moretna Jiru	10
	Woramba	10
	Total sample	202

2.3. Data Analysis

Descriptive and graphical analyses were employed to present the results of the farmers' satisfaction assessment with site-specific fertilizer recommendations. Mean, frequency, percentages, and standard deviations were used to analyze the demographic and socioeconomic characteristics and satisfaction levels of farmers regarding SSFR. Additionally, an Ordered Probit model was applied to identify the factors influencing farmers' satisfaction with SSFR[26]. This model was chosen as the satisfaction variable was measured on a Likert scale. Before fitting the probit model, factor analysis—primarily through principal component analysis (PCA)—was conducted to reduce the number of independent variables, understand variable relationships, address multicollinearity, and enhance the overall quality of the statistical analysis in the Ordered Probit model[27].

2.3.1. Factor Analysis

Factor Analysis is a statistical technique that identifies groups of latent variables (factors) by analyzing patterns of intercorrelations among household and plot characteristics. This method simplifies complex datasets by reducing numerous variables into a smaller set of factors that explain most of the variance within the data. A Varimax orthogonal rotation was used to produce a rotated component matrix, enhancing the interpretability of factors by clearly indicating each variable's factor loading. This analysis retained variables with factor loadings of 0.40 or higher[28, 29]. The number of factors retained was determined using a scree plot test, which involves examining a graph of eigenvalues to find the natural "elbow" point, where the curve flattens.

The Kaiser-Meyer-Olkin (KMO) measure assesses the adequacy of sampling for factor analysis by evaluating how well the variables correlate with each other; a KMO value above 0.5 indicates that the data are suitable for factor analysis. Bartlett's Test of Sphericity tests whether the correlations between variables are significantly different from zero, a necessary condition for factor analysis. A p-value from Bartlett's Test below a chosen significance level (usually 0.05) suggests that the variables are sufficiently correlated.

2.3.2. Ordered Probit Model

Ordered regression models are particularly useful for handling the categorical variation of variables, making them well-suited for analyzing satisfaction-related research findings[30, 31]. The ordered probit model, frequently used in customer satisfaction studies, enables the analysis of data structures involving an ordinal response variable[30]. In this model, there is an observed ordinal variable Y, which is a function of an unobserved or latent variable Y^* that cannot be directly measured[32]. In an ordered model, the latent variable Y^* defines the observed ordinal variable Y based on specific threshold values. The observed variable Y_i takes on values depending on whether Y^* crosses a certain threshold, as described below.

$$\begin{gathered} y_i* = x'_i\beta + u_i \\ y_i = j \text{ if } a_{j-1} < y_i \leq a_j \end{gathered} \tag{1}$$

The probability that observation i will select alternative j is:

$$p_{ij} = p(y_i =_j) = p(a_{j-1} < y_i \le a_j) \\ = F(a_j - x'_i\beta) - F(aj_{-1} - x'_i\beta) \quad (2)$$

Marginal effect of an increase in a regressor x_r on the probability of selecting alternative j is:

$$dp_{ij}/dx_{ri} = F(a_j - x'_i\beta) - F(aj_{-1} - x'_i\beta) \quad (3)$$

3. Results

3.1. Characteristics of Respondents

Table 2 presents the socio-economic attributes of the respondents, highlighting seven key factors: age, gender, family size, education level, landholding, and livestock size. For example, the average age of respondents was 44 years, with a range from 22 to 82 years and a standard deviation of ±11 years. The average household family size was 6 members, varying from 1 to 18. Land and livestock holdings, essential socio-economic characteristics, averaged 1.52 hectares and 5.55 Tropical Livestock Units (TLU) per household, respectively. Additionally, the results indicated that 81% of respondents were male, and 97% were married household heads.

Table 2. Socio-economic characteristics of respondents. Values in the parenthesis are standard deviations.

Socio-Economic Characteristics	Values
Average age (years)	43.99 (±10.73)
Average family size (no./hh[§])	6.24 (2.53)
Gender (Male %)	81.2
Average education (years)	5.20 (±3.14)
Married household (%)	97%
Average landholding (ha/hh)	1.52 (±1.26)
Average livestock holding (TLU[¥]/hh)	5.55 (±4.60)

[§] Household; [¥] Tropical Livestock Unit.

Table 3 presents the definition of 22 variables used in this study. As indicated in the table, 20 independent variables are classified as either continuous or categorical while the dependent variable reflects farmers' satisfaction level with SSFR.

Table 3. Variable definitions and their descriptive statistics.

Variables	Descriptions of Variable	Min	Max	Mean	Std. Dev.	Expected Sign
Age	Continuous variables	22	82	43.990	10.730	±
Gender	Dummy (1: Male, 0: Female)	0	1	0.812	0.392	±
Marital status	Dummy (1: Married, 0: Otherwise)	0	1	0.97	0.170	±
Education	Continuous variables (years attended)	0	13	5.200	3.142	+
Family size	Continuous variables (number)	1	18	6.240	2.532	+
Landholding	Continuous variables (ha)	0.25	10	1.521	1.265	+
Tropical Livestock Unit (TLU)	Continuous variables (TLU)	0	40	5.546	4.601	+
Implementing partners	1: Digital Green, 2: LERSHA, 3: MoA	1	3	2.140	0.858	±
SSFR dissemination using orientation training	Dummy (1: Yes, 0: No)	0	1	0.807	0.396	+
SSFR dissemination using SMS message	Dummy (1: Yes, 0: No)	0	1	0.820	0.384	+
SSFR dissemination using group leader farmer	Dummy (1: Yes, 0: No)	0	1	0.310	0.462	+
SSFR dissemination using DAs' visit and advice	Dummy (1: Yes, 0: No)	0	1	0.690	0.462	+
Recommendation unit	1: Cluster-based, 0: Plot Based	0	1	0.525	0.501	±
Availability of fertilizers	Dummy (1:Yes, 0: No)	0	1	0.910	0.293	+
Affordability of fertilizers	Dummy (1:Yes, 0: No)	0	1	0.800	0.399	+
Trainings on SSFR	Dummy (1:Yes, 0: No)	0	1	0.950	0.217	+
Information obtained on land preparation	Dummy (1: Yes, 0: No)	0	1	0.886	0.318	+
Information obtained on planting time	Dummy (1: Yes, 0: No)	0	1	0.827	0.380	+
Information obtained on disease management	Dummy (1: Yes, 0: No)	0	1	0.866	0.341	+
Information obtained on seasonal weather forecast	Dummy (1: Yes, 0: No)	0	1	0.480	0.501	+
Overall farmers' satisfaction with SSFR	Categorical (1: Dissatisfied, 2: Moderately satisfied, 3: Satisfied, 4: Strongly Satisfied)	2.00	4	3.371	0.542	

3.2. Level of Satisfaction of Farmers on SSFR Advisory

Table 4 shows the farmers' satisfaction levels with the extension agents, based on two key indicators for site-specific fertilizer recommendations (SSFR): the recommended fertilizer rate and the timing of application. **Table 3** details farmers' satisfaction with both the SSFR rate and timing. A notable finding is that a significant portion of respondents were satisfied with the SSFR rate (58.4%) and timing (56.9%). Additionally, a considerable share of respondents expressed strong satisfaction, with 37.6% highly satisfied with the recommended fertilizer rates and 39.6% strongly satisfied with the timing of application. Only a small fraction (4%) was moderately satisfied with both the rate and timing of SSFR. Dissatisfaction was minimal, as only one respondent (0.5%) reported dissatisfaction, yet still preferred the timely application recommendations.

Table 4. Level of satisfaction of farmers with site-specific fertilizer recommendation (SSFR) in Ethiopia.

Satisfaction Level	Rate of SSFR		Time of Application Recommendation	
	Frequency	**%**	**Frequency**	**%**
Strongly Satisfied	75	37.6	79	39.6
Satisfied	117	58.4	113	56.4
Moderately satisfied	8	4.0	7	3.5
Dissatisfied	0	0	1	0.5

Figure 3 illustrates the proportion of respondents (%) satisfied with site-specific fertilizer recommendations (SSFR) implemented by various partners, including Digital Green, the Ministry of Agriculture (MoA), and LERSHA. The y-axis represents the proportion of respondents, while the x-axis indicates satisfaction levels, ranging from "strongly satisfied" on the left to "not satisfied at all" on the right. The results indicate that MoA achieved the highest satisfaction rates across all levels, while LERSHA recorded the lowest. Specifically, the highest overall satisfaction level (44.6%) was noted for farmers under MoA implementation, followed by Digital Green at 30.7% and LERSHA at 24.8%.

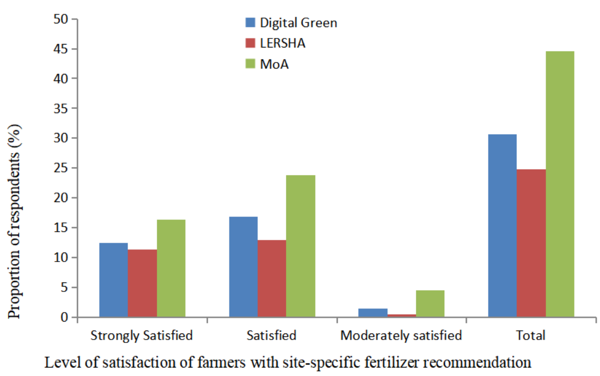

Figure 3. Level of satisfaction of farmers with site-specific fertilizer recommendation (SSFR) in Ethiopia across the tree implementing partners including Digital Green, MoA (Ministry of Agriculture), and LERSHA.

3.3. Factor Analysis Results

The results indicated a high KMO value (≈0.63), suggesting that the variables in the survey are interrelated enough to justify meaningful factor analysis. Additionally, Bartlett's Test of Sphericity produced a highly significant result ($p < 0.001$), further validating the application of factor analysis to the dataset. Out of 24 original factors, 20 were retained for factor analysis, while four were discarded due to low factor loadings ($< |0.4|$). Following Principal Component Analysis (PCA), seven independent and non-correlated components (factors) were identified, collectively explaining 69% of the total variance observed in the sample (**Table 5**). Component I, which focuses on information dissemination and education, includes four variables and accounts for 15.3% of the variance. Component II centers on farmer experience and knowledge, encompassing three variables including recommendation unit, household farm size and Development Agents' (DAs) visits and , explaining 11.22% of the variance. Component III is associated with implementing partners and the use of SMS for SSFR dissemination, contributing 9.5% of the variance. Component IV relates to household demographics and livestock endowment (measured in Tropical Livestock Units, TLU), accounting for 9.13% of the variance. Component V highlights information-sharing strategies, including advice on planting times and weather forecasts, representing 8.78% of the variance. Component VI addresses SSFR accessibility, explaining 8.6% of the total variance. Component VII explores inclusive training and gender considerations, contributing approximately 6.6% of the total variance.

Table 5. Rotated component matrix of factor analysis.

Variables	Components/Factors							Extraction
	I	II	III	IV	V	VI	VII	
Information on planting time	0.883							0.804
Dissemination using orientation training	0.873							0.788
Information on disease management	0.858							0.751
Education	−0.405							0.400
Dissemination using DAs farm visit and advice		−0.798						0.763
Farm size ha		0.739						0.737
Recommendation Unit		0.594						0.616
Implementing partners			−0.877					0.789
Dissemination using SMS			0.632					0.764
Family size				0.816				0.705
Age				0.682				0.706
Marital status				−0.486				0.495
Tropical Livestock Unit (TLU)				0.464				0.832
Dissemination using group leader farmer					0.901			0.722
Information on seasonal weather forecast					0.623			0.738
Information on land preparation					−0.545			0.574
Affordability						0.837		0.795
Availability						0.813		0.751
Trainings on SSFR							−0.826	0.788
Gender							0.465	0.355
Explained variance (X)	15.30	11.22	9.54	9.13	8.74	8.56	6.610	

Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalisation, Rotation converged in 7 iterations.

All 20 dependent variables were clustered into seven components, based on the rotated component matrix and extraction values. The dependent variables for each component are detailed in **Table 6.** As shown in the table, components I and IV included four dependent variables, while components II and V contained three. Components III, VI, and VII each comprised two dependent variables.

Table 6. Key components that affect farmers' satisfaction with site-specific fertilizer recommendation.

Key Factors	Explanations
Component I	Information on agronomic practices (such as planting time and disease management), education level of household head, and information dissemination through orientation training
Component II	Information dissemination through DA, farm size, and type of recommendation unit
Component III	Types of implementing partners and dissemination of information using SMS
Component IV	Socio-economic characteristics of households (age, farm size, livestock size, and marital status of the household head)
Component V	Dissemination of site-specific organization through group leader farmers, information received on land preparation, and seasonal weather forecast
Component VI	Availability and accessibility of site-specific fertilizer recommendations
Component VII	Gender and training on site-specific fertilizer recommendation

3.4. Factors Affecting Farmers' Satisfaction with SSFR

The analysis results indicated that the model fit information was significant, suggesting a considerable enhancement in fit compared to the null model, thus demonstrating a strong fit. A goodness of fit test assesses how well the observed data align with the proposed model. Goodness of fit statistics are considered to be a good fit when the significant value is >0.05. The results show a p-value of 1.000, which means that there is no significant difference between the observed data and the fitted (assumed) model. The model summary also shows pseudo R-Square values, which provide an approximation of the variance explained in the criterion variable by the predictors. The improvements in predictive power over the null model are as follows: 25% for Cox and Snell, 31.5% for Nagelkerke, and 18.2% for McFadden. Of these, the McFadden R-squared is often considered the most appropriate measure for estimating the pseudo R-squared in the probit model. Accordingly, the results demonstrate an 18.2% improvement in the model capacity to predict outcomes based on the specific predictors compared to the null model.

Table 7 presents the findings of an Ordered Probit model analyzing the factors influencing farmers' satisfaction with site-specific fertilizer recommendations (SSFR) in Ethiopia. The results reveal that several factors exert both positive and negative effects on farmers' satisfaction with the SSFR piloting program. While some factors do not show statistically significant impacts, others do. Notably, factors such as education level, farm size, availability and affordability of SSFR recommendations, the quality of planting time information, and the type of recommendations unit have been found to positively and significantly influence farmers' satisfaction with SSFR. In contrast, factors such as livestock size in Tropical Livestock Units (TLU) and information on land preparation have been identified as having a negative and statistically significant impact on farmers' satisfaction with SSFR.

Farmers with *higher education levels* are more likely to be in the strongly satisfied category with the SSFR program due to their ability to better understand and leverage the piloting program's resources. These farmers possess the knowledge and skills to effectively implement the piloting program's recommendations and adapt them to their specific farming context. For instance, a farmer with a higher education level may be better able to interpret complex data provided by the pilot program, implement innovative techniques, and make informed decisions about SSFR.

Farmers with *larger farm sizes* are more likely to be strongly satisfied with site-specific recommendations in Ethiopia because they often have more resources and capacity to implement the recommendations effectively. With a larger landholding, these farmers can more easily experiment with, adopt and scale up the recommended practices, leading to improved yields and profitability. For example, a farmer with a larger farm size may have sufficient land area to efficiently test and implement site-specific recommendations such as precision agriculture techniques or customized fertilization schedules across their fields. This ability to effectively apply the recommendations on a larger scale can lead to higher productivity and satisfaction with the piloting program's outcomes.

Farmers who are part of a cluster recommendation unit are more likely to be in the strongly satisfied category with SSFR in Ethiopia due to the benefits of collective learning, shared resources, and peer support within the group. By being part of a cluster, farmers can share knowledge and experience, access shared resources, and collaborate to implement the recommendations. For instance, within a cluster, farmers can observe the outcomes of site-specific recommendations implemented by their peers, learn from each other's successes and challenges, and collectively address any problems that may arise. This shared learning and support system can lead to better adoption of SSFR practices, increased productivity, and ultimately greater satisfaction among farmers within the cluster.

Farmers' satisfaction with site-specific fertilizer recommendations (SSFR) is higher when the availability of SSFRs is accessible and affordable because it reduces barriers to implementation and adoption of SSFR. When SSFRs are readily available and cost-effective, farmers are more likely to use them to optimize fertilizer application based on their specific soil and crop needs. This can lead to improved fertilizer efficiency, higher crop yields, and ultimately greater satisfaction among farmers who observe tangible benefits from using the SSFRs. Ease of access and affordability make it more feasible for farmers to incorporate these recommendations into their farming practices, leading to positive outcomes and satisfaction.

Farmers who receive information on planting time as part of the program are more likely to be strongly satisfied with site-specific fertilizer recommendations because planting time and fertilizer applications are closely linked for optimizing crop growth and yield. Understanding the synergy between planting time and fertilizer practices can lead to better implementation of site-specific fertilizer recommendations. For instance, if farmers are educated on planting time that complement their specific soil conditions and crop requirements, they can make informed decisions about the type and timing of fertilizer application. This integrated approach can enhance the effectiveness of fertilizer recommendations, leading to improved crop performance and increased satisfaction among farmers. By incorporating knowledge of planting time alongside fertilizer recommendations, farmers can achieve better results in terms of crop health, nutrient uptake, and overall productivity. This holistic approach not only enhances the impact of site-specific fertilizer recommendations but also empowers farmers to make informed choices that contribute to their satisfaction with the program. Farmers who learned about the program via SMS (Short Message Service) reported greater satisfaction with site-specific fertilizer recommendations. This is largely due to the advantages of SMS communication, which boosts farmer engagement and understanding. For one, farmers can access information from anywhere as long as they have a phone. On the other hand, effective use of SMS for outreach and information sharing enhances satisfaction by delivering timely, convenient, personalized, and engaging communication that caters to farmers' diverse needs.

Table 7. Estimates result of the ordered probit model on factors affecting farmers' satisfaction with site-specific fertilizer recommendation (SSFR) in Ethiopia.

Ordered probit regression	Number of observations	=	202
	LR Chi2(20)	=	63.6
	Probability >Chi2	=	0.0000
Log Likelihood = −145.50595	Pseudo R2	=	0.1793

Variables	**Coefficients**	**Std. Err**	**z**	**P >|z|**	**95% Conf. Interval] Lower Limit**	**Upper Limit**
Implementing partners	0.023548	0.155566	0.15	0.880	−0.281354	0.328450
Age	0.001982	0.010075	0.20	0.844	−0.017764	0.021727
Gender	0.101020	0.237339	0.43	0.670	−0.364158	0.566198
Marital status	0.294153	0.627358	0.47	0.639	−0.935446	1.523753
Education	0.095331**	0.032970	2.89	**0.004**	0.030711	0.159952
Family size	−0.044293	0.046229	−0.96	0.338	−0.134900	0.046315
Farm size	0.308065**	0.103921	2.96	**0.003**	0.104384	0.511746
TLU	−0.066703**	0.028956	−2.30	**0.021**	−0.123457	−0.009949
Dissemination using orientation training	−0.427255	0.398849	−1.07	0.284	−1.208990	0.354475
Dissemination using SMS	0.621583*	0.306328	2.03	**0.042**	0.021190	1.221975
Dissemination using lead framers	−0.488722	0.261355	−1.87	0.061	−1.000969	0.023525
Dissemination using DAs	0.179866	0.278048	0.65	0.518	−0.365099	0.724830
Recommendation unit using cluster	0.549423*	0.243137	2.26	**0.024**	0.072883	1.025963
Availability	1.131971**	0.396419	2.86	**0.004**	0.355005	1.908937
Affordability	0.590387*	0.302757	1.95	**0.050**	−0.003006	1.183778
Training on SSFR	0.521481	0.459238	1.14	0.256	−0.378610	1.421572
Information on land preparation	−1.261240**	0.400488	−3.15	**0.002**	−2.046181	−0.476299
Information on planting time	0.854753*	0.419862	2.04	**0.042**	0.031839	1.677668
Information on disease management	0.187123	0.447665	0.42	0.676	−0.690283	1.064530
Information on seasonal weather forecast	0.253697	0.260722	0.97	0.331	−0.257309	0.764703
/cut1	1.300671	1.288908			−1.225542	3.826883
/cut2	3.483182	1.306423			0.922641	6.043723

Std. err: Standard error; z: t-test; *: $p < 0.05$; **: $p < 0.01$.

Table 8 illustrates the marginal effect estimates of twenty factors on farmers' satisfaction with credit usage. As shown in the table, married respondents were 3% more likely to be in the 'strongly satisfied' category. A one-unit increase in the education level of the household head resulted in a 2% decrease in overall satisfaction but a 3% increase in the likelihood of being "strongly satisfied". Conversely, a one-unit increase in the size of the household farm led to a 3.2% and 6.3% decrease in the likelihood of being "moderately satisfied" and "satisfied", respectively, while the likelihood of being "strongly satisfied" went up 9.5%. A one-unit increase in the TLU of the household made it 0.7%, and 1.4% more likely to be in the "moderately satisfied" and "satisfied" categories, respectively, and 2.1% less likely to be "strongly satisfied". The results also indicated that farmers' perceptions of the availability of SSFR in their local area had a significant influence on their level of satisfaction, with farmers being 11.6% less likely to be in the "moderately satisfied" category and 23.5% less likely to be in the "satisfied" category. Conversely, they were 35% more likely to be in the "strongly satisfied" category. The results demonstrated a significant influence of information dissemination and training on farmers' satisfaction levels with agricultural practices. Specifically, when farmers received information on land preparation, they were 39% more likely to be categorized as "strongly satisfied", while they were 13% and 26% are less likely to be in the "moderately satisfied" and "satisfied" categories, respectively.

The analysis revealed that training and information dissemination significantly enhanced farmers' satisfaction with their farming practices. Specifically, when farmers received training on SSFR, they were 5% less likely to be "moderately satisfied", and 11% less likely to be "satisfied". Notably, this training increased the likelihood of farmers being strongly satisfied by 16%. Similarly, when farmers were given information on the optimal planting time for wheat, they were 9% less likely to be "moderately satisfied" and 18% less likely to be "satisfied. This information led to a 27% increase in the likelihood of farmers being "strongly satisfied". This underscores the importance of providing timely and relevant information to farmers, as it significantly enhances their satisfaction and potentially improves agricultural outcomes.

Table 8. Marginal effect on overall satisfaction with site-specific fertilizer recommendation (SSFR).

Variables	dy/dx(Moderately Satisfied)	dy/dx(Satisfied)	dy/dx(Strongly Satisfied)
Implementing partners	−0.002431	−0.004889	0.007320
Age	−0.000205	−0.000411	0.000616
Gender	−0.010429	−0.020973	0.031402
Marital status	−0.030368	−0.061069	0.091436
Education	−0.009842	−0.019792	0.029633
Family size	0.004573	0.009196	−0.013768
Farm size	−0.031804	−0.063957	0.095761
Tropical Livestock Unit (TLU)	0.006886	0.013848	−0.020734
Dissemination using orientation training	0.044109	0.088701	−0.132810
Dissemination using SMS	−0.064171	−0.129045	0.193216
Dissemination using lead framers	0.050455	0.101463	−0.151920
Dissemination using DAs	−0.018569	−0.037341	0.055910
Recommendation unit using cluster	−0.056721	−0.114065	0.170786
Availability	−0.116862	−0.235006	0.351867
Affordability	−0.060950	−0.122569	0.183519
Training on SSFR	−0.053836	−0.108264	0.162099
Information on land preparation	0.130207	0.261843	−0.392050
Information on planting time	−0.088242	−0.177453	0.265696
Information on disease management	−0.019318	−0.038848	0.058166
Information on seasonal weather forecast	0.058167	−0.0526694	0.078861

4. Discussion

The study provides valuable insights into the factors affecting farmers' satisfaction with site-specific fertilizer recommendations (SSFR) in Ethiopia, as analyzed using an Ordered Probit model. The model fitting information indicates a strong improvement in fit over the null model, demonstrated by a p-value of 1.000, suggesting no significant difference between the observed data and the fitted model. This excellent model fit, along with the calculated Pseudo R-Square value showing an 18.2% improvement according to McFadden's criterion, underscores the robustness of the predictors included in the model. The analysis identified several significant predictors of farmer satisfaction, including education level, farm size, availability and affordability of SSFR recommendations, quality of planting time information, information on land preparation, use of SMS for SSFR dissemination, recommendation of SSFR using a cluster approach and livestock size.

The positive correlation between education level and satisfaction with SSFR suggests that better-educated farmers are more equipped to understand and apply the recommendations effectively. This finding supports the notion that education facilitates the comprehension of complex agricultural data, enabling farmers to make informed decisions that can lead to improved yields and sustainability [33, 34]. Farmers with higher levels of education are likely to be more engaged in the piloting program, which may foster a sense of satisfaction as they witness the positive impacts of their informed decisions [33, 35]. The findings indicate that farmers with large farm sizes are significantly more likely to express high levels of satisfaction with SSFR. This trend can be attributed to several interrelated factors. Larger land holdings provide farmers with the necessary resources and capacity to effectively implement recommendations [36]. With extensive cultivation areas, farmers are well-positioned to test, adopt, and scale up innovative practices, thereby increasing their productivity and profitability [37]. For instance, a farmer with a large plot of land can experiment with various site-specific techniques, such as precision agriculture or tailored fertilization schedules, across different sections of their fields [38]. This ability to apply recommendations on a broader scale not only facilitates greater learning and adaptation but also amplifies the benefits of advanced agricultural techniques. As a result, farmers experience tangible improvements in crop yields and overall profitability, which enhances their satisfaction and reinforces their commitment to using SSFR. In addition to farm size, the research highlights the positive influence of cluster recommendation units on farmers' satisfaction with SSFR [39]. Being part of such clusters fosters an environment of collective learning, resource sharing, and peer support, significantly enhancing the adoption and effectiveness of site-specific recommendations [40]. Within these clusters, farmers benefit from the exchange of knowledge and experiences related to implementing SSFR. They can observe the results achieved by their peers, learning from each other's successes and challenges faced during the application of recommendations. This collaborative approach not only cultivates a sense of community but also empowers farmers by providing them with shared resources and joint problem-solving opportunities. The social dynamics inherent in cluster groups can thus drive higher adoption rates and better outcomes, leading to increased productivity and satisfaction with the SSFR recommendation [40].

The negative impact of livestock size (measured in Tropical Livestock Units) and the information about land preparation on farmers' satisfaction is significant. This may suggest that farmers who are heavily reliant on livestock feel that the SSFR program does not adequately address their integrated farming needs, or that competition between livestock and crop production for resources leads to frustration with their farming practices [41, 42]. Furthermore, inadequate information on land preparation methods may reduce overall satisfaction, indicating the necessity for a more holistic approach in delivering agricultural recommendations that include both crop and livestock management [43].

The importance of receiving timely information on planting time cannot be overstated, as it is intrinsically linked to fertilizer application practices that optimize crop growth and yield [44, 45]. Educating farmers on the nuances of planting time techniques that complement fertilizer application is essential to maximize crop performance. When farmers understand how planting time correlates with specific soil conditions and crop requirements, they can make informed decisions that enhance the effectiveness of fertilizer application [46]. For instance, guidance on the best planting windows and corresponding fertilizer application schedules can lead to improved nutrient uptake and crop health. This integrated approach emphasizes the synergy between planting practices and fertilizer application, which translates directly into increased farmers' satisfaction as they observe improvements in crop productivity. By providing comprehensive training that links planting time education with SSFR, programs can empower farmers, enhance their skills, and foster a deeper understanding of sustainable agricultural practices. The results of this study showed that farmers' satisfaction with SSFR is strongly influenced by the availability and affordability of these recommendations. Accessibility reduces the barriers that farmers face in implementing new practices, thereby encouraging adoption [47, 48]. When SSFR resources, such as fertilizer types and tailored fertilizer recommendations are readily available and cost-effective, farmers can optimize their fertilizer use according to their specific soil conditions and crop needs. For example, when recommended fertilizer is readily available and affordable, farmers can ascertain their nutrient requirements, leading to more targeted fertilizer applications. This approach not only improves fertilizer efficiency but also enhances crop yields. Consequently, farmers witness tangible benefits from using SSFR, which fosters a sense of satisfaction with the program. The use of SMS as a communication tool to disseminate information about SSFR has been shown to significantly enhance farmers' satisfaction with the program. SMS technology offers a versatile platform for reaching farmers, particularly in remote areas where traditional communication methods may be less effective [49]. Through SMS, farmers can access vital information about SSFR at their convenience, allowing them to make timely decisions. The advantages of SMS include personalized, engaging, and timely messages that cater to the diverse needs of farmers [50]. By delivering critical information on fertilizer recommendations, planting times, and best practices directly to farmers' mobile devices, SMS facilitates enhanced understanding and engagement. As farmers feel more connected and informed, their overall satisfaction with the SSFR program increases. This highlights the importance of leveraging modern technology in agricultural communication strategies to enable effective outreach and greater farmer engagement.

5. Conclusions

In conclusion, the study shows that farmers in Ethiopia are generally satisfied with the site-specific fertilizer recommendations (SSFRs), with over half of the participants expressing satisfaction with both the rate and timing of these recommendations. The analysis revealed that several key factors contribute positively to this satisfaction, including farmers' level of education, farm sizes, the availability and affordability of SSFR, quality of information on planting time, and the structure of recommendation units. Conversely, certain factors, such as livestock size and inadequate land preparation information were found to have a negative impact on satisfaction. The research underscores the significance of effective information dissemination and accessibility of resources, as well as the benefits of peer support through cluster recommendation units, in enhancing farmers' experiences with SSFR programs. In summary, the study highlights the various factors that influence farmers' satisfaction with site-specific fertilizer recommendations in Ethiopia. By considering these factors, agricultural stakeholders can foster a more supportive environment for farmers, which will facilitate greater adoption of SSFR and lead to better agricultural performance. Such comprehensive strategies not only enhance farmer satisfaction but are also aligned with the broader objectives of food security and sustainable agricultural development in Ethiopia. Looking ahead, efforts should aim to refine these strategies to ensure that all farmers—regardless of their scale or available resources—can benefit from advances in agricultural practices and thereby improve their productivity and well-being. Key strategies include ensuring the accessibility and affordability of SSFR, integrating information on planting times with fertilizer application, and effectively using SMS communication to maximize the impact of agricultural programs.

Authors Contributions

Conceptualization, Z.A., W.A., and L.T.; methodology, Z.A., T.M., D.T., and M.E.; validation, T.M., and D.T.; formal analysis, Z.A.; data curation, Z.A. and M.E.; writing—original draft preparation, Z.A.; writing—review and editing, Z.A., T.M., D.T., M.E., W.A., and L.T.; visualization, Z.A., T.M., and D.T.; supervision, W.A. and L.T.; project administration, W.A. and L.T.; funding acquisition, W.A. and L.T. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data that support the findings of this study will be available on request from the corresponding author.

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Conflict of Interest

The authors declare no conflict of interest.

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