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## **Determinants of Farmers' Knowledge on Soil and Water Conservation Technologies in Dry Zones of Central Highlands, Kenya**

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## Abstract

*This study ascertained the socioeconomic determinants of farmers' knowledge on soil and water conservation technologies in Dry zones of Central Highlands of Kenya involving 400 farming households. Results showed that the majority of the farmers had inadequate knowledge on the use and benefits of soil and water conservation technologies. The socio-economic factors that influence knowledge levels of the knowledge-intensive technologies were education level, gender, perceptions on soil fertility, farmer group membership, access to training, farm size, access to credit, number of livestock kept and access to farm equipment. This implies that there is the need to come up with an all-inclusive policy that can be employed in improving farmer's level of knowledge through the use of more innovative methods of information dissemination. This can be done by strengthening the existing farmer groups, enhancing extension services, and also formulating gender-friendly policies.*

**Keywords** Socio-economic factors, farmer's knowledge level, combined organic and inorganic fertilizer, mulch and zai pit

## Introduction

Climate change and soil degradation are acute problems affecting smallholder farmers in arid and semi-arid land (ASALs) of Sub-Saharan Africa (SSA) (Yazar & Ali, 2016). This has led to dwindling agricultural productivity, food insecurity, and poor livelihoods among the rural people (Salahuddin *et al.*, 2020). High dependency on rain-fed agriculture that is highly affected by changes in climate and soil fertility depletion is the major cause of poor livelihoods (Vanlauwe *et al.*, 2017). In most farms in SSA, nutrients outflow through nutrient mining and run-off far exceeds nutrient inflow resulting in negative nutrient balance (Kiboi *et al.*, 2017). This is mainly due to land use intensification without adequate use of agricultural inputs such as fertilizer and organic amendments, and low use of sustainable technologies (Vanlauwe *et al.*, 2017). Decreasing land size as a result of high population density has made continuous farming rampant. Therefore, studies have explored and recommended soil and water conservation technologies which can enhance soil fertility and increase crop yield sustainably in the wake of climate change (Kiboi *et al.*, 2017; Kimaru-Muchai *et al.*, 2020).

However, adoption of these technologies has not been as expected, considering the urgency with which the technologies are in need (Mucheru-Muna *et al.*, 2021). In many parts of the developing world, the transition from indigenous agricultural practices to modern technologies is often viewed as a critical step towards achieving broad agricultural development objectives such as food security or self-sufficiency (Waha *et al.*, 2018). The transition has however had hitches. Inadequate knowledge of the technologies among the farmers is one of the major factors that affects uptake and eventual adoption of new agricultural technologies (Lambrecht *et al.*, 2016; Seitova & Stamkulova, 2017). Considerable literature has pointed how farmers' level

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of knowledge affects their adoption decisions in soil improvement technologies (Luangduangsitthideth *et al.*, 2019; Mucheru-Muna *et al.*, 2021). Farmers adopt different technologies based on their degree of knowledge.

Knowledge is fact, information, and skill attained through experience or education on a particular subject, which could either be practical or theoretical (Zagzebski, 2017). This is inclusive of the traditional knowledge to modern education regardless of area of knowledge acquisition (Baldos *et al.*, 2019). Traditional knowledge that is mostly acquired through experience has enabled farmers to cope with various issues such as climate change and the right use of farming practices (Makondo & Thomas, 2018; Cheik & Jouquet, 2020). Knowledge of the proper use and benefits of soil and water conservation technologies is crucial in increasing their uptake. However, farmers have been reported to possess little knowledge of the benefits and right use of practices such as inorganic fertilizer and manure use. For instance, they are not aware of the right fertilizer to use, the correct time, mode and rate of application (Mucheru-Muna *et al.*, 2021). The low knowledge level is linked to farmer's poor access to timely and quality information (Adolwa *et al.*, 2017). Therefore, several studies have pointed to the need for information to be adequate and customized to farmers' needs (Adolwa *et al.*, 2018; Spurk *et al.*, 2020).

The knowledge level of various soil and water conservation technologies is affected by various socio-economic factors among the communities. Some of the factors include age, economic ability, gender, and education level among other factors (Figure1). These factors dictate what is within the farmer's reach (Kanyenji *et al.*, 2020). However, there has been an unclear correlation of how various socio-economic factors influence farmers' level of knowledge of soil and water conservation technologies (Mucheru-Muna *et al.*, 2021). This could be due to high heterogeneity among the communities with different people reacting differently in various situations. The heterogeneity has made the effects of various socio-economic factors unclear for various technologies. The study thus sought to: i) assess farmers' knowledge level on the selected soil and water conservation technologies and, ii) determine the households' socio-economic determinants of farmers' level of knowledge on soil and water conservation technologies in the dry ones of the central highlands of Kenya.

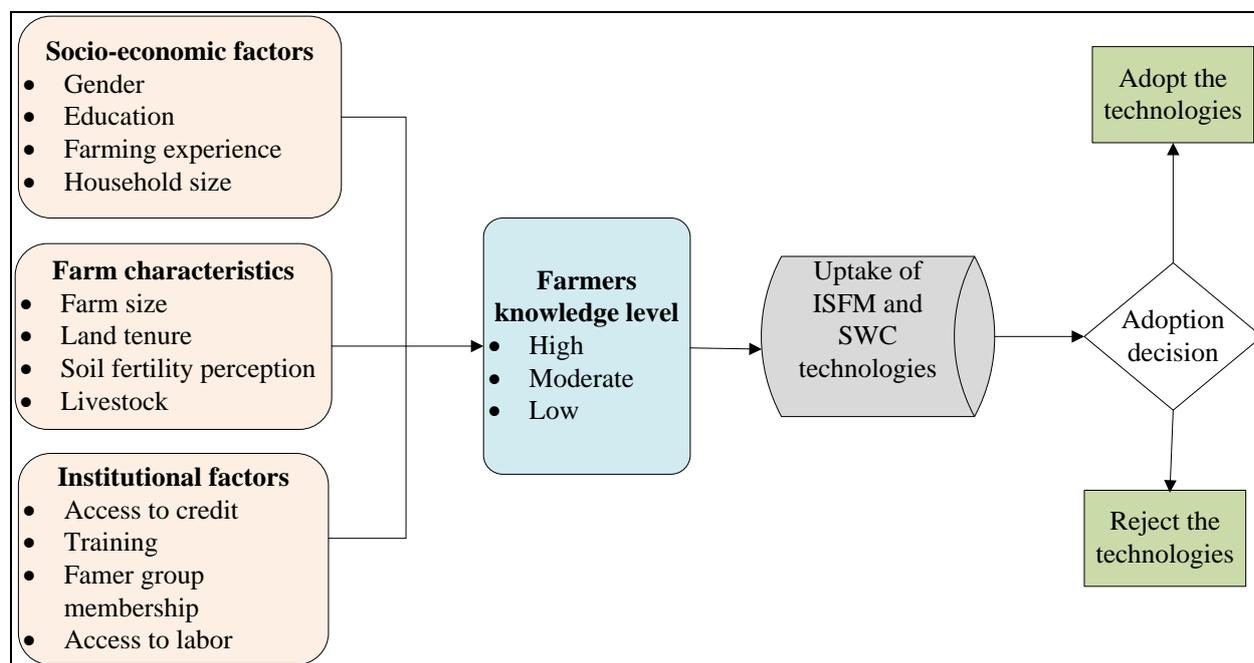


Figure 1: Factors informing farmer's knowledge levels and adoption of the technologies

### Methodology

The study was conducted in Chiakariga, Marimanti and Nkondi wards of Tharaka south sub county, Tharaka-Nithi County. The County lies between latitude 00° 07' and 00° 26' south and between longitudes 37° 19' and 37° 46' east. Tharaka south sub-county was purposively selected because of its agricultural potential and because the technologies had been promoted.. It has a population of 75,250 persons and 18,646 households (KNBS, 2019). The area experiences a mean annual rainfall of 200-800 mm and an annual temperature of 22-36°C. The major soils are the *ferrasols* that are highly weathered and infertile (Mugi-Ngenga *et al.*, 2016).

Multi-stage sampling procedure, probability proportionate to size and random sampling technique were used in selecting households to be sampled. In the first stage, Tharaka South Sub-County was purposively selected, the justification being that the selected soil and water conservation technologies had been promoted in the area (Kiboi *et al.*, 2017; Kimaru-Muchai *et al.*, 2020). In the second stage, all the three wards in Tharaka south sub-county (Ciakariga, Marimanti, and Nkondi) were selected. In the third stage, 400 farming households were randomly selected. Given the variations in the number of households in the three wards, proportionate to size sampling technique was employed to determine the number of households to be interviewed. List of households which formed the sampling frame was obtained from the sub-county agricultural offices. A sample size of 400 households was arrived at using (Eq 1).

$$n = \frac{Z^2 pq}{d^2} = \frac{1.96^2 * (0.5) * (1-0.5)}{0.049^2} = 400 \quad (\text{Eq1})$$

Where  $n$  = sample size,  $Z= 1.96$  the standard normal deviate at the required confidence level,  $p = (0.5)$  the proportion in the target population estimated to have the characteristic under observation,  $q = 1-p = 0.5$  = the proportion of the population without the characteristics being measured  $d = 0.049$  = the desired level of precision.

To assess the farmer's knowledge level, 28 questions were asked requiring an answer of either true or false. Respondents scored (1) for every correct answer and (0) for every wrong answer. The farmers' knowledge was standardized by analyzing its content validity. After obtaining the knowledge index, mean ( $\mu$ ), and standard deviation of the index (s.d) were calculated. The respondents were classified into three categories; the respondents having scores in the range of ( $\mu \pm s.d$ ) were categorized as having moderate knowledge level, high knowledge level for those with a score greater than ( $\mu + s.d$ ) and low knowledge level for those having a lower score than ( $\mu - s.d$ ) (Luangduangsitthideth *et al.*, 2019). Knowledge index was calculated as per equation 2.

$$\text{Knowledge Index (KI)} = \frac{n}{N} \quad (2)$$

Where, KI = Knowledge index,  $n$  = Total score of respondent for correct answer,  $N$  = Maximum obtainable score.

With knowledge levels having more than two levels, multinomial logistic regression was appropriate for analysis.

## Results and Discussion

### Farmers' Knowledge Level

Table 1 show that the majority of the farmers had moderate knowledge levels for combined organic and inorganic fertilizer (52%), mulch (61%) and Zai pits (58%). This finding agrees with those of Luangduangsitthideth *et al.* (2019) and Mucheru-Muna *et al.* (2021) that show farmers to possess moderate knowledge level on soil improvement technologies.

**Table 1: Farmers' knowledge level on combined organic and inorganic fertilizer, mulch and Zai pit**

Technologies	Knowledge level		
	Low	Moderate	High
Combined organic and inorganic fertilizers	18%	52%	30%
Mulch	17%	61%	22%
Zai pits	23%	58%	19%

### Factors Informing Knowledge Level of the Different Soil and Water Conservation Technologies

Farming experience positively predicted ( $\beta = 1.053$ ) how knowledgeable the farmer is on the use of combined organic and inorganic fertilizers, implying that one-year increase in farming experience increases the probability of having a low knowledge level as compared to a high knowledge level by 1.053 times (Table 2). This is because older and experienced farmers tend to be conservative and trust the traditional farming methods than the less experienced and younger farmers (Mugi-

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Ngenga *et al.*, 2016). According to Manda *et al.* (2016) older farmers are more rigid and reluctant to take risks hence less willing to access and utilize information on new technologies. They will therefore not be interested in learning new knowledge.

The education level of the household heads positively influenced the households' knowledge level. Households with non-formal education as compared to those with tertiary education were 11.844 times more likely to have low knowledge level as compared to high ( $\beta = 11.844$ ). Similarly, households with primary knowledge level ( $\beta = 4.409$ ) as compared to those who had tertiary education were 4.409 times more likely to have low knowledge levels as compared to high. Equally, households with non-formal education ( $\beta = 5.029$ ) as compared to those with tertiary education were 5.029 times more likely to have moderate knowledge levels as compared to high. Households with primary ( $\beta = 3.383$ ) and secondary education ( $\beta = 3.880$ ) as compared to those who had tertiary education were 3.383 and 3.880 times more likely to have moderate knowledge level as compared to high knowledge level respectively (Table 2). These findings are in tandem with that reported by Cheruiyot (2020). Being informed about technology is normally preceded by an individual's ability to realize the need for information. Education exposes one to awareness and this enhances the adoption and knowledge level of the farmer (Kimaru-Muchai *et al.*, 2020). Educated farmers seek information, are more likely to process, and realize the need for knowledge in soil conservation technologies as compared to less educated farmers (Mwungu *et al.*, 2018; Cheruiyot, 2020). The soil and water conservation technologies are knowledge-intensive hence; education level is linked to information literacy on use of combined organic and inorganic fertilizers (Mucheru-Muna *et al.*, 2021).

The model showed access to farm equipment to positively influence ( $\beta = 10.587$ ) farmers' knowledge level. This implies that farmers with access to farm equipment were 10.587 times more likely to have high knowledge level as compared to low knowledge level. Likewise, farmers with access to farm equipment ( $\beta = 6.750$ ) were 6.750 times more likely to have a high knowledge level as compared to moderate (Table 2). This could be attributed to the technology being labor-intensive and farmers having huge tracts of land hence access to farm equipment would be important if the farmer is to adopt the technology (Marteyet *et al.*, 2014). This in turn influences how knowledgeable a farmer is on use of combined organic and inorganic fertilizers.

Additionally, livestock keeping positively predicted how knowledgeable a household is ( $\beta = 3.461$ ). This suggests that households with more number of cattle, and who have more manure are more likely to adopt the technology hence will be more knowledgeable than farmers with fewer cattle. Cattle manure is a key resource for ISFM and has been used for a long time in the region (Mugi-Ngenga *et al.*, 2016). The availability of manure contributed to the adoption of this technology making farmers with livestock to be more knowledgeable.

Further, farmers' perceptions of soil fertility positively ( $\beta = 11.631$ ) influenced farmers' knowledge level on combined organic and inorganic fertilizer. This implies that

farmers that perceive their farms to be fertile were 11.631 times more likely to have high knowledge level as compared to low. Farmers can only perceive their farms as fertile if they have used soil fertility improvement technologies (Manda *et al.* 2016), therefore they could be more knowledgeable about the technology. According to Kasefu *et al.* (2018) farmers' perception of soil fertility were consistent with the laboratory analysis results, showing farmers' accuracy in understanding their farms. Perception of soil fertility positively influences the adoption of ISFM technologies. There is therefore a need to sensitize farmers about their soil fertility status.

Farm size positively ( $\beta = 1.082$ ) influenced households' knowledge level in combined organic and inorganic fertilizers (Table 2). This implies that an increase in a unit of land increases the probability of having a moderate knowledge level as compared to high. The smaller the farm size, the more knowledgeable the household is. This finding agrees with Macharia *et al.* (2014) who found that farm size influenced farmers' knowledge level on the use of ISFM. This could be attributed to households' trying to intensify agricultural productivity to reap maximum benefits from their small plots of land. Agricultural intensification requires a lot of information regarding nutrient supply and soil improvement thus creating room for households to learn more about combined organic and inorganic fertilizers thus gaining more knowledge (Mucheru-Muna *et al.*, 2021).

**Table 2: Factors influencing farmer's knowledge level on combined organic and inorganic fertilizers**

High knowledge (Reference)		Low knowledge level			Moderate knowledge level		
		B	Std. Error	Exp (B)	B	Std. Error	Exp (B)
Intercept		-3.10	1.319		.184	.918	
Farming experience		.052	.025	<b>1.053*</b>	.049	.019	<b>1.050*</b>
HH size		-.078	.087	.925	-.107	.064	.899
Farm size		.045	.052	1.046	.078	.038	<b>1.082*</b>
Gender	Male	-.057	.393	.945	-.176	.295	.839
Education level	Non formal	2.472	.950	<b>11.844*</b>	1.615	.777	<b>5.029*</b>
	Primary	1.484	.597	<b>4.409*</b>	1.219	.389	<b>3.383*</b>
	Secondary	.872	.723	2.392	1.356	.443	<b>3.880*</b>
Credit Access	No	.674	.441	1.963	.185	.329	1.203
Land ownership	Without tittle deed	-.369	.423	.691	.353	.306	1.423
Labor access	No	.341	.551	1.406	.429	.430	1.536
Farm equipment Access	No	2.360	.528	<b>10.587*</b>	1.910	.452	<b>6.750*</b>
Livestock keeping	No	1.242	.618	<b>3.461*</b>	-.318	.549	.727
Soil fertility perceptions	Infertile	2.454	.440	<b>11.631*</b>	1.069	.302	<b>2.913*</b>
Training Farmer	No	.193	.408	1.212	.044	.302	1.045
group membershi	No	-.416	.437	.659	-.343	.314	.710

\*P ≤ 0.05

The gender of the household head was a significant negative predictor ( $\beta = -0.496$ ) of farmers' knowledge level on use of mulch. This implies that male-headed households as compared to female-headed households were more likely to have a high knowledge level as compared to low. This could be as a result of male-headed households having better access to extension services and agricultural information as compared to their counterparts. According to Nwangi & Kariuki (2015), men are the landowners and make almost all agricultural decisions including what information to access. This could also be attributed to the negative influence of cultural norms and traditions and the lack of appropriate schedules for extension services for the female (Aravindakshan *et al.*, 2020). This result also agrees with Cheruiyot (2020) who found that men had better access to information than women.

Farmers belonging to the farmer group were 3.340 times more likely to have high knowledge level on mulch as compared to low ( $\beta = 3.340$ ) and 4.464 times more likely to have high knowledge level as compared to moderate ( $\beta = 4.464$ ) (Table 3). Farmer groups and social organizations provide forums for farmers to share experience, challenge, and exchange of ideas (Kanyenji *et al.*, 2020). Groups are also seen to play a key role in persuading farmers to try new technologies and share new information (Macharia *et al.*, 2014). Additionally, farmer groups provide opportunities for collective bargaining and access to capacity building such as training that enable farmers to access information (Aravindakshan *et al.*, 2020).

Credit access was a significant factor that positively influenced household knowledge level on mulch. Households with access to credit were 2.937 times more likely to have a high knowledge level as compared to low ( $\beta = 3.991$ ). Similarly, access to credit ( $\beta = 1.751$ ) increased the likelihood of having high knowledge as compared to moderate by 1.751 times (Table 3). This could be because the technology being labor-intensive, access to credit helps farmers to hire labor, purchase inputs, and invest in integrated soil fertility and soil water conservation technologies (Kakaire *et al.*, 2016). Therefore, households with access to credit invest in mulching making them more knowledgeable than households with no access to credit. This could explain the positive influence of access to farm equipment on farmers' knowledge level.

**Table 3: Factors influencing farmer's knowledge level on use of mulch**

High knowledge (reference)		Low knowledge level			Moderate knowledge level		
		B	Std. Error	Exp (B)	B	Std. Error	Exp (B)
Intercept		-					
		2.225	1.329		-.027	.990	
Farming experience		.024	.027	1.024	-.014	.021	.986
HH size		.089	.092	1.093	.071	.071	1.074
Farm size		.036	.052	1.037	.019	.043	1.020
Gender	Male	-.701	<b>.391*</b>	.496	-.007	.304	.993
Education level	Non formal	.862	.900	2.367	-.155	.727	.856
	Primary	.737	.659	2.091	.345	.409	1.411
	Secondary	-.033	.781	.968	.202	.467	1.224
Credit Access	No	1.384	<b>.452*</b>	3.991	.560	.306	<b>1.751*</b>
Land ownership	Without title deed	.271	.413	1.312	.481	.326	1.618
Labor access	No	.023	.504	1.023	-.196	.412	.822
Farm equipment Access	No	1.077	<b>.419*</b>	2.937	-.408	.343	.665
Livestock keeping	No	.011	.640	1.011	-.056	.523	.946
Soil fertility perceptions	Infertile	-.317	.415	.728	- 1.265	.312	<b>.282*</b>
Training Farmer group membership	No No	.453 1.206	.400 <b>.512*</b>	1.574 3.340	.090 1.496	.304 .417	1.095 <b>4.464*</b>

\*P ≤ 0.05

Training positively influenced farmers' knowledge levels on the use of Zai pits. Farmers who accessed training in the last one year ( $\beta = 3.375$ ) were 3.375 times more likely to have high knowledge level as compared to low knowledge level. Similarly, farmers with access to training ( $\beta = 2.938$ ) were 2.938 more likely to have high knowledge level as compared to moderate knowledge level (Table 4). This finding is in agreement with Danquah *et al.* (2019) and Kimaru-Muchai *et al.* (2020) who found that training positively influenced information access and hence the adoption of Zai pits. As noted by Lukuyu *et al.* (2012) training is a vehicle by which important agricultural information is disseminated and plays a vital role in promoting agricultural technologies. Training has also been reported to be an important component of imparting skills and knowledge hence building the capacity of the target group (Kimaru-Muchai *et al.*, 2020).

Access to credit positively influenced farmers' knowledge level on Zai pits. Households with access to credit ( $\beta = 2.598$ ) were 2.598 times more likely to have high knowledge level as compared to low knowledge. Similarly, households with access to credit ( $\beta = 3.171$ ) were 3.171 more likely to have a high knowledge level as compared to moderate knowledge level (Table 4). Several studies have noted that the implementation of Zai pits technology is labour-intensive (Schuler *et al.*, 2016; Etongo *et al.*, 2018). Barro & Lee (2005) noted that it takes about 300 hours/ha to dig Zai pits and another 250 hours/ha to apply fertilizer in the holes (Kabore & Reij, 2004). This implies that farmers with access to credit are more likely to adopt the technology since they can afford the laborers to work for them. This could in turn influence farmers' knowledge level. Further, there was a positive influence of access to farm equipment on the farmers' level of knowledge. Households with access to farm equipment are more likely to have a high knowledge level as compared to low.

Education negatively influenced farmers' level on Zai pits. Households with non-formal education ( $\beta = -0.19$ ) as compared to those with tertiary education level were 0.19 times more likely to have a high knowledge level as compared to moderate knowledge level (Table 4). Similarly, households with primary education level ( $\beta = -0.413$ ) as compared to tertiary education level were 0.413 more likely to have a high knowledge level as compared to moderate knowledge level. Similarly, households with access to farmer equipment ( $\beta = 6.903$ ) were 6.903 times more likely to have a high knowledge level as compared to low and 3.510 times more likely to have high knowledge level as compared to moderate knowledge level ( $\beta = 3.510$ ,  $p = 0.010$ ) (Table 4). This could be because high level of education can lead to individuals having more available occupations thereby, spend less time farming. This could then result to them being less knowledgeable on agricultural technologies. This finding is in agreement with Kanyenji *et al.* (2020) who found education to negatively influence knowledge and adoption of soil improvement technologies.

**Table 4: Factors influencing farmer's knowledge level on Zai pits**

High knowledge (reference)		Low knowledge level			Moderate knowledge level		
		B	Std. Error	Exp (B)	B	Std. Error	Exp (B)
Intercept		1.926	1.638		3.261	1.458	
Farming experience		.019	.028	1.019	.008	.024	1.008
HH size		-.019	.090	.981	-.008	.076	.992
Farm size		.063	.059	1.065	.025	.053	1.026
Gender	Male	-.424	.414	.654	-.550	.356	.577
Education level	Non formal	.516	1.001	1.676	-	.924	<b>.197*</b>
	Primary	-.230	.606	.794	-.884	.484	<b>.413*</b>
	Secondary	-.022	.707	.978	-.290	.556	.748
Credit Access	No	.955	.430	<b>2.598*</b>	1.154	.364	<b>3.171*</b>
Land ownership	Without tittle deed	-.096	.440	.909	.176	.376	1.192
Labor access	No	.484	.569	1.622	.009	.505	1.009
Farm equipment Access	No	1.932	.517	<b>6.903*</b>	1.256	.485	<b>3.510*</b>
Livestock keeping	No	-.520	.751	.595	-.372	.630	.689
Soil fertility perceptions	Infertile	.142	.434	1.153	-	.358	<b>.248*</b>
Training Farmer group membership	No	1.216	.428	<b>3.375*</b>	1.078	.367	<b>2.938*</b>
	No	-.325	.485	.722	.005	.408	1.005

\*P ≤ 0.05

## **Conclusion and Recommendations**

The factors that inform knowledge were education level, gender, farming experience, perceptions on soil fertility, farmer group membership, access to training, farm size, access to credit, livestock keeping, and access to farm equipment. This implies the need to come up with an all-inclusive policy that can be employed in improving farmer's level of knowledge through the use of more innovative methods of information dissemination. This can be done by strengthening the existing farmer groups, enhancing extension services, and formulating gender-friendly policies. Farmers should also be sensitized about their soil fertility status.

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