

Research Article

Assessing the Role of Training in Improving Pasture Management Among Smallholder Dairy Farmers in Muheza District, Tanzania

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Abstract

In Tanzania, smallholder dairy farmers mainly rely on natural pastures as the primary feed source for their livestock; however, pasture productivity and forage availability remain major challenges, particularly during the dry season. This study aimed to assess the role of training in enhancing pasture management among smallholder dairy farmers in Muheza District. Specifically, it evaluated the adoption of improved pasture management and forage conservation practices by trained versus untrained farmers. A cross-sectional research design was used, and data were collected from 210 dairy farmers (105 trained and 105 untrained) selected through stratified random sampling. A structured questionnaire was administered, and qualitative information was also gathered from key informants. Quantitative data were analyzed using STATA version 17. Descriptive statistics, Chi-square tests were used to examine group differences and associations between categorical variables, while multivariate probit model was employed to identify socio-economic factors influencing adoption of improved practices. Findings revealed that trained farmers were more likely to implement improved pasture management strategies such as rotational grazing, pasture rest and recovery periods, and efficient water use. They also adopted superior forage conservation techniques, including drying, baling, and the use of additives. In contrast, untrained farmers primarily relied on traditional and less efficient practices. The multivariate analysis showed that factors such as age, education level, household income, farm size, and access to institutional support significantly influence the adoption levels. The study concludes that training interventions, when combined with supportive socio-economic and institutional frameworks, play a key role in enhancing the adoption of improved pasture and forage conservation practices. Scaling up such training efforts is recommended to boost livestock productivity and sustainability among smallholder dairy farmers in Tanzania.

Keywords

Training, Smallholder Dairy Farmers, Pasture Management, Forage Conservation, Innovations

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1. Introduction

Smallholder dairy farming is vital for enhancing food security, improving rural livelihoods, and contributing to economic development in many developing countries Tanzania included [1]. This sector not only provides essential nutritional benefits through milk production but also serves as a significant source of income for rural communities [2]. However, smallholder dairy farmers predominantly rely on natural pasture as their primary feed source for livestock; nonetheless, pasture productivity remains a persistent challenge [3]. The above is often attributed to insufficient knowledge and skills in effective pasture management and forage conservation techniques [4]. Moreover, the lack of awareness and expertise in these areas leads to low-quality fodder, seasonal feed shortages, and overall insufficiencies in milk production [5]. Training programs have been developed to equip smallholder dairy farmers with best practices in pasture management and forage conservation, thereby improving productivity and promoting sustainability [6].

Farmers' training is a key intervention when it comes to agricultural development, as it equips them with essential knowledge and skills to enhance their production efficiency [7]. When it comes to pasture management, training plays a vital role in addressing crucial aspects such as pasture selection and establishment, rotational grazing, weed and pest control, soil fertility management, rest and recovery periods and appropriate conservation methods, for example, hay-making and silage preparation [8]. Proper implementation of the above significantly improves pasture quality, ensures year-round availability of fodder, and reduces farmers' dependency on external feed resources [9]. Therefore, the importance of training to farmers on improved pasture management and conservation techniques for increased adoption rates [10].

Furthermore, training not only informs farmers but also empowers them with confidence to integrate innovative techniques into their farming systems [11]. However, the degree to which smallholder dairy farmers adopt these best practices following training varies considerably. Several factors influence adoption, including socio-economic characteristics, farm size, access to resources, labor availability and existing traditional practices [7]. Some farmers may quickly integrate new techniques into their operations, while others may face constraints that hinder their ability to do so [12]. Understanding these factors is essential in refining training programs and designing targeted interventions that maximize adoption and long-term impact.

In line with the above, the "Maziwa Faida Project" financed by the Irish Embassy in Tanzania and jointly managed by Tanzania Livestock Research Institute (TALIRI) and Livestock Training Agency (LITA) offered training to smallholder dairy farmers in Muheza District, Tanga region. The training was conducted by LITA-Buhuri campus and it centered on improved pasture production and management.

Specifically, the training emphasized land preparation, pasture seed selection, sowing (planting), fertilization, irrigation, weeding, conservation, storage and animal feeding. However, there is a lack of empirical evidence regarding how the project-trained farmers have adopted the aforementioned technologies and innovations. In addition, little is known about how the training has resulted in improved pasture management and increased milk productivity (Liters/Cow/Day). Therefore, the study on which this paper is based aimed to determine the effectiveness of the training offered by LITA-Buhuri on smallholder dairy farmers' pasture management, compare the adoption of best practices between trained and untrained farmers, and identify key factors influencing (i.e., enabling and inhibiting) the adoption of improved pasture management and conservation practices.

Furthermore, the study is in line with Tanzania's 2006 Livestock Policy, which, among other things, aims to increase and improve the production of pasture and pasture seeds for sustainable livestock production and productivity [13]. The study is also aligned to the Sustainable Development Goals (SDGs), SDGs 1 (No Poverty), 2 (No Hunger), 6 (Decent Employment) and 11 (Climate Action) which among other things aim to improve people's well-being, including those of Smallholder dairy farmers [14]. Lastly, the study findings could be used by policymakers and other stakeholders interested in raising smallholder dairy farmers' pasture productivity for increased milk productivity, household food security, and income. Generally, the study was guided by the following research questions: What are the best pasture management and forage conservation practices adopted by both trained and untrained smallholder dairy farmers? What barriers or challenges do smallholder dairy farmers face in adopting improved pasture management and forage conservation practices? By addressing the above questions, the study offers valuable insights into the effectiveness of training initiatives on smallholder farmers' improved pasture management and conservation for increased milk productivity; at the same time, it highlights gaps that need further interventions [6]. Moreover, the study's examination of how training influences smallholder dairy farmers' pasture management and conservation bridges the knowledge gap mentioned earlier. Furthermore, it is envisaged that well-informed and trained smallholder dairy farmers will be able to increase their contribution to the growth of Tanzania's dairy industry and its role in national development [2, 15].

1.1. Conceptualization of Key Concepts

Farmer training: Is a planned process of teaching farmers specific skills that help improve their ability to carry out farming activities and increase farm output in a competent and efficient manner [16].

Trained and untrained farmers: Farmers classified as trained have received specific instruction on dairy farming from the *Maziwa Faida* project or a training Institute (such as LITA-Buhuri), whereas farmers classified as untrained have not received any training on dairy farming [17].

Innovation: Innovation is the act of developing and utilizing fresh concepts, techniques, goods, or services that result in notable progress [18].

Pasture: Pasture refers to a piece of land that is covered with grass, herbaceous legumes, forbs, shrubs, and trees and is utilized for feeding livestock or for environmental conservation [19].

Forage: Forage refers to any aboveground plant material used for feeding livestock, excluding concentrates and industrial by-products [19].

Smallholder dairy farmer: A farmer with a small flock size (<10 dairy cows), and family-based labor producing commercial milk [20].

1.2. Empirical Review

The implementation of pasture management innovations and forage conservation methods by smallholder dairy farmers has been extensively researched, with multiple factors affecting adoption and productivity results. Research indicates that various socio-economic and demographic factors, including age, gender, education levels, farming experience, land ownership, and availability of extension services, significantly influence farmers' willingness to adopt new technologies [21]. In addition, their training status has also become a crucial factor influencing the uptake and effectiveness of agricultural innovations [22].

A study Ndah [23] examined the impact of training on pasture management. The results showed that trained farmers had significantly higher adoption rates of improved pasture species and conservation techniques compared to their untrained counterparts. Similarly, research conducted Singh [10] highlighted that farmers with higher education levels, income and more experience in dairy farming were more likely to adopt pasture management innovations. Additionally, farm size and access to extension services were found to be significant predictors of technology adoption [24].

The evaluation of pasture productivity between trained and untrained farmers has produced consistent findings, showing that trained farmers frequently report higher fodder yields and enhanced milk production [25]. This improvement is attributed to better forage management practices, timely harvesting, and conservation techniques. For example, the study Balehgn [26] showed that properly implemented silage-making and hay-baling techniques improved forage availability during the dry season, thus ensuring continuous dairy productivity. In Tanzania, studies on the adoption of pasture innovations have identified several barriers. These include a lack of capital, inadequate extension services, and limited access to quality seeds for improved pastures [10].

Additionally, cultural perceptions and traditional knowledge systems play a significant role in farmers' willingness to adopt new practices [27]. Overall, literature underscores the importance of training and socio-economic factors in the adoption of pasture innovations by smallholder dairy farmers. These insights were key in analyzing findings from Muheza District after the “*Maziwa Faida Project*”, which aimed to enhance milk productivity through better pasture management and conservation. This also allows for comparisons with broader regional and global trends in pasture.

1.3. Theoretical Framework

The study was guided by the Rogers' Diffusion of Innovation Theory (DIT) (1962) which explains how new agricultural technologies and practices are adopted by farmers. According to the DIT, innovation adoption follows a five-stage process: knowledge, persuasion, decision, implementation, and affirmation [28]. In addition, the theory categorizes adopters into five groups: innovators, early adopters, early majority, late majority, and laggards [29, 30]. The DIT also highlights several factors that influence the adoption of innovations; these include perceived advantages, compatibility with existing practices, complexity, trialability, and observability [29]. As pointed out earlier, the “*Maziwa Faida Project*” in partnership with LITA – Buhuri offered training to smallholder farmers on improved pasture management and conservation practices to enhance pasture and milk productivity. Therefore, the use of the DIT in examining the farmers' adoption of the above-mentioned was deemed appropriate. Generally, trained farmers were expected to fall within the early adopters and early majority categories, as they have been exposed to new technologies and skills through formal training. In contrast, untrained farmers may exhibit characteristics of the late majority or laggards due to a lack of direct exposure to innovations and their reliance on traditional methods. Furthermore, in the context of pasture management, perceived benefits such as increased forage availability and improved milk production can encourage adoption. However, barriers such as high costs and limited access to quality seeds may hinder widespread adoption [21]. By applying Rogers' framework, the study analyzed pasture management and conservation patterns among smallholder dairy farmers in Muheza district and evaluated the impact of training and socio-economic factors on their adoption decisions.

1.4. Conceptual Framework

The framework (Figure 1), shows how factors like training, age, education, household size, and milk income affect the adoption of better pasture management practices. Training and institutional support boost farmers' knowledge and confidence, leading to higher adoption rates, especially among younger, more educated farmers with higher milk income and smaller land. Institutional supports also help by provid-

ing technical assistance and motivation.

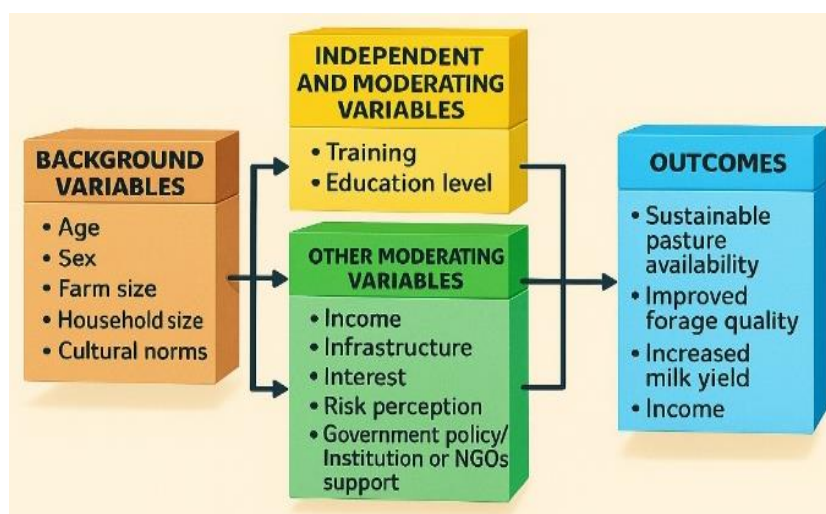


Figure 1. Conceptual framework for the effectiveness of training on smallholder dairy farmers' improved pasture management.

2. Materials and Methods

2.1. Description of the Study Area

Muheza district in Tanga, Tanzania, covers 1,498 km², bordered by Tanga city, the Indian Ocean, and neighboring districts. Located between latitudes 5°10'0.01''S and 5°10'54'', and longitudes 38°46'59.99''E and 38°4'18''E, it has an altitude of 195 to 1050 meters. The climate is tropical wet and dry, with temperatures ranging from 22.7°C in July to 31.53°C in February. Precipitation peaks in April (238.46 mm), with the dry season from July to October. The area's soils are Ferrasols and Acrisols supporting forage species like *Cynodon species*, *Urochloa brizantha*, *Pennisetum species*, *Tripsacum laxum* and *Luceana leucocephala* [10, 31]. Economically, Muheza relies on agriculture, growing food crops (banana, maize, cassava) and cash crops (citrus, cloves, tea). Livestock farming includes cattle, goats, and poultry, with about 3,000 smallholder dairy farmers working across eight wards (Amani, Ngomeni, Mkuzi, Pande Darajani, Misarai, Kilulu, Genge and Mbomole)..

2.2. Research Design

The study used a cross-sectional design for its efficiency to provide a current snapshot, allowing for analysis of variables relationship [32].

2.3. Study Population, Sampling Technique and Sample Size

The study involved 3,000 smallholder dairy farmers from

eight wards in Muheza who were identified by district extension services, selected through stratified random sampling. The sample size was calculated using Nassiuma's (2000) formula: $n = NC^2 \div C^2 + (N-1) e^2$. Whereas n = sample size, N = population size, C = coefficient of variation ≤ 21 -30% and e = margin error fixed between 2-5% as it has been applied by Cholo [33] to determine the sample size. Therefore, $n = 3000 * 0.3^2 \div 0.3^2 + (3000-1) 0.02^2$, whereby a total of 210 (105 trained farmers and 105 untrained farmers) were involved in the study.

2.4. Data Collection

The primary data were collected from 210 smallholder dairy farmers using a structured questionnaire containing both closed and open-ended questions. Additionally, qualitative data were obtained from 20 key informants (extension officers and LITA-Buhuri tutors) through a guided checklist. The study focused on the adoption of best practices in pasture management, such as rotational grazing, weed and pest control, soil fertility management, forage diversity, stocking rate, water management, rest and recovery periods, nutrient cycling, monitoring and recording [34]. Forage conservation techniques assessed were timely harvesting, proper drying techniques, ensiling, baling, additive use, proper storage, wrapping, regular monitoring, utilization of crop residuals, integrated pest management (IPM), baling (storing pasture bales), and minimum handling [34].

2.5. Data Analysis

To identify adopted best practices, as well as determine factors influencing the adoption of innovations, a comprehensive methodology was employed. Data collected through

structured questionnaires were analyzed using descriptive statistics, Chi-square tests, and Multivariate Probit (MVP) regression modeling. Firstly, descriptive statistics (frequencies, percentages, means and standard deviations) were calculated to summarize socio-economic, demographic, farm-specific and institutional characteristics related to respondents' adoption of pasture management and forage conservation practices. Secondly, Chi-square tests were performed to identify associations between categorical variables such as training received and adoption of specific practices. The Chi-square statistic was calculated as:

$$\chi^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Where O_{ij} represents the observed frequency and E_{ij} is the expected frequency.

Also, a Multivariate Probit (MVP) regression model was used to identify the factors influencing the adoption of the improved pasture management and conservation practices. This model analyzes multiple binary outcomes and accounts for correlations in error terms, reflecting smallholder dairy farmers' simultaneous decision-making behavior [35].

The general form of the MVP model used is specified as follows:

$$Y_{ij}^* = X_i' \beta_j + \epsilon_{ij}, \quad j = 1, 2, \dots, J$$

Where:

- 1) Y_{ij}^* is a latent variable representing the propensity of farmer i to adopt practice j .
- 2) Y_{ij} (Observed adoption decision) equals 1 if $Y_{ij}^* > 0$ and 0 otherwise.
- 3) X_i' Represents a vector of explanatory variables including socioeconomic (age, sex, education level, household size), farm-specific characteristics (farm size, income, market access), institutional factors (training received, government support), and cultural and climatic variables.
- 4) β_j Is a vector of coefficients associated with each explanatory variable for practice j .
- 5) ϵ_{ij} Represents error terms assumed to follow a multivariate normal distribution with mean vector zero and covariance matrix Ω .

The probability that farmer i adopts practice j is given by:

$$P(Y_{ij} = 1 | X_i) = P(\epsilon_{ij} > -X_i' \beta_j)$$

The MVP model was estimated using the simultaneous maximum likelihood method to handle the complexity of

multivariate normal integrals. Marginal effects quantified the influence of each independent variable on adoption probability, highlighting key factors that influence the adoption.

The Multivariate Probit Model Specification

Let Y_{ij}^* represent the unobserved latent utility associated with the adoption of practice j by farmer i , modeled as:

$$Y_{ij}^* = X_i' \beta_j + \epsilon_{ij}$$

$$Y_{ij} = \begin{cases} 1 & \text{if } Y_{ij}^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

Where:

- 1) Y_{ij} is the observed binary indicator of adoption,
- 2) X_i is the vector of explanatory variables,
- 3) β_j is the vector of coefficients for practice j ,
- 4) ϵ_{ij} Is the error term, jointly normally distributed across all practices.

The model was estimated using maximum simulated likelihood estimation in STATA 17, with robust standard errors. Model fit was assessed using Wald chi-square tests, Likelihood Ratio (LR) tests for inter-equation error correlation (ρ), and McFadden's Pseudo R^2 .

3. Results

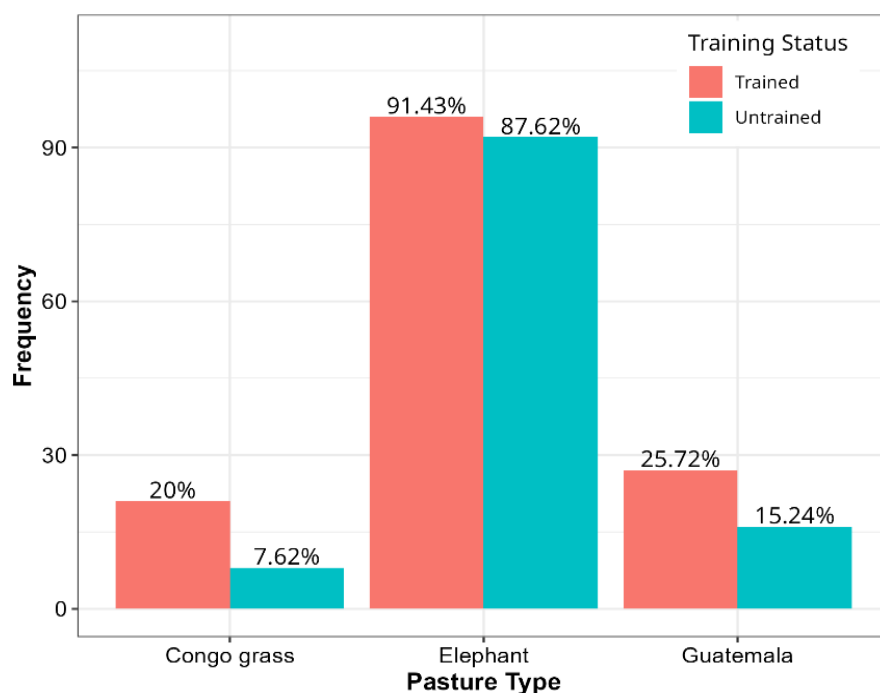
3.1. Socio-demographic and Economic Characteristics of Respondents

Table 1 presents statistically significant socio-demographic differences between trained and untrained smallholder dairy farmers. A significant difference in sex was observed ($\chi^2=6.241$, $p<0.01$), with a higher proportion of females among trained farmers (45.7%) than untrained ones (29.5%). Age distribution also varied significantly at 10% level ($\chi^2=8.472$, $p=0.076$), young farmers (18-35 years) were more commonly among the untrained, whereas mature farmers (36-60 years) predominated in the trained group. There was also no significant difference in household size ($\chi^2=0.759$, $p=0.859$) or education level ($\chi^2=2.783$, $p=0.427$). However, trained farmers were more likely to have smaller farm sizes (<1 ha) ($\chi^2=24.832$, $P<0.001$), and pasture plots (only 2.9% had none, against 25.7% of untrained). Monthly income from milk was also significantly associated with training ($\chi^2=14.627$, $p < 0.01$), with trained farmers more often earning over 800 000 TZS. Institutional support was also overwhelmingly higher among trained farmers (99%) compared to untrained (7.6%), a statistically significant difference ($\chi^2=187.459$, $p<0.001$).

Table 1. Socio-demographic and economic characteristics of farmers (n=210).

Characteristic	Treatment						Pearson Chi-Square Tests		
	Untrained		Trained		Total		Chi-square	Df	Sig.
	Freq	%	Freq	%	Freq	%			
Sex									
Female	31	29.5	48	45.7	79	37.6	6.241	1	0.012*
Male	74	70.5	57	54.3	131	62.4			
Age category									
18 – 35	18	17.1	10	9.5	28	13.3	8.472	4	0.076
36 -60	60	57.2	69	65.7	129	61.5			
Above 60	27	25.7	26	24.8	53	25.2			
Education level									
No formal	2	1.9	0	0.0	2	1.0	2.783	3	0.427
Primary school	70	66.7	75	71.4	145	69.0			
Secondary school	24	22.9	22	21.0	46	21.9			
College/ University	9	8.6	8	7.6	17	8.1			
Household size									
1-3	24	22.9	29	27.6	53	25.2	0.759	3	0.859
4-6	68	64.8	64	61.0	132	62.9			
7-9	12	11.4	11	10.5	23	11.0			
≥10	1	1.0	1	1.0	2	1.0			
Farm size (ha)									
0 ha	27	25.7	3	2.9	30	14.3	24.832	4	0.000*
< 1ha	77	73.3	99	94.2	176	83.8			
1-3 ha	1	1.0	2	1.9	3	1.4			
3 ha	0	0.0	1	1.0	1	0.5			
Average Income from Milk Sales TZS/=per month									
Less than 350,000	70	66.7	47	44.8	117	55.7	14.627	3	0.002*
350,000-700,000	29	27.6	37	35.2	66	31.4			
800,000-1,500,000	5	4.8	18	17.1	23	11.0			
≥1,500,000	1	1.0	3	2.9	4	1.9			
Govt./ NGOs/CBOs' support									
No	97	92.4	1	1.0	98	46.7	187.459	1	0.000*
Yes	8	7.6	104	99.0	112	53.3			

*The Chi-square statistic is significant at the .05 level. Govt. = Government



n = 210

Figure 2. Pasture species usage across trained and untrained farmers (n=210).

3.2. Adoption of Improved Pasture Species

Figure 2 presents the adoption of improved pasture species between trained and untrained smallholder dairy farmers in Muheza District. Trained farmers adopted improved pasture

species at significantly higher rates. Elephant grass (*Penisetum purpureum*) was used by 91.43% of trained against 87.62 of untrained, Guatemala grass (*Tripsacum laxum*) by 25.72% against 15.24%, and Congo grass (*Brachiaria ruziziensis*) by 20% against 7.62%.

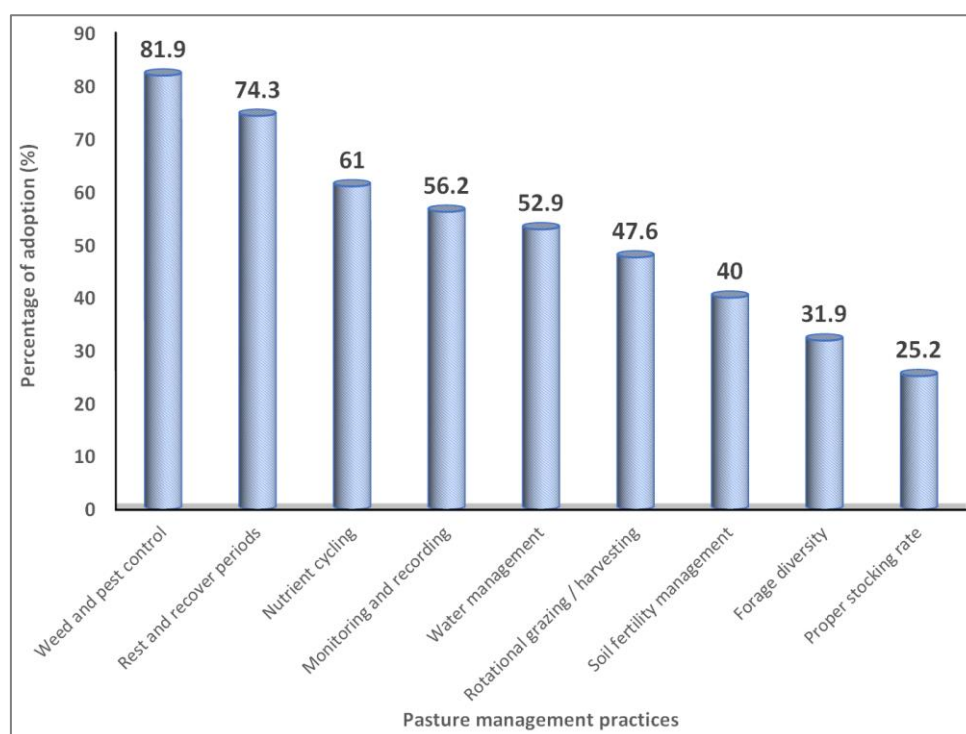


Figure 3. Farmer's adoption of improved pasture management practices.

3.3. Adoption Rate of Pasture Management Practices

Figure 3 shows overall pasture management practices among smallholder dairy farmers, further illustrates the depth of knowledge and application among farmers. Weed and pest control emerged as the most adopted practice, reported by (81.9%), followed closely by rest and recovery periods (74.3%) and nutrient cycling (61%). Monitoring and recording (56.2%) and water management (52.9%). However, the relatively lower adoption rates of rotational grazing or harvesting (47.6%), soil fertility management (40%), forage diversity (31.9%), and proper stocking rate (25.2%).

3.4. Comparison of Pasture Management Practices Among Trained and Untrained Farmers

The comparison of pasture management practices between

trained and untrained farmers shows that trained farmers have significantly higher rates than untrained farmers (Table 2). Rotational grazing or harvesting, was practised by 90% of trained farmers but only 10% of untrained ones, a stark contrast supported by a highly significant Chi-square value ($p < 0.001$). Similarly, practices like soil fertility management (79.76% against 20.24%), forage diversity (64.18% against 35.82%), water management (82.88% against 17.12%), rest and recovery periods (58.97% against 41.03%), and monitoring and recording (66.1% against 33.9%), with all differences statistically significant at the 0.05 level or lower (Table 4). Contrary to expectations, Table 2 shows some practices, such as weed and pest control (49.42% against 50.58%), nutrient cycling (51.56% against 48.44%), and proper stocking rate (39.62% against 60.38%), did not show significant differences between the two groups.

Table 2. Cross-tabulation of pasture management practices across treatment groups ($n=210$).

Variables		Treatment						Pearson Chi-Square Tests		
		Untrained		Trained		Total		Chi-square	df	Sig.
		Freq	%	Freq	%	Freq	%			
Rotational grazing / harvesting	No	95	86.36	15	13.64	110	52.38	127.97	1	0.000*
	Yes	10	10.00	90	90.00	100	47.62			
Weed and pest control	No	18	47.37	20	52.63	38	18.10	0.394	1	0.822
	Yes	87	50.58	85	49.42	172	81.90			
Soil fertility management	No	88	69.84	38	30.16	126	60.00	11.379	1	0.001*
	Yes	17	20.24	67	79.76	84	40.00			
Forage diversity	No	81	56.64	62	43.36	143	68.10	76.164	1	0.000*
	Yes	24	35.82	43	64.18	67	31.90			
Proper stocking rate	No	73	46.50	84	53.50	157	74.76	3.228	1	0.091
	Yes	32	60.38	21	39.62	53	25.24			
Water management	No	86	86.87	13	13.13	99	47.14	102.58	1	0.000*
	Yes	19	17.12	92	82.88	111	52.86			
Rest and recover periods	No	41	75.93	13	24.07	54	25.71	53.82	1	0.000*
	Yes	64	41.03	92	58.97	156	74.29			
Nutrient cycling	No	43	52.44	39	47.56	82	39.05	0.441	1	0.672
	Yes	62	48.44	66	51.56	128	60.95			
Monitoring and recording	No	65	70.65	27	29.35	92	43.81	28.573	1	0.000*
	Yes	40	33.90	78	66.10	118	56.19			

* The Chi-square statistic is significant at the .05 level.

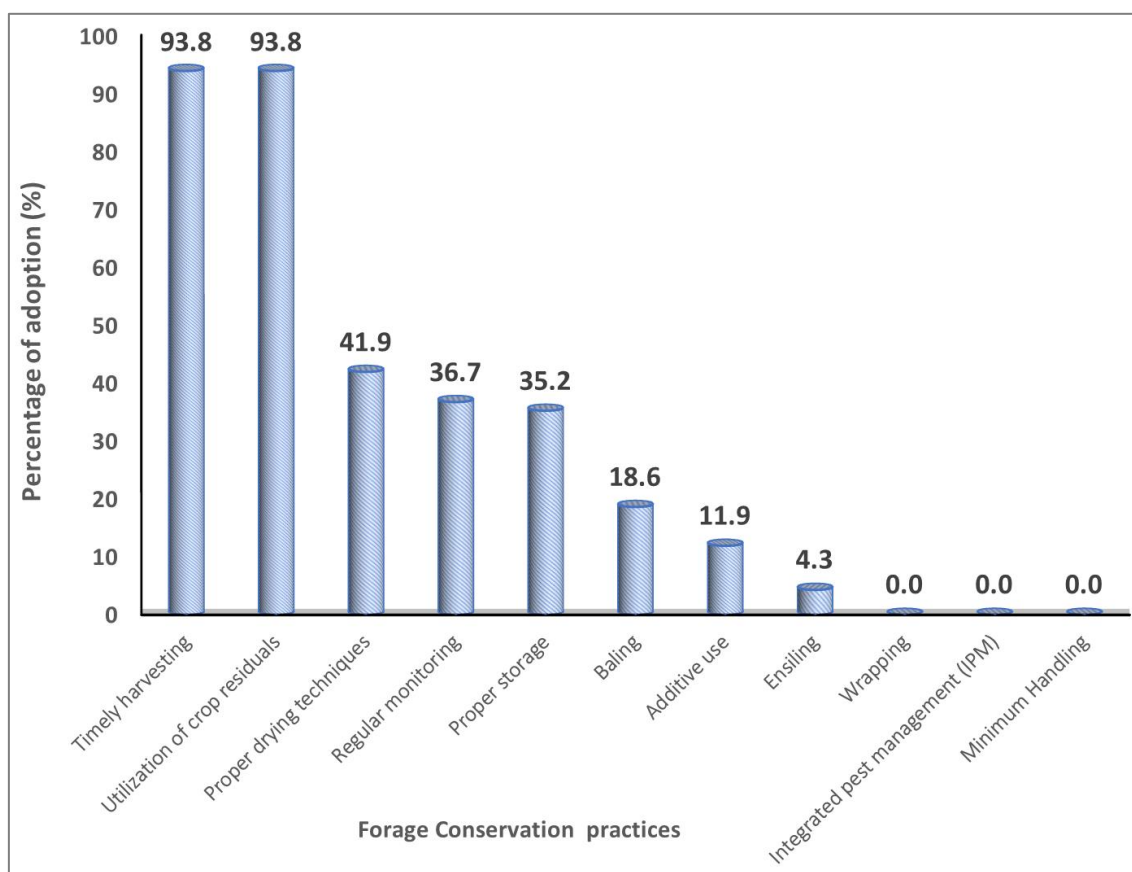


Figure 4. Proportion of farmers in the adoption of forage conservation practices.

3.5. Adoption Rate of Forage Conservation Techniques

Study findings (Figure 4) show overall adoption of forage conservation techniques among smallholder dairy farmers. Basic techniques like timely harvesting and use of crop residues had the highest adoption (93.8%), while ad-

vanced techniques such as proper drying (41.9%), monitoring and recording (36.7%) and storage (35.2%) were moderately adopted. Practices like baling (18.6%), additive use (11.9%), and ensiling (4.3%) were least adopted, while practices like wrapping, integrated pest management and minimum handling were not practiced by any farmers across all groups.

Table 3. Cross-tabulation of forage conservation practices across treatment groups (n=210).

Variables	Category	Training on forage conservation						Pearson Chi-Square Tests		
		Untrained		Trained		Total		Chi-square	df	Sig.
		Freq	%	Freq	%	Freq	%			
Timely harvesting	No	6	46.15	7	53.85	13	6.19	1.9	1.00	0.880
	Yes	99	50.25	98	49.75	197	93.81			
Proper drying techniques	No	99	81.15	23	18.85	122	58.10	13.9	1.00	0.001*
	Yes	6	6.82	82	93.18	88	41.90			
Ensiling	No	104	51.74	97	48.26	201	95.71	23.3	1.00	0.000*
	Yes	1	11.11	8	88.89	9	4.29			

Variables	Category	Training on forage conservation						Pearson Chi-Square Tests		
		Untrained		Trained		Total		Chi-square	df	Sig.
		Freq	%	Freq	%	Freq	%			
Baling	No	101	59.06	70	40.94	171	81.43	31.5	1.00	0.000*
	Yes	4	10.26	35	89.74	39	18.57			
Additive use	No	102	55.14	83	44.86	185	88.10	32.0	1.00	0.000*
	Yes	3	12.00	22	88.00	25	11.90			
Proper storage	No	79	58.09	57	41.91	136	64.76	20.6	1.00	0.000*
	Yes	26	35.14	48	64.86	74	35.24			
Wrapping	No	105	50.00	105	50.00	210	100.00	NA	NA.	NA.
Regular monitoring	No	89	66.92	44	33.08	133	63.33	20.3	1.00	0.000*
	Yes	16	20.78	61	79.22	77	36.67			
Utilization of crop residuals	No	6	46.15	7	53.85	13	6.19	1.9	1.00	0.880
	Yes	99	50.25	98	49.75	197	93.81			
Integrated pest management (IPM)	No	105	50.00	105	50.00	210	100.00	NA	NA.	NA.
Minimum Handling	No	6	46.15	7	53.85	13	6.19	NA	NA.	NA.

* The Chi-square statistic is significant at the .05 level

3.6. Comparison of Forage Conservation Techniques Among Trained and Untrained Farmers

Table 3 confirms trained farmers had significantly higher adoption of advanced forage conservation methods than untrained counterparts. Drying (93.18% against 6.82%), monitoring and recording (79.22% against 20.78%), baling (89.74% against 10.26%), additive use (88.0% against 12.0%), and storage (64.86% against 35.14%). Furthermore, some of the most advanced techniques such as ensiling though still relatively low in overall uptake, were more frequently implemented by trained farmers (88.89%) compared to untrained (11.11%), a difference which is also statistically significant ($p < 0.01$). On other hand, practices such as wrapping, integrated pest management (IPM) and minimum handling techniques had no reported usage among either group.

3.7. Factors Associated with Small Holder Dairy Farmers Adoption of Pasture Management Practices

Table 4 presents the (MVP results), highlighting factors influencing smallholder dairy farmers' adoption of pasture

management based on their socio-economic characteristics. Across the board, younger farmers (especially aged 18–35) are significantly more likely to adopt all practices compared to those aged 46–60. For instance, being in the 18–35 age group increases the probability of adopting rotational grazing ($\beta = 0.73$, $p < 0.001$), water management ($\beta = 0.67$, $p < 0.01$), and monitoring ($\beta = 0.51$, $p < 0.001$), reflecting higher openness among youth to modern pasture techniques. In terms of education, Table 4 shows that farmers with secondary and tertiary education demonstrate consistently higher adoption across all six practices. The coefficients are especially strong for college/university-educated farmers (e.g., $\beta = 0.68$, $p < 0.01$ for rotational grazing) and ($\beta = 0.61$, $p < 0.01$ for water management). Household size of 7–9 members slightly increase adoption ($\beta = 0.32$, $p < 0.05$ for rotational grazing). Small land size (< 1 ha) had a significantly higher likelihood of adopting all practices (e.g., $\beta = 0.57$ for rotational grazing, $p < 0.001$). Similarly, income above TZS 800,000 strongly predicts adoption ($\beta = 0.61$ for rotational grazing, $p < 0.01$), ($\beta = 0.53$, $p < 0.01$ for monitoring and recording). Lastly, government/NGOs support emerges as the strongest predictor across all practices (e.g., $\beta = 0.88$ for rotational grazing, $p < 0.001$) confirming the pivotal role of institutional engagement.

Table 4. Multivariate Probit Estimates for Pasture Management Practice Adoption.

Variable	Rotational Grazing	Water Management	Rest & Recovery	Soil Fertility Management	Forage Diversity	Monitoring & Recording
Age (Ref: Above 60)						
18–35	0.73*** (0.24)	0.67** (0.23)	0.54** (0.21)	0.45** (0.19)	0.38* (0.18)	0.51*** (0.17)
36–60	0.56** (0.22)	0.52** (0.20)	0.42* (0.18)	0.34* (0.17)	0.28 (0.17)	0.42** (0.16)
Sex (1 = Male)	-0.13 (0.11)	-0.09 (0.09)	-0.07 (0.10)	-0.08 (0.09)	-0.06 (0.09)	-0.11 (0.09)
Education (Ref: No education)						
Primary	0.23 (0.21)	0.27 (0.19)	0.21 (0.19)	0.25 (0.18)	0.22 (0.17)	0.20 (0.17)
Secondary	0.52** (0.21)	0.48** (0.19)	0.40** (0.18)	0.39* (0.18)	0.35* (0.17)	0.36** (0.16)
College/University	0.68*** (0.22)	0.61** (0.21)	0.51** (0.19)	0.48** (0.19)	0.43** (0.18)	0.46** (0.17)
Household Size (Ref: 1–3 members)						
4–6 members	0.21 (0.14)	0.19 (0.13)	0.17 (0.12)	0.15 (0.13)	0.13 (0.12)	0.15 (0.13)
7–9 members	0.32* (0.15)	0.28* (0.14)	0.23 (0.14)	0.21 (0.13)	0.18 (0.13)	0.22 (0.12)
Farm Size (Ref: No pasture plot)						
<1 ha	0.57*** (0.16)	0.53*** (0.15)	0.49*** (0.15)	0.46*** (0.15)	0.42** (0.15)	0.48*** (0.14)
1–3 ha	0.40* (0.17)	0.35* (0.16)	0.31 (0.15)	0.28 (0.15)	0.25 (0.14)	0.33* (0.14)
Milk Income (Ref: <350,000)						
350K–700K	0.36* (0.15)	0.34* (0.15)	0.32 (0.14)	0.31 (0.14)	0.28 (0.13)	0.33* (0.13)
800K–1.5M	0.61** (0.18)	0.55** (0.17)	0.50* (0.17)	0.47* (0.17)	0.44* (0.16)	0.53** (0.15)
Gov't/NGO Support (Yes=1)	0.88*** (0.16)	0.83*** (0.15)	0.79*** (0.14)	0.77*** (0.14)	0.74*** (0.14)	0.81*** (0.14)

Note: *indicates statistical significance of the result specifically the p-values, Coefficients with robust SEs in parentheses, Likelihood Ratio (LR) test of $\rho = 0$: $\chi^2 (15) = 58.93$, $p < 0.001$, Wald χ^2 (overall model significance): $\chi^2 (96) = 152.47$, $p < 0.001$, McFadden's Pseudo R^2 0.342

3.8. Interdependence in the Adoption of Pasture Management Practices

Table 5 shows that adopting one pasture management practice significantly relates to adopting others, justifying a Multivariate approach. For example, the positive and significant ρ values between practices (e.g., water management and soil fertility, $\rho = 0.41***$) suggest strong interdepend-

ence. Also, the correlations occur between rotational grazing and soil fertility management and ($\rho = 0.35***$), Soil fertility and monitoring and forage diversity ($\rho = 0.36**$). Unobserved factors (like motivation, access, or awareness) simultaneously influence multiple adoption decisions. The significant LR test ($\chi^2 (15) = 52.76$, $p < 0.001$) confirms that these practices are statistically interrelated rather than independently adopted.

Table 5. Estimated Error Correlation Matrix (ρ) – Pasture Management Practices.

	Rotational Grazing	Water Management	Rest & Recovery	Soil Fertility	Forage Diversity	Monitoring & Recording
Rotational Grazing	1.000	0.38***	0.30**	0.35***	0.29**	0.25**
Water Management	—	1.000	0.33***	0.41***	0.26**	0.31**
Rest & Recovery Periods	—	—	1.000	0.27*	0.22	0.29**

	Rotational Grazing	Water Management	Rest & Recovery	Soil Fertility	Forage Diversity	Monitoring & Recording
Soil Fertility Management	—	—	—	1.000	0.36**	0.34**
Forage Diversity	—	—	—	—	1.000	0.32**
Monitoring & Recording	—	—	—	—	—	1.000

Note: Stars (*) indicate statistical significance: * for $p < 0.05$, ** for $p < 0.01$, and *** for $p < 0.001$, reflecting evidence against the null hypothesis.

3.9. Factors Influencing Adoption of Forage Conservation

The MVP results in Table 6 show factors affecting small-holder dairy farmers' adoption of forage conservation practices. Younger farmers, specifically those in the 18–35 age group, are significantly more likely to adopt practices such as proper drying ($\beta = 0.69$, $p < 0.01$), monitoring ($\beta = 0.64$, $p <$

0.01), and the use of additives ($\beta = 0.43$, $p < 0.05$). Additionally, education had a high and significant coefficient for all practices: $\beta = 0.62$, $p < 0.001$ for drying and $\beta = 0.51$, $p < 0.01$ for storage. Similarly, farmers with small land sizes (< 1 ha) are more likely to adopt all practices (β ranges from 0.33 to 0.60, all significant). Table 6 further shows that institutional support is the strongest predictor ($\beta = 0.92$ for drying, $p < 0.001$). Larger households also had a minor positive effect.

Table 6. Multivariate Probit Estimates for Forage Conservation Practice Adoption.

Variables	Drying	Monitoring	Storage	Additive Use	Baling	Ensiling
(Coefficients with robust SEs in parentheses)						
Age (Ref: Above 60)						
18–35	0.69** (0.24)	0.64** (0.23)	0.53** (0.22)	0.43* (0.21)	0.39* (0.19)	0.25 (0.17)
35–60	0.54* (0.22)	0.48* (0.21)	0.40* (0.19)	0.32* (0.19)	0.26 (0.18)	0.21 (0.17)
Education (Ref: No education)						
Secondary	0.48** (0.21)	0.43* (0.19)	0.38* (0.18)	0.34* (0.17)	0.31* (0.17)	0.25 (0.16)
College/University	0.62*** (0.22)	0.56** (0.21)	0.51** (0.19)	0.46** (0.19)	0.42* (0.18)	0.32* (0.17)
Household Size (Ref: 1–3 members)						
7–9 members	0.29* (0.15)	0.26* (0.14)	0.22 (0.13)	0.20 (0.13)	0.16 (0.12)	0.12 (0.11)
Farm Size (Ref: No pasture plot)						
< 1 ha	0.60*** (0.16)	0.55*** (0.15)	0.53*** (0.15)	0.48** (0.15)	0.46** (0.14)	0.33* (0.14)
Gov't/NGO Support (Yes=1)	0.92*** (0.16)	0.87*** (0.15)	0.82*** (0.14)	0.76*** (0.14)	0.70*** (0.13)	0.50*** (0.13)

Note: *indicates statistical significance of the result specifically the p-values, Likelihood Ratio (LR) test of $p = 0$: $\chi^2 (15) = 54.27$, $p < 0.001$, Wald χ^2 (overall model significance): $\chi^2 (92) = 143.89$, $p < 0.001$, McFadden's Pseudo R^2 : 0.325

3.10. Interdependence in the Adoption of Forage Conservation Practices

The correlation matrix (Table 7) reveals co-adoption between drying and storage ($\rho = 0.43$ ***), monitoring and ad-

ditive use ($\rho = 0.38$ **), and baling and storage ($\rho = 0.36$ **). The LR test ($\chi^2 (15) = 48.95$, $p < 0.01$) confirms significant interdependence between the conservation practices, supporting the use of a multivariate analytical approach. McFadden's R^2 of 0.298 shows a good explanatory fit for the adoption decisions.

Table 7. Estimated Error Correlation Matrix (ρ) – Forage Conservation Practices.

	Drying	Monitoring	Storage	Additive Use	Baling	Ensiling
Proper Drying	1.000	0.41***	0.43***	0.35**	0.33**	0.24*
Monitoring	—	1.000	0.38**	0.38**	0.30*	0.28*
Proper Storage	—	—	1.000	0.36**	0.36**	0.29*
Additive Use	—	—	—	1.000	0.34**	0.31*
Baling	—	—	—	—	1.000	0.27*
Ensiling	—	—	—	—	—	1.000

Note: Stars (*) indicate statistical significance: * for $p < 0.05$, ** for $p < 0.01$, and *** for $p < 0.001$, reflecting evidence against the null hypothesis

4. Discussion

The findings of this study provide compelling evidence that training significantly influences the adoption of improved pasture management and conservation practices among smallholder Dairy farmers in Muheza District, Tanzania. The higher participation of female farmers in training programs suggests successful gender inclusive targeting by implementing agencies. This aligns with findings Lukuyu [36], who reported that women are more likely to engage in forage interventions when such efforts were supported by extension services. It may also imply that women are increasingly taking active roles in dairy production, and targeted training empowers them with relevant knowledge and skills. Age-wise, mature farmers were more represented among the trained group, while younger farmers were common among the untrained. This may indicate that older farmers are more stable and engaged in dairy farming as a livelihood and therefore more willing to attend training. However, multivariate probit result shows that young farmers (18-35 years) are more likely to adopt multiple improved practices. This suggests that although youth may be underrepresented in training programs, they tend to be more open to innovation and receptive to technical information once exposed, indicating the importance of tailoring training to attract younger demographics, as youth are generally adaptable to new technologies [37, 38].

The observation that household size and education level had no significant influence on training participation suggests that programs were relatively inclusive. Yet, education strongly influenced the adoption of both pasture management and forage conservation. Farmers with secondary and tertiary education were more likely to adopt practices such as rotational grazing, water management, and additive use in forage conservation. This supports findings Twinamatsiko [24] and Zemarku [39], who reported that higher educational attainment enhances the ability to absorb and apply technical in-

novations in dairy farming systems. The results also demonstrate that trained farmers typically had a smaller land size (< 1 ha), yet they adopt more improved practices. This could reflect the necessity among land-constrained farmers to maximize outputs through efficient pasture management. This observation aligns with findings that low-resource farmers are more likely to adopt cost-effective forage technologies when provided with training [36].

The statistically significant association between training and higher monthly income from milk sales underscores the economic benefits of technical training. Trained farmers' higher earnings suggest improved productivity and efficiency, likely due to better pasture and forage utilization. This finding echoes observations that training significantly increased milk yield and annual income per animal by more than Rs 2,600, while institutional support was considerably higher among trained farmers (99% compared to 7.6% among untrained), underscoring its importance in capacity building and adoption of improved practices [40]. External agencies, including NGOs, government and community-based organizations, play a pivotal role in farmer development. These results support the view that continuous institutional support through training, subsidies, and input provision is crucial for enhancing the adoption of modern dairy practices [41]. Adoption of improved pasture species was also higher among trained farmers. Their use of *Brachiaria ruziziensis*, high-biomass and protein-rich grass, reflects successful knowledge transfer and adaptation of improved forages. According to Maina [42], *Brachiaria spp* grasses are well suited for tropical conditions and offer nutritional and environmental benefits. Similarly, higher usage of *Pennisetum purpureum* (Elephant grass) reflects its adaptability and productivity, as documented Balehgn [26]. The results affirm the impact of training programs such as *Maziwa Faida*, which emphasized diversification and improved forage quality, consistent with insights Bang [38] on the role of structured capacity building.

Adoption of improved pasture management was notably higher among trained farmers, particularly advanced techniques like rotational grazing, water management, monitor-

ing, soil fertility improvement. These practices contribute to sustainable land use, increased pasture regeneration, and improved animal nutrition. The relatively low adoption of these practices among untrained farmers indicates a knowledge gap. In contrast, basic practices like weed control and nutrient cycling were more commonly adopted across both groups, likely due to lower input or technical requirements. This suggests that foundational practices are intuitive or traditionally taught, while advanced ones require formal training, supporting the findings by Turner [11].

Similarly, forage conservation results show high adoption of basic techniques (timely harvesting, crop residue use) across both groups. However, more technical practices (e.g., proper drying, monitoring, baling, additive use, and ensiling) were more prevalent among trained farmers. These findings emphasize that training improves not just awareness but also the technical competence to apply advanced methods, thereby reducing post-harvest losses and improving feed quality. This is consistent with findings that practical barriers such as cost and limited knowledge hinder the adoption of advanced conservation techniques among untrained farmers [26].

MVP regression confirmed that socio-economic variables such as youth, education, small land size, higher income and institutional support significantly influence adoption of both pasture and conservation practices. The strong influence of external support aligns with evidence reaffirming that institutional engagement is pivotal for disseminating and scaling innovations [41]. Finally, the strong interdependence between practices indicates that adoption decisions are not made independently. For example, proper water management was often accompanied by improved soil fertility and monitoring, while forage drying was highly correlated with proper storage and baling. These co-adoption patterns were statistically confirmed and resemble adoption behaviors identified Rahman [43], who argued that adoption is influenced by common underlying factors like awareness, motivation, and resource access. This reinforces the need for integrated extension packages that promote bundled practices rather than isolated ones.

5. Conclusion

The study aimed at evaluating the contribution of training to improving smallholder dairy farmers pasture management in Muheza District, Tanzania. Specifically, it aimed at determining the farmers' adoption of improved pasture management and forage conservation practices. It can generally be concluded that structured training, alongside supportive socio-economic and institutional conditions, enhances the adoption of improved pasture management and conservation practices. It is also concluded that farmers with training in improved pasture management and conservation practices have a higher likelihood of adopting practices such as rotational grazing, effective water use, and pasture rest and recovery compared to untrained ones. It is further concluded

that trained farmers are more likely to adopt improved forage conservation strategies, including drying, baling, and using additives relative to untrained ones. Lastly, it is concluded that factors such as age, education level, farm size, household income and institutional support the adoption of the above-mentioned practices.

6. Recommendations

Based on the findings of this study it is recommended that policymakers and development partners prioritize the expansion and institutionalization of structured training programs on pasture management and forage conservation for smallholder dairy farmers. The programs should be context-specific, inclusive and sustained through coordinate efforts among government agencies, research institutions, and local extension services. Furthermore, to maximize adoption, training initiatives should be complemented with affordable innovations, practical demonstrations, and ongoing support mechanisms particularly targeting farmers with limited land resources. Emphasis should also be placed on strengthening institutional support system, including access to quality pasture seeds, conservation equipment, and advisory services. Future research should explore long-term impacts of training on milk productivity, farmers livelihoods, and environmental sustainability across diverse agroecological zones in Tanzania.

Abbreviations

DIT	Diffusion of Innovation Theory
IPM	Integrated Pest Management
MVP	Multivariate Probit Model
LITA	Livestock Training Agency
SDGs	Sustainable Development Goals
TALIRI	Tanzania Livestock Research Institute

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Author Contributions

Calvin Aron James, as the first author, was actively involved in data collection, analysis, interpretation, and the writing of the entire manuscript. Dorice Lutatenekwa, serving as a co-supervisor, contributed to data interpretation and

critically reviewed this paper. Zabron Nziku, serving as a co-supervisor, contributed to data analysis and interpretation. Justin K. Urassa, the main supervisor, guided the study through data interpretation, manuscript writing, and review of the paper. All authors read and approved the final manuscript.

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Ethical Statement

The Tanzania Livestock Research Institute (TALIRI) Ethics Review Board granted permission for the study through the Ministry of Livestock and Fisheries, and the study was assigned the Ethical Approval Reference Number TLRI/CC.21/064. The head of the agriculture, livestock, and fisheries department and the Muheza district executive director (DED) were consulted after the Tanga regional administrative secretary (RAS) was granted permission to conduct research. The study's goals were explained to livestock field officers and farmers, who were then requested for their permission to take part.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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