Determinants of Adoption of Improved Panicum Forage by Agro- pastorals in Dasenech District, South Omo, Southern Ethiopia

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Abstract: *Adoption of improved forage remains vital in combating feed shortages and reducing livestock deaths in pastoral and agro-pastoral areas of Ethiopia. However, it depends on household characteristics, institutional and socioeconomic factors, and the perception of the community. Thus, this study examined the determinants of adoption and intensity of improved panicum forage technologies in the Dasenech district. A multistage sampling technique was employed to select 140 forage-producing agro-pastoral households. A double hurdle model was used to analyze the data. The results indicated that agro-pastoralists' adoption and intensity of adoption of panicum forage production in the Dasenech district is high. However, more than 60% of agro-pastoralists who had adopted and cultivated panicum forage claimed problems in accessing irrigation water, which was associated with high fuel for operating irrigation water pumps. Moreover, the probability of adoption of panicum forage production in the district is influenced by access to irrigation water, forage production experience, cooperative membership, and distance to the training center. The intensity of adoption of panicum forage production was also influenced by the sex of the respondent, credit access, distance to market, production experience, price of seed, and livestock holdings. Working on issues related to the improvement of access to irrigation water, establishing cooperatives of agro-pastoralists, and provision of credit opportunities and market information by respective stakeholders is proposed to enhance the adoption and production of panicum forage in the study area.*

Keywords: Adoption intensity, Agro-pastoral, Double hurdle, Panicum forage

1. Introduction

Livestock farming in Ethiopia is economically and socially very important and generates a large amount of export income both at the domestic and international levels. The entire livestock industry, which includes cattle, sheep, goats, equines, and poultry, contributes 15–17% of the GDP, 47.7% of the agricultural GDP, and 37–87% of household incomes (ILRI, 2010; Behnke and Metaferie, 2011). Despite playing a range of roles in both the domestic and global economies of the nation, the contribution of the livestock sub-sector is now below its potential due to several technical and non-technical issues. The most pressing technical problem is the lack of cultivated and wild feed, both in terms of quantity and quality (CSA, 2016).

In Ethiopia, cattle perform poorly because feed quality and quantity are inconsistent, especially during the dry seasons of the year (Ayantunde *et al.*, 2005). This requirement necessitates the use of improved forage, which has various advantages over currently available traditional feed resources. In different parts of Ethiopia, the government of Ethiopia has introduced various improved forages that are utilized as animal feed and to conserve soil and water. However, little is known about how farmers feel about growing and using such forages. Regarding the types of improved forages grown in natural resource conservation areas of an agro-ecological zone and institutional barriers preventing individual farmers from using feed resource management technology, farmer perceptions of technology were one of the factors that could support or hinder the adoption of improved forage technology (Gecho and Punjabi, 2011).

Moreover, the main livestock feed resources accessible in Ethiopia are natural pastures, crop residues, and grazing (Tolera, 2008; Assefa, 2012).

However, these feed resources are very low in quality, having high fiber, low to moderate digestibility, and low levels of nitrogen (Habte, 2000), which might be linked with a low voluntary intake, thus resulting in inadequate nutrient supply, low productivity, and even weight loss. On the other hand, the organic matter content of the soil diminishes as a result of keeping feed supplies within the fields, which worsens the topsoil structure and speeds up erosion (Alemayehu *et al.*, 2016). This situation calls for the inclusion of improved forages, which could provide several advantages over the currently available traditional feed sources or overgrazing in the field.

Adoption of those improved forages refers to a business, a farmer, or a reflection of a farmer's decision to employ a new technology of improved forages, method, and practice in the farming system's production process. Farmers will then only use the technologies that are appropriate for their needs. This may present a chance for smallholder farmers to increase their income and output (Zakarias, 2016).

Forage development strategies have been used for a long time in Ethiopia, but their uptake by the farming community has been very low due to several factors, including a lack of and inability to adopt forage technologies; weak extension services; a lack of and high cost of planting materials; resistance on the part of most smallholder farmers; and the size of livestock ownership and farm size (Othill, 1986; Assefa, 2012; Beshir, 2014). Lack of sufficient land is one of the key obstacles to the adoption of new technologies in the Ethiopian farming system. This is a limitation that farmers are reluctant to plant forage and allocate their land for food crops. As a result, adopting specialization or intercropping forage with other crops has little effect on land allocation and optimizes land for both forage and food crops (Teshome, 2014).

Numerous researchers have tried to identify a lack of knowledge as a constraint for farmers which affect adoption. After having forages on their hands they do not know what is best to do with them or how to use them efficiently. Lessening the problem can be possible with the help of good extension services. It is well recognized that extension service is an important pillar in the transformation of subsistence agriculture to market-oriented agriculture (Gebremedhin *et al.*, 2006). Lack of funds for covering the costs of creating specific forage technologies is the other significant reason preventing many Ethiopian farmers from adopting new forage technologies. Primary variables that influenced farmers' adoption of forage technology were their physical and social capital holdings, educational accomplishments, household parameters, and income level (Cramb, 2000; Shelton *et al.*, 2005; Mapiye *et al.*, 2006; Gillah *et al.*, 2012).

Many previous studies conducted on the adoption of improved forage technologies and its intensity of usage as well as the impact on livestock productivity suggested that adoption did not result in higher income for beneficiaries of the technology as a result of different socioeconomic and institutional factors of production among others (Njarui *et al.*, 2017; Beshir, 2014; Gebremedhin *et al.*, 2003; Mwangi and Wambugu, 2003; Kumwenda and Ngwira, 2003). These studies evaluated the intensity and rate of adoption of better fodder technologies. However, they were unable to evaluate the specific panicum forage technologies that have recently been made available to farmers and agro-pastoralists.

Therefore, this study is aimed at identifying determinants of adoption decisions and the intensity of adoption of improved panicum forage technologies in pastoral/agro-pastoral areas of Southern Ethiopia. Furthermore, South Omo is one of the zones in southern Ethiopia with total area coverage of 108ha for panicum forage production (SOZLFO, 2020). However, the information regarding how many pastoralists or agro-pastoralists grow panicum forages on their farm, the knowhow about what is best to do with panicum forages or how to use them efficiently, and what associated social, economic, household, and institutional constraints of production or determinants of adoption decision and adoption intensity of panicum forage production has not yet been seen in the study site.

2. Research Methodology

2.1. Description of the study area

Dasenech district is one of the ten districts in the South Omo zone of Southern Ethiopia. The economic activity in the district is mainly based on livestock, crop, and fishing production. Crop production is mainly dependent on irrigation from the Omo River and Omo overflow. In the district, rainfall is both low and irregular, making the pastoralists and agro-pastoralists vulnerable to famine and drought. Flood-recession agriculture along the banks of the Omo River is considered more reliable than rain-fed shifting cultivation. However, this system of production is limited in extent and contributes little to the overall subsistence needs of the local agro-pastoral groups. Major crops grown are sorghum, maize, and bananas. Major livestock types kept in the district are cattle, sheep, and goats. In terms of livelihood patterns of households, the district is under the South Omo Pastoral Livelihood, distinguished by its semi-arid climate, with low and erratic rainfall, low altitudes, and warm temperatures. According to the Central Statistical Agency projection, the estimated population in the district is about 66,000. The district is administratively divided into 39 kebeles, of which 28 kebeles are along the Omo River practicing flood-recession agriculture in addition to cattle rearing and recently practicing forage production, particularly panicum, Rhodes, and elephant grass.

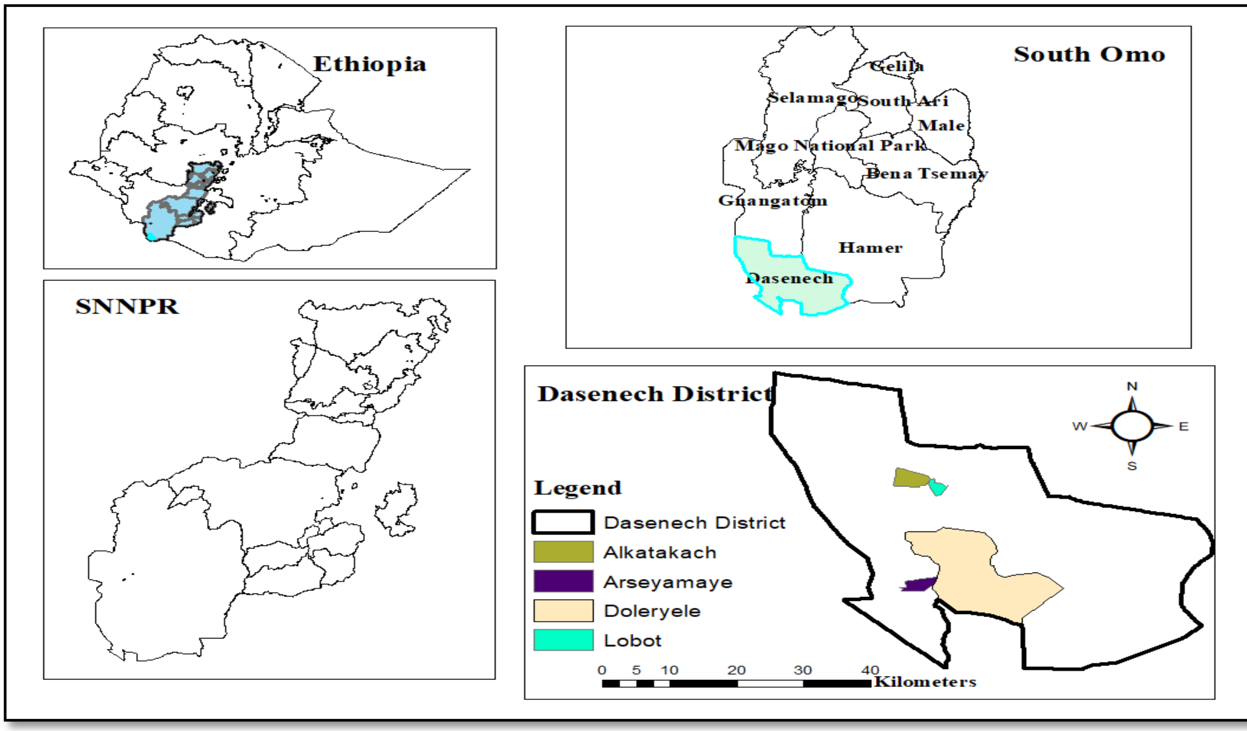

Figure 1: Map of the study area

2.2. Research design, data types and sources

The study employed a cross-sectional survey research design. Primary data was collected from the study population at a single point in time to examine the relationship between variables of interest. Both qualitative and quantitative data types were collected from primary and secondary data sources. The primary data collected from households includes information on household households, socioeconomic, land characteristics, institutional factors, and other factors that are supposed to explain smallholder improved panicum forage producers. Secondary data sources used for this study were journals, relevant textbooks, government and non-government reports, and South Omo zone agricultural office and district agricultural office reports.

2.3. Sampling procedure, sample size determination, and method of collection

The study site was purposefully selected based on improved panicum forage production and availability. Multistage stage sampling techniques were employed to draw sample household heads. In the first stage, potential kebeles in panicum forage production were identified based on district information and consequently, five kebeles were randomly selected. In the second stage, the number of sample households from each sample kebele was determined from the recent lists of households using a proportional size. In the third stage, given the relative homogeneity of households in terms of their socioeconomic characteristics and livelihood styles, samples of households were drawn using a simple random sampling method from each kebele. To determine sample size the formula described by Yemane (1967) was used [1]. Accordingly, the sample size was 154, which was adjusted to 140 pastoral households during data cleaning to be consistent and reliable for the analysis.

$$n = \frac{N}{1+N(e)2} \quad [1]$$

Where

- n is sample size for the study
- N is the population of interest (14895)
- e is the precision level, which was 0.08

Formal and informal methods of data collection were implemented to acquire primary data. A key informant interview and focus group discussion with pre-defined social groups (3 elderly, 3 agro-pastoralists, 2 youth, 2 women, and 2 development agents) were conducted before the formal survey to collect general information about the study site and improve panicum forage production. A checklist was used to guide the informal discussion conducted to generate data that could not be collected from individual interviews. Formal data collection was employed with the help of a pre-tested structured questionnaire. With the help of local enumerators, researchers collected data during the 2021 production season.

2.4. Descriptive analysis and Double hurdle model

The descriptive statistics employed were mean, standard deviation, frequency distribution, percentages, chi-square tests (for categorical variables), and t-tests (continuous variables) and were used to describe and examine adopters and non-adopters of panicum forage technology.

2.4.1. *The adoption decision of smallholder agro-pastoralists and the intensity of improved panicum forage production*

The intensity of increased panicum forage production and the decision to adopt it were examined using the Double Hurdle Model. This concept presupposes that farmers must overcome two obstacles when making agricultural decisions (Cragg, 1971; Sanchez, 2006; Humphreys, 2013). According to Cragg (1971), there are two stages of adoption challenges. The first stage involves deciding whether or not to embrace the technology, while the second stage has to do with the adoption level. It is believed that there is a connection between the two layers (Berhanu and Swinton, 2003). Therefore, this proposed association has been examined in a number of recent studies (Gebremichael and Gebremedhin, 2014; *Katengeza et al.*, 2012; Akpan *et al.*, 2012; Mal *et al.*, 2013).

Therefore, a double hurdle model was chosen because it allows for the distinction between the determinants of adoption and the level of adoption of improved panicum forage production through two separate stages. This model estimation procedure involves running a probit regression to identify determinants of adoption decisions in the activity using all of the sample population in the first stage, and a truncated regression model on the adopting households to analyze the adoption intensity in the second stage. In our case, the first stage of the double hurdle model examined the determinants of the adoption decision to panicum forage and was analyzed by means of the probit.

Burke (2009) claims that the double hurdle model (DHM) is helpful because it enables a subset of the data to accumulate at a certain value without introducing bias in the second stage's estimation of the determinants of the continuous dependent variable, allowing you to collect all the data from the participant's remaining sample. Therefore, there are no limitations on the components of explanatory variables in each decision stage in the double hurdle model. Therefore, the factors influencing the decision to use improved panicum forage and the degree of adoption can be studied individually.

As a result of this, estimates for adoption decisions can be generated using probit regression, and truncated regression can be used to investigate the number of adoption decisions. Burke (2009) asserts that the separable in estimates should not be confused with the possibility of separability. We start in the first stage (adoption decision), where households are classified according to whether they are adopters or not by using probit analysis, and from there we calculate the likelihood function. To do so, let Pi denote a binary indicator function, taking the value "1" if agro-pastoralists adopted panicum forage in the 2021 production year and "0" otherwise. Further, let Qi denote the proportion of area covered by panicum forage of the total land owned in the specified production year. We can then derive the likelihood function for the standard double hurdle model as follows:

$$logLprobit = L(\alpha,\beta) = [1-\phi(pi\alpha)\phi\frac{xi\beta}{\sigma} \quad [2]$$

$$\text{Log}\, truncate = \textbf{[} [[\frac{\phi(pif)}{\sigma}][\frac{Q(Q1-x\prime L\beta}{\sigma}]]\textbf{]} \quad [3]$$

Where

- Φ denotes the standard normal CDF, is the univariate standard normal PDF
- σ is the variance of error terms
- logLprobit is the log-likelihood for a probit
- Log truncate is log-likelihood for a truncated regression with truncation at zero value of the continuous dependent variable in the second stage (proportion of area covered by panicum forage from the total land owned).

The log-likelihood from the Cragg-type double hurdle model is therefore the sum of the log-likelihood from a probit and a truncated regression.

The fact that these two component parts can be completely separated and used individually to estimate, reduced regression is more beneficial (Ground and Koch, 2008; Aristei and Pieroni, 2008; Burke, 2009). Then the log-likelihood function for the double hurdle model was:

$$LogL = L(\alpha,\beta) = [1-\phi(pi\alpha)\phi\frac{xi\beta}{\sigma}] + \textbf{[}[[\frac{\phi(pif)}{\sigma}][\frac{Q(Q1-x\prime L\beta}{\sigma}]]\textbf{]}$$
[4]

Where

- Φ and ϕ were the standard normal cumulative distribution function and density function, respectively.

The maximum likelihood estimation (MLE) method was used to estimate the log-likelihood function. The test statistics double hurdle model was as described by Greene (2000):

$$LR = -2[logLLT - (logLLP + logLLTR)] \approx x^2 \; or$$

$$LR = -2[LLTobit - LLHurdle] \quad [5]$$

Where:

- LT, LP and LTP are the log-likelihoods of the Tobit, probit and truncated regression models, respectively.

Rejecting the null hypothesis indicates that the choices regarding adoption and level adoptions are made at two different phases and support the double-hurdle model's superiority over the Tobit model.

2.4.2. *Constraints on the production of improved panicum forage*

Kendall's coefficient of concordance was used to rank constraints associated with improved panicum forage production from most important to least important. The respondents mentioned and ranked constraints they face on improved panicum forage production using the five-point Likert scale where +1 = most important constraint, 1 = more important constraint, 0 = important constraint, -0.5 = less important constraint, and -1 = least important constraint. The values of Kendall's coefficient of concordance were calculated using the formula below [6].

$$W = \frac{n[\Sigma T^2 - (\Sigma T)^2 / n}{nm^2(n^2 - 1)} \quad [6]$$

Where

- W stands for Kendall's coefficient of concordance
- m stands for the number of respondents
- n stands for the number of constraints
- T stands for the sum of rankings for the constraints being ranked

2.5. Variable definition and measurement as well as prior expectations

This section illustrates the variable description, measurement of variables, and prior expectations as indicated in Table 1.

Table 1: Variables, their measurements and expectations in the Double Hurdle Model

Variables	Measurement	Expected sign
Dependent variables		
Adoption	1 if agro pastoralist has adopted panicum forage, 0 if agro pastoralist has not adopted	
Intensity of adoption	Proportion of area covered by improved panicum forage from the total land owned	
Explanatory variables		
Sex	1 if male, 0 if female agro pastoralist	-/+
Age	Years	-/+
Education level (formal)	Years of schooling	+
Farm size	The total area of land managed by a household head	-/+
Family size	Number of family members in a household living for more than 6 months	+
Livestock holding	Number of livestock owned by a household head(TLU)	+
Price of forage seed	Market price of a forage seed (ETB)	+
Extension contact	1 if agro pastoralist contact with extension agents in a month, 0 otherwise	+
Credit access	1 if agro pastoral get credit services, 0 otherwise	+
Feed shortage	1 if feed shortage is a problem for agro pastoral, 0 otherwise	-
Irrigation to access	1 if access to irrigation, 0 otherwise	+
Member of cooperative	1 if member of panicum forage production cooperative, 0 otherwise	+
Experience in forage production	Number of years, agro pastorals cultivated panicum forage	+
Distance to market center	Distance to nearest market center in hours/minute	-
Distance to training center	Distance to nearest agro pastoral training center in hours/minute	-

3. Results and Discussion

3.1. Socioeconomic, institutional, and household characteristics of respondents

3.1.1. *Sex, age, education level, and family size of the respondent*

Male household heads made up 75% of adopters and more than 74% of panicum growers in the pooled sample. The average age of panicum forage growers was 37 years, showing that panicum forage growers in the research area are in their productive age category. On average, both adopters and non-adopters have less than one year of formal education. As a result, neither adopters nor non-adopters of panicum forage producers have completed primary school, suggesting that both groups had limited access to formal education and a low level of education overall in the research area. The average family size is nearly seven in pooled data, indicating family size for both adopters and non-adopters of panicum forage.

3.1.2. *Experience of forage production, feed shortage and extension visit*

Panicum forage growers at the study site had an average of 4 years and a maximum of 8 years of experience in growing forage, indicating that some of them had good knowledge of forage production. On average, an adopter of panicum forage has been working in forage production for two more years than a non-adopter. Major feed resources for livestock in the study site are free grazing, crop residue, panicum forage, and elephant grass. However, about 51% of the agro-pastoralists in the pooled sample faced feed shortages and did not produce improved forages due to lack of irrigation water access and limited supply of improved seed; and more than half (51%) of the adopters have faced feed shortages for livestock. Thus, the lack of improved feed and forage limits the productivity of livestock production in the study site, and the study by Galmessa *et al.* (2013) reported that an inadequate supply of quality feed is the major factor limiting dairy productivity. In 2021, 88% of adopters had visits by extension agents regarding forage cultivation, including panicum forage, whereas 54% of non-adopters did not. The aggregate data suggests that around 81% of the respondents had extension contacts. This demonstrates that extension work regarding forage cultivation is relatively good in the area.

3.1.3. *Access to irrigation water and credit services, and cooperative membership*

About 91% of adopters had access to irrigation water for panicum forage production, compared with 67% of non-adopters at survey time. The aggregate data reveals that about 77% of the respondents had access to irrigation water. Only 9% of adopters and 3% of non-adopters had access to credit services. In the pooled sample, 8% of the panicum growers had used credit services. This demonstrates that the agro-pastoralists in the study area are less experienced in obtaining financial services. Additionally, the absence of financing has frequently been mentioned as a productivity problem, particularly for small-scale farmers and pastoral herders (O'Lakes, 2010). About 37% of the panicum producers in the pooled sample were involved in panicum forage production cooperatives. This shows that agro-pastoralists in the study site are less involved in panicum forage production cooperatives. About 47% of adopters were involved in cooperatives for panicum forage production, compared with 3% of non-adopters at survey time.

3.1.4. *Distance to agro-pastoral training and nearest market center, and market price of panicum forage*

Both adopters and non-adopters have nearly the same walking distance to a knowledge and experience sharing center or agro-pastoral training center. This might be due to agro-pastorals being settled in certain common places in a group manner as a government strategy to settle them rather than their previous experience of mobile nature in the area. The distance between adopters and non-adopters to the nearest market is only one to two minutes walking distance. The aggregate data indicates that agro-pastorals have an average of a 15-minute walking distance to the nearest market to sell or buy either panicum seed or other agricultural inputs or products. Awareness about the current market price of panicum forage stimulates the adoption decision to grow panicum forage. Adopters reported that the current market price of panicum forage seed is 240 ETB per kilogram, whereas non-adopters reported 119 ETB per kilogram. But during survey time, the market price of panicum forage in the district market was 350 ETB per kilogram. This implies that adopters have slightly better information regarding panicum forage seed than non-adopters in knowing the real market prices

3.1.5. *Livestock holding and farm size*

The mean tropical livestock unit (TLU) for adopters is about one unit higher than that of non-adopters. This means the adopters have more livestock holdings than non-adopters. The mean TLU for adopters and non-adopters was 9 and 8, respectively. The mean landholding for adopters is about 0.81 hectares, which is higher than that of non-adopters (0.77 hectares). This suggests that adaptors with higher land holdings could allocate land for panicum forage compared to non-adopters with lower land holdings. The average proportional area covered by panicum forage for adopters was 0.22 hectares.

As per the key informant discussion, panicum forage production has been started in 2018 by PCDP and the district livestock and fishery office. Following a slow initial rate of uptake in the first few years, the adoption rate accelerated and almost 150 households had adopted and planted panicum forages at the individual farm level by 2021. Planted forages had also spread in the area and were incorporated into development plans by local governments, NGOs, and development projects. Planting panicum forage is now becoming the 'normal practice' in the district and currently, about 28 kebeles are producing panicum forage. Various stakeholders such as the office of livestock and fishery resource, Jinka Agricultural Research center, RPLRP, FAO, PCDP, and others were engaged in the promotion of different forages mainly grass types such as panicum, Buffelgrass, Rhodes, elephant grass; legumes type lablab, cowpea and tree type like Pigeon pea, Sesbania sesban, and Leucaena. The different varieties of forage have varying levels of adoption rates. As revealed in key informant discussions with experts and focus groups discussions with agro-pastoralists the two major forages that have relatively been expanded and grown in the study sites included panicum and elephant grass. The others forage types mentioned were less adopted forage by agro-pastoralists. The reasons behind the less adoption rates of forage are associated with the interest of the agro-pastoralists to give priority to cash forage like panicum and less managed forage like elephant grass.

Table 2: Descriptive statistics of socioeconomic, institutional and household characteristics

Variables	Adopters (n=109)					Non-adopters (n=31)					All (n=140)					
	N	*Mean*	*Std. dev.*	*Min*	*Max*	*N*	*Mean*	*Std. dev.*	*Min*	*Max*	*t-test*	*N*	*Mean*	*Std. dev.*	*Min*	*Max*
Sex (1=male)	109	0.75	0.43	0	1	31	0.68	0.48	0	1	-0.83	140	0.74	0.44	0	1
Age (years)	109	37.97	9.11	19	65	31	34.58	7.89	22	55	-1.88*	140	37.22	8.95	19	65
Education (years)	109	0.19	0.09	0	8	31	0.48	1.39	0	6	1.32	140	0.26	1.09	0	8
Family size (number)	109	6.73	2.44	1	15	31	6.94	3.13	2	14	0.38	140	6.78	2.59	1	15
Feed shortage (1=yes)	109	0.51	0.50	0	1	31	0.48	0.51	0	1	-0.29	140	0.51	0.50	0	1
Experience of forage production (years)	109	4.18	1.81	0	8	31	1.58	2.20	0	6	-6.72***	140	3.61	2.18	0	8
Panicum forage production cooperative membership (1=yes)	109	0.47	0.50	0	1	31	0.03	0.18	0	1	-4.74***	140	0.37	0.48	0	1
Market price of panicum forage (ETB)	109	240.3	91.2	0	350	31	119.4	145.3	0	350	-5.64***	140	213.5	116.4	0	350
Access to credit service (1=yes)	109	0.09	0.29	0	1	31	0.03	0.18	0	1	-1.08	140	0.08	0.27	0	1
Distance market center(minute)	109	15.32	12.02	0	45	31	14.19	13.86	0	40	-0.44	140	15.07	12.41	0	45
Extension visit (1=yes)	109	0.88	0.33	0	1	31	0.54	0.51	0	1	-4.38***	140	0.81	0.39	0	1
Access to irrigation water (1=yes)	109	0.91	0.42	0	1	31	0.67	0.52	0	1	-2.58**	140	0.77	0.41	0	1
Livestock holding (TLU)	109	8.67	15.9	0	159	31	7.79	5.58	1.25	20.53	-0.29	140	8.45	14.28	0	159
Distance to agro pastoral training center (minute)	109	20.01	10.40	0	70	31	20.23	10.45	0	50	0.72	140	20.06	14.1	0	70
Farm size (ha)	109	0.81	0.33	0.5	2	31	0.77	0.36	0.25	2	0.43	140	0.78	0.35	0.25	2
Adoption (1=yes)	-	-	-	-	-	-	-	-	-	-	-	140	0.78	0.42	0	1
Proportion of area covered by panicum forage	109	0.22	0.20	0	1.25	-	-	-	-	-	-	-	-	-	-	-

3.2. Constraints of panicum forage production

Table 3 shows the major constraints prioritized by the respondents on panicum forage production including problems in irrigation water pump or breaking down of primary canals, informal seed suppliers/sellers harvesting of immature seeds due to awareness problems, insufficient seed provision by the government and weak extension support and training. Insufficient irrigation water pump and or break down of primary canals harvesting immature seeds were the 1st and 2nd main constraints in panicum forage production. On the other hand, the involvement of informal seed suppliers/sellers and fluctuations in seed supply by governments and NGOs to agro-pastoralists were mentioned as the third and fourth main constraints in panicum forage production. The absence of sufficient planting material as well as limited extension provision on forage management and harvesting has been indicated as a hindering factor to the adoption of improved forage (Ndah *et al.*, 2022). These constraints could lead to less adoption of panicum forage, reduced economic benefits and incomes from the production of improved forages. Kendall's coefficient of concordance shows that there was a low (31.7%) level of agreement among smallholder agro-pastoralists in ranking of constraints.

Table 3: Major constraints of agro-pastoralists in panicum production

Constraints	Level of agreements (frequency/percent)					Mean rank	Ranking
	Strongly agree	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*		
Informal seed suppliers/sellers	38(27.1)	29(20.7)	51(36.4)	10(7.1)	12(8.6)	3.88	3rd
Fluctuation of seed provision by government and support	8(5.7)	10(7.1)	54(38.6)	50(35.7)	18(12.9)	2.92	4th
Market access problem	8(5.7)	8(5.7)	63(45)	18(12.9)	43(30.7)	2.47	6th
Awareness problem of harvesting un matured seed	53(37.9)	28(20)	35(25)	11(7.9)	13(9.3)	4.18	2nd
Irrigation water pump problems or breaking of primary cannels	71(50.7)	49(35)	15(10.7)	3(2.1)	2(1.4)	4.88	1st
Weak extension support	14(10)	36(25.7)	21(15)	33(23.6)	36(25.7)	2.58	5h
Test statistics							
Number of observations	140						
Kendall's coefficient of concordance	0.317						
Chi-square	221.595						
Degree of freedom	5						
Asymptotic significance	0.000						

Source: own result, 2021

3.3. Determinants of adoption decision and intensity of adoption of improved Panicum forage

3.3.1. *Sex of the respondents*

The sex of the respondents is negatively related to the adoption intensity of improved panicum forage production (Table 4). This means that male agro-pastorals allocate a lower proportion of area to improved panicum forage production as compared to their female counterparts. The reason for this is that male agro-pastorals might compare many alternatives to growing either forage or crops while allocating land because of their access to more agricultural information than their female counterparts. Female agro-pastorals in the study site cut and carry panicum forage to feed cattle and shoat, sell fresher biomass than their male counterparts, and want to allocate more land for panicum forage production. The marginal effect indicates that the proportion of area allocated to improved panicum forage production by male forage producers decreases by 5.6% compared to their female counterparts. However, the study by Gebremedhin *et al.* (2003) disclosed that the gender of the household head had no impact on forage adoption.

3.3.2. *Experience in panicum forage production*

It is positively related to agro-pastoral adoption decisions (Table 4). The likelihood that agro-pastoralists will adopt improved panicum forage likewise rises as years of forage planting and gaining advantages grow. When all other conditions are maintained constant, the marginal effect shows that one additional year of growing panicum forage improves the likelihood of adoption and intensity by 3.1%. This might be due to agro-pastoralists getting more benefits from panicum production and being willing to expand the production. Because they can access information from a variety of sources, more experienced agro-pastoralists are more likely to have access to forage value and seed price information than less experienced ones. This is because households have already been exposed to technologies and realized their importance. An analogous result was stated by Van Den Berg (2013) on the adoption of improved farming practices.

3.3.3. *Access to irrigation water*

Access to irrigation water had a direct relationship with the adoption of improved panicum forage production. Agro-pastoralists who had access to irrigation water in the 2021 production season had about 0.59% more probability of adopting panicum forage than those with no access to irrigation water. Access to irrigation water enables agro-pastoralists to plant panicum seeds, irrigate them and get more benefits from them than those who have no access to irrigation water. The result is consistent with the study by Asmera and Yidnekachew (2021), which indicated that agro-pastoralists who are nearby the water source may have more access to water for their household consumption, livestock, and crop watering than those who are distant from water sources. Irrigation access offers the chance for forage production to the farmers, and those farmers who have good access to irrigation grow forage three times a year (Shiferaw *et al.*, 2018).

3.3.4. *Cooperatives in panicum forage production*

The forage production cooperative was positively related to the adoption decision of the improved panicum forage production (Table 4). When all other factors are held constant, being a member of a panicum-growing cooperative enhances the adoption of panicum forage by 6.1% as compared to non-members of cooperatives. This is because agro-pastoralists in groups have easier access to financing, agricultural inputs, capacity-building programs, success stories from other agro-pastoralists, and extension services since a group can access these resources more easily than individuals. Amfo and Ali (2020) assert that farmers in cooperatives are more likely to exchange ideas and learn from one another over time, increasing the adoption of agricultural technologies. Cooperative membership of beneficiaries to introduced technologies could enhance individual farmers' bargaining power and reduce transaction costs, hence creating an opportunity for extremes that could be used to announce improved forages for dairy cows (Kassie *et al.*, 2013).

3.3.5. *Distance to training center*

Distance to the training center was negatively related to the adoption decision of improved panicum forage production. The marginal effect indicates that as the distance from the agro-pastoral home to the agro-pastoral training center increases by one more minute, the adoption of panicum forage decreases by 2.1%. This is because the adoption process may be aided by being close to the training facility and receiving knowledge about various agricultural inputs. Growers of panicum forage who were closer to the training center and those who received information were more likely to adopt the panicum forage than those who were farther away. According to Zekarias (2016), farmers who live a long distance away from a farmer's training center have less access and utilization opportunities for forage technology, which lowers the adoption probability of improved forages. Similarly, findings by Mwakaje (2012) and Kassie *et al.* (2013) reported that access to training centers and information plays a key role in the adoption of introduced forage technologies.

3.3.6. ***Market price of panicum forage***

Market price was positively related to the intensity of the adoption of panicum forage. Agro-pastoralists who sell panicum biomass and seed and get a high price advantage have a higher probability of allocating more areas for panicum forage than those who do not get income or sell panicum seed or biomass. From the marginal effect, a unit increase in a panicum seed price increases the area allocated to panicum forage by 0.03%, other factors being held constant. The positive result of the market price of panicum forage, either to sell or to buy to grow, is an essential factor in deciding the allocation of land. Previous findings by Wandji *et al.* (2012) noted that the positive perception and knowledge of the price of characteristics of new technology have a significant effect on their adoption. The high price of forage seeds and farm inputs is one of the reasons for the non-adoption of some improved forages in Africa (Gebremedhin *et al.,* 2003; Mwangi and Wambugu, 2003; Kumwenda and Ngwira, 2003; Morris *et al.,* 2015).

3.3.7. ***Distance to marketing center***

It had a negative relationship to the intensity of adoption of improved panicum forage. The marginal effect suggests that a one-minute increase in walking distance from the agro-pastoral home to the market center decreases the tendency of the area allocated to panicum forage production by 11.4%, all other things being constant. This implies that the panicum forage growers who were further away from the market center were less likely to allocate an area to panicum forage than those who were closer to the market center. This might be due to less access to market information like the price of panicum seed and its importance. Similar findings by Beshir (2014) reported that distance from farmers' homes to the market center has a negative effect on the adoption of improved forages as farmers get different inputs from nearby markets. Proximity to markets usually encourages market participation by reducing transaction costs, thereby enhancing the adoption of improved forages (Gebremedhin *et al.,* 2003).

3.3.8. ***Access to credit service***

Credit access was positively related to the adoption intensity of panicum forage production (Table 4). The marginal effect indicates that agro-pastoralists who have access to credit services have a higher adoption intensity of panicum forage production compared to their counterparts by about 9.9%, other factors held constant. This means that agro-pastoralists who have access to credit services allocate more land for panicum forage production than those who have no access. This is because it enhances the opportunity to get additional income, and its accessibility reduces the transport cost, and farmers may learn more about the technology by observing; this furthers its adoption (Dehinenet et al., 2014). The study by Adicha and Mada (2020) revealed that the accessibility of credit facilities is a prerequisite for a technology to be adopted and promoted properly. According to earlier research, having access to financial services gives farmers a strong chance to build up assets and buy various agricultural technologies, such as panicum forage technologies (Yehuala *et al.,* 2013; Muzari *et al.,* 2012; Akudugu *et al.,* 2012; AE *et al.,* 2017; and Quddus, 2012).

3.3.9. ***Livestock holding***

It had positively related to the allocation of the area to grow panicum forage. Other factors held constant, a one-unit increase in total tropical units increases the area allocated to panicum forage by 0.3%. This indicates that agro-pastoralists with a great number of livestock were more likely to allocate land and grow panicum forage for their livestock feed as well as have a chance to sell biomass and seed. Similar findings by Beshir (2014) suggest that livestock holding in tropical livestock units has a positive effect on the probability of adoption of improved forages due to the availability of cash to buy the technology, as livestock in agro-pastoral areas is considered an asset that could be used either in the production process or in exchange. Njarui *et al.* (2017) reported that a large herd of cattle requires a large amount of feed and an area allocation to grow forage.

Table 4: Determinants of adoption decision and intensity of adoption of improved panicum forage

Explanatory variables	Coefficients (standard error)		
	Adoption	Intensity of adoption	Average marginal effects
Sex (1=male)	0.630(0.404)	-0.180(0.069)***	-0.056(0.030)*
Age (years)	0.009(0.024)	-0.002(0.004)	-0.0005(0.002)
Education (years)	-0.196(0.109)*	0.018(0.023)	0.001(0.010)
Family size (number)	-0.038(0.065)	0.014(0.012)	.0049(0.0052)
Feed shortage (1=yes)	-0.413(0.336)	0.109(0.058)*	0.033(0.031)
Panicum forage production experience (years)	0.372(0.101)***	0.041(0.018)**	0.031(0.008)***
Panicum forage production cooperative membership (1=yes)	1.913(0.452)***	-0.016(0.061)	0.061(0.018) ***
Market price of panicum forage (ETB)	0.0016(0.0015)	0.0006(0.0003)**	0.0003(0.0001)**
Access to credit service (1=yes)	-	0.229(0.136)*	0.099(0.046)**
Distance to market center(minute)	-	-0.264(0.120)**	-0.114(0.032)***
Extension visit (1=yes)	0.008(0.013)	0.002(0.002)	0.001(0.001)
Access to irrigation water (1=yes)	0.054(0.017)***	0.003(0.002)	0.003(0.001)**
Livestock holding (TLU)	0.010(0.011)	0.005(0.0006)***	0.003(0.0006)***
Distance agro pastoral training center (minute)	-0.335(0.108)***	-0.021(0.017)	-0.021(0.008)***
Farm size (ha)	-0.529 (0.364)	0.111(0.089)	0.029(0.031)
Constant	-.677(0.961)	-0.017(0.187)	-
Number of observations	140		
Wald chi-squared (15)	163.55		
Probability chi-squared	0.0000		
Log pseudo likelihood	23.158		
Lnsigma			
Constant	-1.534(0.165)*		
/sigma	0.216(0.036)		
Model variance-covariance matrix of the estimators (VCE)		Robust	

Note: Selection and intensity models must differ at least in one explanatory variable in order to use Cragg hurdle regression. Thus, selection model did not include access to credit services or the distance to market center. Significant levels at 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

4. Conclusions and Recommendations

Improved panicum forage production is becoming an important vendor in livestock feed production systems and a source for income generation of agro-pastorals. Understanding how household characteristics and institutional and socioeconomic factors affect the adoption and intensity of improved panicum forage production in the area was very important. Access to irrigation water, market distance, and membership in cooperative were major factors for the production of the feed in the study site. According to the study results adoption decision for panicum forage production is influenced by access to irrigation water, the education level of household heads, experiences in panicum forage production, cooperative membership and distance to the training center. The intensity of adoption is influenced by feed shortage, sex of the respondents, credit access, distance to market or market information, experience in panicum forage production, prices of biomass and seed, and the number of livestock holdings. Working towards the improved accessibility of irrigation water, the establishment of cooperatives of agro-pastoralists, provision of credit opportunities and market information by responsible stakeholders are recommended to enhance the adoption and production of panicum forage in the study area.

Competing interests

Authors declare that there is no conflict of interest.

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