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Determinants of Adopting of Improved Sorghum Variety *(Assosa_1 & Adukara)* Under Smallholder Farmers in Metekel Zone, Benishangul Gumuz Region, North Western Ethiopia

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Abstract: **Sorghum (Sorghum bicolor) is a vital cereal crop, particularly for food security in arid and semi-arid regions. This study investigates the adoption determinants of improved sorghum varieties (Assosa-1 and Adukara) by smallholder farmers in the Metekel Zone, Benishangul-Gumuz Region, Northwestern Ethiopia. Employing a double-hurdle econometric model, the research analyzes primary and secondary data from 142 households sampled through multistage probability techniques. The findings reveal significant factors influencing both the decision to adopt and the extent of adoption, including access to credit, market access, proximity to cooperatives, sorghum yield, and total sorghum sold.**

Male-headed households, closer distance to cooperatives, and access to financial and extension services were positively correlated with adoption levels. However, challenges such as limited access to improved seeds, financial constraints, and inadequate market infrastructure hinder broader adoption. The study underscores the importance of addressing these barriers through targeted policy interventions to enhance sorghum productivity and farmer livelihoods. The findings contribute to understanding technology adoption dynamics in humid lowland agroecologies, offering insights for agricultural development and food security strategies.

Keywords: **Adoption, Improved Sorghum Variety, Metekel Zone, Double Hurdle Model.**

1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is a crucial crop for food security and industrial purposes, widely cultivated by smallholder farmers and investors alike (ATA, 2015-2020). Globally, it ranks as the fifth most significant cereal crop after maize, rice, wheat, and barley (FAO STAT, 2022). For centuries, smallholder farmers in sub-Saharan Africa and Asia have relied on sorghum as a staple food crop, valuing its adaptability to extreme conditions, including high temperatures, drought, and poor soil fertility. In Ethiopia, particularly in semi-arid regions like Tigray, Amhara, Somali, and Oromia, sorghum serves as a vital food source, animal feed, and a base for local beverages ((Solomon Assefa Derese, Hussein Shimelis, Mark Laing & Fentahum Mengistu, 2018). Over 500 million people in developing nations consume sorghum as a primary food source (Burke et al., 2013). It is a gluten-free grain that can be directly milled into flour, providing essential nutrients such as carbohydrates, protein, vitamins, and minerals (Taylor et al., 2006; Perazza et al., 2014) (Solomon Assefa Derese, Hussein Shimelis, Mark Laing & Fentahum Mengistu, 2018).

In Ethiopia, sorghum is widely cultivated and consumed, particularly in the arid, semi-arid, and humid lowlands. Its ability to thrive under challenging environmental conditions makes it a critical food security crop. According to CSA (2019), sorghum ranks third in area coverage and fourth in production, following maize, teff, and wheat. In the Benishangul-Gumuz region of Western Ethiopia, sorghum is predominantly grown as a rain-fed crop and serves as a staple food for smallholder farmers. The crop is second only to maize regarding area coverage and production, accounting for approximately 24.23% of grain production (CSA, 2022). Sorghum plays a vital role in local livelihoods, providing grain for foods like *injera*, bread, and porridge, while its stalks are used for livestock feed, fuel, and construction materials.

Research efforts by the Ethiopian Institute of Agricultural Research (2014) have focused on improving sorghum production by categorizing the country's sorghum-growing regions into four agroecologies: dry lowlands, humid lowlands, intermediate altitudes, and high elevations. Over the past four decades, more than 41 improved sorghum varieties have been developed for these diverse agroecologies. Breeding efforts in humid lowland regions such as Benishangul-Gumuz have targeted disease-resistant varieties suitable for high rainfall and humid conditions.

The Assosa and Pawe Agricultural Research Center has played a significant role in developing and disseminating improved sorghum varieties, specifically Assosa-1 and Adukara, released in 2014/15. These varieties have been promoted extensively to boost regional productivity, with coordinated efforts from development stakeholders since 2015.

Despite these efforts, limited research exists on adopting improved sorghum varieties in humid lowland areas. Factors influencing farmers' acceptance towards the newly released improved sorghum variety adapted to the humid lowland areas. While previous studies have examined adoption in dry lowland regions (e.g., Somali and Amhara), findings may not fully apply to humid lowland agroecologies due to differences in environmental and socio-economic conditions. For instance, the research conducted by (Mahdi Egge, 2012) stated that education, age, larger farm size, more shoat, and owning a radio positively affect adopting improved dry lowland sorghum varieties in the Somali regional states. Another research conducted in the arid and semiarid region Somali which is suitable for dry lowland sorghum variety production investigated by (Abdukerim Ahmed Mumed, Abdi Hassen Habib, 2023) on the Adoption of Improved Sorghum Variety (Melkam) and Its Impact on Household Food Security in Babile District, Eastern Ethiopia found that education, land holding, income, credit access, extension contact and membership of cooperative were positively influenced the adoption of improved sorghum variety. Moreover, (Solomon Assefa Derese, Hussein Shimelis, Mark Laing & Fentahum Mengistu, 2018) researched The Impact of drought on sorghum production, and farmer's varietal and trait preferences, in northeastern Ethiopia: implications for breeding only specified to the dry lowland improved sorghum variety which suitable to adopt drought, disease and gives higher yield. The research found recurrent droughts, Striga infestation, insects, birds, diseases, a lack of varieties with farmers-preferred traits and high yield potential, limited policy support, a lack of improved seed system, poor sorghum production practices and application of crop input, and poor soil fertility were the main constraints of sorghum production in the semiarid Eastern Amhara regional State. In addition to this, it examined that Severe drought in the post-flowering stage was the main sorghum production constraint in the study area. This research is limited to include all agroecology of the sorghum production practices including the humid lowland agro-ecology.

Even a few researchers recently focused on humid lowland agroecology. Some of them are the research conducted by (Abebe, 2024) conducted research on the determinants of adopting improved sorghum variety in the western Oromia regional state. The authors mainly found that some socio-economic factors like education and access to extension services were positively affected while animal holding in TLU negatively affected the adoption of improved sorghum variety in the western Oromia regional states.

Most of the research is conducted in the dry lowland agroecology and even the research conducted in the humid agroecology does not touch the same socio-economic, institutional, and demographic factors as well as the study area of the Metekel Zone. additionally, this research intended to investigate the determinants of adoption decision and extent of adoption of improved sorghum variety in humid lowlands. Furthermore, this research used a double hurdle model to investigate the adoption decision and extent of adoption which is the Tobit model is more restricted to identifying these factors

2. RESEARCH METHODOLOGY

Description of the study area

The study was conducted in two districts within the Benishangul Gumuz Regional State, Northwestern Ethiopia: **Pawe District** and **Dibate District**. Both districts are located in the northwestern part of Ethiopia, approximately 575 km and 547 km from Addis Ababa, respectively. Below is a detailed description of each study area:

Pawe District

Location: Pawe District is located at latitude of 11°09' N and a longitude of 36°03' E. It is bordered by Jawi District to the east and north, Mandura District to the south, and Dangur District to the west.

Area and Topography: The district covers a total area of 64,300 square kilometers, with 60% of the land characterized by gentle slopes. Approximately 50.4% of the total area is arable land, making it suitable for agricultural activities.

Climate: The district has an average altitude of 1,120 meters above sea level (m.a.s.l.). According to meteorological data from the Pawe Agricultural Research Center (PARC), the area experiences an average annual temperature of 32.7°C and receives an average annual rainfall of 1,582 mm over the past 30 years. Agro-ecologically, most of the district is classified as *kola* (lowland).

Agricultural System: The district practices a mixed-farming system dominated by grain and legume production. Major crops include cereals such as maize, finger millet, sorghum, rice, and teff, as well as pulses like soybean, groundnut, and sesame. These crops serve both as a source of income and for household consumption.

Land Use: In the 2021 cropping season, a total of 24,670 hectares of land were cultivated with various crops.

Population: The district has a total population of 67,862 (PDANRO, 2022) and comprises 20 rural kebeles, all of which are potential areas for sorghum production.

2. Dibate District

Location: Dibate District is located in the Metekel Zone of the Benishangul Gumuz Region, approximately 547 km northwest of Addis Ababa. It is situated at latitude of 10°39'00.48'' N and a longitude of 36°12'55.57'' E. The district is bordered by Guangua and Zigem districts to the east, Mandura district to the north, Yaso district to the south, and Bullen district to the west.

Area and Topography: The district covers a total area of 368,289 hectares, with altitudes ranging between 1,080 and 1,700 meters above sea level.

Climate: Dibate is characterized as a warm, humid lowland area with a unimodal rainfall pattern. The rainy season extends from May to October, with the district receiving an average annual rainfall of 1,175 mm. The mean annual temperature ranges from 15°C to 29°C, with extremes of 12°C to 32°C.

Agricultural System: Similar to Pawe, Dibate practices a mixed-farming system dominated by cereal and pulse crops. The district is known for its high rainfall and fertile land, making it suitable for agricultural production.

Population: The district has an estimated population of 67,227 inhabitants, with 50.80% being male (DDAO, 2022). It comprises 29 kebeles, all of which are rural and engaged in agricultural activities.

Both districts are agriculturally productive, with a focus on mixed farming systems that combine crop production and livestock rearing. The warm, humid climate and fertile soils make these areas suitable for the cultivation of a variety of crops, which are essential for both household consumption and income generation.

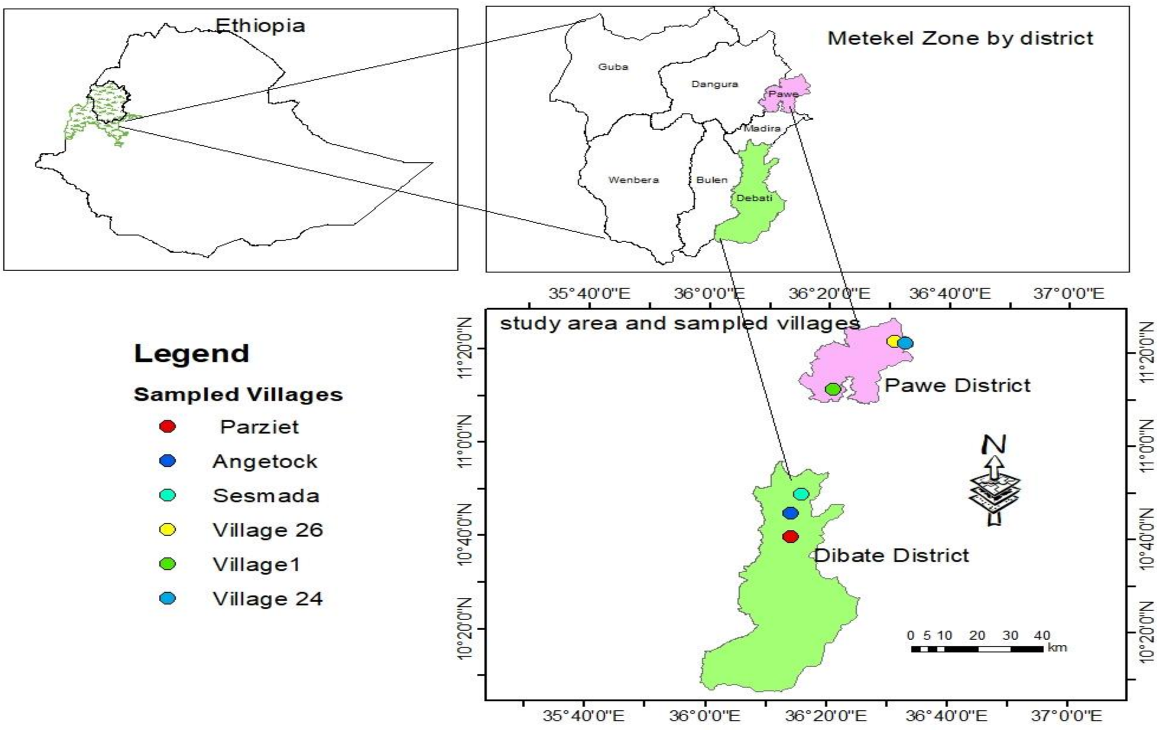

Figure 1: Map of the study area

Sample Size Determination and Sampling Techniques :

The study employed a multi-stage probability sampling approach. In the first stage, districts were randomly selected based on their similarity in sorghum production and agroecological characteristics. Using this criterion, Pawe and Dibate districts were randomly chosen from the Metekel zone in the Benishangul-Gumuz Regional State.

In the second stage, sorghum-producing kebeles (the smallest administrative units) in each district were listed and assigned consecutive serial numbers. From these lists, three kebeles were randomly selected from Pawe and another three from Dibate using a simple random sampling method.

In the third stage, smallholder sorghum producers within each selected kebele were listed and assigned consecutive serial numbers. Finally, smallholder farmers were selected using a systematic sampling method, with the sample size proportionate to the population size in each kebele. This ensured a representative and unbiased selection of participants for the study.

To determine the sample size factors like research budget, time, human resources, accessibility, and availability of technology users were considered. By considering these issues and using Cochran's (1977) formula the sample size is determined as follows.

$$\frac{Z^2\ (P\ Q)}{e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,

n - Is the number of sample size, Z - Is 95% confidence

p - Is 0.4 (proportion of the population to be included in the sample i.e 30%)

q – Is 0.6 proportion of the population not to be included in the sample i.e 60%)

e - Is the margin of error or degree of accuracy desired (0.05)

According to this formula, 142 sample households were taken from two districts. The sample distribution is illustrated as follows.

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Table 1: Selected Sample sorghum Producers by Districts and Kebeles

District	Kebele	Adoption Status		Total
		Adopter	Non-adopter	
Pawe	Village-26	13	11	24
	Village-24	9	14	23
	Village-1	11	10	21
Debate	Parziet	9	15	24
	Sesmandin	9	15	24
	Angetock	10	16	26
Metekel –zone Total				
Total				**142**

Source: (Survey data, 2022)

Types and method of data collection

The study used primary and secondary data collected through structured questionnaires and checklists respectively. Trained enumerators collected primary data from sample households of Rice producers through face-to-face interviews. In contrast, secondary data were collected from published and unpublished documents of zonal and district administrative offices. In addition to. this, personal observation, focus group discussion, and key informant interviews were conducted to support the interpretation of the results obtained from the field survey

3. METHOD OF DATA ANALYSIS

Microeconomic Background; Microeconomic theory helps explain farmers' decisions regarding adopting new technologies and highlights the factors that hinder these decisions. Most adoption studies employ the **random** utility framework, which assumes that decision-makers consider a discrete set of options and choose the one that maximizes their expected utility. Regarding technology adoption, farmers select the option that offers the greatest utility under their specific conditions.

However, adopting new technology, such as improved crop varieties, is often a two-stage decision-making process:

1. The decision to adopt or not (binary choice).
2. The extent of adoption (continuous decision), refers to how much of the technology is adopted.

This paper extends the traditional framework by incorporating both dimensions of adoption. The extent of adoption is treated as a **continuous variable** that is constrained at zero (i.e., non-adopters).

A household utility function can be expressed as

$U = U(A,X,Z)$

where:

- A is the extent of adoption (≥ 0),
- X is a set of decision variables,
- Z represents external conditions,

Households maximize their expected utility based on their limited knowledge of how decisions affect outcomes. Thus, the optimal extent of adoption (A^*) depends on external factors, household preferences, and available information:

$A^* = f(Z, W, M)$ where M represents the household's available information

In this model:

- $A^*=0$: Non-adoption is optimal given the constraints and preferences.
- $A^*>0$: Partial or full adoption is optimal.

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This approach used to separately analyze the means of the **adoption decision** and the **extent of adoption**.

Econometric Specification

To analyze the adoption of improved Sorghum varieties, many studies traditionally use **probit** or **logit** models for binary decisions (adopt or not). In contrast, **Tobit models** are often applied when the technology is divisible. However, the Tobit model assumes that the same factors influence the decision to adopt and the extent of adoption, which may not always hold. Hence, This Research use the Double-Hurdle Model (DHM) developed by Cragg (1971) to address this limitation.

The Double-Hurdle Model allows for a two-stage decision process:

1. **The first stage** examines whether a household adopts the technology (binary decision).
2. **The second stage** analyzes the extent of adoption (continuous decision) among those who adopt.

The first stage is modeled using a **probit regression**:

$D_i^* = \theta Z + \mu$ $\quad$ $D_i = \{1 = \text{IF } D_i^* > 0, 0 \text{ otherwise}$

Where D_i^* = is the latent variable representing the HH’s likelihood to adopt

Z_i = is the set of explanatory variables θ_i = represents coefficients to be estimated

μi is a random error term

The second stage uses a **truncated regression** to model the extent of adoption (A_i^*):

$A_i^* = \beta X_i + \varepsilon_i$

Where:

- A_i^* is the latent extent of adoption,
- X_i is the set of explanatory variables influencing the extent of adoption,
- β_i is the vector of coefficients,
- ε_i is a random error term.

The DHM assumes that the error terms (are independent, meaning $COV(u,\epsilon) = 0$.

The DHM is advantageous because it allows for:

- Different factors (Zi and Xi) influence the two decisions (adoption and extent),
- Separate effects of the same variables in each decision stage ($\theta \neq \beta$).

For comparison and robustness, we also estimate a **Tobit model**, which assumes a single decision-making process. However, the DHM is preferred because it relaxes the restrictive assumptions of the Tobit model, providing more consistent estimates when adoption decisions involve two distinct stages.

In this study:

- **The binary decision to adopt** is indicated by whether a farmer uses improved sunflower seeds (certified or QDS).
- **The extent of adoption** is measured the improved sorghum variety covered area divided by total sorghum area cultivated.

4. RESULT AND DISCUSSION

Characterization of Sample Sorghum Producers in North Western Ethiopia

Sex of Household head: The majority of the households in the sample (92.25%) were headed by males, while 7.75% were led by females. The chi2 test does not show a statistical significance. It implies there is no association between adopting of improved sorghum variety and Sex of Household head.

The Number of extensions Contact: development agents are the key bridges to create awareness, demand, and transfer of newly released agricultural technologies to smallholder farmers. they scheduled timetable and contact smallholder farmers to advise on improved agricultural technologies and disbursements. Most of the time they advised weekly. Most of the sample households responded that they got agricultural services twice per week. Most of the adopters were got agricultural service twice per month. The chi2 test showed a statistical significance at a 5% probability level. It implies there is an association between adopting of improved sorghum variety and extension contact.

Method of Weeding: The sample household used both weeding and spraying chemicals to control weeds in their sorghum farmland. 59.86% of the sample households used the hand weeding method to control weeds in the sorghum farmland which is 51.61% and 66.25% of the adopters and non-adopters used the hand weeding system of weed control method. The rest 40.14% of the sample households used chemicals to control weeds. The chi2 test showed a statistical significance at a 10% probability level. It implies there is an association between adopting of improved sorghum variety and the method of weeding.

Source of Labor: 90.14% of the sample households used their family labor for different agricultural farming activities such as cleaning, plowing, weeding harvesting, threshing, and transportation of the sorghum output gained. Only 9.86% of the sample households use family and hired labor. The chi2 statistics showed statistical significance at a 5% probability level. It indicated an association between adopting improved sorghum variety and the source of labor.

Use of Improved inputs and Agronomic Practices: Rural households used improved seeds, inorganic and inorganic fertilizer, best agronomic practices like row planting, and chemicals to control weeds, to decrease nutrient competition among plants to increase production. However, as the respondents reported, only 2.82% of sample respondents' used row planting, 5% of them used organic fertilizer and sample respondents used inorganic fertilizer. The adopters and non-adopters used few inorganic fertilizers due to the shortage of inorganic fertilizers in the zone as a consequence of civil violations in the zone. The low rate of inorganic fertilizer usage in sorghum production by both adopters and non-adopters. The only improved technology they introduced in sorghum production is the use of improved sorghum variety (**Assosa-1 and Adukara**)

Educational Level: - on average the adopter of improved sorghum varieties completed 6.4 classes whereas the non-adopters completed 4.5 classes. This showed at a 1% probability level, this difference was statistically significance. The descriptive statistics revealed that the adopters of improved sorghum varieties are more educated than the non-adopters. The result is in line with (Abdukerim Ahmed Mumed, Abdi Hassen Habib, 2023) but the opposite of (Abebe Dagnew, 2023)

Sorghum Farming Experience: - the average sorghum farm experience of adopters and non-adopters is 9.27 and 6.78 years respectively. There are two years of sorghum farm experience difference between them. The difference is statistically significance at 1% of probability level. This indicated that adopter of improved sorghum varieties had more experience in sorghum farming than their counterfactual. The result is in line with (Abebe Dagnew, 2023)

Distance to Cooperative: The whole sample travels 24.04 minute while adopters and non-adopters traveled 18.18 and 28.58 minute respectively to receive an improved agricultural technology such as improved seeds, credits from cooperatives and other related information. This indicated most of the adopters are found nearest to the agricultural cooperative office. The nearest to agricultural cooperative had an advantageous to easily accessible information on time and transported with least costs to their residency. The t-test showed statistical significance at 1% of probability level.

Livestock in TLU: owning and rearing of livestock have an advantageous on earning additional income by selling some of the animals. This in turn solve the smallholder farmers shortage of money for improved agricultural inputs and labor costs at peak agricultural time. The more livestock owned, the more probability of adopting agricultural inputs. On average the sample households owned a livestock of 4.41 while 5.18 and 3.82 of livestock in TLU owned by the adopters and non-adopters respectively. The t-test showed statistical difference at 10% between adopters and non-adopters. The adopters had more livestock in TLU than the non-adopters. The result is in line with abebe **dagnew**

Yield and Total Sold sorghum Outputs: On average the sample households produced 12.13 quintal yield of per hectare while adopters and non-adopters produced 16.26 and 8.94 qt/ha respectively. The average productivity of sorghum is below the average productivity of the region which is 21 qt/ha CSA. Sample households responds that they sell some portion of their sorghum outputs to bought industrial materials, pay agricultural input costs, labor costs and bought cloths to their family. The sample household sold 4.15 quintal on average while adopters and non-adopters sold 5.42 and 3.16 quintal of sorghum respectively. The t-test showed adopters were produced more sorghum yield and sold more of sorghum output than the non-adopters. It is statistically significance at 1% and 5% of probability level. The result is in line with abebe **dagnew**

Table 2: Equality Association tests of dummy and discrete variables

Variable	Adopter	Non-Adopter	Whole	Chi²
	Frequency	Frequency	Frequency	
Sex HH	**62**	**80**	**142**	**0.57**
Male	**56**	**75**	**131**	
Female	**6**	**5**	**11**	
Market Access				**0.21**
Good	**18**	**21**	**39**	
Medium	**28**	**36**	**64**	
Poor	**16**	**23**	**39**	
Credit Access				**0.25**
Yes	**14**	**21**	**35**	
No	**48**	**59**	**107**	
Number of Extension Contact				**13.74*** **
Weekly	**5**	**4**	**9**	
Twice per Month	**15**	**16**	**31**	
Once per Month	**12**	**3**	**15**	
Use of Organic Fertilizer				0.002
Yes	3	4	7	
Use of Inorganic Fertilizer				-
No	62	80	142	
Method of Planting				1.64
Row Planting	3	1	4	1.64
Broadcasting	59	79	138	
Method of Weeding				3.11*
Hand Weeding	32	53	85	
Spraying Chemicals	30	27	57	
Source of Labor				5.45**
Family	60	68	128	
Both Family and hired	2	12	14	

Source: (Survey data, 2022)

Table 3: Equality Mean Test for Improved Sorghum Variety Producers

Variable	Adopter		Non-Adopter		Whole		T-Value
	Mean	Std. Err	Mean	Std. Err	Mean	Std. Err	
Extent of Adoption	**0.41**	**0.034**	**0**	**0**	**0.18**	**.023**	**13.75*** **
Age HH	42.45	1.28	40.13	1.24	41.14	0.90	-1.29
Edu HH	**6.40**	**0.39**	**4.51**	**0.44**	**5.34**	**0.31**	**3.14*** **
Family Size	3.34	021	2.99	0.17	3.14	0.13	-1.32
Sorghum Farm Experience	**9.27**	**0.95**	**6.78**	**0.56**	**7.87**	**0.53**	**2.39*** **
Distance to **Cooperative**	**18.18**	**3.49**	**28.58**	**4.48**	**24.04**	**2.97**	**-1.75***
Distance to FTC	12.64	2.12	14.14	1.47	13.49	1.24	0.59
Land Size	4.26	0.16	4.23	0.13	4.24	0.10	-0.16
Total Sold	**5.42**	**0.69**	**3.16**	**0.32**	**4.15**	**0.36**	**3.18*** **
TLU	**5.18**	**0.64**	**3.82**	**0.36**	**4.41**	**0.35**	**1.96*** *
Yield	**16.26**	**2.00**	**8.94**	**0.83**	**12.13**	**1.03**	**3.68*** *

Source: (Survey data, 2022)

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Explanatory variables influence the improved Sorghum Variety decision to adopt and the extent of adoption in Northwestern Ethiopia.

The first Double Hurdle Model (DHM) regression showed the factors that affected the decision to adopt the improved sorghum variety or not to adopt and the level of adopting the improved sorghum variety in terms of improve sorghum variety total area covered by improved sorghum variety out of the total area sown in sorghum. The research tries to analyze by running the first DHM regression and got the sex of household head, distance to the cooperative and agricultural office, market access, yield, and total sold of sorghum output affects the decision much of cultivated land will be allocated for sorghum production.

The decision to adopt the improved sorghum variety is influenced by yield, and total sold of sorghum output.

Sex of Household head: being male of the household head influences deciding how much improved agricultural inputs are used for their cultivated land as well as which crop will be sown. The rural household heads have full responsibility for cultivate their farm land, and experience which crop is suitable for a particular land. As head of the family, he is exposed to different socio-economic experience sharing, training, and field days that capacitated his decision-making. The first result of the double hurdle model regression showed a male influence how much of improved sorghum varieties in kg to use.

Distance to Cooperative and Farmer Training Center: The distance from the sample household's residence and Keble Cooperative and FTC office affects the smallholder farmers and how many amounts of improved seed will be used. The nearest households have the advantage of using enough amount of improved sorghum variety than the furthest. This is due to transport costs and associated lumpsum costs.

Total Yield and Sold of Sorghum Output: The amount of sorghum yield produced per given hectare of the land influences the adopters to decide how much of the improved sorghum variety will be used as well as how much-cultivated land will be allocated for sorghum production. The amount of sorghum output sold influence positively how much seed would be used. The double hurdle model regression showed sorghum yield produced and sold influences the extent of adopting improved sorghum variety at a 5% probability level.

Access to credit: The amount of credit borrowed from financial institutions influences the decision of how much-improved sorghum variety in kg to use. Access to financial services especially at the peak of the agricultural period solves the rural household's financial constraints which can bough the required amount of improved Agricultural inputs including improved seeds. The double hurdle model regression showed access to credit influences the extent of adopting improved sorghum variety at a 1% probability level.

Market Access: The market is a place where buyers and sellers meet together to sell and buy goods and services they want. The market creates a great opportunity for surplus producers to supply their agricultural outputs and earn a profit. An efficient market benefits both buyers and sellers. As result the market is also sustainable for a long time. Hence good Market access influences how much-improved seed to use to produce more output for the next year. The double hurdle model regression output indicated that access to market influences the extent of adopting improved sorghum variety at a 1% probability level.

Both the decision to adopt and the extent of improved sorghum variety adoption influenced by the market access and total sold of sorghum output effects.

Double Hurdle Regression Model

Number of observations = 142

LR Chi2(12) = 200.72

Prob> = 0.000

Pseudo R2 = 0.5204

Log-likelihood = 92.51

Table 4: Extent of Adoption decision of improved sorghum Variety

Variables	Coefficient	Std. err	Z Value	P>|Z|
Sorghum Cultivated in Ha				
Age HH	-0.01	0.01	-0.84	0.4
Sex HH	**0.37**	**0.17**	**2.20****	**0.03**
Family Size	0.02	0.06	0.44	0.7
Distance to Cooperative	**-0.01**	**0.002**	**-2.23****	**0.03**
Access to Credit	**0.38**	**0.13**	**3.02****	**0.003**
Distance to Extension	**-0.01**	**0.004**	**-2.11****	**0.04**
Market Access	**0.21**	**0.08**	**2.73*****	**0.01**
Extension Contact	0.16	0.13	1.21	0.23
Edu HH	0.02	0.02	0.99	0.32
Total Sold	**0.19**	**0.013**	**14.40*****	**0.000**
Yield	**0.01**	**0.004**	**3.23*****	**0.001**
Sorghum Farm experience	0.01	0.009	0.8	0.43
Constant	0.18	0.35	0.52	0.60
Selection_ll	**Adoption decision equation**			
Land Size	0.06	0.12	0.51	0.60
Yield	0.01	0.02	0.38	0.70
TLU	-0.02	0.04	-0.5	0.60
Market Access	**0.65**	**0.22**	**2.92*****	**0.003**
Total Sold	**0.42**	**0.10**	**4.30*****	**0.000**
Sorghum Farm experience	-0.03	0.03	-1.00	0.32
Distance to Main Road	0.06	0.05	1.08	0.28
Constant	-1.33	0.94	1.41	0.16
Sigma/σ/	**-0.7976**	**0.0833**	**-9.58*****	**0.000**

Determinants of Adopting Improve Sorghum Variety in Northwestern Ethiopia:

The research is tied to identifying the factors that promote and hinder the adoption of improving sorghum variety in Northwestern Ethiopia, particularly Metekel Zone Benshangul Gumuz regional state. The Double Hurdle Two Stage estimation was used to identify the factors that determine the adoption rate of improved sorghum variety in Northwestern Ethiopia. According to the DHM output, Access to credit, distance to the agricultural office, market access, yield and total sold of sorghum outputs are the factors that positively influence the extent of adopting improved sorghum variety. In contrast, the sex of household heads influenced negatively. Each of the variables is described as follows

Sex of Household head: being male of the household head influences deciding how much improved agricultural inputs are used on their cultivated land and which crop will be sown. The rural household heads are responsible for cultivated their farmland, and experiencing which crop is suitable for a particular land. As head of the family, he is exposed to different socio-economic experiences sharing, training, and field days that capacitated his decision-making. The second stage of double hurdle model regression showed male-headed households determine the extent of adopting improved sorghum variety at a 5% probability level. The marginal effect tells us, that being a male has a 21.4% increment of the probability of adopting improved sorghum variety. The result is the same as [7].

Access to credit: - Credit solves farmers' shortage of liquidity of money particularly at peak agricultural time when labor is scarce and purchasing all agricultural inputs by own capital only at the same time is difficult**.** Supply money to smallholder farmers is crucial at agricultural peak time to purchase improved agricultural technologies like inorganic fertilizer, improved seeds, and farm tools. As a result, access to credit influenced the adoption of improved sorghum variety positively and statistically significantly at 1%. The marginal effect tells us, that access to credit has a 22% increment of the probability of adopting improved sorghum variety the result is the same as [7].

Access to Extension: - Currently there are three development agents per keble to consult, facilitate technology adoption, and help technical how to implement the technology at the farm level to smallholder farmers. except for socioeconomic problems, most smallholder farmers are willing to adopt more than one technology per cropping season. Consequently, access to extension services influences the adoption of improved sorghum variety positively and statistically significant at 5%. The marginal effect tells us, that access to extension has a 4% increment of the probability of adopting improved sorghum variety. The result is in line with [5] , [13]and [17], and [9]

Distance to Cooperative: - The distance between agricultural input suppliers and sample households negatively affects the timely accessibility of improved sorghum variety in rural Ethiopia. As a result, the amount of seed will be exhausted before he comes and takes improved technologies. In other words, sample households did not get information on time and the time of improved technology distribution was passed them. Distance to cooperatives influenced the adoption of improved agricultural technologies negatively and statistically significant at 5%. The marginal effect tells us, that distance to the cooperative has 0.3% decreased the probability of adopting improved sorghum variety. The result is in line with [9] .

Total Yield and Sold of Sorghum Output: The amount of sorghum yield produced per given hectare of land influences the adopters to decide how much of the improved sorghum variety will be used as well as how much cultivated land will be allocated for sorghum production. The amount of sorghum output sold in turn affects positively how much seed will be used. The double hurdle model regression showed total sorghum yield and sold has an influence on extent of adopting improved sorghum variety at 1% of probability level. The marginal effect tells us, that total sold has a 15.2% increment of the probability of adopting improved sorghum variety while yield of sorghum has 0.8% increment of the probability of adopting improved sorghum variety the result is the same as [7].

Market Access: Market is the place where buyers and seller met together to sell and buy goods and service that they want. Market create great opportunity for surplus producers to supply their agricultural outputs and earn a profit. Efficient market benefits both buyers and sellers as well as the market sustainable for long time. Hence good Market access has an influence of how much of improved seed to use to produce more output for the next year. The double hurdle model regression showed market access has an influence on extent of adopting improved sorghum variety at 1% of probability level. The marginal effect tells us, that market access has a 18.83% increment of the probability of adopting improved sorghum variety. The result is the same as [7].

Table 5: Average Marginal Effects

Variables	Coefficient	Std. err	Z Value	P>|Z|
Sorghum Cultivated in Ha				
Age HH	-0.004	0.005	-0.85	0.4
Sex HH	**-0.214**	**0.096**	**-2.23****	**0.03**
Family Size	0.014	0.032	0.44	0.66
Distance to Cooperative	**-0.003**	**0.001**	**2.26****	**0.02**
Access Credit	**0.22**	**0.072**	**3.07*****	**0.002**
Access to Extension	**0.04**	**0.002**	**2.12****	**0.03**
Market Access	**0.1883**	**0.049**	**3.88*****	**0.000**
Extension Contact	0.926	0.077	1.21	0.23
Edu HH	0.009	0.009	1.00	0.32
Total Sold	**0.152**	**0.01**	**16.95*****	**0.000**
Yield	**0.008**	**0.003**	**2.78*****	**0.006**
Sorghum Farm Experience	0.001	0.007	0.19	0.85
Land Size	0.006	0.012	0.51	0.61
TLU	-0.002	0.004	-0.50	0.61
Distance to Main Road	0.006	0.005	1.08	0.28

Source: (Survey data, 2022)

Opportunity and Challenges of Sorghum Cultivation

Cereal crops have diverse advantageous on rural household economy. They cultivated to fulfil their family calorie demand and money shortage. Sorghum is the main staple crop in the humid lowland agroecologies, Metekel zone, Benshangul Gumuz regional State. Sample households cultivated sorghum main for home consumption and source of income. The sample households reported that cultivation of sorghum has an opportunity of market and fair price in the local and district markets. However, they faced different challenges to expand the sorghum cultivation and adopting of improved sorghum varieties. The improved sorghum seed inaccessibility, amount of delivered and flock of birds are among the major challenges in Metekel zone, Benishangul Gumuz regional State.

Table 6: Opportunity and Challenges of Sorghum Cultivation

Variable	Adopter	Non-Adopter	Whole	Chi^2
	Frequency	Frequency	Frequency	
Opportunity				**0.81**
Good price	**50**	**69**	**119**	
Marketable product	**12**	**11**	**23**	
Challenges				**0.29**
Improve seed inaccessible	**36**	**50**	**86**	
Flock of birds	**26**	**30**	**56**	

Source: (Survey data, 2022)

5. CONCLUSION

The adoption of improved sorghum varieties (Assosa-1 and Adukara) in the Metekel Zone, Benishangul-Gumuz Region, has been influenced by a complex interplay of socio-economic, institutional, and environmental factors. This study highlights that access to credit, proximity to cooperatives and extension services, market access, and total sorghum yield are critical determinants of both the decision to adopt and the extent of adoption among smallholder farmers.

Male-headed households are more likely to adopt improved sorghum varieties, leveraging their exposure to training and socio-economic experiences. Closer distances to cooperatives and agricultural extension offices facilitate timely access to inputs, reducing costs and logistical barriers. Access to credit alleviates financial constraints, enabling farmers to invest in improved seeds and other necessary agricultural inputs. Furthermore, better market access encourages farmers to adopt improved varieties by providing incentives for increased production through better price opportunities.

However, the study also identifies significant challenges that hinder widespread adoption. These include limited availability of improved seeds, lack of financial resources, inadequate extension services, and infrastructural limitations. Additionally, socio-economic disparities, such as educational attainment and farm experience, also play a role in adoption rates.

The findings emphasize the need for targeted policy interventions to improve adoption rates. Strengthening extension services, enhancing access to financial resources, promoting efficient input distribution systems, and investing in market infrastructure can significantly boost the adoption of improved sorghum varieties. Addressing these challenges will not only enhance sorghum productivity but also contribute to improved livelihoods and food security in the region.

In conclusion, while progress has been made in introducing improved sorghum varieties, a concerted effort by policymakers, researchers, and development stakeholders is required to address the existing barriers and unlock the full potential of these technologies for smallholder farmers in humid lowland agro ecologies

6. RECOMMENDATIONS

To enhance the adoption and extent of adoption of improved sorghum varieties in the Metekel Zone, several targeted actions are recommended:

Enhance Access to Credit Services: Facilitate the establishment of rural financial institutions and cooperative credit programs to address the financial constraints faced by smallholder farmers. Introduce tailored financial products, such as low-interest loans and flexible repayment plans, specifically designed for agricultural inputs like improved seeds and fertilizers.

Strengthen Agricultural Extension Services: Increase the number of extension agents and ensure their capacity is enhanced through training on modern agricultural practices. Encourage regular and structured interactions between extension agents and farmers to improve awareness and understanding of the benefits of adopting improved sorghum varieties.

Improve Seed Distribution Systems: Strengthen the supply chain for improved sorghum seeds by establishing decentralized seed distribution points in proximity to farming communities. Ensure a consistent and timely supply of high-quality seeds to meet the demand of smallholder farmers.

Invest in Infrastructure Development: Improve road networks and transportation systems to enhance access to agricultural cooperatives and markets. Develop storage facilities to reduce post-harvest losses and maintain the quality of sorghum outputs.

Promote Market Access and Value Chain Development: Establish market linkages between farmers and buyers to create sustainable and reliable outlets for sorghum production. Support farmers in organizing cooperatives or unions to strengthen their bargaining power and access better market opportunities.

Encourage Gender-Inclusive Policies: Develop programs aimed at supporting female-headed households to overcome specific barriers to adoption, including access to resources, training, and extension services. Address socio-cultural constraints that limit the participation of women in decision-making and agricultural activities.

Focus on Farmer Training and Capacity Building: Organize field demonstrations and training sessions on the benefits and proper use of improved sorghum varieties. Promote farmer-to-farmer knowledge sharing to accelerate the diffusion of technology adoption.

Support Research and Development: Continue breeding efforts to develop varieties with traits preferred by farmers, such as high yield, disease resistance, and adaptability to local conditions. Conduct further studies to evaluate the long-term impacts of adopting improved sorghum varieties on household food security and livelihoods.

Address Challenges of Input Accessibility: Develop strategies to mitigate the impact of distance from cooperatives and input suppliers, such as mobile input delivery systems. Ensure adequate planning and resource allocation to address seasonal shortages of inputs like fertilizers and seeds. By implementing these recommendations, stakeholders, including policymakers, researchers, and development partners, can create an enabling environment that supports the widespread adoption of improved sorghum varieties, thereby enhancing productivity, food security, and rural livelihoods in the region.

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