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Research Article

Pre-extension demonstration of ploughing dimension in sweet potato (*Ipomoea batatas* L.) cultivation at Laska Zuria district, Basketo Zone of South Ethiopia

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Abstract

In sweet potato cultivation, the land preparation method plays a significant role in yield improvement and soil and water conservation. Depending on their experiences, farmers continuously use vertical ploughing dimensions for sweet potato cultivation without clear justification in the Basketo Zone without considering its long term impact. The aim of the study was to show the comparative advantage of applying ploughing dimensions on sweet potato cultivation at farm land measured with a moderate slope 10-15%s of Laska Zuria district of Basketo Zone in the 2024 Belg cropping season. A total of 12 trial farmers were selected from two sweet potato growing kebeles. The selected trial farmers prepared their farmlands in vertical and horizontal ploughing dimensions. Locally adapted sweet potato (FAO) was used as a test crop. Spacing of 60 cm between rows and 30 cm between plants with a seed rate of 55,555 cuttings per hectare, stem cutting length of 25 cm, and a plot size of 200m^2 in each ploughing dimensions was used. A thick geo-membrane plastic sheet was used to collect eroded soil particles. A total of 42 participants took part in training from 2 kebeles. Agronomic data were collected and analyzed using the mean. Other social data were collected using focus group discussion. A sweet potato yields 12.5 and 14 t/ ha of vertical and horizontal ploughing dimensions, respectively, and yield advantage of 12 % per hectare and mean annual soil losses reduced to 21.6% (6.5 t/ha) in horizontal ploughing dimension. The result revealed that the practice of vertical ploughing increases soil loss where farmers commonly set rows parallel to slope direction. This means the rainwater may take soil sediment and increase the water lodging condition. Accordingly, the farmer's first preference was implementing horizontal ploughing on their farm land in terms of fewer occurrences of flood and good root yield and better soil and water conservation. Thus, the horizontal ploughing dimension of the land preparation method can be recommended to increase the yield of sweet potato and conserve soil in the study area and similar land settings.

Keywords: Demonstration ratio; Horizontal ploughing; Moderate slope; Root yield; Soil loss; Vertical ploughing

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1. Introduction

Sweet potato is one of the most valuable root crops cultivated for various purposes in warm temperate, tropical, and sub-tropical regions of the world (Abebe et al., 2023).Although the actual origin of sweet potatoes is unknown, it is thought to have originated in Mexico and the United States of America (Silva et al., 2015).The greatest diversity was discovered in Central America using molecular markers, confirming the theory that this region is the main center of diversity and most likely the origin of sweet potatoes (Huang and Sun, 2000). Globally China is the leading sweet potato producing country with production of 70,963,630 metric tons, followed by Nigeria (3,478,270), Tanzania (3,345,170) and Ethiopia (2,701,599) metric tones. China contributes annually more than half of the world's total sweet potato production for the world (Fekadu et al., 2015).

Sweet potatoes rank fifth in Africa after rice, Wheat, Maize, Potato, Barley, and Cassava, making it one of the most important crops in the world (Laban et al., 2015, Low etal.,2017).Sweet potatoes are significant in the context of African agricultural systems because they yield quickly and provide urban dwellers with an additional food source in the face of rising grain costs. Africa produces about 7 million tons of sweet potatoes annually, 5% of the world's total. It is primarily grown in highland regions of Indonesia (Asmara et al.,2022; Hidayah et al., 2017; Awang et al., 2021).

In Ethiopia, sweet potato is widely grown in the South, South Western and Eastern parts by small-scale farmers with limited land, labour and capital. Ethiopia is one of the largest sweet potato-producing countries in the world. Rainfall is erosive in Ethiopia, and water-induced soil erosion is a significant environmental problem (Gurmu et al., 2024; Ejigu et al., 2025). A quarter of the highland region is thought to have been severely eroded. In Ethiopia's rural areas, most farmers focus on subsistence farming, growing poor soils on marginal and sloppy ground that is vulnerable to soil erosion and other degrading factors. The sustainability and suitability of the soil for the production of sweet potatoes and other crops are seriously threatened by the pressure of heavy human activity and poor farming and management techniques as a result of poor extension system (Jan & Graham, 2020). In Southern part of Ethiopia, sweet potato cultivation is common production system. However, because farmers typically lay the potato bed's ridge parallel to the slope direction (vertical ploughing dimension), these farming techniques may put the land at significant risk for soil erosion (Henny et al., 2011, Muliastuty, 2015). It's found that when sweet potatoes were planted up and down on an 11% slope, the 3-year annual seasonal soil loss rates on 10-by-30-meter plots were 24.3 tons per hectare (Tamad et al., 2023). In a 3.54-hectare drainage basin with an average slope of 5% under a barley/rye grass potato-potato-barley-potato cycle the production of the crop is low. 62% of farmers believed that vertical ploughing dimension decreased crop productivity (Dan et al., 2013).It has been shown that a horizontal ploughing dimension system, in which the sweet potato bed ridge is positioned across the slope direction, can reduce soil erosion in place of this vertical ploughing system (Wijaya & Masrukhi, 2020). The applied horizontal ploughing dimension had no effect on the production of sweet potatoes is good but yield dropped by almost 23% (Henny et al., 2011, Jiang et al., 2024).This is due to the fact that sweet potato beds are typically planted in rows parallel to the slope rather than across it, which increases the danger of soil erosion and soil loss. Similarly, at the Basketo zones of South Ethiopia, depending on their experiences, farmers cultivate sweet potatoes on steep slopes using vertical ploughing dimension without a clear regarding the long term effect of the practice.Threfore, the objective of this study was to show the comparative advantage of horizontal ploughing dimension over vertical ploughing dimension, to investigate farmers preference at farmers condition at midland areas of Basketo zone South Ethiopia.

2. Materials and Method

2.1 Description of the study area

The research was conducted at Laska zuria district, among the sweet potato potential districts of South Ethiopia, in the 2024 Belg cropping season. The latitude and latitude and longitude of the experimental site is 62500N and 365833 E respectively (Figure 1). The altitude of the experimental site ranges from 780 to 2200 meters above sea level. The mean annual rainfall of the district is 1200 mm, with an average temperature of 21ºC, which is considered suitable rainfall for sweet potato production. The district has 3 agro ecologies: 32.35% lowland, 61.76% midland, and 5.88% lowland. The topography of Laska zuria District is characterized by slightly undulating from hill-tops towards rivers, with its slope ranging from 3 to 8%. Most of the farmlands are relatively moderate slopes, with an average of 10-15%, which is easily exposed to soil erosion. The total land use type by hectare includes: 27,639.79 of cultivated land, 6190.55 of cultivable land, and 932.48 of grazing land, 2,543.9 of forest, and 3,142 of swamp. The soils of the district are 18% clay, 52% loam, and 30% sand in all agro ecologies (FAO, 2012). The type of soil on which the demonstration was conducted is vertisol. Conventional ploughing using hand tools and 2 oxen-driven were common practices used to grow crops. All operations, such as land preparation, sowing, and harvesting, are operated by manpower. The major crops grown in the area include Maize, Teff, Wheat, Ginger, Coffee, Sesame, Common bean, Sorghum, Onion, Sweet potato, Cassava, Taro, and Enset.

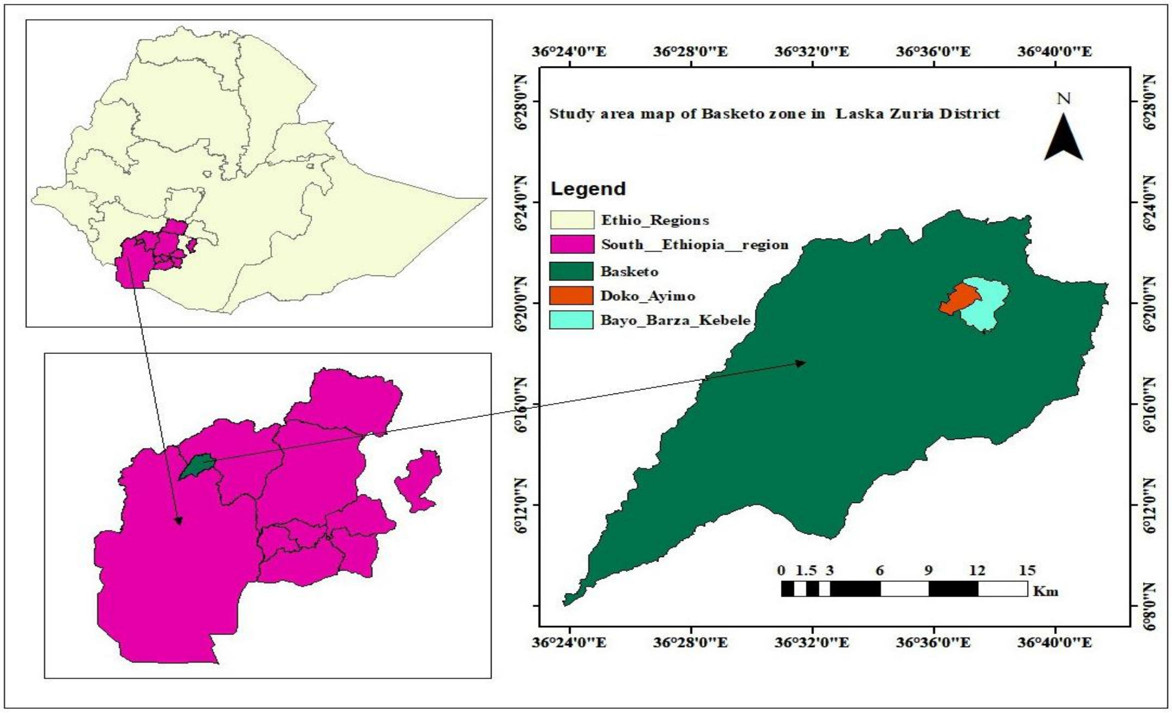

Figure 1. Map of the study area

2.2. Site and farmers selection

Laska zuria district was selected based on potential of sweet potato and the topography of the area, because of the identified problem in soil loss due to a lack of sustainable land management practices. Similarly, two potential Kebele, namely Doka Ayima and Bayo-Barza, were purposively selected based on their slope and potential to cultivate sweet potato. A total of 12 farmers were selected based on the farmland measured with a moderate slope 10-15% based on FAO (2012) slope categorization, and willingness to implement the activity (Table 1).

Table 1. Number of farmers field selected for the experment

Kebele	Demonstrated variety	Ploughing dimension	Plot size	No of farmers
Doka Ayima	Locallly adapted	Vertical and horizontal	10 x 20 m	6
Bayo Boreza	Locally adapted	Vertical and horizontal	10 x 20 m	6

2.3. Approaches used to implement the experiment

For the experiment, multidisciplinary approaches were used. Target farmers contributed land preparation and other farm operations, applied all packages according to manuals, participate in visiting and make others to visit his/her field during field days, transfer relevant technology related information to other farmers.Basketo Zone,Laska Zuria District and respective Kebele office of Agriculture organizations assigned an expert as a contact person who closely follow up the implementation of the tasks, make monitoring and evaluation at different levels and record all important data during the process, facilitate ways for farmers to get sufficient fertilizers, collect all required data and transfer for responsible bodies, participate in preparation of small meetings and field days. Agricultural Technology Transfer and Communication Researchers from the Arba Minch Agricultural Research Center and researchers from the Directorate of natural resource were fully involved in all stages from the development of the activities to the results. Extension materials like banners, posters, brochures, leaflets were used during the field day.

2.4 Capacity building training

One of the best methods utilized in technology transfer is training. Training and field day can boost farmers knowledge and skill (Kebede et al., 2023).Training was given to the farmers and stake holders in order to create demand of the technologies that fit the environments, the needs, and realities of the farmers with the full packages, there by increasing the relevance of extension messages to the farmers' conditions through helping them acquire knowledge and skills of sweet potato production, management practices and ploughing dimensions. A theoretical training session was given for farmers and other stake holders like Development Agents, district level Subject Matter Specialists, Kebele adminstratives at the demonstration site. A multidisciplinary team of researchers from the Arba Minch Agricultural Research Centre gave training on the following topics: land preparation, incise geomembrane plastic, planting, weed and pest management, and post-harvest handling. Different extension materials were prepared and distributed for the participants. For those individuals, 20 leaflets and 10 small training manuals on the technology, which are organized in the Amharic and Basketogna language, were distributed. Among them, 20 farmers, 9 Development Agents, and 5 administrative staff from the 2 districts were involved (Table 2).

Table 2. Number of training participants from selected kebele

Items	Doka-Ayima			Bayo-Boreza			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Development agents	3	2	5	3	1	4	6	3	9
Farmers	10	0	10	9	1	10	19	1	20
Administrative	3	0	3	2	0	0	3	2	5
Total	**16**	**2**	**18**	**14**	**2**	**19**	**30**	**4**	**34**

During training session, different researchers were participated and shared their knowledge and skills through Power Point presentations and deliver of extension materials, such as leaflets and a training manual. Participants of the training gained valuable knowledge and skills on the vertical and horizontal ploughing dimensions of sweet potato cultivation

2.5 Research design and field layout

The materials used for the demonstration include sweet potato cuttings, a stick board, and geomembrane plastic. The experiment was laid out on a simple plot design on 12 farmer's field in the 2024 Meher cropping season. Plot size of each variety was 200 m^2 with 6 rows, each row length of 20m. Farmers prepared rows manually with a hoe. These replications were laid out in similar agro-ecology, slope and characteristics of farm lands. In many places farmers traditionally use 2 vine cuttings per planting hole, however this requires a lot of extra planting materials, and researchers recommend using just one cutting per hole and then gap filling any plants that fail to establish. The plots were separated with a stick boarder a vines were planted 40 cm in height (15 cm into the soil and 25 cm above the soil (Figure 2). All plots were lined with a thick geotextile plastic sheet to collect eroded soil particles. The selected trial farmers prepared their farmlands as part of their usual land preparation in vertical and horizontal ploughing dimensions. The demonstration boundaries were marked by placing permanent large rows. Locally adapted sweet potato, locally named as FAO, was used as a test crop because its highly preferred by farmers in the area. It is high-yielding with good storability. It can produce a good yield in about 6 months, which has a red skin with cream white flesh.

The spacing between plots was 1 meter using the row planting technique in a farmer's field. Spacing of 60 cm between rows and 30 cm between plants were done. The number of stem cuttings was 55,555 cuttings per hectare, with a stem cutting length of 25 cm (Table 3). Throughout the growing period, all necessary field management practices, including weeding, were equally carried out at 4 and 6 weeks after planting. Five tons per hectare of Manures can be very essential, if available, but may be more likely to be applied in a garden setting than in large farms.

Table 3. Design of the experiment

Practice	Ploughing dimensions	
	Vertical	Horizontal
Sweet potato variety	Locally adapted (FAO)	Locally adapted (FAO)
Land preparation	2-3 times ploughing with manual hand hoe	2-3 times ploughing with manual hand hoe
Plot size	10 *20 = 200 m^2	10 *20 = 200 m^2
Spacing	Between 60 cm row and 30 cm plant	Between 60cm row and 30 cm plant
Number of cuttings	55,555 hectare	55,555 hectare
Stem length	2 Cutting/hole about 25 cm	2 cuttings/hole about 25 cm
Fertilizer(manure)	5 toneha-1 before planting	5 toneha-1 before planting

The 5 t/ha of manure, which supplies soil nutrients and organic matter, thereby improving the soil structure, was applied (Ossmo, 2010). Cuttings of 3 nodes about 20-30 cm and manual removal weed management were used (Table 3).

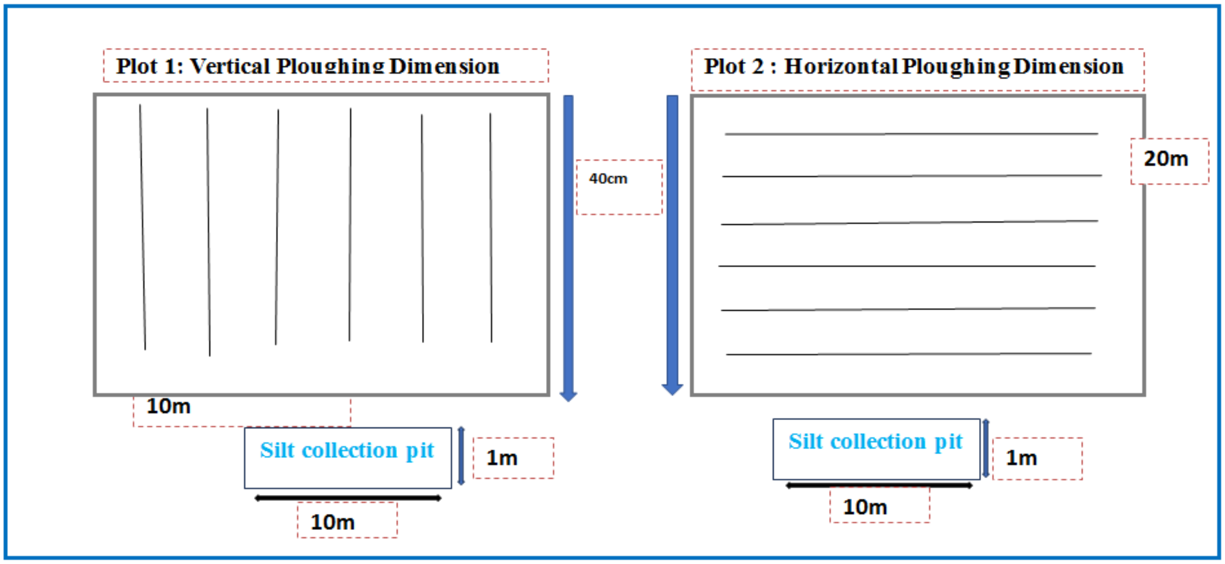

Figure 2. Layout of the experiment

2.6 Description of field layout and management

The spacing between plots was 80 cm. The border between plots was marked by placing permanent large rows to protect the border effect (40 cm border). Each catch pit is prepared with a length of 10 meters, a width of 1 meter, and a depth of 1 meter. Each plot was covered with a thick geo-membrane plastic sheet to collect eroded soil. During land preparation, the mounds, beds were prepared by heaping soil up (Figure 3).

Figure 3. Laska Zuria district farmers land preparation and planting method (a) Farmers sweet potato vertical bed preparation, and (b) Sweet potato performance in vertical dimension

2.7 Method of data collection

All rows of the plot were harvested for data collection. The data on tuber yield, soil loss (t/ha) was measured by a trapezoidal soil loss collector pit during the harvest time of sweet potato. Soil loss was measured from the collected soil sediment per catch pit after the soil sediment had been oven-dried at 105°C for 24 hours. Farmer's preference data was collected in terms of focus group discussion during the mini field day.

The demonstration field was prepared at planting time on 12 farmers' fields on a slope of 10-15%. The fields were set up, and the soil collected in the catch pit was measured during harvesting of the sweet potato. The fields were bounded by a ditch to a depth of 20 meters to prevent runoff water from outside the fields from entering the fields, and that from runoff plots from flowing out uncontrolled.

2.8 Methods of data analysis

Root yield performance and soil loss data was analyzed by mean, frequency and percentage. Farmer's preference was analyzed using farmers preference ranking. Yield advantage of the horizontal ploughing dimension over vertical ploughing dimension was calculated by the formula (Eq.1).

$$\text{Yield advantage of HPD} = \frac{\text{Yield of Horizontal PD} - \text{Yield of Vertical PD}}{\text{Yield of Vertical PD}} * 100 \qquad (1)$$

Where HPD = Horizontal ploughing dimension and VPD=Vertical ploughing dimension

2.9 Monitoring and evaluation

To demonstrate the technologies on a wider scale, a mini field day organized that included farmers, experts, officials, and other relevant stakeholders' and feedbacks were collected at the end of the session.Field day increase technology adoption by 12.2% (Emerick & Dar,2020). Focus of the field day in this research was to show the advantage of horizontal over vertical ploughing dimension and promotion of its benefits in local farming practices.

Finally, in order to evaluate the performance and final outputs of the varieties and share the lessons with different stakeholders', kebele level field days were organized. 156 participants; 119 farmers, 12 Development Agents and 25 other experts and administrates were directly participated in 2 Kebeles and appreciated all the things done at farmers field and farmers training centers (Table 4). The host farmers also gave a brief explanation about what benefit they get from the horizontal ploughing dimension.

Table 4. Number of participants in field day

Category	Kebele	Participants					
		Farmers		Development agents		Other experts	
		Male	Female	Male	Female	Male	Female
Field day	Doko Ayima	52	15	4	2	12	-
	Bayo Boreza	40	12	5	1	12	-1
Total		92	27	9	3	24	1

3. Results and Discussions

3.1 Root yield performance of sweet potato

The percentage increase of the sweet potato in horizontal ploughing over the vertical ploughing system was 12 % under farmer conditions (Table 5). The mean root yield increased from 12.5 to 14 t/ha (Table 5).Higher yields of sweet potato from the horizontal method of planting obtained (Chagonda, 2014,Mohammed, 2019 & Pakkies et al.2019). However, Bongihosi, (2021), Tamirat and Wondimu (2023), which is 11.7t/ha at West Omo zone of South west Ethiopia, reported higher yields of sweet potatoes with the vertical method of planting.

Table 5. Root yield performance of sweet potato across dimensions (n=12)

Treatments	Mean tuber yield (t/ha)	Standard deviation
Vertical ploughing dimension	12.5	0.02
Horizontal ploughing dimension	14	0.027

3.2 Soil loss analysis

Soil loss was determined from the collected soil sediment per catchment area. Means soil loss rates recorded from this experiment showed minimal benefit from applying more than 30 t/ha soil lost in vertical ploughing dimension and 6.5 t/ha in horizontal ploughing dimension with slope of 10-15%. This shows there was a significant difference between ploughing dimensions in sediment accumulation (Table 6). Thus, as a horizontal plounghing method, decreases water speeds and forms a broad, identical planting surface for the uptake of nutrients. However, below-normal, soil loss rates were experienced throughout this study as evidenced by a mean annual soil loss of 30 t/ha from the vertical ploughing dimension on the 10-15 % slope.

Table 6. Soil loss of sweet potato on different ploughing dimensions (n=12)

Treatments	Sediment accumulation		
	(t/200 m^2)	(t/ha)	percentage
Vertical ploughing	0.06	30	
Horizontal ploughing	0.0012	6.5	2l.6

3.3 Farmers preferences

The opinion of those farmers on ploughing system preference was collected during the mini field day by including non-participant farmers, experts, and stakeholders. Farmers were asked to give a rank from 1-5 (1=Very poor, 2=Poor 3=Good, 4=Very good and 5=Excellent) on each attribute of the crop based on 6 (IOF= Increase occurrence of flood, HLC= Require high labor man hour per hectare, GTY=Good root yield, TD=Increase tuber damage during harvesting, EHM=Easy to harvest mature roots and CWL= Control of water loading) criteria's given below.

After scoring, each value of the score were added and divided to the number of the criteria's listed by the farmers and finally ranked based on the mean score. Farmers set criteria after having know-how about the ploughing system, and using those criteria, determine the ploughing dimensions at harvest time. The major criteria were control of water lodging, occurrence of flood, labor consumption/requirement, root yield, and root damage during harvesting time. Root damage levels are also likely to be severe under such conditions/soil loss is greatly increased, so harvesting should not be conducted under such conditions. Such a ploughing dimension involves much more bending of their backbone. Based on farmers' feedback, vertical ploughing is labour effective and does not consume time in using human labor, and it's good for households where labor is scarce. In addition, it is easy to harvest the mature roots (Table 7).

Table 7. Preference ranking criteria and score of ploughing dimension at the Doka Ayima and Bayo Boreza kebeles

Kebele and parameters	IOF	HLC	GTY	TD	EHM	CWL	Scores		Rank
							Total	Mean	
Doka Ayima kebele									
HPD	3.43	4.84	4.86	4.4	5	2.4	29.1	4.85	1st
VPD	5.00	2.14	2.71	3.86	3.14	5.00	17.71	2.95	2nd
Bayo Boreza kebele									
HPD	5.00	4.86	5.00	5.60	5.00	2.85	29.31	3.88	1st
VPD	2.45	1.14	2.60	3.60	4.41	3.55	15.81	1.64	2nd

HPD= Horizontal ploughing dimension, VPD=Vertical ploughing dimension, IOF= Increase occurrence of flood, HLC= Require high labor man hour per hectare, GTY=Good root yield, TD= Increase tuber damage during harvesting, EHM= Easy to harvest mature roots and CWL= Control of water loading

In contrast to the above concept, vertical ploughing dimensions are readily washed away by rain during the cropping season. The farmers' research groups have appreciated the new horizontal dimension technology for the following merits: perceived better yield, perceived better seed size than the vertical ploughing dimension. Based on the results of this experiment, the horizontal ploughing required the least energy and labor in terms of draft. Farmers well understood the results of vertical ploughing on their farms and recognized the loss of topsoil and reduction of yield. This could be due to the removal of plant nutrient-rich topsoil and thus, soil fertility decline, as the majority of the farmers responded.

4. Conclusion

Pre-extension demonstration of soil and water conservation through ploughing dimension in sweet potato potential areas of Laska Zuria District, Basketo Zone of South Ethiopia was conducted on 12 farmers' fields in 2 kebeles in 2024 Belg cropping season. The study result showed that vertical ploughing dimensions may cause an increase in soil loss, which also negatively affects the crop yield. The volume of soil loss in vertical ploughing is high. Horizontal ploughing dimension produced higher root yields and also has a yield advantage of over 12%. Farmers well understood the results of vertical ploughing dimensions on their farms and recognized the loss of topsoil and reduction of the sweet potato yield. This could be due to the removal of plant nutrients from the topsoil, resulting in soil fertility decline. To increase productivity and conserve soil on slopes of 10-15%, horizontal ploughing is the best method to prepare soil for sweet potato cultivation and recommended to scale up this ploughing dimension for future sweet potato cultivation in terms of reducing soil loss and enhancing root yield in the study area.

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Conflict of Interest

The authors declare no conflict of interest

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