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Demonstration and Evaluation of Soil Drainage Technology for Haricot Bean Productivity in Waterlogged Vertisol Areas of Abeshge District, Gurage Zone, Southern Ethiopia

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Abstract: Although it has high potential crop productivity, poor internal drainage and water logging during the wet season made the vertisol difficult for crop production including haricot bean in the study area. Cognizant of this fact, this study aimed to demonstrate and evaluate the yield and yield related performance and economic feasibility of haricot bean production in vertisoil using drainage technology in the study area. Thus, a comparative demonstration and assessment local farmers vertisol management practices and 40*80 drainage technology has been done on selected eight farmers found in Abeshge district for two consecutive years. The required data for the study was collected through a participatory open-ended interview guide and focus group discussion (FGD) of representative farmers in the study area. Moreover, the economic feasibility of the technology was analyzed using partial budget analysis. The finding of the study shows that the average yield advantage of 40*80 vertisol drainage management practice over local farmers practice was 45% and 3% in the year 2021 and 2022 respectively. Moreover, farmers preference to the explicitly show that 40*80 drainage technology is more productive than the local practice. The economic feasibility assessment of the technology also depicted that the demonstrated 40*80 drainage technology is lucrative and profitable with MRR of 1670%. Thereby it’s recommended for further scaling up in similar agro-ecologies.

Keywords: Broad Bed Furrow, Drainage, Haricot Bean, Vertisol, Waterlogging

1. Introduction

Due to the significant amount of clay in vertisol (heavy black clay soils), it is well known that it has a relatively high ability to retain water [1]. As a result, the moisture level of the soil influences how well it works for agricultural operations like tillage and planting. Moreover, there is a quite small range of soil moisture in which vertisols' physical characteristics are suitable for farming activities [2]. As a result, the soil is difficult to cultivate because it is both overly sticky and tough to work when wet and very hard when dry. According to a study by [3], vertisol's hydro-physical properties make it difficult to cultivate the soil in both dry and wet conditions. This, combined with the practice of planting crops later than normal to minimize water logging, has resulted to a reduced crop yield from the soil.

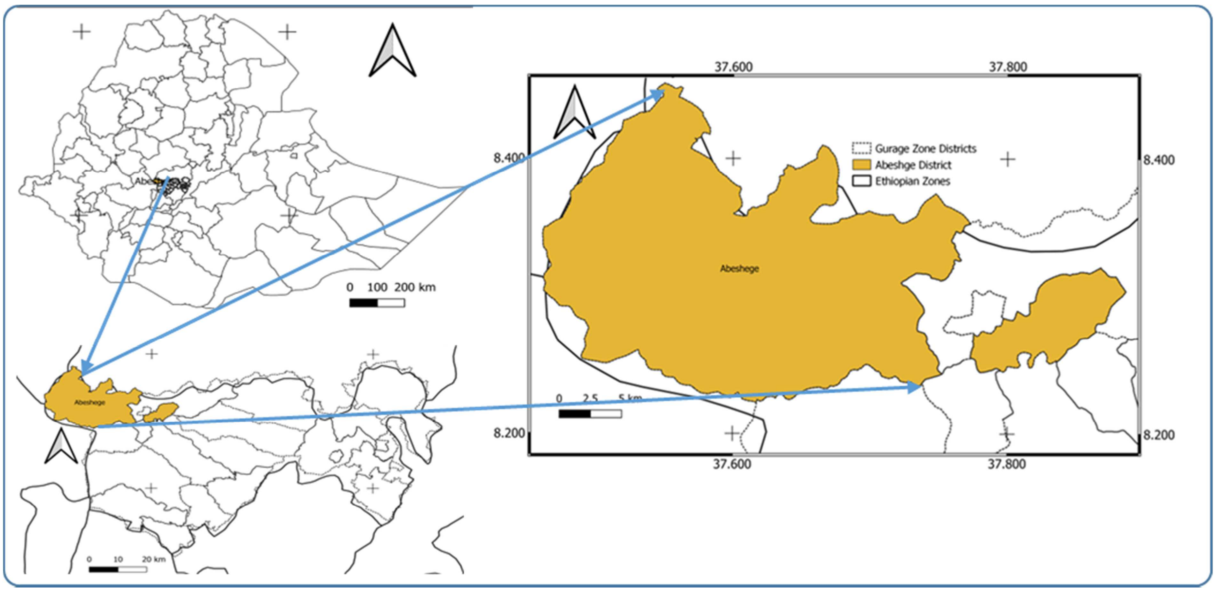
Despite having a high potential for productivity, vertisol, in Ethiopia, is underutilized because of inadequate internal drainage, water logging during the rainy season, and hardness during the dry season [4]. Although it covers 10% of the entire land in Ethiopia, a sizable amount of the country's vertisoil hasn't been used to its full productivity potential [5]. Water logging is a challenge to crop productivity under the rain fed system on Vertisols of central highlands of Ethiopia. Ethiopia has 12.7 million hectares of vertisols, of which 7.6 million hectares (– approximately 60%) are in the highlands [6]. However, the majority of Vertisols have poor workability and, excess water with most of them being used for dry season grazing [7]. Vertisols take a significant share of productive agricultural soils in the Ethiopian highlands, but it is challenging to achieve the expected level of production due to their poor internal drainage and subsequent waterlogging [8].

According to Tekalign, M., Astatke, A., Srivastava, K. L., & Dibabe, A., the application of appropriate drainage system and manipulating planting dates can reduce the effect of water logging and improve productivity of Vertisols [6]. The improved techniques recommended to manage surface drainage in verisol includes the use of the wheel-tool carrier, Broad Bed and Furrow (BBF), conservation tillage and increasing yield with the concept of watershed development and management. Broad Bed and furrow based (BBM) implement is the main element in the packages of vertisols management technology. To this end, the use of the BBM together with appropriate seed and fertilizer greatly helps improves Vertisols productivity.

Haricot bean is a major grain legume consumed worldwide for its edible seeds and pods. In Ethiopia, it is one of the most important cash crops and source of protein in many lowlands and mid land area [9]. Haricot bean production in vertisol is impeded by limited percolation of the soil; thus the crop suffer from prolonged water logging and show signs of poor aeration and nutrient deficiency [10]. Therefore, this study demonstrated and examined the production and economic feasibility of haricot bean production in vertisol areas of the study area.

2. Objectives

1) To evaluate the yield and yield related performance of haricot bean production in vertisoil using drainage technology in the study area.
2) To assess the economic feasibility of haricot bean production in vertisoil areas using drainage technology in the study area.



Source: Ethio-GIS 2015

Figure 1. *Map of the study area.*

3. Materials and Methods

3.1. Description of the Study Area

The study was conducted in the Gurage zone of Abeshige district. It is located about 155km away for the capital city, Addis Abeba, in the southern part. The district is surrounded in north, south and west by Oromia regional state and in the east by Cheha and Kebena districts. There are different relief feature found in the area. The climate of the district extends from cool to warm. The annual average temperature and rainfall of the area is 21.25°C and 801 mm up to 1400 mm within the last ten years respectively. The dominant soil type of the study area is fine to medium textured, sandy loam underlie with ancient Precambrian basement rocks in the plains and Calcoreous soil at the hills.

3.2. Experimental Design and Procedures

The target district and kebeles were selected purposively based on their relative high production of haricot bean and vertisoil coverage in the zone. Moreover, the host farmers were also selected purposively based on their willingness to conduct the demonstration and accessibility of their respective farms for close follow up and monitoring. The field demonstration was carried out for two consecutive years (2020/21 and 2021/22) in selected nine farmers using farmers as a replication. In the field, the improved Vertisol management practices i.e. "Broad Bed Furrow" (BBF) 40cm*80cm and local farmers practices to drain off water for the farm were set on adjacent plots with a plot size of 10mx10m with 1m distance between plots at each experimental sites. One of an improved variety of haricot bean used by farmers in the locality called Hawassa dume was used to compare local farmer’s vertisoil drainage management with 40*80 drainage technology.

3.3. Demonstration Field Management Practices

Agronomic practices were employed based on recommendation. Farmers were advised to plough their land three times before planting. It is recommended that haricot bean to be sown in rows with a seed rate of 100 kg/ha. The spacing between rows were 40 cm, and seeds in the row 10 cm apart. In poor soil, adding 100 kg/ha of DAP (121kg/ha NPS) during planting is recommended. When the plants are deficient in nitrogen, they show leaf yellowing, at this moment, 50-100 kg urea could be applied as top dressing before flowering with considering split application. Hand weeding has been done twice. Accordingly, farmers undertake the first hand weeding two weeks after planting, and the next weeding five weeks after sowing.

3.4. Data Collection and Analysis

Both qualitative and quantitative data collection methods were employed to collect numerical and qualitative data for this study. The qualitative data were collected using an open-ended interview guide and focus group discussion (FGD) topics, which was designed to assess the preference of farmers towards the demonstrated technologies. The quantitative data were collected using different measuring instruments such as ruler and balance. The qualitative data collected through organized group of farmers from the locality on the preference of the demonstrated technologies was analyzed using simple matrix and narration. On the other hand, the quantitative data were analyzed using descriptive statistics. Moreover, partial budget analysis was also done with the aim to recommend technologies that are agronomical different, are economically superior and are socially acceptable to farmers. It also provides the foundation for comparing the relative profitability of alternative treatments, evaluating their riskiness, and testing how robust profits are in the event of changing product or input prices. Therefore, partial budget analysis is employed to estimate the net benefit and marginal rate of return that could be obtained from various alternative treatments [11]. According to similar paper, partial budget and sensitivity analysis were used to determine the level of profitability of improved technologies over the conventional practice indicated below.

$$NB = GB – TC \tag{1}$$

$$MB = NBIV - NBLC \tag{2}$$

$$MC = TCIV - TCLC \tag{3}$$

$$MNB = MR - MC \tag{4}$$

$$MRR = MB/MC*100\% \tag{5}$$

Where, NB= Net benefit; GB= Gross benefit; TC= Total cost; MB= Marginal benefit; MC= Marginal cost; MNB = Marginal net benefit; NBIV= net benefit of improved variety; TCIV= total cost of 40*80 drainage technology; TCLC= total cost of local farmers drainage practices; TR=Total revenue; MR=Marginal revenue; TVC= Total variable cost; MRR= Marginal rate of return.

In this study, 100% was considered as minimum acceptable rate of return for farmers' recommendation. It is important to note that the acceptable minimum rate of return for farmers' recommendation is 50 to 100% [11]. In addition, the yield advantage, technological gap, extension gap and technological index was computed for comparison between varieties using the given formulas below:

$$\text{Technology gap} = \text{Potential yield qt/ha} – \text{demonstration yield} \tag{6}$$

$$\text{Technology index (\%)} = \text{Potential yield /demonstration yield X 100} \tag{7}$$

$$\text{Extension gap (q /ha)} = \text{Demonstration yield (q/ha)} - \text{Farmers yield (q/ha)} \tag{8}$$

Sensitivity analysis

The sensitivity analysis is a change in the net benefit and the return on marginal capital as revenue and input prices vary by 15% above and below their values. As shown in Table 4, the calculated sensitivity analysis at 15% input cost increment revealed that the marginal rate of return for haricot bean production in vertisol using BBF 40*80 drainage management practices and local farmers drainage practice with its full package is higher than the generally accepted minimum rate of return i.e. 100%. Even the price shock exist in input cost increment the use of 40*80 drainage management practices and local farmers drainage management practices with recommended package more profitable than the local variety with farmer practices in both locations.

4. Results and Discussions

4.1. Grain Yield Comparison Between the Vertisol Drainage Management Practices

Table 1. *Haricot bean grain yield in difference between vertisol drainage management practices (N=8).*

Year	Drainage system	Grain yield (q/ha)			Median yield advantage (%)	P-value
		Min	Max	Median		
2021	Local farmers practice	1	12	5.5	45	
	40*80 drainage	5	16	10		0.023**
2022	Local farmers practice	16.19	18.93	17.4	3	0.386
	40*80 drainage	17	23.06	18.1		

Source: Own computation, 2022.

Note: * and ** are significant association at P≤0.05 and P<0.01 respectively; the data are presented as Median and compared using Mann-Whitney U-test;

The result from the above table (Table 1) shows that there is a statistically significant difference (P>0.05) in the total grain yield of haricot bean between 40*80 drainage technology and local farmer drainage practice in the year 2021. While the difference in is not statistically significant in the year 2022. This finding is may be due to the difference in the amount of rainfall between the years. The earlier year receives a relatively high amount of rainfall than the later one. In waterlogged vertisol, as the amount of rainfall increases there is excess water on the soil that is required to be drain off. Moreover, the comparison haricot bean grain yield between the local and improved drainage technology shows that the improved drainage technology (40*80 BBF) has 45% and 3% average yield advantage in the year 2021 and 2022 respectively.

Table 2. *Haricot bean technology, extension gap and technology index analysis of demonstrated technology.*

Vertisol drainage management technology	Technology gap (q/ha)	Technology index (%)	Extension gap (q/ha)
40*80 drainage	1.72	109.4	10.15
Local farmers practice	11.87	246.15	
Mean	6.79	177.7	

Source*:* Own computation, 2022.

Technology Gap (TG) analysis indicates the extent to which technologies have not been adopted. This feedback information is essential to identify the weakness of technology transfer program, to remove bottlenecks and accelerate adoption of improved technologies [12]. The mean value of technology gap (TG) analysis were computed. Hence, the overall technology gap was calculated using the formula (6) and it was found 6.79 q·ha−1. The yield difference may be observed due to the drainage technology demonstrated. Similarly, extension gap (EG) was calculated using the formula (8) and found 10.15 q·ha−1 and the result indicated that it needs emphasis to strengthen the extension service or approach using various methods like offering training to farmers, skill and experience sharing, awareness enhancement via information dissemination channels and other pertinent methods on the demonstrated drainage technology. At the same time, technology index (TI) was computed using formula (7) and recorded 177.7%. This is an indication that realized yields at farmer's farm and even at the demonstration sites still have huge potentials for increase. If this gap is closed, the haricot bean production and productivity will be enhanced.

4.2. Economic Profitability of the Technologies

Table 3. *Partial budget analysis of the demonstrated vertisol drainage management practices.*

Particulars	Drainage system	
	Local farmers practice	40*80 drainage
TR (ETB/ha)	35000	63,350
TVC (ETB/ha)	12,050	13,650
TFC (ETB/ha)	2250	2250
NB (ETB/ha)	22950	49,700
MC (ETB/ha)	-	1600
MB (ETB/ha)	-	26750
MRR% (ETB/ha)		16.7 or 1670%

Where: TR=Total revenue; TVC= Total variable cost; NB= Net benefit; MC= Marginal cost MB= Marginal benefit MRR= Marginal rate of return.

As the above table (Table 3) revealed that the marginal rate of return (MRR) of the demonstrated improved drainage management practices (40*80 BBF) 1670% is greater than the acceptable minimum rate of return (AMRR) 100%. Therefore, the 40*80 drainage practices is lucrative and recommended for further scaling up in the study area or areas with similar agroecology (soil type).

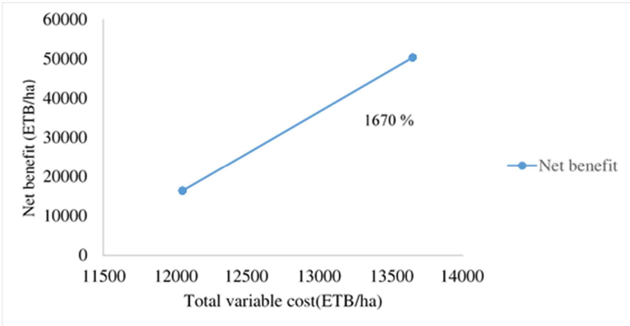


Figure 2. *Net benefit curve of haricot bean production using 40*80 drainage technology.*

Sensitivity analysis

As variation in relative input and output price (change in economic situation) occurs more frequently than variation in yield most especially in an inflationary economy or an economy characterized by unstable currency that is dependent on imported agricultural input. Sensitivity analysis addresses the problem of variability in price. Sensitivity analysis uses different price or yield to determine what would happen to the net benefit and the choice of proposed technology if it were to occur in difference price condition to the expected. What if there is a 15% increment in the price of costs inured to produce haricot bean in the area.

Table 4. *Sensitivity analysis for haricot bean production in vertisol.*

Particulars	Drainage system	
	Local farmers practice	40*80 drainage
TR (ETB/ha)	35000	63,350
TVC (ETB/ha) (15%)	13857.5	15697.5
TFC (ETB/ha) (15%)	2587.7	2587.5
NB (ETB/ha)	21142.5	47,652.5
MC (ETB/ha)	-	1840
MB (ETB/ha)	-	26510
MRR% (ETB/ha)		14.4 or 1440

4.3. Farmer's Preference of the Technologies

During the technology demonstration event organized in selected farmers plot the opinion of participant's farmers on technology preference was collected. Farmers in the study area selected the best Technology by using their own criteria. Farmers set these criteria after having know-how about the technology and using those criteria they selected the Technology at harvest stage. The major criteria used by farmers were number of pod/plant, height of pod, bigger size of seed, better stem strength, root has got soil, unavailability of unproductive plants, good plant height good health plant. Based on the above criteria's; farmers evaluated the Technology and preferred Drainage Technology then traditional practice due to higher number of pod/plant, height of pod, bigger size of seed, better stem strength, Unavailability of unproductive plants and good plant height.

Table 5. *Farmer's evaluation for the demonstrated technologies.*

Number	Practice	Rank	Preference criteria's
1	80*40 drainage technology	1	Low disease occurrence, Higher number of pod/plant, height of pod, lower number of shrinking seed, lower number of sterility. Bigger size of seed, better stem strength, and root has got soil, unavailability of unproductive plants, good plant height.
2	Local farmer Practices	2	High disease occurrence, Lower number of pod/plant, smaller height of pod, higher number of shrinking seed, higher number of sterile seed, smaller size of seed, stem strength is not good, root hasn't got soil, availability of unproductive plant and plant height is not good

5. Conclusion and Recommendations

Generally, through this participatory evaluation and demonstration process, many farmers became aware of the importance of drainage technologies as compared to farmer Practice. The demands for the technology were also created. Demonstration result showed that drainage technology recorded high yielder than farmer practice at all location. It was also preferred by participant farmers for its better Yield and agronomic performance. Based on these facts, Drainage technology was recommended for further scale up and scale out for other similar areas.

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