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CROPPING SYSTEM, SOIL CONSERVATION AND TECHNOLOGY ADOPTION IN THE ENSET (*Ensete ventricosum* (Welw.) Cheesman) BASED FARMING SYSTEM IN GEDEO ZONE, SOUTHERN ETHIOPIA

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Abstract

Enset (Ensete ventricosum) is a multipurpose crop used for food, fodder, fiber production, fuel, traditional medicine, and other cultural practices. The Gedeo enset based farming system is diversified and unique in its design and function. The objective of this study was to assess cropping system, soil conservation, and technology adoption in the Gedeo enset based farming. The enset based farming system of Gedeo was stratified based on the agro-ecological zones. Accordingly, two kebeles from Dega (highlands), four kebeles from Weyna Dega (midland), and one kebele from Kola (lowland) woredas were selected. Data were collected through key informant interviews, structured questionnaires, and focus group discussions. A total of 230 randomly selected households were interviewed, which was about 10% of the total number of enset producers. The study provides an overview of enset based farming systems, traditional and modern tools, soil erosion conservation activities, and technology adoption of the Gedeo. The result revealed that compared to other existed mixed crops, as altitude increases, enset cropland coverage increases. In lowland areas, the land cover of enset was insignificant. Comparative enset-coffee land covers mainly maters in the midland. The type and the number of animals holding differ across and within the households. In the Gedeo agroforestry system, the problem of soil erosion and conservation practices was insignificant. The result suggests the need for the involvement of the concerned body in the introduction and dissemination of improved technologies by considering the agroforestry system and the mixed crops.

Keywords: Cropping system, Enset, Soil conservation, Technology adoption

1 Introduction

Enset (*Ensete ventricosum*) plant belongs to the order Zingiberales, family Musaceae and the genus Ensete. It is a perennial, monocarpic, herbaceous, drought-tolerant, banana-like plant (Birmeta *et al*., 2004; Kress *et al*., 2001). Commonly in Ethiopia known by its vernacular name enset. It is a multipurpose crop used for food, fodder, fiber production, fuel, traditional medicine, and other different cultural practices (Kippe, 2002; Negash and Niehof, 2004; Tsegaye, 2002; Tsehaye and Kebebew, 2006). It is a staple or co-staple food crop for more than one-fifth of Ethiopia's population (Brandt *et al*., 1997). Its multi-annual production time and flexibility in harvesting make the crop a reliable food source (Rahmato, 1995).

Enset has only been domesticated in Ethiopia and produced in Southern Nation and Nationality Peoples, Oromia, and Gambella Regional States of Ethiopia (Tsegaye, 2002). The Gedeo enset farm-

ing system is unique in its design and function. In Gedeo, enset-based agricultural systems date back from the Neolithic (Kippe, 2002).

The diversity of the systems and the ability of enset to produce a relatively large amount of food per unit area and time could be the main factors that contributed to this stability (Tsegayei and Struik, 2001). Enset improves directly or indirectly the local climate and soil conditions (Tsegaye and Struik, 2001).

The decline in productivity was primarily associated with population pressure, recurrent drought, increased incidence of enset pest and disease, degradation of the soil and the environment (Shumbulo *et al.*, 2012; Tsegaye and Struik, 2001). Before modifying existing approaches or technologies to improved new scientific methods, information on the status and conditions of the cropping system is needed. Hence, the objective of this research was to assess cropping system, soil conservation, and technology adoption in the Gedeo enset based farming.

2 Materials and Methods

2.1 Location of the Study Area

Out of the total area of the Gedeo Zone, midlands cover 67.53%, highlands 32.41%, and lowlands 0.06%. The mean annual temperature of the zone ranges between 12.6-22.5°C, and the mean annual rainfall ranges between 1001-1800mm (Kippe, 2002). It is sub-divided into six woredas. It is 90Km far from Hawassa and 360Km from Addis Ababa. The zonal capital is Dilla, situated on the road from Hawassa to Moyale (Figure 1).

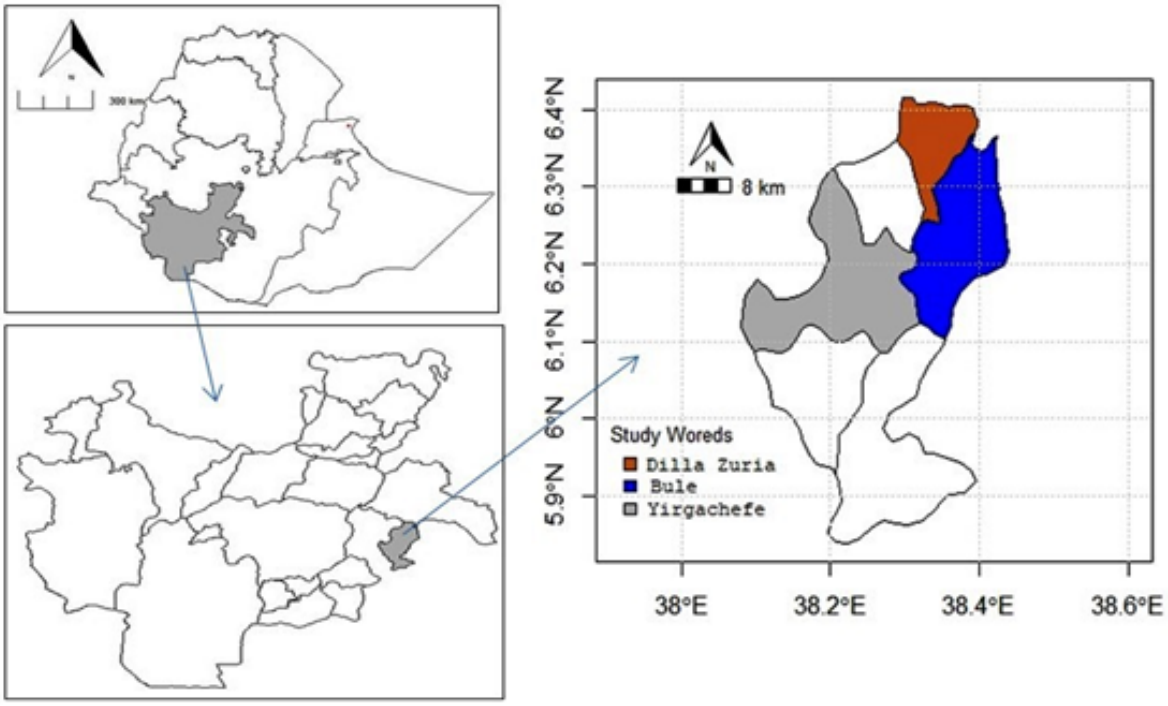

Figure 1. Map of the study area

2.2 Survey Design and Data Collection

The enset farming system of Gedeo was stratified based on the agro-ecologic zones. These were lowlands ($< 1,500$ m.a.s.l), midlands (1,500-2,500 m.a.s.l) and highlands ($> 2,500$ m.a.s.l) (Kippe, 2002). Accordingly, two kebeles ('*Haro Welabu*' and '*Sika*') from Dega (highland) of Bule woreda, four

kebeles (’*Wete*’, ’*Bowcha*’, ’*Amba*’, ’*Haru*’) from Weyna Dega (midland) of Yirgachefe and Dilla Zuria woredas, and one kebele from Kola (lowland) Dilla town were selected. Data were collected through interviews, structured questionnaires, and focus group discussions. Key informants were selected and interviewed by consulting agriculture experts and development agents. Cultural attachment and indigenous knowledge of enset were the main criteria for selecting key informants. From each woreda, three key informants participated in the interview. A semi-structured questionnaire was developed based on key informants and secondary data and pretested before the data collection. A total of 230 households were randomly selected, which was about 10% of the total number of enset producers (Table 1).

Table 1. Socio-economic data of respondents from each Kebeles

Household Characteristics	**Category**	**Respondents’ Frequency (%)**						
		Haro Welabu	**Sika**	**Wete**	**Bowcha**	**Amba**	**Harsu**	**Haroresa**
Gender	F	9.1	20.0	12.8	12.3	46.2	30.0	50.0
	M	90.9	80.0	87.2	87.7	53.8	70.0	50.0
Land size	< 1	0.0	3.5	3.0	66.7	80.0	8.0	12.8
	(1-2]	15.4	50.9	42.4	33.3	10	64	66.3
	(2-2.5)	46.2	17.5	12.1	0.0	0.0	24.0	12.8
	≥ 2.5	38.5	28.1	39.4	0	10	4	8.2
Education level	< 8	46.2	86.0	87.9	83.4	60.0	95.8	86.0
	9-12	30.8	14.0	12.1	0.0	30.0	4.2	14.0
	> 12	23.1	0.0	0.0	16.7	10.0	0.0	0.0
Family size	< 5	0.0	22.8	6.1	50.0	10.0	12.0	8.1
	5-10	38.5	70.2	51.5	33.3	50.0	76.0	82.6
	> 10	61.5	7.0	42.4	16.7	40.0	12.0	9.3
Age	< 30	0.0	29.8	18.2	0.0	10.0	12.0	0.0
	30-60	100.0	64.9	81.8	66.7	90.0	80.0	95.3
	61-80	0.0	5.3		16.7	0.0	8.0	4.7
	> 80	0.0	0.0	0.0	16.7	0.0	0.0	0.0

2.3 Data Analysis

The collected data were checked for completeness and reliability. Data clarification was performed using focus group discussions and field observation. In addition, informal and formal group discussions, and expert elicitations were conducted to verify inconsistencies and enrich and validate information gathered from individual interviews. Descriptive statistical summaries such as frequencies, percentages, and averages performed using R version 4.0.3 (R Development Core Team, 2020).

3 Results and Discussion

3.1 The Farming System

3.1.1. Cropping System

According to most respondents, the land coverage of enset compared to other mixed-crops was almost equal at the lowland (Haroresa) and the lower-midland (Harsu, Amba, and Bowcha; Table 2). The land coverage was high in the higher-midland (Wete) and the lower-highland (Sika), but it was lower in the higher-highland (Haro Welabu; Table 2). Other

authors also reported the intercropping of enset with perennial tree crops, especially fruit and coffee, in enset based farming systems (Temesgen *et al*., 2014; Belachew *et al*., 2017).

According to most respondents, the land coverage of coffee was low in the lower-midlands (Amba and Harsu) and the lowland compared to other existed mixed-crops (Haroresa); (Table 2). In the higher-midland, it was almost in equal coverage with other crops. However, it was nil in the highlands (Haro Welabu and Sika; Table 2). Some farmers (about 40%) from midlands (Wete and Bowcha) covered a large portion of their land by coffee than other mixed crops (Table 2).

Table 2. Relative land coverage of enset and coffee

Description	Relative land coverage	Respondents' Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
Enset compared to other crops	Higher	36.4	56.0	62.8	47.4	0.0	0.0	0.0
	Lower	51.5	32.0	0.0	0.0	7.6	40.0	20.0
	Almost equal	12.1	12.0	37.2	52.6	92.3	60.0	80.0
Coffee compared to other crops	Higher	0.0	0.0	37.2	38.6	0.0	0.0	0.0
	Lower	3.0	4.0	1.2	5.3	69.2	100.0	100.0
	Almost equal	0.0	0.0	61.6	56.1	30.8	0	0.0
	No coverage	97.0	96.0	0.0	0.0	0.0	0.0	0.0
Enset compared to coffee	Higher	100.0	100.0	46.5	17.5	69.2	0.0	80.0
	Lower	0.0	0.0	34.9	73.7	23.1	70.0	20.0
	Almost equal	0.0	0.0	18.6	8.8	7.7	30.0	0.0

Enset coverage compared to coffee was higher in the lowland (Haroresa) than in the highlands (Haro welabu and Sika; Table 2). In the midlands, the enset land coverage fluctuated across the farm. It was higher in Wete and Amba but lower in Bowcha and Harsu (Table 2). In Gedeo, at middle altitude in the range of 1600–2000 m.a.s.l, coffee and enset co-dominate the agroforestry system (Abebe and Bongers, 2012; Sileshi, 2016). The coffee component decreases with increased altitude but enset is found at all altitude ranges (Gebrehiwot and Maryo, 2015). Unlike the present study, other studies showed that at lower altitudes below 1600 m.a.s.l, enset is rare in coffee–fruit crops–tree-based agroforestry (Abebe and Bongers, 2012; Sileshi, 2016).

The enset based cropping system involves intercropping with diverse crop species and landrace (Adem and Kibatu, 2020; Abebe, 2005; Yemataw *et al*., 2018; Tsegaye and Struik, 2002). In southern and southwestern parts of the country, in particular, in Gedeo agroforestry, coffee and enset are the dominant perennials (Taye *et al*., 2001; Anteneh *et al*., 2015; Bishaw *et al*. 2013). In southern Ethiopia, they cover more than 60% of the cropland (Abebe, 2013). The indigenous agroforestry of the Gedeo is interrelated to hundreds of plant species of herbaceous, trees, shrubs, and climbers (Mulugeta and Mabrate, 2017). Gedeo agroforestry is economically viable than other land-use systems because of the constituent high-value cash crops and staple crops. This practice improves the production system and increases productivity per unit area (Tsegaye and Struik, 2002). In coffee-producing areas, the diversification of coffee with compatible crop types like enset increases land resource use efficiency and productivity (Taye *et al*., 2001; Anteneh *et al*., 2015; Famaye, 2005; Begum *et al*., 2015). The mixture helps the farmers to use the enset crop as food and income source. Coffee and enset

optimum-intercropping ratio can enhance land-use efficiency and the yield and productivity of mixed crops (Mekonnen *et al*., 2020).

In Gedeo, planting density of enset showed variability within and across the agroecological zones (Figure 2). The highest planting density was from lowland areas, and the lowest was from midlands and highlands agroecology (Figure 2). Other studies also showed that the average landholding size of agroforestry is small, and they support a very high dense population (Abebe *et al*., 2006).

Planting density significantly affects yield. Optimizing planting density can result in increased crop production (Blomme *et al*., 2018). However, optimizing the Gedeo enset plant density is challenging due to the complex agroforestry system (Legesse *et al*., 2013; Abiyot, 2013; Mulugeta and Mabrate, 2017; Kippe, 2002) and smaller land size (Abebe & Bongers, 2012; Sileshi, 2016). It is also one of the challenges and sources of variation in estimating the area under production and yield for enset in the Gedeo zone (Borrell *et al*., 2020).

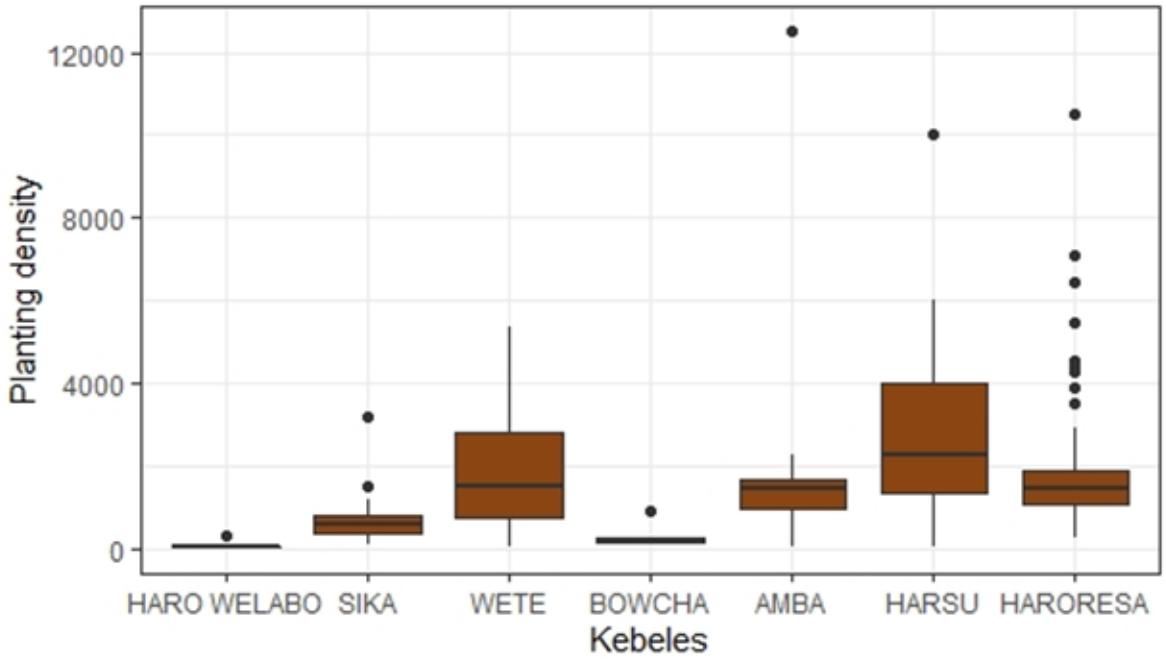

Figure 2. Planting density of enset crop

3.1.2. Animal Husbandry

According to most respondents, the average holding of chicken was much larger than other animal types (Figure 3). From the livestock, the contribution of sheep and goats was higher (Figure 3). Mesele (2007) showed that the livestock component was less compared to the other animals. Other studies also showed that the poultry contribution was higher, followed by sheep and goat (Kippe, 2002; Selamawit and Matious, 2015; Mesele, 2007).

Apart from plants like enset and coffee, livestock animals are a component of Gedeo indigenous agroforestry practices (Kippe, 2002; Debele and Habta, 2015; Mesele, 2007). In this study, the type and the number of animals holding differed across and within the households. Livestock holding is crucial for manure production in enset cultivation. Another study also showed that livestock was kept within farm compounds grazing in front yards and fed with enset leaves and other crop residues. Thus, the production of enset and livestock are interdependent.

The share of livestock was mainly affected by land size and shortage of grazing land (Debele and Habta, 2015). Farmers practiced the cut-and-carry system of chopped enset leaves and corms, particularly during the dry season (Mesele, 2007). So, the potential use of enset as feed in the agroforestry system is very high (Debele and Habta, 2015).

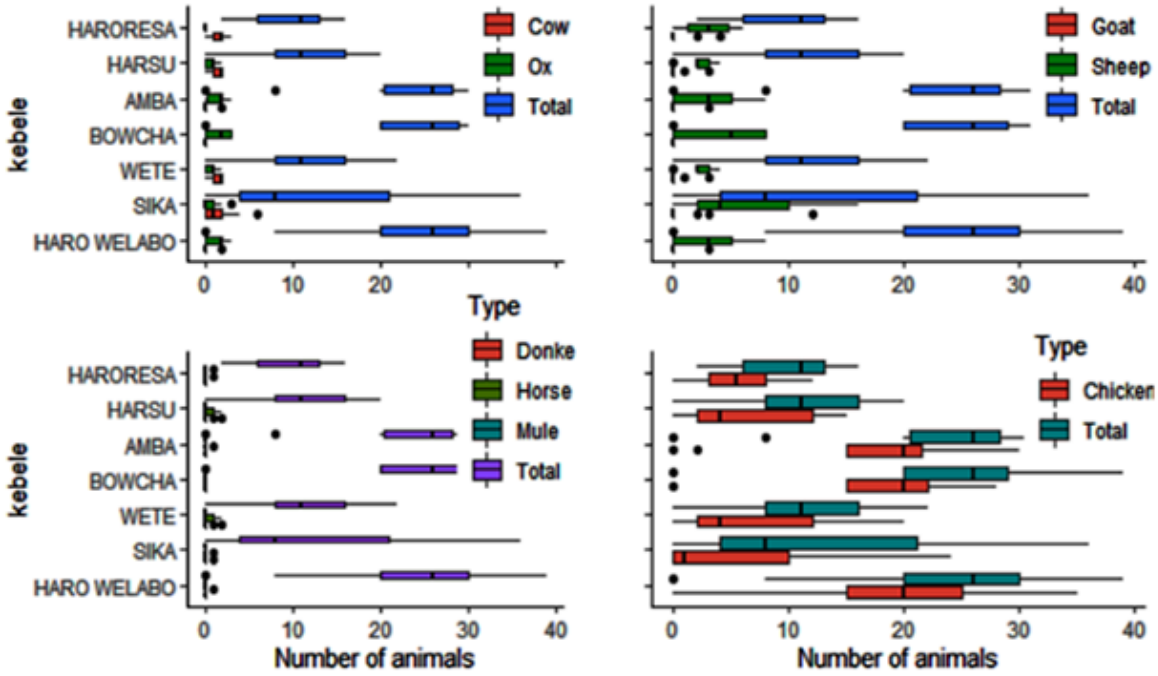

Figure 3. Types and distribution of farm animals

3.2 Soil Erosion and Conservation

3.2.1. Causes and Effects of Soil Erosion

According to most respondents, soil erosion was common and did not change from time to time in highland but decreased in midland and lowland areas. However, some farmers in highland and midland agreed on increased soil erosion (Table 3). In all agroecology of the study area, most farmers agreed on the decrease in crop yield as the main effect of soil erosion. However, a significant number of farmers also indicated land size and crop shifting as an additional effect of soil erosion (Table 3). Although much of the landscape of Gedeo is very steeply sloped, incidences of runoff and erosion are minimal because of the vegetation cover in the agroforestry system (Bishaw *et al.*, 2013). One of the typical characteristics of the Gedeo agroforestry system is its productivity on slopes as steep as 80% (EPA, 2004), which is steeper than the optimal slope for agriculture (Gebrehiwot and Maryo, 2015).

Table 3. Soil erosion in the Gedeo enset based agriculture

Description	Category	Respondents' Frequency (%)		
		Highlands	Midlands	Lowlands
Soil erosion status	Cannot predict	10.3	6.0	40.0
	Decreased	5.2	60.2	60.0
	Increased	37.9	33.7	0.0
	No change	46.6	0.0	0.0
Effect of soil erosion	Decreased yield	74.1	83.1	100.0
	Decreased land size	0.0	43.4	0.0
	Crop shifting	0.0	30.1	0.0
Cause of soil erosion	Deforestation	34.5	40.4	100.0
	Sloppy area plow	32.8	68.1	100.0
	Over plow	3.4	40.4	100.0
	Heavy rain	0.0	51.2	100.0
	Over grazing	0.0	38.6	100.0
	No government control	0.0	51.2	100.0

3.2.2. Soil Conservation Practices

According to our study, almost half of the respondents from the highland (Haro Welabu and Sika) did not implement soil conservation practices (Table 4). However, in the higher-midland (Wete and Bowcha), most households perform soil conservation practices. In lower-midlands (Amba and Harsu) and lowland (Haroresa), almost all farmers did not perform conservation practices (Table 4). In the higher midland, at Bowcha, labor exchange was a common practice, but at Wete, most households used their family while some used payment and labor exchange schemes (Table 4). In the highland, it was mainly performed by payment while sometimes using labor exchange. Other studies also showed that in the construction of soil and water conservations, food for work and cash for labor schemes were applied including in their lands (Shiferaw and Holden, 1998; Bekele, 2003; Amsalu and De Graaff, 2007; Bewket, 2007; Birhanu and Meseret, 2013).

Conservation practices and soil erosion are highly affected by agroecology and farming systems. In the Ethiopian highlands, suitable soil conservation measures are necessary to control soil erosion due to runoff and slope gradients (Adimassu *et al*., 2012a; Adimassu *et al*., 2012b). However, in Gedeo highlands and sloppy areas, soil and water conservation practices are low due to the agroforestry system (Mesele, 2013). Gedeo indigenous agroforestry is the oldest agricultural self-sufficient system fully packaged with production and ecological services (Mulugeta and Mabrate, 2017; Kippe, 2002; Legesse *et al*., 2013). The Gedeo community practices least a home-garden type of agroforestry system (Legesse *et al*., 2013). The agroforestry system maintained the soil from erosion by decreasing runoffs, mulching, and maintaining moisture (Kippe, 2002; Brandt *et al*., 1997; Mesele, 2013).

Table 4. Soil conservation practices in the Gedeo enset farming system

Description	Category	Respondents' Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
Practiced soil-conservation	Yes	48.5	44.0	52.3	89.5	0.0	0.0	0.0
	No	51.5	56.0	47.7	10.5	100.0	100.0	100.0
Conservation-practices scheme	Family	0.0	0.0	41.3	3.9	0.0	0.0	0.0
	Payment	56.3	71.4	29.4	0.0	0.0	0.0	0.0
	Labor exchange	43.8	28.6	29.4	96.1	0.0	0.0	0.0

3.3 Technology Adoption and Extension Services

3.3.1. Traditional Implements

The present study identified different farming tools such as sickle, spade and machete are common in other crop production systems. However, Sisa, Chuko, Meta, Woreme, and Cheko are commonly used for enset based farming systems. Figure 4 shows tools typical to cultivation and harvesting of enset with a cultural attachment to the society. In other enset growing areas, similar traditional tools and implements are used (Pijls *et al*., 1995).

Almost all farming communities have traditional agricultural tools and implements (Das and Nag, 2006). Traditional tools and implements refer to those invented in ancient times, and used for a long time, until recently or still being used now (Sarkar *et al*., 2015). Farming tools and implements were developed and then modified through experience over generations for self-subsistence and to meet emerging socio-economic and farming challenges (Sarkar *et al*., 2015). Usually, for similar purposes, similar types of farming tools are used. However, they may differ in name and in the way they were made. For instance, in the Gurage zone, tools to scrape the leaf sheath are made out of bamboo wood, but in Gedeo it is made up of metal (Figure 4; Pijls *et al*., 1995).

According to the respondents, almost all tools used for kocho extraction were traditional (Table 5). These tools were easy to move and flexible to work in a stand or sit without damaging the enset plant or the products (Table 5). In other enset farming areas, similar trend of using traditional tools were observed (Pijls *et al*., 1995; Garedew *et al*., 2017; Yemataw *et al*., 2016).

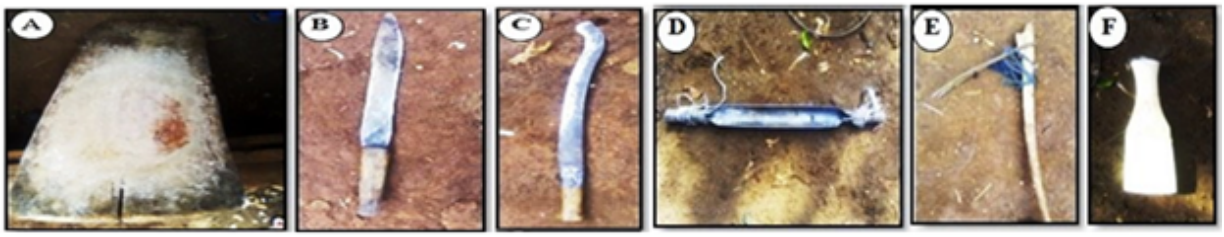

Figure 4. Some of enset farming materials: (A) Wooden chopping board: used for chopping kocho (B) Worme (C) Godesa (D) Sisa: a sharp-edged tool made up of iron used to scrap the leaf sheath (E) Mercha (F) Cheko: about 35cm length used for chopping the corm.

Table 5. The utility of conventional tools in the Gedeo farming system

Description	Category	Respondents' Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
Types of *kocho* extraction-tools	Traditional	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Modern	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traditional tools damage-the plant	Yes	12.0	17.6	0.0	20.0	0.0	0.0	40.0
	No	88.0	82.4	100.0	80.0	100.0	100.0	60.0
Traditional tools are easy-to move	Yes	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	No	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traditional tools are easy-for working in stand or sit	Yes	72.0	82.4	100.0	100.0	100.0	100.0	100.0
	No	28.0	17.6	0.0	0.0	0.0	0.0	0.0

3.3.2. Technology Adoption

This study showed that the majority of the farmers (94-100%) in the study area used none of the previously improved varieties except in Wete (60%) from the midland (Table 6). On the other hand, most farmers from highlands and midlands agreed on using modern improved tools for increasing yield and income and decreasing risk. In the lowland, farmers have limited knowledge about the difference between the traditional and modern tools due to less exposure to the tools. It is also unfocused areas for enset production and government support. According to the farmers, high cost was the main problem that hinders the adoption of modern tools, except for farmers from Wete and Bowcha (Table 6).

Table 6. Adoption and outlook of modified enset farming technology

Adoption of new enset technology	Category	Respondents' Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
Use of improved varieties	Yes	0	0	60	5.9	0	0	0
	No	100	100	40	94	100	100	100
Increased yield	Agree	56	47	94	100	100	100	60
	Not Agree	32	41	4.7	0	0	0	20
	Cannot tell	12	12	1.2	0	0	0	20
Risky for usage	Agree	36	41	33	12	0	0	30
	Not Agree	48	47	67	85	0	0	60
	Cannot tell	16	12	0	2.9	100	100	20
Increased income	Agree	44	53	90	97	0	0	0
	Not Agree	40	35	4.7	2.9	0	0	40
	Cannot tell	16	12	5.8	0	100	100	60
High cost	Agree	60	59	0	29	0	0	60
	Not Agree	24	24	92	71	0	0	40
	Cannot tell	16	18	8.1	0	100	100	0

Traditionally, farmers used different tools in their day-to-day life for agricultural operations to save labor, money, and time (Karthikeyan *et al*., 2009). Women use conventional tools for laborious and tiresome enset processing activities (Kibatu *et al*., 2021, Borrell *et al*., 2020). Modified tools can increase work efficiency and production (Sarkar *et al*., 2015). In Gedeo, farmers use locally available materials to make farming tools. (Nijra and Daimary, 2017).

4 Conclusion

This study provides an overview of enset based farming systems, farming tools, soil erosion and conservation activities, and technology adoption in the Gedeo Zone. The study revealed that as altitude increases, the enset cropland coverage increases compared to other existed crops. In lowland areas, the land cover of enset was lower. Comparative enset-coffee land covers mainly maters in the midland. The type and the number of animals holding differ across and within the households. Soil erosion problem was minimal. Thus, the practice of soil conservation was also minimal. Improved varieties coverage in most of the study areas was low. Women used conventional tools for harvesting and processing of enset. Therefore, it would be better if the district agricultural office collaborates with research centers and other concerned bodies to introduce and disseminate improved technology in the area by considering the agroforestry system and mixed crops.

Acknowledgments

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Conflict of Interest

The authors declare that there is no conflict of interest.

References

Abebe T., and Bongers F. (2012). Land-use dynamics in enset-based agroforestry home gardens in Ethiopia. **In**: Arts B., van Bommel S., Ros-Tonen M., Verschoor G. (eds). *Forest people interfaces: understanding community forestry and biocultural diversity*. Wageningen Academic Publishers, Wageningen. 69–85.

Abebe T., Wiersum K.F., Bongers F., Sterck F.J. (2006). Diversity and dynamics in homegardens of southern Ethiopia. **In**: Kumar B.M., Nair PKR (eds) *Tropical homegardens: timetested example of sustainable agroforestry*. Springer, Dordrecht. 123–142.

Abebe (2005). Diversity in home garden agroforestry systems of southern Ethiopia. Dissertation, Wageningen University, The Netherlands.

Abebe T. (2013). Determinants of crop diversity and composition in Enset-coffee agroforestry home gardens of Southern Ethiopia. *J. Agric. and Rural Development in Tropics and Subtropics*, 114(**1**):29–38.

Abiyot Legesse (2013). The dynamics of indigenous knowledge pertaining to agroforestry systems of Gedeo: implications for sustainability, University of South Africa, Pretoria. http://hdl.handle.net/10500/14617.

Adem A. and Kibatu T. (2020). On-farm genetic diversity and distribution pattern of Enset (*Ensete ventricosum* (Welw.) Cheesman) cultivars in Gedeo Zone of Ethiopia. *Journal of Genetics, Genomics & Plant Breeding*. 4(**4**):188-197.

Adimassu Z., Kessler, A. and Hengsdijk, H. (2012a). Exploring determinants of farmers' investments in land management in the Central Rift Valley of Ethiopia. *Applied Geography*. 35:191-198.

Adimassu Z., Mekonnen K., Yirga C. and Kessler, A. (2012b). The effect of soil bunds on runoff, losses of soil and nutrients, and crop yield in the central highlands of Ethiopia. *Land Degradation*

& Development. hhtps://www.doi.org/10.1002/ldr.2182.

Amsalu A., de Graaff, J. (2007). Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. *Ecol. Econ*. 61:294-302.

Anteneh N., Taye K. and Tesfaye S. (2015). Review of Arabica Coffee Management Research in Ethiopia. *Journal of Biology, Agriculture and Healthcare*. 5(**13**):235-258.

Begum, S., Zaman, M. and Khan, A. (2015). Intercropping of root crops with chili in char lands of Mymensingh. *Progressive Agriculture*. 26:109-114.

Belachew G., Aklilu A., Bewuketu H. and Habtamu K. (2017). Indigenous knowledge of Enset (*Ensete ventricosum* (Welw.) Cheesman) cultivation and management practice by Shekicho People, Southwest Ethiopia. *Journal of Plant Sciences*. 5(**1**):6-18.

Bewket W. (2007). Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers. *Land Use Policy*. 24:404-416.

Birhanu A. and Meseret D. (2013). Structural soil and water conservation practices in Farta District, North Western Ethiopia: An investigation on factors influencing continued use. *Science, Technology and Arts Research Journal*. 2(**4**):114-121.

Bishaw B., Neufeldt, H., Mowo, J., Abdelkadir A., Muriuki, J., Dalle G., Assefa T., Guillozet, K., Kassa H., Dawson, I.K., Luedeling, E., Mbow, C. (2013). **In**: Davis, C.M., Bernart, B., Dmitriev A. (eds), *Farmers' strategies for adapting to and mitigating climate variability and change through agroforestry in Ethiopia and Kenya*. Forestry Communications Group, Oregon State University, Corvallis, Oregon.

Blomme, G., Sebuwufu, G., Addis T., & Turyagyenda, L.F. (2008). Relative performance of root and shoot development in Enset and East African highland bananas. *African Crop Science Journal*. 16(**1**):51–57.

Borrell, J.S., Goodwin, M., Blomme, G., Jacobsen, K., Wendawek A., Gashu D., Lulekal E., Asfaw Z., Demissew S., Wilkin, P. (2020). Enset-based agricultural systems in Ethiopia: a systematic review of production trends, agronomy, processing and the wider food security applications of a neglected banana relative. *Plants People Planet*. 2:212–228.

Brandt, S.A., A. Spring, C. Hiebsch, G. Yntiso, E. Tabogie, M. Diro, G. W/Michael, S. Tesfaye, J.T. McCabe & M. Shigeta (1997). The tree against hunger: Enset-Based Agricultural Systems in Ethiopia. American Association for the Advancement of Science with Awassa Agricultural Research Centre, Kyoto University Centre for African Area Studies and University of Florida. Directorate for International Programs. Washington, DC.

Das, P.K. and Nag, D. (2006). Traditional agricultural tools: A Review. *Indian Journal of Traditional Knowledge*. 5(**1**):41-46.

Debele S. and Habta M. (2015). Sheep and goat production practices in agroforestry systems of Gedeo zone, SNNPR, Ethiopia. *International Journal of Animal Health and Livestock Production Research*. 1(**1**):37-47.

Elzubeir, A.S. (2014). Traditional agricultural tools and implements used in Sudan. *International Journal of Agricultural Sciences*. 4(**2**):140-146

Environmental Protection Authority (2004). The 3rd national report on the implementation of the UNCCD/NAP in Ethiopia, Report prepared for the third session of the committee for the review of implementation, 2-11 May. Addis Ababa.

Famaye, A.O. (2005). Evaluation of nutrient uptake in coffee intercropped with maize, cassava and

plantain in Nigeria. *Nigerian Journal of Applied Science*. 23:1-5.

Garedew B., Ayiza A., Haile B., Kasaye H. (2017). Indigenous knowledge of enset (*Ensete ventricosum* (Welw.) Cheesman): cultivation and management practice by Shekicho People, Southwest Ethiopia. Journal of Plant Sciences. 5:6–18.

Gebrehiwot B. and Maryo M. (2015). 'Evaluation of land use patterns across agro-ecological and slope classes using gis and remote sensing: The Case of Gedeo Zone, Southern Ethiopia'. *International Journal of Advanced Remote Sensing and GIS*. 4(**1**):1385-1399.

Karthikeyan, C., Veeraragavathatham, D., Karpagam, D., Firdouse, S.A. (2009). Traditional tools in agricultural practices. *Indian Journal of Traditional Knowledge*. 8(**2**):212-217.

Kibatu T., Tigabu B., Mamo M., Girma F., Tolosa S., Debebe N. and Shewarega M. (2021). On-Farm Management, Processing and Postharvest Handling of the Indigenous Enset (*Ensete ventricosum* (Welw.) Cheesman) in Gedeo Zone, Southern Ethiopia. Ethiop. *J. Agric. Sci*. 31(**2**)73-85.

Kippe T. (2002). Five thousand years of sustainability. A case study on dedeo land use, southern Ethiopia. Doctoral Thesis, Treemail Publishers, Heelsum.

Legesse A., Bogale T. and Baudouin, A. (2013). Indigenous agroforestry knowledge transmission and young people's participation in agroforestry practices: The case of Wonago Woreda, Gedeo Zone, Southern Ethiopia', *Acta Geographica-Trondheim*. University of Trondheim, Norway.

Mekonnen B., Getachew E., Temteme S., Shimber, T. and Netsere A. (2020). Intercropping of Coffee with Enset (*Enset ventricosum* (Welw.) Cheesman) at Teppi, Southwestern Ethiopia. *Plant*. 8(**4**):64-71.

Mesele N. (2007). Tree management and livelihoods in Gedeo's agroforests, Ethiopia. *Forest, Trees and Livelihoods*. 17(**2**):157-168.

Mesele N. (2013). The indigenous agroforestry systems of the south-eastern Rift Valley escarpment, Ethiopia: their biodiversity, carbon stocks, and litterfall. *Tropical Forestry Reports* No. 44. Doctoral Thesis. University of Helsinki.

Mulugeta G. and Mabrate A. (2017). Production and Ecological Potentials of Gedeo's Indigenous Agroforestry Practices in Southern Ethiopia. *Journal of Resources Development and Management*. 30:68-76.

Negash A., Niehof, A. (2004). The significance of enset culture and biodiversity for rural household food and livelihood security in southwestern Ethiopia. *Agriculture and Human Values*. 21:61–71.

Nijra, Brahma, N. and Daimary, L. (2017). The Traditional Agricultural Tools and Technology used by the Bodos. *IOSR-JHSS*, 22(**5**):65-72 .

Pijls, L.T., Timmer, A.A., Wolde-Gebriel Z., West, C.E. (1995). Cultivation, preparation and consumption of enset in Ethiopia. *Journal of Science, Food and Agriculture*. 67:1–11.

R Development Core Team (2020). R Development Core Team R: A Language and Environment for Statistical Computing. Version 4.0.3. https://www.rproject.org/

Rahmato D. (1995). Resilience and Vulnerability: Enset Agriculture in Southern Ethiopia. *Journal of Ethiopian Studies*. 28(**1**):23-51.

Sarkar, B., Kumar, P.,Sundaram, A.D., Ujjwal, K., Kamal, S. and Bhatt, B.P. (2015). Traditional Agricultural Tools used by Tribal Farmers in Eastern India. *Research Journal of Agricultural Sciences*. 6(**1**):215-219.

Selamawit Debele and Matious Habta (2015). Sheep and goat production practices in agroforestry systems of Gedeo zone, SNNPR, Ethiopia. *International Journal of Animal Health and Livestock Production Research*. 1(**1**):37-47.

Shambulo, A., Gecho, Y., and Tora, M. (2012). Diversity, challenges and potentials of Enset (*Ensete ventricosum*) production; in case of Offa Woreda, Wolaita Zone, Southern Ethiopia. *Food Sci. and Qual. Mgt*. 7:24–31.

Sileshi D. (2016). Home garden agroforestry practices in the Gedeo zone, Ethiopia: a sustainable land management system for socioecological benefits. **In**: UNU-IAS and IR3S/UTIAS (2016), *Socioecological production landscapes and seascapes (SEPLS) in Africa*. United Nations University Institute for the Advanced Study of Sustainability, Tokyo. 28-36.

Taye K., Tesfaye S., Alemseged Y., Anteneh N., Endale T., and Endale T. (2001). The impact of close spacing on yield of Arabica coffee under contrasting agro-ecologies of Ethiopia. *African Crop Sci, J.* 9:401-409.

Temesgen M., Bizuayehu T., Marcello, C. and Mario, E. (2014). Indigenous knowledge, use and on-farm management of enset (*Ensete ventricosum* (Welw.) Cheesman) diversity in Wolaita, Southern Ethiopia. *Journal of Ethnobiology and Ethnomedicine*. 10(**41**):1-18.

Tsegaye A. and Struik, P.C. (2001). Enset (*Ensete ventricosum* (Welw.) Cheesman) kocho yield under different crop establishment methods as compared to yields of other carbohydrate-rich food crops. *NJAS - Wageningen Journal of Life Sciences*. 49:81–94

Tsegaye A. and Struik, P.C. (2002). Analysis of enset (Ensete ventricosum) indigenous production methods and farm-based biodiversity in major enset-growing regions of southern Ethiopia. *Experimental Agriculture*. 38:291–315.

Tsegaye A. (2002). On indigenous production, genetic diversity and crop ecology of enset (*Ensete ventricosum* (Welw.) Cheesman). Ph.D. thesis, The Netherlands: Wageningen University.

Tsehaye, Y., and Kebebew, F. (2006). Diversity and cultural use of enset (*Ensete ventricosum* (Welw.) Cheesman) in Bonga in situ, Ethiopia. *Ethnobot. Res. Appl*. 4:147–157.

Yemataw, Z., Muzemil, S., Ambachew, D., Tripathi, L., Tesfaye, K., Chala, A., Farbos, A., O'Neill, P., Moore, K., Grant, M., and Studholme, D.J. (2018). Genome sequence data from 17 accessions of *Ensete ventricosum*, a staple food crop for millions in Ethiopia. *Data in Brief*. 18:285–293.

Yemataw, Z., Tesfaye, K., Zeberga, A., and Blomme, G. (2016). Exploiting indigenous knowledge of subsistence farmers for the management and conservation of enset (*Ensete ventricosum* (Welw.) Cheesman) (Musaceae family) diversity on-farm. *J. Ethnobiol. Ethnomed*. 12:34.

Yeshitla M. and Yemataw Z. (2012). Past research achievement and existing gaps on enset (*Ensete Ventricosum* (Welw.) Cheesman) breeding. **In**: *Enset Research and Development Experiences in Ethiopia*. Proceedings of Enset National Workshop, 19–20 August 2010, Y. Mohammed and H. Tariku, eds. (Wolkite, Ethiopia). 22–36.