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Land use Dynamics and challenges of Enset (Ensete ventricosum) agriculture in the upper reaches of Baso-Deme watershed, Gamo Highland, SW Ethiopia

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Short maturing Enset tree in the outfield, Gamo highland, Ethiopia

Abstract

Enset (*Ensete Ventricosum)* is a perennial security crop that feed over 14 million people in the Southern Ethiopia and not known outside Ethiopia as food crop. This plant is related to banana (*Mussa*) family and both the pseudo stem and corm are pulped for food (*kocho*) and fiber. Several studies have confirmed the environmental, food security and socio-cultural significance of enset tree. But due to decline in soil fertility, unavailability of *cattle dung*, and above all the prevalence of *bacterial wilt*, enset agriculture in the study area were constrained at a significant amount. Thus, the objective of the study was to examine the long term change in land use and assess the challenges of enset agriculture in the area. The research was designed using mixed approach. In collecting and analysis of socio-economic data both qualitative and quantitative techniques were utilized. In addition, composite soil samples were analyzed in the laboratory for its soil nutrient content. Furthermore, spatial and temporal land use/ cover data was quantified and mapped using GIS technique. Land use/ cover change detection analysis over thirty years (1985-2014) depicts that there was a substantial alteration of cover types. Thus, over studied period cropland was revealed significant positive change by 46.8%. In contrary, enset farm, woodland and grassland were squeezed by 15.4 %, 33.3 % and 32.8 % respectively. It was revealed that enset has the highest carrying capacity (more than 53%) compares to barley provided both crops are cultivated under the same agro-climatic and farm input conditions. Soil data analysis depicted that there was significant variation in chemical properties of soil (such as nitrogen, potassium, available phosphorus, CEC, pH factor) in between land use types. The survey finding further showed that low soil fertility, climatic factor, enset diseases and enset damaging wild animals are considered to be the major production constraint in the area.

***Key words**: Land use dynamics, cropping pattern, carrying capacity, enset, chemical properties of soil and GIS technique.*

Introduction

Gamo highland is located in the Ethiopia's South most administrative zone Gamo Gofa, SNNP Region in the western escarpment of the great East African rift valley system. Gamo highland is among the earlier inhabited and populous part in the Ethiopian mountain system, where natural vegetation is severely depleted and farm sizes are extremely marginal. It consists of extensive mountain grassland of intrinsic ecological values that have long suffered from soil nutrient depletion and land use/ cover change of varying levels, which is resulted from historic settlement and inappropriate tillage practices. Many of traditional agricultural systems that were ecologically stable before decades were breaking down now due to environmental degradation (village elder's view).

Studies have shown that there were significant land-use dynamics in the Ethiopian highlands during the second half of the 20th century (Taddese, 2001, Kidanu, 2004). As reported by Bewket (2009) the Ethiopian mountains are the most affected part in terms of changes in land-use and land-cover and related disruptions in ecosystem function and livelihood. At a local level, changes in land-use and land-cover affect patterns and dynamics of catchment biophysical and socio-economic processes (Briassoulis 2000), which have direct impact on livelihood of the local communities. Therefore, land use change and excessive human pressure on these marginal lands may lead to severe loss of soil productivity and reduction of both livestock and human carrying capacity.

The negative effect of population pressure over natural environment was forwarded by scholars such as Bewket (2003) and Kidanu (2004) in Northern Ethiopia. They stated that over-uses of natural resource and degradation are the consequences of population pressure. Literatures have critically documented the impact of population pressure on environment and agricultural production in the upper reaches of yellow river, China (Zeng, et.al. 2003) and in the highlands of Madagascar (Tor-Gunnar 2006).

Soil plays an important role in the ability of ecosystems to provide diverse services necessary for human wellbeing. However, as a response to mismanagement by human being, there has been a continuous deterioration of soil resource, due to soil erosion. Soil erosion includes loss of nutrients, declining crop yields, and reduction in soil productivity (Nyakatawa et al. 2001). Bedadi (2004) has estimated soil erosion rate in Ethiopia as 1.5 billion tons compared to 5 billion tons in China (Liu 2004). Thus, even if erosion rate of 1.5 billion tons soil seems lower compared to China's experience, much must be done to control soil nutrients loss and physical soil degradation type in Ethiopia.

As a result of soil degradation, soil organic matter has declined, soil nutrients are depleted, and soil depth has decreased, leading to declining crop yields and forage.

In the study area, Enet (*Ensete Ventricosum)* being a security crop, especially during period of food deficit it supports large human population. But due to soil nutrients depletion, insufficient application of animal *dung*, mismanagement and above all prevalence of *bacterial wilt*, enset agriculture in the study area is negatively threatened. Thus the increasing damage to enset tree (staple food of the study community) by bacterial wilt and wild beasts, and the rising demand of construction materials in the neighboring urban centers had aggravated the situation of land-use/cover conflict in the area. The land-use conflict between enset on one side and cereals and eucalyptus tree on other side became increasingly dominant, where the former is dwindling while the latters are progressively occupying more area. Therefore, the objective of the study was to examine the long term change in land use and assess challenges of enset plant in the area.

Study Area and Methodology

The study area:

The area is located between 6° 10'N to 6° 23'N latitude and 37° 27'E to 37° 39' 30"'E longitude (Fig. 1). It is located in the Ethiopia's south most provinces of Gamo Gofa along the North-western margin of the Great East African Rift valley system. The area is an extended rugged plateau stretched from Chencha woreda in the east to Dita woreda in the west for about 30 km.

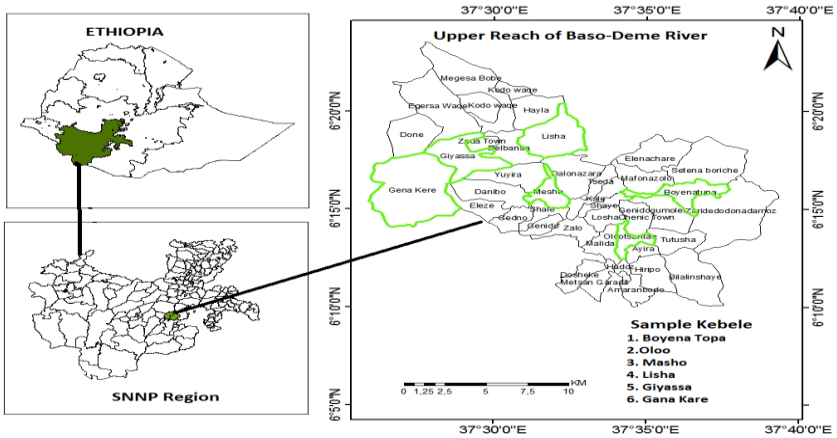


Fig. 1 Location Map of upper Baso-Deme Watershed

Physiologically, most area has rugged landscape and dominated by plateau terrain. The altitude of the watershed ranges between 1289 m asl and 3490 m asl. As can be seen in Figure 2, almost all area has cool tropical climatic, but its mean annual rainfall varies significantly throughout the watershed (i. e., between 1050 mm and 1550 mm), but mean annual temperature shows insignificant variation throughout the watershed (i.e., 14.6 ^{0}c and 15.2 ^{0}c).

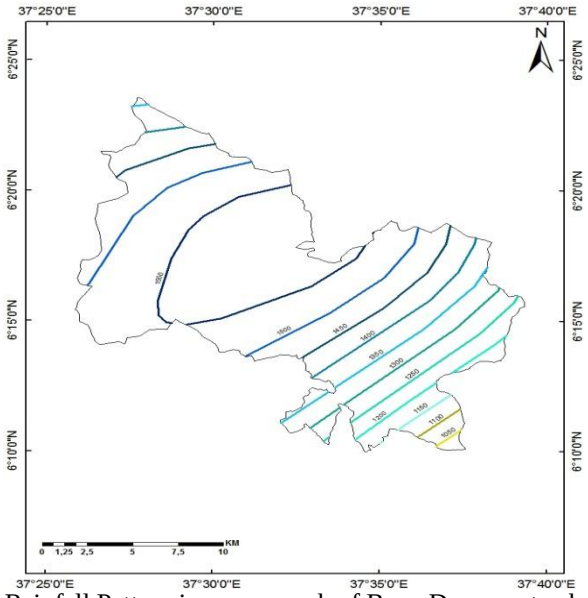


Fig. 2: Rainfall Pattern in upper reach of Baso-Deme watershed

Due to historic settlement and age old management practices forest cover in the area is badly depleted. Remnant trees such as Arundinaria Alpina, Eucalyptus Globulus and Juniperus Procera in upland and Carissa Spinarum, Hagenia Abyssinica, and Syzygium Guineense in the midland are the dominant tree species grown.

According to FAO/UNESCO System of Soil Classification, the study area has five 2nd class soil groups, namely *Dystric Fluvisols, Dystric Nitisols, Eutric Fluvisols and Orthic Acrisols* (Figure 3). In the study area, Acrisols and Nitosols are the principal soil types.

Livelihood of the people

Population of the study area is about 180,000. Per capita landholding is less than 0.50 hectare. Here, livelihood of the people is basically agricultural (crop-livestock farming) but off farm activities are carried out during the off farming season. The people have the characteristics of high density Enset horticulturalist and well known by their traditional weaving and indigenous terrace farming culture. They cultivate a variety of crops, including cereals, fruits and the all-important staple enset (*Ensete Ventricosum*).

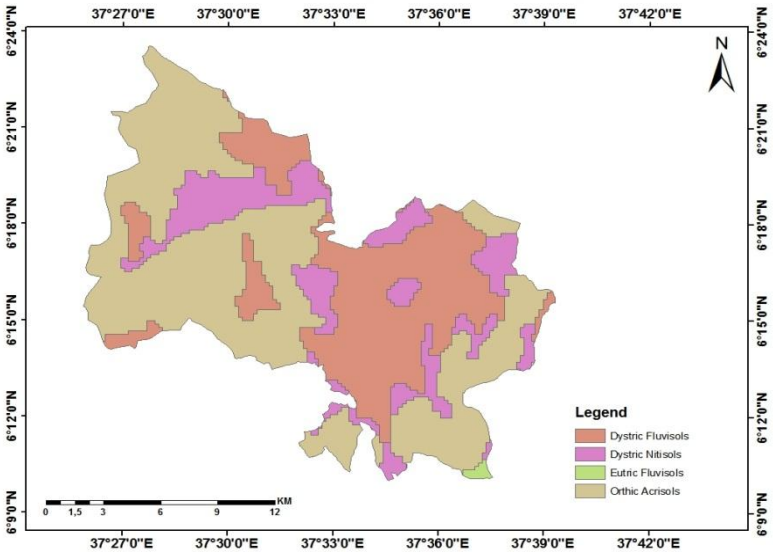


Fig. 3: soil group in the upper reach of Baso-Deme watershed, 2015

In the study area agriculture revolves around perennial tree plant, where enset acts as a co-staple food crop with barley. In Baso-Deme watershed enset is a homestead tree plant where its stem is chopped and pulped to make *Qocho* (edible material) for household consumption (Fig. 4).

Fig. 4 Woman is Pulping Enset Stem to Make '*Qocho'* (edible material) in Baso-Deme watershed

Methodology:

The research is designed in a mixed approach (qualitative and quantitative). The researcher focuses on the cross-sectional survey design to collect qualitative and quantitative data (Creswell, 2009). In the study, the primary data was generated through four main tools such as satellite imageries, composite soil sample, household survey and focus group discussion. Remote sensing and geographic information system, GIS has been efficient and powerful tool in providing reliable information on natural resource classification and mapping of land-use/ cover change over space and time (Roy et al., 1991). Satellite images and aerial photographs are useful for both visual and digital assessment of natural resource dynamics occurring at particular time and space as well as quantitative evaluation of land cover changes over time (Kibrom and Lars, 2000). Spatio-temporal changes of land-use/cover of upper reach of Baso-Deme watershed was monitored by analyzing multi-temporal remote sensing images, using Landsat and Spot 5 images that are taken in 1985, 1995 and 2010 respectively. In addition, survey of Ethiopia Topo sheet (1976) of the area was used for geo-referencing and field check. Composite soil samples were collected from varying land use/cover types of two agro-ecologies. Sample soils were collected from 30 cm depth of each auger points by using auger and Geographic Position System (GPS). In this case, 24 sample units were collected and dried and grinded for laboratory soil test of physical and chemical properties. A household survey was conducted from June to July 2014 in six sample villages. In addition 3925 household heads, 194 sample household heads were selected by using systematic random sampling technique. They were interviewed using structured survey questionnaire on issues like land use/cover and challenges of enset agriculture. Furthermore, key informant discussion was undertaken to strengthen quantitative data.

In the analysis and interpretation of land-use/cover and soil data; GIS and Remote sensing techniques, and analysis of variance (ANVA) was utilized. Data on challenges of enset agriculture was assessed using Chi square test. In addition, qualitative data was elaborated by using narration and verbal expression.

Result and Discussion

On an average one plant of 5 years old enset tree can yield up to 50kg dry kocho (respondents view). Compared to grain crops, enset is inferior in its nutritional value, containing only about 200 cal. per 100 grams of dry *kocho* (edible material) which is about 60 percent of the average calorie content in cereal crops (Muluneh1994). Enset cultivation is superior to seed farming in reducing soil erosion and it has high agronomic yield of 5000 kg kocho per hectares, (Brandt 1997) as compared to cereals, 922 kg barley (*Hordeum-vulgare-L.*) per hectare (CSA 2013).

As to the human carrying capacity of enset is high and is likely greater than cereals provided that they are cultivated in the same agro ecology, soil and input situation. Although enset agriculture seems to support higher population density than cereal crop, it is difficult to compare these systems, because of lack of quantitative data, absence of uniform spacing between enset trees and the perennial nature of the crop. However, using single year production data it is possible to suggest the superiority of enset over cereals. Assuming that one hectare of Enset

farm yields 5000 kilograms of Enset food (dry *'kocho'*) per year and 100 grams of dry 'kocho' is equivalent to 200 calories, thus one hectare of Enset farm yields 10,000,000 calories of food (50 x 100 x 1000 x 1 x 2cal).

On the other hand, in a similar sized plot, if cereal or for instance barley is cultivated, it would give an average yield of 922 kg per hectare and with a calorie content of 339 cal. per 100 grams of cereals. The total calorie of cereal produced from an average plot with a size of one hectare per year would be 3,125,580 calories of food (9.22 x 100 x 1000 x3.39 cal.), which is about 31.3 percent of the calorie yield of enset production.

When considering the population supporting capacity of Enset and cereal, with current household and farmland size situation in the study area, one can observe an amazing situation. According to the quantitative data, in the study area average enset and cereal plots are 0.18 and 0.49 hectare respectively. Similarly, the average family size was 6.9. Hence on an average, 0.18 hectare of enset farm can yield 1,800,000 calories (50 x 100 x 1000 x 0.18 x 2cal.) of '*kocho*' food in a year (considering 100grams of dry 'kocho' is equivalent to 200 calories).

Similarly, 0.49 hectare of cereal farm can yield 1,531,534 calories (9.22 x 100 x 1000 x 0.49 x 3.39cal.) of food per a year (by considering 339 cal. per 100 grams of cereal). Thus, 1,800,000 cal. of food obtained from Enset farm (0.18 ha) can support 2.1 persons for a year, consuming 1170 grams of dry kocho or 2340 cal. per head per day. While, the yield of cereal obtained at household level can support 1.8 persons per year, consuming 690gm cereal or 2340 cal. per head per day. This means that of the total household farm size (i.e., 0.67 ha), about 30.4% and 26% family size was supported by 26.9% and 73.1% farm size respectively. Therefore, from the aforementioned analysis it can be conclude that under the existing condition of demographic pressure and land scarcity in the study area, enset cultivation has the capacity to support more population as compared to the grain crops.

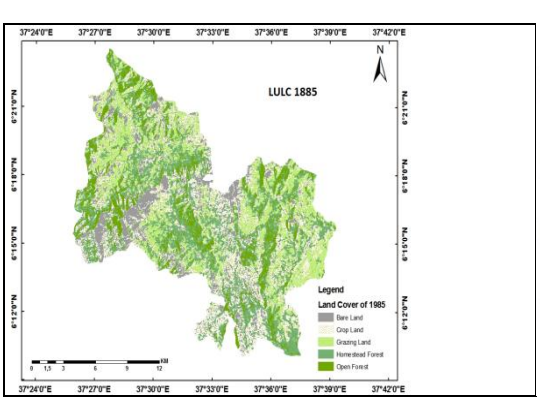
Having such a significant contribution in fulfilling the household food demand, in the study area enset agriculture was subjected to varying threatening conditions as discussed hereunder. The first most mentioning challenge was progressive reduction in the size of enset farm. In the upper reaches of Baso-Deme watershed, five major land-cover/use types were identified in three period satellite images (1985, 1995 and 2010). When assessing the spatio-temporal changes in the overall studied period (1985-2010), three land use/cover categories i.e., cropland, woodland and bare land revealed a positive change at varying magnitudes in the first period, but it was only crop land and bare land that continued in the same trend in the subsequent period. But wood land showed a negative trend.

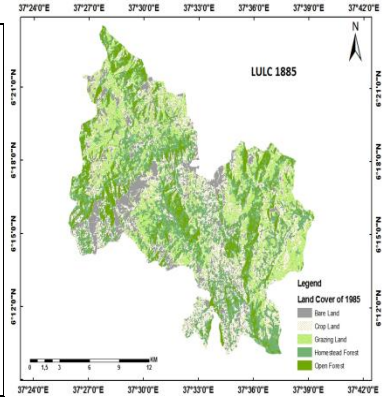
Table 5: Land-Use/Cover Development for 1985, 1995 & 2010

Land-cover type	1985 Area(km^2)	%	1995 Area(km^2)	%	2010 Area(km^2)	%	Change b/n 1985 & 1995 (%)	Change b/n 1995 & 2010 (%)
woodland	36	12.1	37	12.4	24	8.1	2.8	-35.1
enset farm	68	22.8	65	21.8	57.5	19.3	-4.4	-11.5
Grassland	72	24.2	66	22.1	48.4	16.2	-8.3	-26.7
cropland	90	30.2	95	31.9	132.1	44.3	5.6	39.1
Bare land	32	10.7	35	11.8	36	12.1	9.4	2.9
Total	298	100	298	100	298	100	-	-

* Changes were calculated in reference to the base year (1985 and 1995)

In the studied period the most dramatic change was found to be decline in woodland and grassland (i.e., 33.3 % and 32.8%) but the increase of cropland was paramount (46.8 %). The study showed that 160 hectares of additional land was encroached into farmland from other land use/ cover types every year. Furthermore, image data revealed that in the entire study period area occupied by enset farm showed a decrease by 15.4 %, which is about 40.4 hectares of enset farm was converted to other land uses mainly into cropland. This finding was supported by responses from key informants and focus group discussion result.





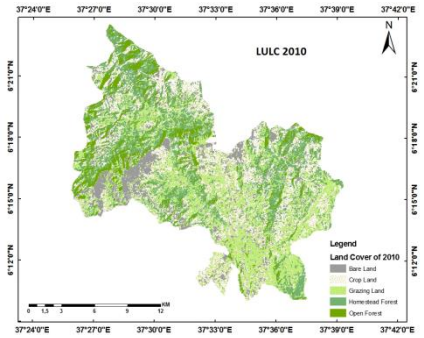


Figure 5 Spatio-temporal Cover change in Baso-Deme watershed (1985- 2010)

Informants in the study area confirmed that enset fields in their localities are progressively declining in the last three decades. They outlined damage by of bacterial wilt, lack of animal manure and ineffective management practices resulted from declined agricultural labor force especially in Dorze sub region as the main cause. Over 26 years study period, the expansion crop land was amounted to about 4,160 hectares, and the estimated annual increment was 160 hectares. This is primarily resulted from cultivation of grassland and forestland. Thus, cultivation of grassland and forestland has destroyed soil structure, increased soil erosion, and triggered environmental degradation. In addition to decline of enset farms by 1,050 hectares or 40.4 hectare per annum that uses much of homemade animal manure to be applied on enset farm to raise productivity was not utilized.

As to soil micro-nutrients in varying land use/ cover types is concerned there observed significant variation. For instance, soil pH analysis indicates great variation between enset farm (5.5) and teff (Eragrostic-tef) farms (7.47) (Table 1).

Soil texture is an important property that controls moisture holding capacity, supply of nutrients, water percolation and aeration etc (Sehgal 1996). However, extreme textures of soil are unfavorable for most plant species. Cereals are known to give best productivity on moderately fine textured soils; while fine textured soils and deep soil have been favorable for tap rooted plants. (Haile and Fetene 2012). Accordingly, the most dominant soil texture groups in enset and cereal farms are clay and silt clay in nature. When observing soil reactions at land-use level, except enset fields all other land-use types have slightly acidic to moderately acidic soil reaction. As noted by Miller et al., (1997), the soil pH greatly affects the solubility of minerals, the availability of toxic metals, nutrients and soil microorganisms. On enset farm, due to continuous application of animal dung (organic manure) soil reaction has neutral behavior (appendix 1). But the application of manure in the outfield was low, as a result pH reaction of the soil was less than 27.6% compared to homestead fields. This finding was further confirmed by ANOVA result, that showed a significant variation of soil pH factor (P-value of 0.048) at 0.05 level of significance.

Soil organic matter is primarily plant residues, in different stage of decomposition. Soil organic matter affects the soil structure by serving as a cementing agent, returns plant nutrients to the soil (P, S, N), helps to store soil moisture, enhances aeration and water penetration, makes soil more tillable for farming. As revealed in the analysis that soil organic matter and fertility status greatly differ on enset farm as compared to barley fields. This is due application of manure, crop residue and household refuse on enset farm which enriches organic matter content of the soil. In the out fields, due to labor constraint and age old farm land management practice organic matter content of the soil was very low (which is between 0.34 percent and 1.31 percent).

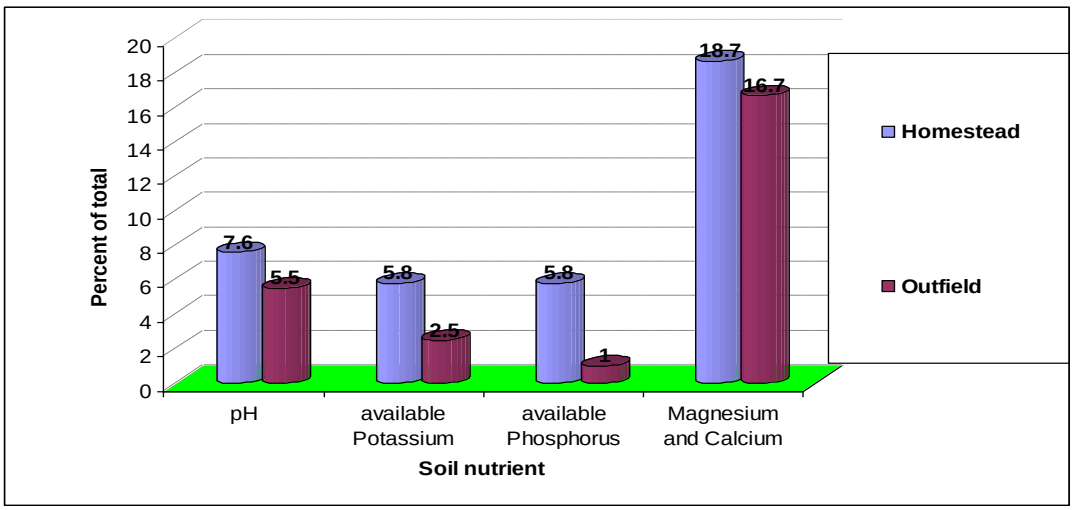


Fig. 6 availability of Soil micro-nutrients in the Homestead and Outfield, Baso-Deme watershed

As can be seen in fig. 7 that there is significant decrease in the amount of organic matter in the farm fields with distance from the dwellings; where concentration of organic matter is reduced to 31.4% compared to the homesteads.

Total Nitrogen is a measure of both inorganic and organic forms of nitrogen and expressed as percentage. The soil analysis at watershed level ranges between 0.07 percent (in lowland are) to 0.8 percent (in the midland area). Hence, according to Kjeldah method, which is used for nitrogen determination in the soil, total nitrogen content is low. However, when consider data at the land-use level, except cereal fields all land-use types have high Nitrogen content (more than 0.15 percent). The study further showed significant decrease of total nitrogen with distance from the homesteads. The concentration of total nitrogen in the outfields was 34.8 percent lower than that of the homestead fields. Generally, nitrogen content of the soil in the study area reveals a significant variation among different land-uses. The ANOVA test also confirms this situation (P value of 0.032).

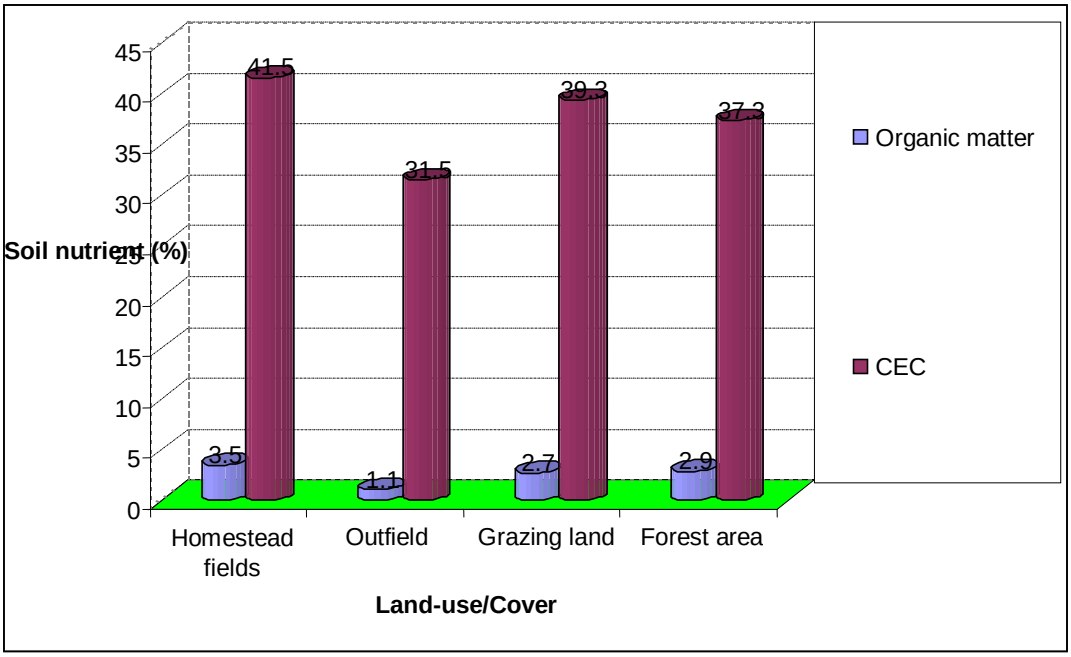


Fig. 7 proportion of Soil micro-nutrients in Sample Land-Use/Cover type

Phosphorus is a fertilizer nutrient used by plants. Plants can take phosphorus when it is in the available state. Thus, phosphorus, nitrogen and potassium are the three essential nutrients needed by plants. As the chemical analysis in appendix 2 shows the available phosphorus are between 9.12 ppm and 19.1 ppm in midland and lowland areas, respectively. ANOVA result reveals that the available phosphorus and potassium showed insignificant difference among the study land-uses. A study by Morgan (1980) suggests that when available phosphorus in the soil is less than 7 ppm, it should be supplemented with phosphorus fertilizer. Based on Morgans' finding, most land-uses in the uplands have insufficient amount of available phosphorus in the soil, thus for optimum yield enset farm have to be supplemented by phosphorus fertilizer.

Cation-exchange capacity, here after CEC**,** is a measure of the quantity of cations that can be adsorbed and held by a soil. Thus, Cations refers to the basic cations, calcium (Ca^{+}_{2}), magnesium (Mg^{+}_{2}), potassium (K^{+}_{1}), sodium (Na^{+}_{1}) and the acidic cations, hydrogen (H^{+}_{1}) and alimunium (Al^{+}_{3}). The amount of these positively charged cations that a soil can hold is described as the CEC and expressed in milliequivalents per 100 grams of soil or centimodeles of positive charge per kilogram of soil.

Soil analytical result indicates that the average CEC value in soils of midland and Lowland kebeles are 33.5meq/100g and 39.9meq/100g, which is considered as high. This is due to large amount of clay particles and organic content in the soils. However, similar to soil organic matter, the proportion of CEC in the outfield was lowered by 76 percent as compared to homestead fields, suggesting that the availability of CEC in the soil is influenced by sources of animal manure. Nevertheless, the statistical analysis of ANOVA showed insignificant variation at 0.01 alpha levels in the CEC value among the study kebeles.

Production Constraints of Enset agriculture

As can be discussed in the foregoing section, principal soil nutrients/ fertility of soil was extremely impoverished due to traditional management and age old farming practices. This finding was further supported by survey results that were conducted in the hilly upland kebele (Gana kare). The survey result stated that about 63.3 percent of the respondents complained that due to infertility of soil farm yields on their locality were progressively decreasing for the last ten years.

Enset tree (*Ensete ventricosum*) is susceptible to several diseases, but the most widespread and destructive among such diseases, appears to be bacterial wilt. According to the survey result, 29 % and 92 % of the sample households in Gana kare and Olo'o kebele reported enset disease in their farm. From the survey result, it was evident that there is spatial variation in the distribution of enset damaging disease in the study area. This showed that warm tropical climate seems to be the ideal environment for the multiplication of enset infecting viruses. Regarding the severity of disease, about 74.5 % of the overall respondents reported that bacterial wilt is highly widespread, while the remaining 25.5 % responded replied as corm rot is most severe.

The chi-square result also revealed significant variation in the severity of disease between the study kebeles .This is because the calculated value ($x^2 = 9.11$) is greater than the critical value (5.99) at 0.05 probability level, implying a considerable variation between the study localities (Table 7).

Table 7: Severity of Enset Disease between agro-climatic zone

Severity of disease	Agro-climate zone				Chi-square result
	Gana kare (highland)		Olo'o (midland)		
	Act	Exp	Act	Exp	
Bacterial wilt	52	59.5	24	20.4	Cal = 9.11
Corm-rot	24	16.5	2	5.6	Tabu =5.99

Significant at 0.05 probability level

Generally, it was fair to suggest that in the study area bacterial wilt is the most widespread type of enset disease followed by corm-rot. In addition, wild animals are considered to be the other prevalent challenge to enset agriculture. Over 80 percent of the sample households at Olo'o kebele complained porcupines as major problems of enset, but 60.8 percent 0f Gana kare respondents reported mole- rat as their major challenge. These animals usually attack enset clones whose corms are sweet, which met farmers' immediate consumption needs.

Survey findings further implied that among the most serious enset damaging wild animals, porcupine in the midland and mole rat in the highlands are the most damaging animals. The chi-square result also supported the argument that a significant variation exists between enset damaging wild animals between agro-climatic zones. This is because the calculated chi-square value (x^2 =67.00) was greater than the critical value (5.99) at 0.05 significant levels (Table 8)

Table 8: Enset damaging wild animals between agro-climatic zones

Wild animals	Agro-ecologies				Chi-square value
	Gana Kare (highland)		Olo'o (midland)		
	Act	Exp	Act	Exp	
Mole rat	58	33	2	11.3	Cal =67.00
porcupine	18	43	24	14.7	Tabu =5.99

Significant at 0.05 probability level

Conclusion

Baso-Deme watershed is part of the high potential perennial zone where farming is largely hoe based, and it is one of the principal areas of the enset-mixed with cereals farming system. During the 26 study period, land use/ cover change detection analysis depicts that there was a substantial dynamics (negative) of all cover types; mainly woodlands, grasslands and enset lands, which was badly damaged. **But agricultural land is still the main type of land use we have, leading to increased runoff, erosion, flooding, and resulted in declining soil infertility. Under condition of ever increasing rural population and degraded soil, in the area enset is considered** as the major food security tree crop especially during food insecure seasons, beyond its environmental and socio-cultural significance. However, enset agriculture is highly susceptible to increasing damaged by wild beasts and above all bacterial wilt. Hence, this precious plant must be protected from all sources of damages so as to benefit both environment and its people. As a result much is expected from the research institutions and agronomists to upgrade its productivity and produce disease resisting enset variety.

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