Characterization of Farming Systems in Kedida Gamela, Kacha Bira and Damboya Woredas (Administrative Districts) in Southern Ethiopia

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Abstract
The existence of diversity of crops and farming systems in Ethiopia even in smaller administrative unit is due to the extremely varied topography and agro-ecology. The objective of this research was to characterize the farming system of Kedida Gamela, Kecha Bira and Damboya woredas by identifying crop types and their yields in different landscape positions, fertilizer application practices at different landscape positions. Totally 463 geo referenced plots of small holder farmers were surveyed by using grid based survey. In all farm plots, site information such as crop types, the type and rate of fertilizers applied, the yield with and without fertilizer, geographical locations of the field, farming system, land use and fertility management practices were recorded on site description sheet and then analyzed by using statistical tools. The common crop types in the study area were found to be maize, teff, wheat, sorghum, barley, enset, haircot bean, potato, faba bean and vegetables in a decreasing order of magnitude. The distribution and average yield of crops varied from one landscape to other landscape even in the same altitude. The average yield of the crops at all landscape positions was below optimum level due to the lack of site specific soil fertility management, low soil fertility status, decline in soil fertility, unbalanced and little fertilizer use, cultivation of steep slope, lack of improved varieties, improper agronomic practices, lack of control of weeds and diseases, post harvest loss and other biological and physical factors. The only inorganic fertilizers that were used by farmers in the study area were DAP and urea with rate below blanket recommendation rate. Some farmers didn't use both of inorganic fertilizer at all. In the study areas many tree species such as eucalyptus and shrubs were observed. In order to improve the agricultural production in study area, site specific soil fertility management and the fertilizer rate which is based on soil test with proper agronomic practice and improved crop varieties are highly recommended.
Keywords: Crop diversity, Crop yield, fertilizer use, and vegetation

Introduction

Agriculture is the major source of livelihood and economy of Ethiopia. It accounts for about 41.6 percent of the GDP, employs about 83 percent of the labor force and contributes around 90 percent of the total export earnings of the country (MoFED, 2014). The sector is dominated by about 11.7 million smallholders responsible for about 95 percent of the national agricultural production while large farms contribute only 5 percent of the total production (MoA, 2011). This shows that the overall economy of the country and the food security of the majority of the population depend on small-scale agriculture. However, Ethiopian agriculture has been characterized by low productivity, mainly, caused by low soil fertility and absence of efficient, sustainable and site specific soil fertility management practices (AbushTesfaye *et al*, 2011), among others.

The agricultural sector in Ethiopia is being increasingly confronted with the pressure from a rapidly growing population and diminishing natural resources (Mulugeta, 2004; Abate, 2010). One of the immediate problems facing Ethiopia today is land degradation, particularly loss of vegetation cover, soil fertility depletion and soil erosion that significantly contribute to low agricultural productivity (Kahsay, 2004). To mitigate this problem, the country initiated community-owed participatory watershed management (Lekew et al., 2005), and to date, it has rehabilitated millions of hectares of degraded land generally in the country and particularly in SNNPRS.

Regardless of the diversity of the agricultural products and crop species in Ethiopia, the production performance is below optimum level still (Taddese, 2001) despite the fact that agriculture grew by an average of 8.1% annually during the last decade (CSA, 2013). Among factors behind the poor performance of Ethiopian agriculture are diminishing farm size and subsistence farming, soil degradation, inadequate and variable rainfall, climate-related disasters, weak agricultural research base and extension system, lack of finance, weak agriculture market linkage, unbalanced and low fertilizer application and poor infrastructure (Asefa, *et. al.*2003, Chilo and Hassan 2008, Spielman, *et.al*, 2013; Kassa, 2003 and Tadesse and Kassa, 2004,). Until recently, smallholder farmers used to produce food that was only adequate for home consumption. Crops are the major products and sources of food in the country since most of the population depend on agriculture (Degefe, 2000). Therefore, in order to increase crop production and productivity and to realize government's strategy of commercialization of smallholder agriculture, characterization and documentation of land use and recommendation of relevant land management systems becomes very vital.

Fertilizer application plays a major role in increasing the food production to meet the demand of the growing population. Fertilizer application has resulted in remarkable crop yield increases, which for most crops was more than hundred percent (Mengle and Kirkby, 1996). However,–until recently, fertilizer application in Ethiopia has been highly skewed towards blanket recommendations ever since its inception in the late 1960s (Adamu Molla, 2013). Moreover, farmers do not often go along with the recommended practices but follow practices they can afford, and often, they apply half of or lower than the recommended rate. The average annual soil loss from croplands was estimated at 42 t/ha and that is about six times the rate of soil formation in some of the Ethiopian highlands (Hurni,1993), this may not be correct nowadays since the country has implemented massive land rehabilitation activities through community mobilization and implementation of community owned watershed development activities.

According to the Environmental Protection Authority (EPA, 2003), the environmental situation of Kambata Tembaro (KT) zone is marked by problems of soil erosion, deforestation, and energy and water scarcity. The magnitude and degree of seriousness of these problems vary from woreda to woreda depending on a number of factors. The study area, along with many other Ethiopian local areas, is caught up by a vicious cycle of food insecurity, poverty, low agricultural productivity and land degradation. Therefore, the aim of this research was to characterize the farming system and soil fertility management practices of Kedida Gamela, Kecha Bira and Damboya woredas by assessing crops grown and their yields in different landscape positions, fertilizer application rate at different landscape positions and vegetation covers and their impacts on soil fertility.

Material and Methods

Descriptions of Study Areas

This study was conducted in three selected woredas of Kambata and Tembaro (KT) Zone namely Damboya, Kechabira, and Kedida Gamela woredas . Kembata and Tembaro is one of the zones of the SNNPRS and is situated approximately 250 km south‐west of Addis Ababa. The whole KT zone is situated between 500 and 3500 meters above sea level, and the topography is characterized by steep slope at the foot of Anbericho, Dato and Ketta mountains. This influences the agronomic practices in the woredas, since ~~the~~ land degradation and soil erosion are the main problems due to its landscape and high altitude. The zone is divided into three agro-ecological zones, such as highland (*dega*), mid highland (*woina dega*) and lowland (*kolla*).

Methods of sampling and data collection

The land-use/land cover of the three woredas was pre-assessed by using Google Earth remote sensing pictures. Then the sampling farms were geo referenced and predefined by using both using Google Earth remote sensing pictures and Arc GIS soft ware. Central point of each sampling point (equilateral grids) was labeled with 750m grid to create sampling numbers within generated data points in the study areas covering agricultural and potential lands.

The number of sampling sites varied from one Peasant Associations (PA) to another depending on the agricultural land size and other features. From all PAs in three weredas, a total of 463 sampling sites were selected by grid sampling method with 750m grid average distance.

Field studies were conducted from March to October, 2014.Topographic map of the area was used to collect physiographic and landscape data. Samsung tablets equipped with GPS receivers were used to reach to the pre-defined geo-referenced sampling places. The location information such as altitude, longitude and elevation were recorded by ODK collector software loaded on the Samsung tablets. Slopes were measured by clinometers. Site topography, dominant crops on and soil colour were recorded through direct observation of sampling plots during survey and informal discussion with the farmers. Data on fertilizer type, application rate and last date of application, the yield of crop per ha with and without fertilizer, management practices such as crop rotation and residue management and farming system were recorded on site description sheets by interviewing the owner farmers and using semi structured questioners. The altitude was divided into three positions: high altitude (2200-2637 m a.s.l), medium altitude (2000-2200 m.a .s.l) and low altitude (1689-2000 m a.s.l) for the sake of comparison of different crop type and average yield.

Statistical analysis

A descriptive statistical method was employed to analyze and summarize the data and to calculate percentages, means and other measures of central tendencies. Analysis of variance (one-way ANOVA) was used to determine statistically significant differences of crop yields among different altitude zones. Differences at the 0.05 level of significance were reported as significant. Simple linear correlation analysis was carried out between elevation and crop yield to show how crop yield varies through different altitude zones.

Results and Discussion

***Crop* diversity and farming System**

It was found that in all study cites, mixed crop-livestock production system is the dominant farming system in the study area. Cattle are the dominant species, mainly used for draught power and manure for maintaining soil fertility by 95 % of survived farmers.

All farmers practiced intercropping of maize and haricot beans at high altitude zone. They responded that they benefit more from intercropping system than mono cropping. According to Matusso (2014), cereal-legume intercropping systems have shown improvements in both soil fertility and crop yields, particularly for cereal crop which is the staple food crop for smallholder farmers in SSA countries. Also, planting of coffee, chat and enset was found to be common practice at the same attitude zone. It was found that crop rotation is common practice by all farmers. Cereal dominated cropping systems such as maize; tef [*Eragrostis tef (Zucc) Trotter*] and bread wheat *(Triticum aesstivum* L.) were found to be the most important crops in low and medium altitudes whereas sorghum was the common crop at low altitudes. This result is in agreement with that of Yigram *et al.* (2009). In the high altitude, wheat is the most important crop followed by faba bean and barley. At high altitude, enset (*Ensete ventricosum*) and potato were cultivated by many farmers in the area. Enset is used for both human food and livestock feed. According to farmers in the study area, crop residues were removed and used as fuel. The common crops for each woreda are described as follows:

KedidaGamela woreda

The result of plot based survey indicated that the major crops in the Kedida Gamela woreda are maize , tef, wheat , sorghum, enset, haricot beans, potato and barley (Figure 1). As indicated in Table 2 and Figure 1, the crop diversity and average yield varied with difference in altitude. The survey result revealed that maize covered about 22.44% of the agricultural land of the woreda from which 62.8%, 22.68% and 14.29 were found to be at low, mid and high altitude zones of the woreda, respectively. This agrees with the finding of Osterle *et al.,* (2012) who reported that maize was the major crop at low altitude in southern Ethiopia. The woreda's average yield of maize was found to be 2.67 t/ha and 0.66 t/ha with and without fertilizer application, respectively. Also, the yield varied between different altitude zones ($P < 0.01$). The average yield in low, mid and high altitude was 3.28, 2.55 and 1.54 t/ha, respectively. The correlation analysis indicated that the effect of altitude on maize yield was significant with $r=0.61$ and $P<0.01$. However, the average maize yield is below the national average yield level (3.01t/ha) (CSA,2013). When compared the average yield of the crop of woreda, it is far less than both the worlds' average yield (5.15t/ha) and major producing countries such as USA (9.86t/ha),Chain (5.43t/ha), Brazil (4.05 t/ha), Mexico (3.27t/ha), India (2.33 t/ha), Argentina (6.61 t/ha) and Europe (2.55t/ha) (FAOSTAT, 2013). However, it is better than it in SSA where the average yield is 1.81 t/ha (FAOSTAT, 2014). The low maize in the study area, yield due to the decline of the soil fertility due to runoff, lack of site specific soil fertility management practices, information on the kind and amount of fertilizer needed, adequate and timely supplies of fertilizer and adequate credit and distribution system, improved seed varieties, insect and diseases control, the correct agronomic practices, unfavorable relationship between fertilizer and crop costs and the resistance to farmers for new ideas. However, in sub-humid agro-ecosystem of Western Ethiopia, the highest maize **grain yield** (11.0 t ha^{-1}) was recorded under the farmers' field for Sasokawa Global 2000 (Wakene Negassa 2007). In order to improve maize production and productivity in the study areas, an efficient use of production inputs such as balanced fertilizer with recommended rate, improved variety and proper agronomic practices have to be adopted by smallholder farmers. For instance, Msuya *et al.*, (2008), Wakene Negassa *et al.,* (2005), Kimetu *et al,.* (2004); Mucheru-Muna *et al.* (2000); Jama *et al.*(2000) and Daniel *et al. (*2010) reported that the maize yield could be improved by using integrated soil fertility management, proper agronomic practices and improved variety.

Tef, which is the second dominant crop in the woreda, covered 19.95% of agricultural lands with distribution of 57.14%, 35.71% and 7.14% in low, mid and high altitudes, respectively. The average yield of the crop in the woreda was 1.0 and 0.28 t/ha with and without fertilizer, respectively. Berhane *et al*., (2011) and ATA (2013) reported that, tef is the most dominate crop in terms of area coverage and second in terms of total production in Ethiopia. In the country of nearly 90 million people, approximately 6 million households grow the crop (Crymes, 2015).The value of the commercial surplus of tef is second only to coffee (Minten *et al*., 2013). The average yield in low, mid and high altitude areas was 1.04, 0.94 and 0.9 t/ha, respectively but its variation was statistically insignificant ($P>0.05$). Also, correlation analysis showed that there was no effect of altitude on tef yield in the woreda.

This finding confirmed that agricultural landscapes in all range of altitudes are equally productive for tef in the woreda. Regardless of this, the average yield of tef was below national average (1.28t/ha) (CSA, 2013), in all agro ecological zones, due to lack of site specific soil fertility management, declining of soil fertility, application of unbalanced and less fertilizer than the recommended level for the area, lack of high yielding cultivars, lodging, water logging, low moisture stress and poor agronomic management practices such as sowing and weeding. Agreeing with the result of this study, Habtegebrial *et al*., (2007), Berhe *et al.,* (2011) and Fufa *et al.* (2011) reported that tef yield is low in the country because of agronomic constraints that include lodging, low modern input use, and high post-harvest losses. Also, tef research has received limited national and international attention, the latter presumably because of its localized importance in Ethiopia (Berhane *et al.* 2011, Fufa *et al.* 2011).

When farmers are asked the method of sowing tef, 70 % of them responded that they broadcast tef seeds even though they understood the fact that row planting technology increases the crop yield. They added that the major factor that prevents them using the row planting technology is their small household size to meet the requirement of high labor. The farmers, whose soils are black soils (Vertisols), responded that their soils mostly have a great tendency sticking its particles which made it very difficult for human movement at time of work and it is very impossible to dig row lines in order to open furrows for the application of row planting. The remaining 30 % of them responded that they are using row planting technology to with full filling all extensional packages which resulted in doubling their tef yield. Joachim *et al*., (2014) reported the similar findings. The result of this study confirms that, in order to increase the tef yield to optimum level, the small holder farmers should use improved variety, the proper agronomic practices, balanced fertilizers with recommended rate and site specific soil fertility management. For instance, Bekabil *et al*, (2011) reported that tef yield is as high as 2.7 t/ha by using recommended rate of fertilizer, proper agronomic practices and improved variety (Quncho). In the same way, ATA (2013) reported that most of the farmers who employed new tef technologies experienced yield increases across all regions.

Wheat was found to be the other dominant crop in the woreda next to maize and tef by covering 12.17% of the agricultural lands with distribution of 10.53% and 89.47 % in mid and high altitudes, respectively. When farmers in the woreda in low altitude area were asked why they don't cultivate wheat, they responded that they prefer cultivating maize to wheat since maize requires low labor than wheat. This revealed that there is need for awareness creation for farmers about the wide use of wheat, the better price they can get on market, including the potential to stop wheat import if they produce locally. The average yield of wheat in the woreda was 0.48 and 1.85 t/ha without and with fertilizer, respectively, indicating that it is by far less than the national average of 2.11 t/ha (CSA, 2013). In contrast to this, Mathewos Ashamo and Ashenafi Mekonin,(2014), reported 4 t/ha in the same woreda in experimental condition. This indicated that despite the low average yield, the woreda has the potential to improve the wheat yield. It was observed that the average yield in both altitudes were statistically *at par*. Higher yield was obtained at mid altitude than at high altitude with $P<0.05$ (Table 2).When compared the average yield of the crop of woreda, it is far less than both the worlds' average yield (3.04 t/ha) and major producing countries such as Chain (4.75 t/ha),India (2.85 t/ha), USA(3.04t/ha),Rasia federation (2.22), France(7.2 t/ha), Canada(2.81 t/ha),Germany (7.74 t/ha) and Pakistan 2.55(t/ha) (FAOSTAT, 2013). However, it is better than in SSA where the average yield is 1.7 tons/ha and ranges from 0.7 tons/ha in Burundi to 3.4 tons/ha in Mali (FAOSTAT, 2014).

Haricot beans and barley were the other crops in the study woreda, that covered 1.92% with average yield of 1.33 ha and 1.87 t/ha, respectively with fertilizer application. Also, root crops such as enset and potato were common in the woreda (Table 1). The rest of the sites of the woreda were covered by vegetables and open grasses during the field survey. Also, some plots were reserved as fallow to replenish soil fertility.

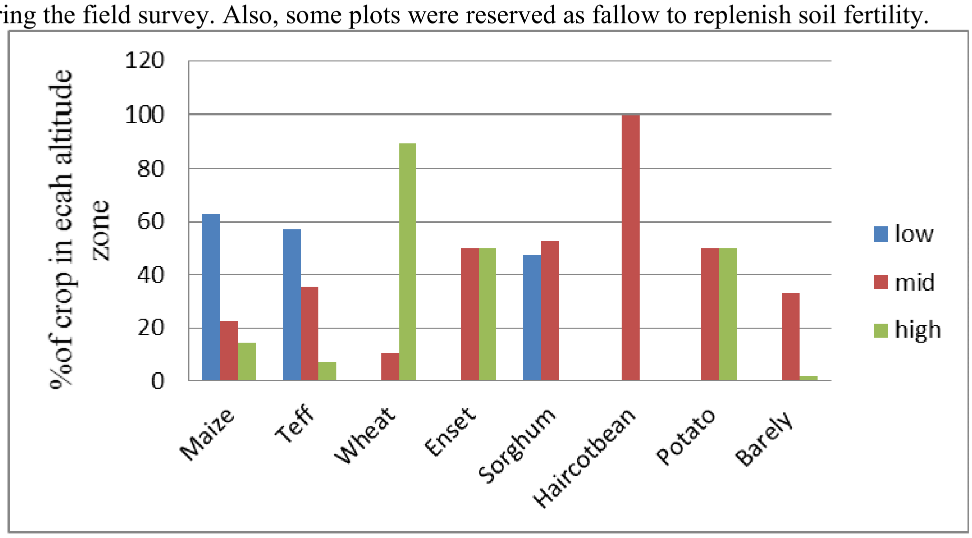

Figure 1. Crops in different altitude zones of Kedida Gamela woreda
(Source: own survey, 2014)

Table 1: Average crop yield in different altitude zones of Kedida Gamela woreda

Crop	Average yield at different altitude zones (t/ha)			Woreda's Average Yield (t/ha)	
	Low	Mid	High	With fertilizers	Without fertilizers
Maize	3.28	2.55	1.54	2.67	0.66
Tef	1.04	0.95	0.9	1.0	0.28
Wheat	-	2.65	17.53	1.75	0.48
Enset	-	-		-	-
Sorghum	2.69	1.74	-	2.22	0.49
Haricot bean		1.33	-	1.33	0.45
Potato	-	4.43	4.50	4.46	1.23
Barely	-	2.5	1.51	1.87	0.33

Kacha Bira woreda

As indicated in Figure 2, the analysis of plot based survey result showed that the major crops in the woreda were wheat, tef, maize, enset, sorghum, barley, faba bean and potato. Wheat was the most dominant crop in the high altitude zone of the agricultural land of the woreda. Almost all (93.02%) of wheat farms were found to be in high altitude zone of the woreda. The result of analysis of the survey data indicated that average yield of wheat in the woreda was 1.42 and 0.37 t/ha with and without fertilizer application, respectively (Table 2). This revealed that the average yield is below average national yield of 2.11 t/ha even with the application of fertilizer (CSA, 2013). Similarly it was 17.5% below than SSA and 53.3% below than world average yield (FAOSTAT, 2014). The low level average wheat yield may be due the lack of site specific soil fertility management, unbalanced application of fertilizer with rates below optimum , decline of soil fertility due to run off and intensive farming system caused by the shortage of land in the area, lack of improved variety, improper agronomic practices ,weeds, disease, poor distribution of rainfall and post-harvest losses (Spielman *et al.,* 2011; MoA, 2012; Dercon *et al*.,2009; Byerlee *et al* 2007; Howatd *et al*.,2003; Lemma *et al*.,2008;Teadessae et al.,2010; Desta, 2000 and Bogale et al.,2008). Abreha Kidanemariam *et al.,* (2013) reported that soil acidity is one of the main factors responsible for low wheat yield and it was increased when different types of liming materials applied together with recommended rate of NP fertilizers in acidic soils of Tsegede highlands, northern Ethiopia. In order to increase the wheat yield in the study area, farmers should use improved wheat seed, site specific soil fertility management, balanced fertilizer with optimum rate, proper agronomic practices, weed and disease control and correct post harvesting technologies. For instance, using the full-package the crop yield increased 13-14% in ATA wheat initiative woredas (Gashaw Abate *et al,* 2014).

Table 2: Average crop yield in different altitude zones of Kecha bira woreda

Crop	Average yield (t/ha) at different altitude zones			Woreda's Average Yield (t/ha)	
	Low	Mid	High	With fertilizers	Without fertilizers
Wheat	-	0.63	1.44	1.42	0.37
Teff	0.99	1.10	1.06	1.04	0.32
Maize	2.37	1.73	-	2.17	0.8
Enset	-	-		-	
Sorghum	1.77	1.9	2.2	1.88	0.62
Faba bean	-	0.95	0.93	0.94	0.42
Potato	-	-	4.50	8	1.3
Barley	-	-	1.33	1.33	0.37

The second dominant crop next to wheat in the woreda was tef, the proportion of which from the agricultural land in the woreda was 0.2. As indicated in Figure 2, from analysis of plot based survey result, tef covered 40%, 30% and 30% at low, mid and high altitudes, respectively. The average yield of teff in the woreda was 1.04 and 0.32 ton/ha with and without fertilizer, respectively and it varied with altitude by having the highest value (1.06 t/ha), the medium (1.01t/ha) and lowest (0.99 t/ha) at high, mid and low altitude zones. This result is in agreement with the finding of Dereje Gorfu (2011) who reported that tef production is better in cool high altitude than warm low altitude. However, in all altitude zones, the average yield was below that of national average cereal yields: statistically ($P>0.05$), the average yield was at *par* all altitude zones. Also, the tef yield l is 18.5% less than the national average, 1.28t/ha (CSA, 2013).This is due to the low soil fertility, lack of improved variety, site specific soil fertility management, unbalanced fertilizer with rate below recommended rate, improper agronomic practices and post harvest loss. Tef is susceptible to lodging, and this could account for up to 30% of the potential loss of tef yields (Bekabil, *et al*., 2011).

Maize was the third dominant crop which was cultivated in 13 out of 149 sampling sites during the field survey. It spread in both low and mid attitude zones but not in high altitude areas. As presented in Table 3, the average yield of maize in the woreda was 2.1 and 0.89 t/ha with and without fertilize, respectively. The average yield was higher in low altitude (2.37 t/ha) than mid altitude (1.73 t/ha). According to Abdisa *et al.* (2001), maize is classified as one of warm weather cereal crops and its yield is higher at low altitude. Nevertheless, the average yield is far less than national average, worlds' average and average of high producing countries .For instance it is less by 78.7% than USA, 61.33% than China, 48.14% than Brazil and 4.78% than worlds, average .But it is greater by 14.29% than SSA average (FAOSTAT, 2014).

Barley and sorghum were found to be the other cereal crops cultivated in the woreda each covering 6 out of the surveyed 149 sites. Barley was found to be cultivated in high altitude zone whereas sorghum was found in both low and mid altitude zones. This result is in line with that of Asmara *et al* (1998). Their average yield with fertilizer was found to be 1.33 ton/ha and 1.88 t/ha, respectively and without fertilizer application it was 0.37 t/ha and 0.62 t/ha, respectively. Also, faba bean was found to be cultivated in the woreda and it covered 5 out of 149 survived sites. It was disturbed both in mid and high altitude zones. The average yield of the crop was found to be 0.94 and 0.42 t /ha with and without fertilizer application, respectively. The root crops such as enset and potato were found to be the common crops in the woreda each covering 8 and 5 sites out of 149 surveyed sites (Figure 2). The average yield of enset was not recorded because farmers reported that there has not been any trend to measure or guess the yield in the woreda. But the average yield of potato was found to be 8 and 1.3 t /ha with and without application of fertilize, respectively.

The research finding from this study showed that the average yield of all crops was below national average. This may be due to the lack of site specific soil fertility management, low soil fertility status, decline in soil fertility, unbalanced and little fertilizer use, cultivation of steep slope, improper agronomic practices, lack of improved crop variety, post harvest losses and other biological and physical factors

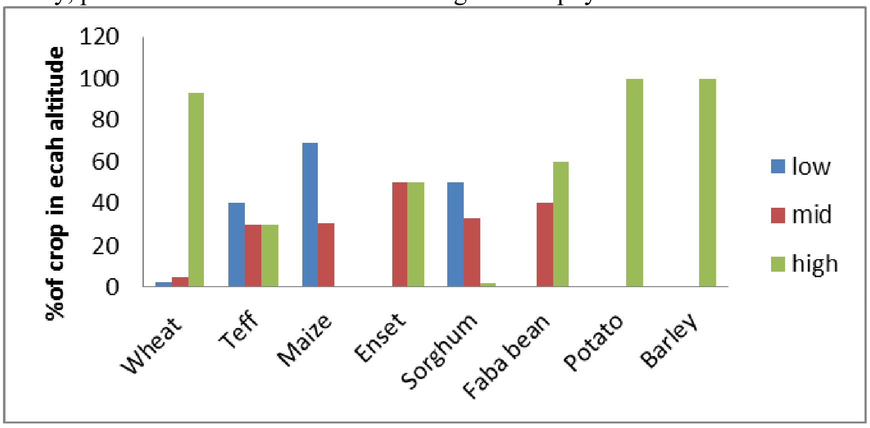

Figure 2. Crops grown in different altitude zones of Kacha Bira woreda
(Source: own survey, 2014)

Dameboya worda

The crop types cultivated in different altitudes and their average yield are presented in Table 3 and Figure 3, respectively. According to the analysis of survey data, the main crops grown in the woreda during field survey were tef, maize, sorghum, potato, haricot bean and enset. Also, some vegetables such as green pepper and onion were found in a few sampling sites.

Table 3: Average crop yield in different altitude zones in Damboya woreda

Crop	Average yield (t/ha)at different altitude zones			Woreda's Average yield (t/ha)	
	Low	Mid	High	With fertilizers	Without fertilizers
Teff	1.09	1.15	1.3	1.15	0.4
Maize	2.34	2.63	2.6	2.53	0.79
Sorghum	1.5	1.8	2	1.83	0.57
Wheat	0.6	2.8	1.55	1.85	0.58
Potato	-	8	4.6	5.38	0.88
Haircot bean	1.46	1.23	-	1.46	0.44

During the field survey, 26.95% of the sampling site was covered by tef. This proved that tef was the most dominant crop in the woreda during the survey period. The average yield of the crop was 1.15 and 0.4 t/ha with and without application of fertilizer, respectively. Tef was spread in all altitudes and its yield varied with altitude having the average yield of 1.09, 1.15 and 1.3 t/ha in low, mid and high altitudes respectively. However, the yield between different altitude zones was not significantly different (P>0.05).

Maize was the second dominant crop in the woreda covering 35 out of 158 sampling sites during field survey. Maize is the second most widely cultivated cereal in Ethiopia in term of area but forms the largest share of production by volume (18%), and appears to be increasing (Chamberlin and Schmidt, 2011). Its average yield was found to be 2.53t/ha and 0.79 t/ha with and without fertilizer, respectively. It was spread in different altitudes with varying average yield of 2.34t/ha, 2.63t/ha and 2.6 t/ha in low, mid and high altitude zones, respectively. The variation of the average yield between different altitude zones was statistically insignificant (P>0.5). When farmers in high altitude zone were asked about their maize yield, they responded that the yield of maize has been increasing during the last few years and they added that before a few years, they didn't grow the maize in their farm. Also, they mentioned their farm is becoming suitable for maize due to the climate change which results in raised temperature and reduced rain fall.

Sorghum and wheat were found to be the other common crops next to tef and maize in the woreda by covering 13 and 12 sampling sites, respectively out of 158 sampling sites. Their average yield was found to be 1.83t/ha and 1.85 t/ha, respectively with fertilizer. Without fertilizer, their average yield was 0.57t/ha and 0.58 t/ha, respectively. The yields of both crops are far less than the world average (3.04 t/ha) and African average (2.5 t/ha) for the later. (FAOSTAT, 2014). Kenya produces nearly double (3t/ha) wheat o f this woreda (FAOSTAT, 2014). In order to narrow this yield gap the small holder farmers should use site specific soil fertility management, balanced fertilizer with optimum rate, improved varieties and proper agronomic practices. Guangdi *et al*.,(2009); Fageria and Baligar (2003); Worku (2008) and Mekonnen Asrat *et al.,(*2014) reported that the increment of the wheat yield by integrated soil fertility management by using improved varieties in different areas. Also, haricot bean was found to be the common crop cultivated in the woreda by covering 6 sites in low and mid altitudes during the survey. Its average yield was 1.46ton/ha and 0.44ton/ha with and without fertilizer, respectively. Root crops such as enset and potato were found to be common in the woreda by covering 8 and 6 sites each.

In addition to the above motioned crops, some agricultural lands were reserved as fallow to restore the declined soil fertility. Also, some potential agricultural lands were found to be covered by open grasses. A few sites were covered by vegetables such as onion, sugar cane and green pepper.

This research finding indicates that the average crop yields in all study sites were below average national level. This may be due to the lack of site specific soil fertility management, low soil fertility status, decline in soil futility, unbalanced and little fertilizer use, cultivation on steep slope and other biological and physical factors. According to Belay (2003) the main reasons for the low agricultural productivity in the country are poor input supply system and institutional capacity (limited capacity of agricultural extension), poor research-extension farmer's linkage and the low level of agricultural technology development, adoption and discontinuance which deter the efficient utilization of the country's natural resources. Also, Addisu Asfaw *et al*.,(2013),reported that the factors responsible for reduced crop yield are inappropriate crop rotation systems, maximum tillage, inadequate rainwater management systems, improper seeding rates, inappropriate fertilizer rate, traditional methods of sowing and harvesting , delayed harvesting. This low crop yield may be improved by proper soil fertility management practices by alleviating the declining soil fertility, by using balanced fertilizer with optimum rate, proper agronomic practices and adopting the modern post harvest technology (Ouedrago *et al.*,2001).

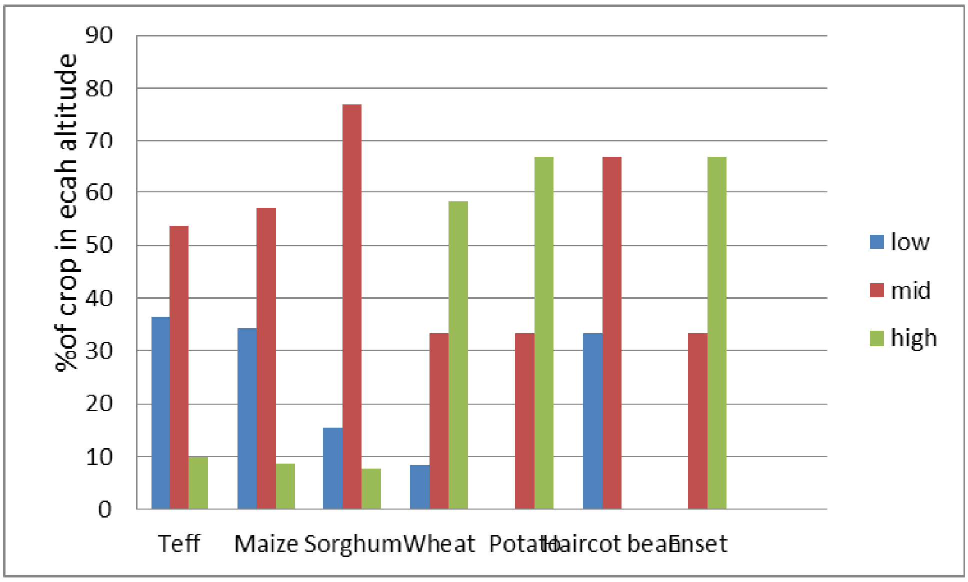

Figure 3. Major crops in different altitude zones of Damboya woreda
(Source: own survey, 2014)

Fertilizer Use

According to farmers' response during the survey, the mineral fertilizers used in the three woredas were DAP

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and urea only with blanket recommendation rate regardless of altitude, soil type, type of crop and other factors. Rate of fertilizer application, as estimated by farmers' varied from farmer to farmer and ranged from 0 to 100 kg per ha DAP and 0 to 50kg/ha for urea. Agreeing with this research result, many authors reported that application rates for inorganic fertilizer vary markedly, even across plots managed by a single household (Rowe et al. 2006; Vanlauwe et al. 2006; Zingore *et al*. 2007). Different rates of fertilizer application which were adopted by farmers in the study area were identified and presented in Table 5. Farmers in the study area responded that 100kg DAP per ha and 50 kg urea per ha are recommended rates for common cereal crops by extension workers. However, most of farmers were using fertilizer rate below recommended rate.

As showed in Table 4, the average percentage of farmers that did not apply fertilizer for maize, teff, wheat sorghum and haricot bean were 21.78%, 15.15%, 9.45% of, 47.41% of and 30.88%, respectively. Also, 27.71%, 20.20%, 8.11%, 26.32 % and 38.46% of farmers applied only DAP at the rate of 100 kg/ha without urea, for maize, tef, wheat, sorghum and haircot bean, respectively. The percentage of farms that received the traditional recommended fertilizer rate (100kg/ha DAP and 50kg/ha urea) were 40.68%, 46.46%, 79.74%, and 13.12% for maize, teff, wheat and sorghum, respectively.

Table 4: Proportions (%) of households using different rates of fertilizers for different crops in Kg/ha in the study areas

Crop	NP fertilizer rates						
	100/50	100/25	100/0	90/45	70/35	50/25	0
Maize	40.68	1.3	27.71	2.41	4.82	1.3	21.78
Teff	46.46	2.02	20.20	3.03	10.10	4.71	15.15
Wheat	79.74	1.35	8.11	1.35	-	-	9.45
Sorghum	13.12	-	26.32	5.26	7.89	-	47.41
Barley							
Haircot bean	-	-	38.46	-	15.38	15.38	30.88

The finding of this research confirmed that most farmers were applying more fertilizers for wheat, teff and maize in their increasing order but most of them applied below recommended rate or not at all for sorghum and haircot bean. Also, farmers in the study area were not applying inorganic fertilizer for same plants such as coffee and enset even though the zone is one of the coffee exporting zones in SNNPRS region. The result of this study agrees with Spielman *et al*., (2010), who reported that only 30–40 percent of Ethiopian smallholders use fertilizer with only 37–40 kilogram physical application per ha, significantly below recommended rates. Also, EIAR (2011), reported similar finding.

As listed out by farmers, the reasons why they apply fertilizer below the recommended rate or not at all were due to the low crop response to fertilizer application, the cost of fertilizer, the crop output price, small farm size and time of fertilizer distribution from the center. Also, some farmers who have limited finical capacity to buy inorganic fertilizers said that they became very happy as they heard the news through the media that Ethiopia has planned to build some fertilizer blending plants in their region through the Growth and Transformation Plan hoping that the fertilize cost will decrease when manufactured locally. According to Gebrerufael Girma (2015), the main challenges of fertilizer application are long fertilizer supply chain and late delivery, absence of agricultural input supply subsidies and access to credit, limited alternatives and package of fertilizer, and poor institutional arrangements and professional incentives. Kefyalew Endale, (2011) reported that the high price of fertilizer, supply shortage and late arrival are the major constraint for fertilizer applications.

Majority of farmers responded that they are using chemical fertilizer as the sole source to increase crops yields because, high application rates, high labor requirements and limited availability of organic fertilizers. However, the use of organic fertilizers such as farm yard manure, compost, green manure and transferred biomass of leguminous trees is an alternative to inorganic fertilizers to improve soil fertility. For instance Shiferaw (2005) reported that the yield of wheat at Kokate and Hossana site of SNNPRS, was increased by 63% and 97% over the control, respectively by application of manure. Similarly, Abebe and Diriba (2003) reported that transferred biomass of *Cajanus cajan* at a rate of 4t/ha increased the grain yield of maize by over 86% compared to the control. Organic fertilizer, in addition to being nutrient sources, improve the physical and chemical characteristics of soil, the water holding capacity, CEC and biological activity of soil (Vanlauwe *et. al*, 2005; Gruhn *et. al*., 2000).

Relatively very few farmers said that they are using a combination of organic and inorganic fertilizers instead of purely relying on inorganic fertilizers and confirmed that their crop yield was increased by combined applications. Many research finding proved that combined application of organic and inorganic fertilizer produce superior yield of crops than either sources applied alone (Ravishankar et. al., 2002; Gruhn *et. al.,* 2000; Gazahagn *et al.,* 2014).Long term trials conducted in Kenya on organic and mineral fertilizer interaction also showed that maize grain yield was consistently higher for 20 years in plots fertilized with mineral NP combined with farmyard manure than plots with sole mineral NP or farmyard manure (Nandewar,1997). Similarly, Habtamu Admas (2015); Bayu *et al* (2006); Makinde and Ayoola, (2006); *Rasheed et al.* (2006), Tadesse *et al.,* (2013) and Dilshad *et al.,* (2013) reported that the maize yield increased by integrated application of inorganic and organic fertilizers over sole inorganic fertilizer applications.

This result revealed that, there is a gap in using organic fertilizers for cereal crops in the study areas. In order to narrow this gap, the awareness on the use of organic fertilizers should be created to farmers by development agents and other concerned stake holders.

When farmers are asked the method of in organic fertilizer applications, majority of them responded that they apply it by drilling in the furrows for row-planted crops and broadcast it for broadcasted crops. Very few farmers responded that they apply it with the seed and they use bottle `cork' to measure the fertilizer rate. They added that when they adopt this new method, the fertilizer use efficiency and their crop yield is increased. This result revealed that the fertilizer application method is also one of constraint of crop yield for majority of farmers in the study areas. Waga Mazengia (2011); Okigbo (1973); Russell (1988), agreeing with this finding, reported that the method of the fertilizer application significantly affect the crop yield. Broadcasting of fertilizers, especially P and K, produces fixation problems due to more soil contact, whereas volatilization of N results in reduction of applied N content to the soil. Only 40 to 50% of N fertilizers, 20 to 30% of P and K fertilizers are effectively used by crops while the remaining become volatilized, leached to groundwater, or get fixed within the soil as per the properties of their contents (Olsen *et al*., 1971; Rowse and Stone, 1980). Contrary to this loss, the basal applications of fertilizers using seed-drills have been found to be effective (Mandal,2010). Therefore, more awareness creation training is needed on these aspects in the study area.

Vegetation (plant diversity) and their effects on soil fertility

A large number of tree and shrub species were observed in farmers' fields, during the field survey. All of the farmers said the forest cover in their respective localities have been diminished in the last 20 years but now it is restoring due to community owned watershed management programs being implemented since the last three years. The older farmers added that there was the same program during the Derg regime but their understanding level at that time very different than now. They said that during the Derg regime, all of them had participated to get food handout since the name of the program itself was food-for-work regardless of their poor understanding about the advantage of the program in rehabilitating the degraded environment. But currently, they are participating independently without any food program because they understood the impacts of the watershed management program in rehabilitation of the declined soil fertility, replenished water sources and other related environmental benefits. However, few respondents asserted that they participated in soil conservation program simply because they were forced to do so by the *kebele* or local administration and the developmental agents in the area.

In some study areas, exotic trees, mostly *eucalyptus*, were found covering the degraded hills and mountains. Also, eucalyptus trees were observed near the crop farms even though farmers were alerted about its impact on soil fertility. All farmers confirmed that the *eucalypts* trees exhaust the productivity of their agricultural lands due to their fast growing characteristics. However, they continue planting *eucalyptus* because of its fast biomass production to sell it after relative short time for cash income and use in construction. According to khawas and Shehata,(2005); Forrester *et al*., (2006) and Jiregna Gindaba (2006), *eucalypts* have detrimental effects on soil productivity. Also, Studies conducted in the highlands of Ethiopia have shown reduction in crop growth and yield when agricultural crops are grown close to eucalypts (Jagger and Pender, 2003; Jiregna Gindaba, 2003; Selamyihun Kidanu *et al.,* 2004,2005; Tilashwork Chanie *et al*., 2013). Some of the hills and mountains were devoid of trees. However, there were still some natural forests of indigenous trees in relatively degraded area but they have been under intense pressure as many farmers were encroaching into the trees despite some efforts made by the local administrations of the study area and neighboring Woreda to stop deforestation.

The fact that most farmers plant perennial crops such as banana, enset and chat could help in protection of the topsoil from being washed away. Chakoro Tamire and Mekuria Argaw (2015), reported that farmers are used to plant enset for rehabilitating the declined soil fertility. Also, some farmers planted elephant grass for soil conservation. They reported that it gives them other economical advantage as fodder for their livestock and they could save money to buy grass before planting elephant grass. This finding line with that of Tilahun Amede(2003). Soil conservation method is very effective where one can integrated both the physical and biological soil conservation practices simultaneously for improved land health (Masebo *et al*., 2014). Mohan *et al .(*1999) reported that agroforestry approaches is one of the best management practices of natural resource which can be foundations for improving economic growth as well as environmental protection. It also enriches the soil fertility by providing organic matters which helps water to infiltrate, increasing soil fauna and flora, lower bulk density when compared to the bare soil (Karlen and Stott, 1994; Rao *et al*, 1998; Dexter, 2004; Fikadu, 2006; Acharya and Kafle, 2009) and improves the chemical properties of the soils. Similarly, Young (1989) and Nair (1993) reported that the biological soil conservation methods have also the potential to increase the production of food, fuel wood, building materials, and fodder while arresting soil erosion and fertility decline. For instance, two and three year *Sesbania sesban*-based crop production have proved highly effective in soil fertility restoration in Zambia (Chinangwa, 2006), leguminous trees based agricultural systems has potential to reduce soil erosion(Young, 1989; Nair, 1993). In addition, Lal (1997) reported that the cover measure involving the use of vegetation for soil protection, maintains the hydrological balance in which the surface run-off component in the hydrological cycle would be minimized. In the same way, Ajayi *et al.* (*2008*) reported that the vegetative barriers are generally used in combination with mechanical land treatments such as micro catchments and trees/shrubs improve the physical properties of soils.

All respondents agreed that though the soil is not washed away due to the biological measures taken by them, soil fertility is declining, because of high population pressure and small farm size(<1 ha); there is no chance for fallowing and they are farming intensively and continuously.

As the cost of commercial fertilizer is increasing, some farmers in the area have begun using compost. Some of the respondents said that they were trained to make compost by development agents in farmers training center (FTC). They explained that before training in FTCs, they had used only dung as organic fertilizer but they stopped it after they learned how to prepare compost by mixing dung, weeds and leaves.

Farmers in the study area have severely been affected by soil erosion. The areas have lots of mountains and hills and most of them are with little or no tree or vegetation cover. The mountains and the foot of the mountains have been washed by floods.

Conclusion and Recommendations

In collusion, the crop types and average yield of the crops are varies from farmers to farmers and site to site. However, the average yield of crops was even below national average yield levels due to soil fertility decline, using unbalanced fertilizer with rate lower than recommended rate, lack of improved varieties and improper agronomic practices among other factors. In order to narrow this gap and to obtain optimum crop yield, action should be taken in regards of soil fertility management, agronomic practices and use of improved agricultural inputs and improved varieties.

The type of inorganic fertilizers that farmers use is only DAP and urea despite the high variability in their soils. Also, almost all farmers are using the fertilizers below the recommended rate (blanket rate) and some are not using at all. From this we can conclude that using only DAP and urea at low rate and absence of soil test based fertilizer recommendation take the lion's share of the factors for reduced yield in the study area. In order to boost the planned agricultural growth, crop yield should be improved. Among the actions taken, the digital soil fertility mapping and recommendation of soil test based fertilizer are very important.

Farmers in the study area are aware about the use of physical and biological soil conservation for rehabilitation of degraded lands and replenishment of the declined soil fertility and increase the underground water. To make this practice sustainable, the impact of the program should be supported by different research works. Also, continuous training to update farmers' knowledge about their agricultural landscape is highly recommended.

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