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Prevalence and Risk Factors for *Eimeria* spp. Infections in Small Scale Dairy Farms in Hawassa and Arsi Negele Towns, Southern Ethiopia

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Abstract

The prevalence and intensity of *Eimeria* spp. infection was investigated and the potential risk factors identified in small scale dairy farms located at Hawassa and Arsi Negele towns. Faecal samples from a total of 768 cattle were examined by McMaster technique. *Eimeria* oocysts were detected in 38.2% of the animals and no significant difference was observed between the two towns ($P > 0.05$). The faecal oocyst counts were highly variable ranging from 50–100,000 oocysts per gram of faeces (OPG) with overall mean OPG of 1891. Unweaned calves had a significantly higher ($P < 0.05$) prevalence and relatively higher mean OPG than either weaned calves or yearlings. Majority (90%) of the study animals were sub clinically infected showing oocyst counts of <5000 OPG. The prevalence of *Eimeria* oocysts was associated with the water source for the animals, housing system and hygienic condition of the farms ($P < 0.05$). Those animals of <6 months, drinking water from river, housed in group pens and kept in poor hygienic conditions were at higher risk of contracting *Eimeria* spp. infection compared to their counterparts. *Eimeria* infection was independent of breed and sex of the animals ($P > 0.05$). The study revealed that age of the animal, river water, group housing and poor hygiene were the major risk factors for the occurrence of *Eimeria* infections in cattle in the study area. Furthermore, the prevalence of *Eimeria* spp. infection and mean OPG was considerably higher in diarrheic than non-diarrheic animals. Thus, all diarrhoeic cases should be treated with effective anticoccidial drugs. Regular use of suitable coccidiostats and improvement of management practices that contribute to infection are also recommended. Since all *Eimeria* spp. are not pathogenic, further study is needed to identify the major species of *Eimeria* circulating in the dairy cattle.

Key words: Cattle, Coccidiosis, Faecal oocyst
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INTRODUCTION

Eimeria infections are one of the most common and important disease of cattle worldwide. There are more than 20 species of *Eimeria* that infect cattle, but most cases of clinical diseases are caused by *E. bovis* and *E. zurnii*. All bovine *Eimeria* have a faecal-oral transmission cycle, with cattle as the sole host (Daugschies and Najdrowski, 2005; Radostits et al., 2007). The prevalence of *Eimeria* infection in cattle is generally high and can reach 100% in calves (Fox, 1985; Cornelissen et al., 1995). All age groups of cattle are susceptible to infection, but clinical disease is most common in calves 3 weeks to 6 months of age (Taylor and Catchpole, 1994; McAllister, 2007), indicating that immunity may play a role in the protection of older animals. High prevalence rates have also been documented in yearlings (Cornelissen et al., 1995).

The disease caused by *Eimeria* spp. is commonly known as coccidiosis. The disease occurs either in clinical or subclinical form. Almost all cattle shed *Eimeria* oocysts at one time or another; however, most remain subclinically infected without showing the clinical signs of the disease. The economic losses associated with subclinical coccidiosis even exceed those resulting from clinical coccidiosis (Fitzgerald, 1980) because the former occurs much more frequently and results in reduced feed consumption, feed conversion and growth performance (Fox, 1985; Cornelissen et al., 1995; Matjila and Penzhorn, 2002). The development of clinical coccidiosis in cattle mainly depends on factors like the species of *Eimeria* involved, age of infected animal, number of oocysts ingested and immunity due to a previous infection (Thomas, 1994; Cornelissen et al., 1995; Daugschies and Najdrowski, 2005). Economic losses from coccidiosis due to mortality, poor performance, cost of treatment and prevention may be considerable, especially in stud farms and calf rearing systems (Fitzgerald, 1980; Thomas, 1994). Coccidiosis costs cattle ranchers more than $ 400 million annually in lost profit due to reduced feed efficiency, slower weight gain and increased susceptibility to other diseases. This can set back calves' growth by as much as 2 months (Thomas, 1994). Animals that have survived severe coccidiosis show retarded growth and it has been suspected that they never become profitable (Fox, 1985).

In spite of the great economic significance of *Eimeria* infection on cattle production and the worldwide distribution, there is scarcity of information in Ethiopia and there are only few published studies on this subject. According to the available studies, the prevalence of *Eimeria* infection in different age groups of cattle falls within the range of 22.7 and 68.1% (Abebe et al., 2008; Dawid et al., 2012; Alemayehu et al., 2013; Yadessa et al., 2014; Tsegaye, 2016). Abebe et al. (2008) reported that there are 12 species of *Eimeria* infecting dairy calves in Ethiopia of which *E. bovis* and *E. zurnii* were the most prevalent. Nonetheless, the available reports on the subject do not depict a complete picture of the disease in Ethiopia and thus further studies are needed to fill the dearth of information. This study investigated the prevalence and intensity of *Eimeria* infections and the potential risk factors in selected small scale dairy farms in Southern part of the country.

MATERIALS AND METHODS

Study area

This study was carried out between November 2010 and April 2011 in two selected towns located in southern Ethiopia: namely Hawassa and Arsi Negele. Hawassa is the capital town of Southern Nations, Nationalities and Peoples Regional State and among the fast growing towns in the country. The town is located 275 km south of Addis Ababa with area coverage of 162,804 hectares. It is situated at an altitude of 1750 m.a.s.l between 4°27′ and 8°30′ N latitude and 34°21′ and 39°1′ E longitude. The mean annual rainfall and temperature is about 800mm and 20 °C, respectively (SZPEDD, 2001). Arsi Negele is a town located at 210 km south of Addis Ababa on the road taking to Hawassa and it is found in the west Arsi Zone of the Oromia Regional State. It is situated at an altitude of 2043 m.a.s.l between 38°42′N latitude and 7°21′E longitude.

Study population, design and sampling method

The study population constituted those cattle owned by small scale dairy farms found at Hawassa and Arsi Negele towns. Based on the agricultural sample enumeration report of 2001-2002, there are about 6189 and 8376 cattle in Hawassa and Arsi Negele towns, respectively (CSA, 2008). All the farms included in the study had 10 or less cows. The study animals were both local and cross breeds (Local x Holstein Friesian). Cattle of all age groups and both sexes were included in the study.

A cross-sectional study design was used to achieve the objective of the study. The sample size required for the study was determined by using the simple random sampling technique (Thrusfield, 2005) with 5% absolute precision and 95% level of confidence. Due to lack of similar previous study in the study areas, 50% expected prevalence was considered during sample size calculation. Accordingly, a total of 768 cattle (384 from each town) were selected randomly from the study population and examined for *Eimeria* oocysts.

Sample collection and laboratory investigation

About 30 g of fresh faecal sample was collected per rectum from each animal using sterile disposable plastic glove. The sample was placed in a labelled clean plastic container and transported in a cool box to the parasitology laboratory of the School of Veterinary Medicine on the same day of collection, and preserved at refrigeration temperature until processing within 48 hours of arrival. At the time of sampling, the name of the farm, date of sampling, consistency of the faeces (soft, diarrhoea or normal), housing condition, hygiene of the farms and the age, sex, breed, and tag number of the animals were recorded.

In the laboratory, the faecal samples were analysed by McMaster technique to detect *Eimeria* oocysts and determine the number of oocysts per gram of faeces (OPG) (Kaufmann, 1996). Based on faecal oocyst counts, the animals were classified as sub clinically infected (<5000 OPG) or clinically affected (>5000 OPG) (Rebhun, 1995; McAllister, 2007).

Statistical analysis

Data collected from the study animals were analysed with STATA 11 (Stata Corp. College Station, Texas, USA). The prevalence was calculated for all data as the number of infected individuals divided by the number of animals sampled × 100. The association between the prevalence of *Eimeria* infection and the hypothesized risk factors (study area, age, breed, sex, water source, housing and hygiene) was analysed by Chi-square (χ^2) test for independence. Faecal oocyst counts in different age groups and faecal consistencies were summarized by using descriptive statistics like range, frequency, proportion and mean.

RESULTS

From the total of 768 cattle screened, 293 animals (38.2%) were positive for *Eimeria* oocysts. No significant difference ($P > 0.05$) was observed in prevalence of *Eimeria* infection between the two study areas (Table 1).

The faecal oocyst counts were highly variable ranging from 50 – 100,000 OPG. The overall mean OPG was 1891. The maximum OPG belonged to two diarrheic female calves of two and three months old. Nearly 90% animals had OPG values of < 5000 and consequently considered as sub clinically infected, while only 10% of the animals were excreting >5000 OPG and thus, had clinical infection (Table 2).

Table 1. Overall prevalence of *Eimeria* spp. infections in cattle by study area

Study area	Number. examined	Number positive	Prevalence (%)	95% CI	χ^2	p
Arsi-Negele	384	137	35.7	31.0 – 40.7		
Hawassa	384	156	40.6	35.7 – 45.7		
Total	768	293	38.2	34.8 – 41.8	1.99	0.158

Table 2. Classification of *Eimeria* infection status based on OPG counts

Range of OPG	Infection status	Number of animals	Proportion (%)
<5000	Sub clinical	263	89.8
>5000	Clinical	30	11.2

Table 3. Description of the prevalence of *Eimeria* spp. infection and the mean OPG at different age groups of animals

Age of the animals	Number examined	Number. Positive (%)	Mean OPG
Unweaned calves (<6 months)	111	75 (67.6)	18148
Weaned calve (6-12 months)	75	50 (66.7)	1008
Yearlings (>12 months)	582	168 (28.9)	242

Eimeria oocysts were present in all age groups of animals. The first age at which oocysts detected was 15 days. Both prevalence of *Eimeria* infection and mean OPG decreased with increasing of age of the animals. Unweaned calves (<6 months) had the highest mean OPG than either weaned calves or yearlings (Table 3).

Eimeria infection was significantly associated with age of the animals, the source of water for the animals, housing condition and hygiene of the farms ($P < 0.05$), while it was found to be independent of breed and sex of the animals ($P > 0.05$) (Table 4).

Clinical examination of the study animals showed that out of the total animals screened 24 were diarrheic, 151 had soft faeces and 593 were non-diarrheic. The prevalence of *Eimeria* oocysts and mean OPG were relatively higher in animals with soft and diarrheic faeces than in non-diarrheic ones. The highest prevalence and oocyst counts were recorded in diarrheic animals (Table 5).

DISCUSSION

The overall prevalence (38.2%) observed in this study has shown that *Eimeria* infection is common in cattle in the study areas. This study was conducted between November and April, a season known to be dry or experiences little rain. The observation of such a level of infection in dry season might be associated with absence of the use of anticoccidial drugs by the dairy farmers and also with existence of conditions (such as poor hygiene) in the farms favourable for the survival and sporulation of oocysts. When compared to the available studies, the current prevalence is higher than the 22.7% report from Dire Dawa (Dawid et al., 2012) and 31.9% from Kombolcha (Alemayehu et al., 2013). However, it is lower than the findings of other studies, viz. 68.1% from Addis Ababa and Debre Zeit (Abebe et al., 2008) and 51.42% from Jimma (Yadessa et al., 2014). Unlike to the current study, the high level of prevalence in Debrezeit and Addis Ababa, and Jima studies could be attributed to the focus of the study only on calves < 1 year of age, which is the age group at most risk. On the other hand, the observed prevalence is comparable to the 38.9% prevalence noted in diarrheic calves in and around Asella (Tsegaye, 2016) and 35% report from Tanzania (Chibunda et al., 1997). In South Africa, the occurrence of *Eimeria* infections was reported to be between 29% and 52% in three localities (Matjila and Penzhorn, 2002). A Kenyan study also reported a higher prevalence of 67.4% (Munyua and Ngotho, 1990).

Table 4. Chi-square analysis of different risk with the prevalence of *Eimeria* spp. infection

Risk factor	No. examined	No. positive	Prevalence (%)	95% CI	χ^2	*P*
Breed						
Cross	658	249	37.8	34.1–41.6		
Local	110	44	40.0	30.9–49.8	0.19	0.666
Age						
Unweaned calves	111	75	67.6	58.0 – 76.0	Ref	
Weaned calves	75	50	66.7	54.8 – 74.9	0.02	0.897
Yearlings	582	168	28.9	25.3 – 32.8	61.29	0.000
Sex						
Male	188	72	38.3	31.4–45.7		
Female	580	221	38.1	34.2–42.2	0.0023	0.962
Water source						
Tap	377	127	37.7	32.8–42.8		
Well	361	153	42.4	37.3–47.7		
River	30	13	43.3	26.0–62.3	6.99	0.030
Housing system						
Individual pen	123	13	10.6	6.0–17.8		
Group	645	290	45.0	41.1–48.9	6.33	0.001
Hygiene						
Good	382	131	34.3	29.6–39.3		
Poor	386	192	49.7	44.6–54.8	18.69	0.0001

Table 5. Description of the prevalence of *Eimeria* spp. Infection and mean OPG in animals with different faecal consistencies

Faecal consistency	Number examined	Prevalence (%)	95% CI	Mean OPG
Normal	593	28.2	24.7 – 32.0	454
Soft	151	69.5	61.4 – 76.6	5,736
Diarrhoea	24	87.5	66.5 – 96.7	36,890

No significant differences were observed in prevalence between Hawassa and Arsi Negele towns showing that the animals were kept under the same management conditions and also the climatic conditions in both areas were not variable enough to induce fluctuations in prevalence of infection.

The first age at which *Eimeria* oocysts detected was 15 days. This concurs with previous reports in the country (Abebe et al., 2008; Yadessa et al., 2014) and also comparable to the 12 days reported in Tanzania (Chibunda et al., 1997). The prevalence of *Eimeria* infection was significantly higher in calves than yearlings. Similarly the oocyst count showed a highly significant decrease with increasing of age. The highest oocyst count was observed in unweaned calves (<6 months) and the lowest in yearlings (>12 months). This decrease in the level and intensity of *Eimeria* infection with increasing age is because animals develop immunity from earlier exposures and without further stressors will maintain this immunity through continuous exposure. It does not however eliminate infection, but decreases the amount of coccidial development in the intestinal tract (Smith and Sherman, 1994). The present finding is in agreement with many other studies (Cornelissen et al., 1995; Chibunda et al., 1997; Waruiru et al., 2000; Faber et al., 2002; Matjila and Penzhorn, 2002; Abebe et al., 2008). Even though prevalence is lower, *Eimeria* infected adult animals may serve as a source of infection for calves (Matjila and Penzhorn, 2002).

The maximum OPG observed in this study is less than half of what has been reported by a previous study (Abebe et al., 2008); however, it is much higher than other reports from Ethiopia and abroad (Munyua and Ngotho, 1990; Arslan and Tuzer, 1998; Lassen et al., 2009; Yadessa et al., 2014). While a count of 5000 OPG is considered high enough by some investigators to warrant the judgment that the animal has the disease (Rebhun, 1995; McAllister, 2007), the majority of animals (90%) in this study were sub clinically infected showing oocyst counts of <5000 OPG. Nevertheless, these subclinical infections could still negatively influence animal productivity and are even more important than clinical coccidiosis because they usually remain unrecognized by cattle producers and damage the absorptive surface of the intestine and weaken the immune system, leading to poorer feed efficiency, slow weight gain, weight loss, longer heifer development periods and increases susceptibility to other disease causing agents (Fitzgerald, 1980; Fox, 1985; Cornelissen et al., 1995; Matjila and Penzhorn, 2002). The present finding is consistent with previous studies (Chibunda et al., 1997; Abebe et al., 2008).

In the current study, the prevalence of *Eimeria* oocysts was significantly higher in animals kept in poor hygienic condition than those in good condition. In poor hygienic farms the animals' manure was not frequently removed which created conducive condition for the sporulation of oocysts. and consequently large numbers of animals were infected. Similarly, the infection was significantly higher in animals housed in groups than those individually penned. In most of the farms animals were kept in overcrowded pens with physical contact with each other. This condition allowed animals to lick each other and favoured transmission of *Eimeria* oocysts.. Moreover overcrowding led to build-up of infective oocysts in the immediate environment of the animals and subsequent massive intake resulting in increased level of infection. These findings are in line with many studies (Step et al., 2002; Daugschies and Najdrowski, 2005; Radostits et al., 2007; Yadessa et al., 2014; Tsegaye, 2016).

Similar to other bovine coccidiosis studies in Ethiopia, the prevalence of *Eimeria* oocysts in the present study was found to be independent of breed and sex of the animal (Dawid et al., 2012; Alemayehu et al., 2013; Tsegaye, 2016). In contrast to the current finding, Yadessa et al. (2014) reported a significantly higher prevalence in cross-bred than local cattle.

The source of water for the animals was significantly associated with the prevalence of *Eimeria* infection. Animals getting water from river had higher prevalence than those getting tap or well water. It is most likely that the river water was contaminated by run-off from pasture grazed by cattle.

In the present study, the prevalence of *Eimeria* infection was significantly higher in diarrheic than in non-diarrheic animals. This suggests that *Eimeria* species may contribute to the diarrhoea, which may also be caused by other microorganisms. This is supported by observation of a considerably higher mean OPG in diarrheic animals than in non-diarrheic ones. Similar findings were reported by other authors (Chibunda et al., 1997; Pérez et al., 1998; von Samson-Himmelstjerna et al., 2006; Abebe et al., 2008, Alemayehu et al., 2013).

CONCLUSION

This is the first study to address the problem of bovine coccidiosis in Southern Ethiopia. It has shown that the age of animals, the source of water for animals, housing and hygienic conditions are the most important risk factors affecting the occurrence of *Eimeria* infections in small scale dairy farms of Southern Ethiopia and therefore, should be considered when planning a control strategy. All diarrhoeic cases should be treated with effective antococcidial drugs. Regular use of suitable coccidiostats and improvement of management practices should be part of the prevention measures. Since all *Eimeria* species are not pathogenic, further studies are required to identify the *Eimeria* spp. circulating in the dairy cattle of the study area.

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Occurrence of Bovine Tuberculosis in Cattle Slaughtered at Yirgalem Municipal Abattoir, Southern Ethiopia

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Abstract

A cross sectional study was conducted at Yirgalem municipal abattoir from November 2011 to March 2012 to estimate the prevalence of Bovine Tuberculosis (BTB) and to assess the associated risk factors based on detail post mortem and histopathological examinations. Accordingly, the randomly selected 402 slaughtered cattle were subjected to postmortem examination out of which 24 (6.0%) were found positive for tuberculous lesion. Of the 24 tissue specimens collected from the gross tuberculous lesion, 12.5% were positive by histopathological examination. The higher proportion of the gross TB lesion was recorded in mesenteric lymph nodes (79.2%, 19/24) followed by medistinal (12.5%, 3/24) and bronchial lymph nodes (8.3%, 2/24). Similarly, with histopathological examination, two-third of the TB lesions (66.7%) were detected in digestive tract while only one-third (33.3%) was recorded in the respiratory system. This indicated the occurrence of larger proportion of TB lesions in the digestive system than in the respiratory pathway. The multivariable logistic regression analysis of the risk factors also revealed higher occurrence of BTB among the cross breed (OR = 5.9, 95%CI = 1.6, 22.1) and animals with poor body condition score (OR = 5.6, 95%CI = 1.6, 19.9) when compared with local and animals with good body condition score. In conclusion, this study revealed the status of BTB in the study area. Further study is required to trace back the disease to the origin of the animals so that the overall epidemiological picture and the route of the disease can be understood.

Keywords: BTB, Prevalence, Postmortem, Yirgalem, SNNPRS
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INTRODUCTION

Tuberculosis is an infectious disease caused by strains of *Mycobacterium tuberculosis* complex and has been a major health risk to human and animal for centuries. It is widely distributed throughout the world affecting all age of human and animals causing significant economic loss (Cosivi et al., 1998). Bovine tuberculosis (BTB) is a chronic infectious disease of animal characterized by the formation of granulomas in tissues and organs more significantly in lung, lymph nodes and kidneys. It is caused by *Mycobacterium bovis* which is the most universal pathogen among Mycobacterium and affects many vertebrate animals although cattle, goats, pigs are found to be most susceptible while sheep and horses are showing a high natural resistance (Shitaye et al.,2007). BTB is zoonotic disease which can also be transmitted to human by aerogenous route and/or through consumption of infected milk and other animal products. Ethiopia is a country where the impact of BTB is particularly important and it is amongst the three African countries with the highest burden of human TB case (WHO, 2005). According to Bogale et al. (2004), Ameni et al. (2006) and Biffa et al. (2009), the prevalence of BTB in certain part of Ethiopia was found to be high ranging from 3.4% in small holder production system to 50% in pre-urban (intensive) dairy production system. Detection of BTB in Ethiopia is carried out most commonly on the bases of tuberculin test, abattoir meat inspection and rarely on bacteriological techniques (Shitaye et al., 2007).

In Ethiopia the routine abattoir inspection for any infection including BTB applies the method developed by meat inspection and quarantine decision of the Ministry of Agriculture. It involves visual examination, palpation and incision of organs like kidney, lung and pleural lymph nodes Condemnation of carcass on the bases of detected tuberculous lesion is a standard practice for the control of zoonotic infection at abattoir (Shitaye et al., 2007). Among the undertaken abattoir studies, prevalence of 5.2% (Ameni and Wudie, 2003), 4.5% (Teklu et al., 2004) and 3.5% (Shitaye et al., 2006) have been reported in the central Ethiopia and information on the status of the diseases at the abattoir level is lacking in most of the Southern parts of Ethiopia including the study area. Hence, this study is designed to estimate the prevalence of BTB and to assess the potential risk factors for the occurrence of the diseases in the study area.

MATERIALS AND METHODS

Study Area

The study was conducted between November 2011 to March 2012 on cattle which were brought to Yirgalem municipal abattoir for slaughter from different areas. Yirgalem was the town of Dale district of Sidama Zone, SNNPRs. The town is located 322km south of Addis Ababa and 47km south east of Hawassa.

Study design

Study population and study type

The study animals were cattle which were brought to Yirgalem municipal abattoir for slaughtering purposes from different districts of Sidama, Arsi and Borona zones. A cross-sectional study was employed at which all cattle which were brought to abattoir for slaughter were subjected to both antemortem and detailed postmortem examinations.

Sample Size and sampling procedure

Sample size was calculated using the formula given by Thrusfield (2005) with 50% expected prevalence, 95% confidence interval and 5% desired absolute precision. Accordingly, the sample size was determined to be 384, and a total of 402 animals were sampled to increase precision. The sampling procedure was carried out using systematic random sampling in such a way that sampling units were selected at equal intervals with the first animal being selected randomly. The estimate of the total number of animals slaughtered during the preceding year (year 2010) was 10,800 cattle which were obtained from the record. The number of slaughtered animal during the 5 months of the year 2010 was calculated to be 4500 cattle, as the current study period was also 5 months. Subsequently, the sampling interval was computed as the total number of cattle slaughtered during the study period divided by the required sample size. Therefore, the sampling interval was 11 (5,400/402). Then the first animal was chosen randomly from the first 11, after which every 11 cattle were included in the sample during the slaughter operation until the required 402 cattle is obtained.

Study Methodology

All the study animals were subjected to antemortem inspection before slaughter to gather all the necessary data with regard to origin, sex, breed, body condition score and age of the animals. Then detail postmortem examination of these cattle was conducted by inspecting organs including lungs, kidneys, liver, spleen and intestine. The lymph nodes which are considered to a predilection site for TB microbes (bronchial, Medistinal, mesenteric, and hepatic) were also inspected for the presence of gross TB lesions. For confirmation, tissue specimens from the TB-suspected lesion were collected for histopathological examination with hematoxylin–eosin stain.

Data Management and Analysis

The collected data was recorded and coded on excel sheet and summarized using descriptive statistics. Logistic regression analysis was employed to analyze the association between TB occurrence and the potential risk factors (sex, age, body condition, breed and origin) using statistical software (STATA version 11). The association was summarized using both univariable and multivariable logistic regression analysis.

RESULTS

Prevalence

Abattoir Survey Result

Based on the detail post mortem examination conducted on 402 cattle, the prevalence of BTB was found to be 6.0% (24/402). The lesions were found in various forms with different sizes in the organs and lymph nodes. The organ level distribution of the lesion was summarized in table 1. Larger proportion of TB lesions was recorded in mesenteric lymph nodes 79.2% (19/24), followed by medistinal (12.5%, 3/24) and bronchial lymph nodes (8.3%, 2/24), respectively. Hence, the higher proportion (79.2%) of the lesions was recorded in the digestive system than respiratory pathway (20.8%). In current study, no TB lesion was observed in muscle, lung tissue, hepatic lymph nodes and heart.

Table 1: Organ level distribution of TB lesion in various organs of cattle slaughtered At Yirgalem municipal abattoir (n = 402)

Organ inspected	Number affected	Relative percentage (%)	Organ level prevalence (%)
Lungs	0	0	0
Bronchial lymph nodes	2	8.3	0.49
Mediastinal lymph nodes	3	12.5	0.75
Prescapular lymph nodes	0	0	0
Liver	0	0	0
Hepatic lymph nodes	0	0	0
Heart	0	0	0
Mesenteric lymph nodes	19	79.2	4.73
Muscle	0	0	0
Total	24	1.00	6.00

Table 2: Summary of organ level distribution of BTB based on histopathological examination (N=402).

Organ inspected	Tubercle lesion positive animal, No (%)	Hematoxylin –Eosin stain positive, No (%)
Bronchial lymph nodes	2 (0.5)	1 (0.3)
Mediastinal lymph nodes	3 (0.8)	0
Mesenteric lymph nodes	19 (4.7)	2 (0.5)
Total	24 (6.0%)	3 (0.75%)

Histopathological Examination Results

Out of the 24 tissue specimens collected from the grossly diagnosed TB lesions, three (12.5%) were found positive and the prevalence of BTB based on histopathological examination with hematoxylin–eosin stain was 0.75% (3/402). The organ level distribution of BTB showed that 66.7% (2/3) of the lesions were in the digestive tract (mesenteric lymph nodes) and 33.3% (1/3) in the respiratory tract (bronchial lymph nodes).

Analysis of risk factors

Logistic regression analysis: The distribution of tuberculous lesion in the slaughtered cattle in relation with the considered potential risk factors was summarized using univariate and multivariate logistic regression analysis as follows. *Univariate regression analysis* of risk factors (Table 3) shows the association between the BTB prevalence and different risk factors. Accordingly, the occurrence of BTB differed significantly among the breed (p=0.001), body condition score (p=0.006), sex (p = 0.030). Hence, this analysis showed the higher chance of occurrence of the disease in cross breed (OR = 5.7, 95%CI = 2.0, 15.8), poor body condition animals (OR = 4.84, 95%CI = 1.58, 14.8) and males (OR = 2.7, 95%CI = 1.1, 6.5) when compared local animals, animals with good body condition and the females, respectively. This analysis indicated that there is no association of tuberculosis occurrence with age and origin of the animals. Similarly, the *multivariable logistic regression analysis* revealed that the occurrence of the BTB significantly vary with breed (p = 0,009) and body condition score (p = 0.007), indicating the higher occurrence chance of BTB among the cross breed (OR = 5.9, 95%CI = 1.6, 22.1) and animals with poor body condition (OR = 5.6, 95%CI = 1.6, 19.9) when compared with local and animals with good body condition. This analysis also did not reveal any association of tuberculosis occurrence with age, sex and origin of the animals.

Table 3: Logistic regression analysis of the association of the potential risk factors with BTB occurrence in cattle

Risk factors		No inspected	No (%) positive	Univariate Analysis		Multivariable Analysis	
				Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Breed	Local	375	18 (4.8)	1		1	
	Cross	27	6 (22.2)	5.7 (2.0, 15.8)	0.001	5.9(1.6, 22.1)	0.009
Sex	Female	66	7 (5.1)	1		1	
	Male	336	17 (10.6)	2.7(1.1, 6.5)	0.030	1.3 (0.4, 4.2)	0.611
Age	≤ 5	125	5 (4.1)	1		1	
	> 5 -7	226	14 (6.2)	1.6(0.5, 4.4)	0.406	1.4 (0.5, 4.1)	0.527
	> 7	51	5 (9.8)	2.5 (0.7, 8.9)	0.170	1.6 (0.4, 6.3)	0.519
BCS	Poor	28	5 (17.9)	1		1	
	Medium	84	6 (6.1)	2.9 (0.8,1.1)	0.097	2.7 (0.7, 10.5)	0.143
	Good	290	13 (4.5)	4.8 (1.6, 14.8)	0.006	5.6 (1.6,19.9)	0.007
Origin	Arsi	50	4 (8)	1		1	
	Sidama	342	20 (5.8)	1.4 (0.5, 4.38)	0.55	1.1 (0.4, 3.7)	0.33
	Borana	10	0*				

*All the 10 cattle from Borana were found negative and comparison during the analysis was made only between the Arsi and Sidama cattle.

DISCUSSION

There are many different reports regarding the status of bovine tuberculosis in different parts of Ethiopia and other countries as it is one of the important infectious diseases affecting both human and animals of all age groups. Most of the works carried out on the investigation of this disease is based on either tuberculin skin test or detail postmortem examination at different abattoirs or both techniques employed together. The respective 6.0% and 0.75% abattoir and histopathology based prevalence report of this study is comparable with the previous records of Ameni and Wudie (2003), Teklu et al. (2004) and Shitaye et al. (2006) who reported a prevalence of 5.2% in Nazareth, 4.5% in Hosanna and 3.46% in Addis Ababa, respectively. Still there was relatively higher prevalence of 8.8% (Ameni et al., 2006), 10.1% (Biffa et al., 2009), 11.6% (Regassa, 2010) at different parts of the country. Exceptionally, a prevalence of 19.8% was reported from cattle slaughtered in rural Tanzania (Cleaveland and Kazawala, 2007). In areas where disease control program is absent, as high as 40% prevalence of BTB can occur in slaughter cattle in public abattoirs (Thoen et al., 2006).

Routine meat inspection carried out at various abattoirs of the country commonly report low levels of BTB prevalence. Bogale et al. (2004) reported prevalence of 1.3% in Hosanna abattoir, Southern Ethiopia. Similarly, a condemnation rate of tuberculous organ from slaughtered cattle at Dire-Dawa slaughterhouse ranged between 1% and 1.5% in 6940 animals slaughtered within 17 months (Shitaye et al., 2006). Collated data from abattoirs in different parts of the country on the number of cases with tuberculous lesions ranged from 0.02% to 1.8% (Shitaye et al., 2007). The earlier report by Gezahegne (1991) from eight export abattoirs showed a prevalence of 0.8% of 144,487 slaughtered animals, in which the whole carcass of 978 animals were condemned. Furthermore, results based on meat inspection data by Shitaye et al. (2007) indicated that BTB had a prevalence of 0.052% in 1,336,266 cattle slaughtered in Addis Ababa and Debre-Zeit abattoirs in the years 1996-2005. The infection proportion in cattle has been found to differ greatly from place to place which most probably be linked to the type of the production system (most notably in extensive/pastoral), which is unlikely to favor the spread of the disease in contrast to intensive dairy farms (Ameni et al., 2006; Shitaye et al., 2007). It could also be associated with the kinetic and the intensity of lesion development (pathology) in different livestock husbandry systems (Ameni et al., 2006). The variations in the prevalence of the BTB observed among these studies could also be partly explained by the low sensitivity of the postmortem based detection of tuberculosis, which is affected by the method employed, expertise of the examiner and the anatomical sites examined. In line with this, several studies have shown that the power of postmortem based detection of tuberculosis infection can be improved with enhanced meat inspection procedures, particularly with multiple slicing of organs and lymph nodes.

Based on the active abattoir survey carried out, the TB tubercles were found in different forms with different sizes in various organs. The organ level distribution of the lesion in the current study indicated that the larger proportion (79.2%) of TB lesions was recorded in the digestive pathways, followed by respiratory pathway (20.8%). The larger proportion of TB lesions recorded in the digestive pathway contradicts the reports of Regassa et al. (2010) who reported 50% of TB lesion in respiratory pathway, followed by 28.6% in digestive system, and 21.4% in prescapular lymph nodes. Additionally and on the contrary to the current report, O'Reilly and Dabron (1995) also mentioned that inhalation was the most important route of infection. However, this finding is in agreement with the report of Cleaveland and Kazawala (2007) in which the majority of visible lesions were recorded in the gastrointestinal tract rather than respiratory tract. This is an indication that ingestion is also one of the important routes of transmission implicating that considerable number of the cases probably may occur during the suckling time from infected dam or by liking, feeding or drinking contaminated materials (Regassa et al., 2010). Concerning the histopathological result, the prevalence (0.75%) is relatively higher than the 0.4% report of Regassa et al. (2010). On the other hand, the positive proportion of histopathology out of the 24 gross lesions was 12.5% which is relatively lower than the 28.6% report of Regassa et al. (2010).

The higher BTB prevalence among the crosses than local cattle recorded in this study is in line with previous report (O'Reilly and Dabron, 1995; Kiros, 1998; Ameni et al., 2006). This could be attributed to the fact that genetically improved cattle may suffer more severely from deficient housing and mal-nutrition and thus become prone to infection than zebu breeds (O'Reilly and Dabron, 1995). The higher BTB prevalence in animals with poor body condition could be due to the fact that they might be immuno-compromised probably due to malnourishment and higher workload. On the other hand, poor body condition score could also be due to the chronic BTB infection and in such case, body condition score is considered as a dependent not as a risk factor. However, in the current study we consider it as a risk factor for the

BTB infection. This finding is in agreement with reports from previous studies in Ethiopia (Bogale et al., 2004).

Detection of BTB in Ethiopia is most commonly carried out by abattoir meat inspection, tuberculin skin test and very rarely by Acid fast stain. BTB has serious public health implication in areas where there is a habit of raw animal product consumption. The present study indicated the importance and magnitude of BTB based detailed postmortem examination of visceral organs and carcasses of cattle. In this study it was observed that some risk factors such as sex, breed and body condition contributed for the occurrence of the disease. In conclusion, the study revealed the status of BTB in the study area. Further study is required to trace back the source and route of the disease and understand the overall epidemiological picture. Additional microbiological and molecular techniques should be employed so as to identify causative agents to the strain level.

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Genotype by Environment Interaction and Stability of Chickpea (*Cicer arietinum* (L.)) Genotypes in Southern Ethiopia

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Abstract

The production of chickpea in Ethiopia is being pushed into less favorable areas adjacent to and in the southern rift valley where it is exposed to severe moisture stress during the post-rainy growing season. Fifteen chickpea genotypes consisting of seven released varieties, six kabuli advanced lines obtained from ICARDA and two local checks, were tested in three replications of RCBD at three locations during 2012 and 2013 (six environments, E1 to E6) in southern Ethiopia. The objectives of the study were to determine the difference in grain yield between the genotypes and between the environments and investigate the magnitude and nature of G x E interaction, assess the stability of the chickpea genotypes and identify those with wide or narrow adaptation. Due to heterogeneity of errors over the six environments a transformation (Geometric mean x Log (Yield in Kg ha^{-1}) was used. The Environment main effect and the GxE interaction were highly significant. Grain yield ranged between 31.8 and 68.7 units (0.66 and 5.2 tons ha^{-1}) at E1 and E2, respectively; a reduction of 53.6% (87.3% in the original units, Kg ha^{-1}) due to moisture stress. Univariate stability parameters identified four high yielding and stable genotypes, Ejeri, Mastewal, Wolayita Local and Habru for wide adaptation. There was no correlation between yield and stability; simultaneous selection for both high yield and stability is possible. Both AMMI and GGE put the lowest yielding environment, E1 as a distinct environment. Yield at E1 was negatively correlated with yield at other environments. AMMI and GGE identified the same four genotypes selected by W_i, (S^2d_i), and ASV_i for wide adaptation (Group I). Ararti, Butajira local, Cheffe and Naatolii (Group II) were adapted to high yielding environments similar to JolleAndegna (Butajira) and Taba in Wolayita. Shasho, FLIP03-28C and FLIP07-81C (Group III) were adapted to low yielding environments such as Halaba (Huletegna Choroko). Compared to Group II, genotypes in Group III had the highest mean yield under stress (E1) (8.8 vs 5.1), geometric mean yield (20.6 vs 17.4), Yield Stability Index (0.18 vs 0.08), Drought Resistance Index (0.24 vs 0.07), and the lowest percent yield reduction (81.7 vs 91.9%) and Drought Susceptibility Index (0.79 vs 0.91).

Keywords: AMMI, drought index, GGE, stability
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INTRODUCTION

Chickpea [*Cicer arietinum* (L.)] is an important food legume of the semi-arid tropics and the warm temperate zones (Onwueme and Sinha, 1991). The crop is considered as one of the most important legumes used as food and feed and is cultivated on over 13.5 million hectares in a wide range of environments across the world (FAOSTAT, 2013). Ethiopia ranks 7th after India, Australia, Pakistan, Turkey, Myanmar, and the Islamic Republic of Iran in area and production of chickpea (FAOSTAT, 2013). With an area of 239,751 ha and annual production 4,586,823 quintals, it ranks 3rd among pulses after faba beans and haricot beans (CSA, 2014/15). On the highlands of Ethiopia, where it is rotated with tef and wheat to enhance soil fertility, chickpea is produced on residual moisture after the end of the main rains from August to December and faces relatively less moisture stress due to the high water holding capacity of the vertisols and the cool growing season (Geletu Bejiga and Ketema Daba, 2003).

Chickpea production is being extended to non-traditional agro-ecologies of the rift valley in southern Ethiopia, where the crop is exposed to a more severe moisture stress during the post-rainy season. The climatic variations between different locations (predictable variation) and the variation within the same location over different years (the unpredictable variation) are higher here than in the highlands. The same location may get rainfall as high as in the highlands and high yields comparable to that in the potential highlands can be obtained in few years, while in most of the years rainfall is so low, its distribution so irregular that hardly any harvest can be expected. Selection for yield under moisture stress is generally considered less efficient than selection for yield under well-watered conditions (Rosielle and Hamblin, 1981). Stability of yield is as important as, or even more important than, high mean yield of a variety to be released for such areas. Baker and Léon (1988) defined GxE interaction as the failure of genotypes to achieve the same relative performance in different environments. Thus, a stable genotype can be referred to as the one that is capable of utilizing the resources available in high yielding environments and has a mean performance that is above average in all environments (Eberhart and Russell, 1966). Knowledge of the magnitude and pattern of GxE interactions and stability analysis are important for understanding the response of different genotypes to varying environments and for identification of stable and widely adapted and unstable but specifically adapted genotypes.

Using the genetic variability within the Ethiopian chickpea germplasm and introductions from ICARDA and ICRISAT, the chickpea improvement program of Ethiopia has released 11 *desi* and 12 *kabuli* type varieties mainly for the highlands and mid-altitudes of the country (MoARD, 2015). The performance of these varieties under the moisture stress conditions of the southern rift valley has not been studied. There is also limited information on the extent and pattern of GxE interaction and the stability of these released chickpea varieties when they are grown in the southern rift valley. Therefore, the objectives of the present study were to evaluate the performance of the released varieties and potential lines in the southern rift valley, determine the extent to which Environment, Genotype and GxE interaction affect grain yield, study the pattern of the GxE interaction and yield stability of the genotypes and identify genotypes that are widely or specifically adapted.

MATERIALS AND METHODS

Description of the experimental sites

The experiments were conducted at three locations in the southern rift valley of Ethiopia, Jolle Andegna, Taba and Huletegna Choroko during 2012 and 2013 (Table 1).

Experimental materials

Fifteen chickpea genotypes (seven released varieties, six elite lines and two land races) were used for the study. The released varieties were obtained from Agronomy section of the School of Plant and Horticultural Sciences, Hawassa University, College of Agriculture, which initially were from Debre Zeit Agricultural Research Center.

The advanced lines were extra-early maturing genotypes obtained from ICARDA in 2011 and have been tested for one year (September, 2011-February, 2012). The local materials were obtained from farmers of Jolle Andegna and Taba vicinity. The description of the genotypes is provided in Table 2.

Table 1. Description of the experiment sites

Location	Altitude (masl*)	Annual RF (mm)	Mean annual Temp (°C)	Soil texture	Zone
Jolle Andegna	1923	922	18.4	Silty clay loam	Gurage
Taba	1915	989	18.7	Silty loam	Wolayita
Huletegna Choroko	1807	774	20.6	Clay loam	Halaba

* masl = meters above sea level

Source: (NMA, 2013) and College of Agriculture, Hawassa University, Soil Laboratory.

Design of the experiment and trial management

The randomized complete block design (RCBD) with three replications was used to conduct the experiments. Plot size was 11.2 m^2 consisting of eight rows, each 3.5 m long. The inter- and intra-row spacing was 40 and 10 cm, respectively.Diammonium Phosphate (DAP) (18:46:0 N:P:K) at the rate of 60 kg ha^{-1} was uniformly applied at planting followed by Zinc fertilizer ($ZnSO_4.7H_2O$) at 25 kg ha^{-1} drilled in rows and incorporated with the soil before planting. The experiments were planted at different dates based on rainfall pattern and soil moisture content across the locations over the years. At Huletegna Choroko the experiment was planted on September 8 in 2012 and August 23 in 2013. At Jolle Andegna, planting was done on September 20 in 2012 and September 4 in 2013, while at Taba planting was done on September 14 in 2012 and September 17 in 2013.

Data collection

The middle six rows of each plot were used for collecting data on phenology (days to flowering and maturity), growth parameters (number of primary and secondary branches, plant height) and seed yield and its components (number of pods per plant, seeds per pod, thousand seed weight, biomass and seed yield, harvest index). In this paper only seed yield was analyzed.

Data analysis

Each location-year combination was considered as a separate environment in this study, producing six environments which were considered random. The General Linear Model (GLM) of SAS software (SAS, 2008) was used for ANOVA of data from individual locations and for the combined data. Prior to the combined ANOVA, homogeneity of error variances over the six environments was tested.

Table 2. Description of chickpea genotypes studied at three sites during 2012-2013 in southern Ethiopia

Genotypes	Code	Days to maturity	Type	Line	Year of release
Arerti	a	105-155	Kabuli	FLIP89-84C	1999
Butajira (local)	b		Desi		Landrace
Cheffe	c	93-150	Kabuli	ICCV-92318	2004
Ejeri	d	118-129	Kabuli	FLIP97-263C	2005
Habru	e	91-150	Kabuli	FLIP88-42C	2004
Mastewal	f	98-142	Desi	ICCV-92006	2006
Naatolii	g	88-142	Desi	ICCX-910112-6	2007
Shasho	h	110-125	Kabuli	ICCV-93512	1999
Wolayita (local)	i		Desi		Landrace
FLI P03-53C	j	119*	Kabuli	FLI P03-53C	Adv. Line
FLI P03-102C	k	122*	Kabuli	FLI P03-102C	Adv. Line
FLI P03-128C	l	119*	Kabuli	FLI P03-128C	Adv. Line
FLI P07-81C	m	125*	Kabuli	FLI P07-81C	Adv. Line
FLI P08-60C	n	128*	Kabuli	FLI P08-60C	Adv. Line
FLIP07-27C	o	126*	Kabuli	FLIP07-27C	Adv. Line

Stability analysis was conducted using the SAS program developed by Hussein *et al.,* (2000). Three most popular univariate stability parameters (Wricke's Ecovalence (W_i) (Wricke, 1962), Deviations from regression (S^2d_i) (Eberhart and Russel, 1966), and AMMII Stability Value (ASV) were used. The slopes were used as measures of responsiveness of each genotype to environment. Two multivariate analytical tools, AMMI (Gauch, 1988; Zobel *et al.,* 1988) and (GGE) biplots were also used to shed more light on the significant GxE interaction and determine the stability and adaptability of each genotype. Some indices of drought tolerance which indicate the response of a specific genotype to drought stress, were also used to compare the genotypes. For this, the environment at which the genotypes are exposed to the most severe moisture stress is taken as Stress environment (Xds or Yds) and the environment under which the highest yield is obtained is considered as non-stress environment (Xns or Yns). The Indices used were:

Drought intensity index (DII) was calculated for the whole experiment.

DII = 1-Xds/Xns, where Xds and Xns are the mean seed yield of all genotypes under drought stress and non-stress environment, respectively. The DII is used to compare the stress between two or more experiments. DII of 0.7 and above indicates severe drought stress, while DII of 0.2 - 0.5 indicates mild drought stress (Fischer and Maurer 1978).

Drought Index (DI) = Xds/Xns. This was also calculated for the whole experiment.

Drought susceptibility index (DSI): DSI = [1-(Yds/Yns)/DII] (Fischer and Maurer 1978).

Where Yds and Yns are the mean seed yield of a specific genotype under drought stressed and non-stressed environments, respectively.

Drought resistance index (DRI) = Yds*((YDS/Yns)/Xds) (Fernandez, 1993)

Geometric mean (GM): = $(\text{Yds x Yns})^{0.5}$, (Fernandez, 1993).

Mean Productivity (MP) = (Yds+Yns)/2.

Percentage yield reduction due to drought = [(Yns – Yds)/Yns] *100

Yield stability index (YSI) =Yds/Yns (Bouslama and Schapaugh (1984) Genotypes with lower values of PYR and DSI, but with higher values of YSI, DRI and GM, are more drought tolerant.

RESULTS

Comparison of Error Mean Squares of the six environments revealed heterogeneity of variance. The Box and Cox (1959) algorithm suggested the following transformation of the original data:

$Y^{(\lambda)}$ =Geom*Log(Yield) (Log is the natural logarithm and λ=0 was used).

$Y^{(\lambda)}$ are the transformed variables; 'Geom' is the geometric mean ($\hat{Y}$), and $\hat{Y} = \ln^{-1}(\frac{1}{n}\sum \ln Y)$.

Results of ANOVA of the transformed data of individual environments revealed that the difference between the genotypes was significant at four of the six environments (Table 4). At E3 (Taba, 2012) and E6 (Huletegna Choroko, 2013) these differences were significant only at p=0.08. Large genotypic variance was observed within the tested genotypes of chickpea. The highest yielding genotypes at E1, E2, E3, E4, E5 and E6 were FLIP07-81C (m), Naatolii (g), Mastewal (f), Butajira local (b), Naatolii (g) and Naatolii (g), respectively.

Results of ANOVA

ANOVA of data combined over the six environments (Env) revealed very highly significant difference between the environments and very highly significant GxE effects (Table 3). Although the difference between genotypes (G) was significant at most of the environments, in the combined analysis these differences were significant only at p=0.08 (Table 3). This is due to the high GxE mean square against which the genotypic mean square was tested. The environments (Env) constituted 82.5% of the treatment sum of squares (Env + G + GxE) while genotypes and the GxE contributed 4.4 and 13.1%, respectively. Most of the variability in seed yield in this study was due to differences between the six environments. The highest yielding (68.7) environment (E2) gave yield which was more than double that of the lowest yielding (31.9) environment (E1) *(5.2 and 0.66 tons ha^{-1})*. The GxE interaction was about 3-fold that of the genotypic variations, indicating the importance of the GxE interaction in determining seed yield of chickpea and the need for further analysis to determine the stability and the adaptation pattern of each genotype

Table 3. Combined ANOVA of grain yield of 15 chickpea genotypes tested at six environments in southern Ethiopia in 2012/13

Source	DF	SS	MS	P-value	Percent SS Explained
Env	5	40004.2	8000.8***	<0.001	82.5
G	14	2130.7	152.2	0.08	4.4
GxE	70	6339.0	90.6***	<0.001	13.1
Rep(E)	12	297.4	24.8*	0.02	
Error	168	1943.5	11.6		
Total	269	50714.9			

R-Square = 0.96 C.V. = 6.8

Seed yield was low at E1, E3 and E5 (Jolle Andegna, Taba and Huletegna Choroko, during 2012, respectively) and high at E2, E4, and E6 (at each of the sites in 2013) (Table 4). This environmental variability was mainly due to the differences in the amount and distribution of rainfall during the growing period; rainfall was higher in 2013 at all three sites (Fig. 1). The correlation between the amount of seasonal rainfall and mean yield of the environments was 0.79 (p=0.06).

For instance, the total rainfall for the growing season at Taba was greater by about 270 mm in 2013 (E4) than in 2012 (E3) (638 vs 368 mm, an increase of 73%). As a result grain yield was increased by 116% (2644 vs 1217 Kg ha^{-1}). A similar trend was observed at Huletegna Choroko 2013 (E6) as compared to E5 (same location in 2012). Seasonal rainfall was higher by 56.2% (628 vs 402 mm and seed yield was higher by 111% (2799 vs 1322 Kg ha^{-1}). The largest difference in seed yield between the two years was observed at Jolle Andegna, where that at E2 (2013) was higher than that at E1 (2012) by 688% (5200 vs 658 Kg ha^{-1}); the seasonal rainfall was higher by 41.5% (737 vs 521 mm). The amount of rainfall in October and November of the year 2012 at Jolle Andegna (E1) was 15.8 mm and 0.0 mm, while the mean temperature was high during the grain filling stage. Besides, the amount of rainfall and its distribution was uneven, most of the days having no rain or rainfall of less than 5 mm. Therefore, the plants were stressed and exposed to forced maturity (50 vs 57 days to flowering and 102 vs 111 days to maturity, as compared to that in 2013).

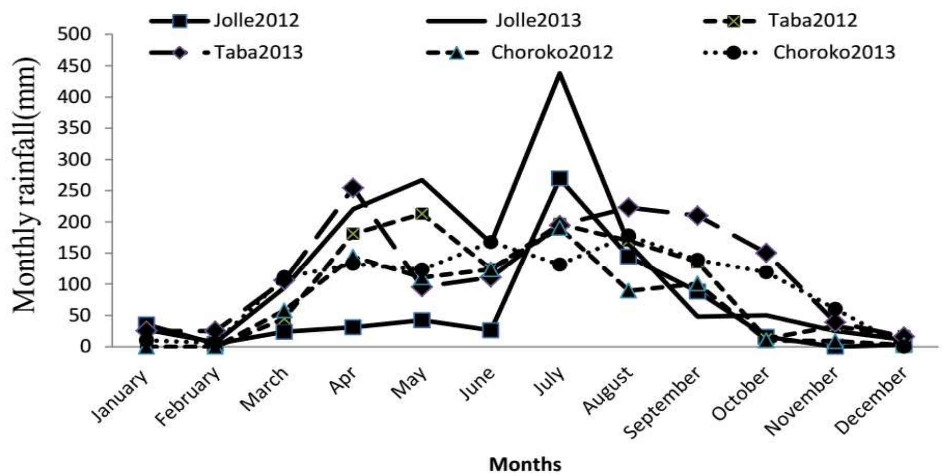


Figure 1. Rainfall at the three locations in southern Ethiopia during 2012 and 2013 (NMA, 2013)

The seven released varieties and the two landraces (genotypes 'a' to 'i') gave above average (50.1 units or 2450 Kg ha^{-1}) grain yield, while the elite lines (genotypes j to o) gave below-average seed yield except FLIP07-81C (m) which gave seed yield slightly above the grand mean (50.38 units) (Table 4). The elite lines were introduced from ICARDA as "Extra-early group", but previous results (Selamawit, 2012) showed that they belong to the medium (100-120 days to maturity) and late group (>120 days to maturity).This was also confirmed by the present work.

Although the two checks and the seven released varieties (a to i) had seed yield higher than the grand mean (except Cheffe (c)), and were superior to the elite lines (j to o), this performance lacks consistency over the six environments; ranks of genotypes were not constant over the six environments.

Table 4. Means of fifteen chickpea genotypes grown at six environments in southern Ethiopia in 2012/13

Genotypes	Code	E1	E2	E3	E4	E5	E6	Mean
Arerti	a	27.9^{f}	71.7^{ab}	43.9^{6*}	60.0^{abc}	49.4^{c}	60.1^{4*}	**52.2^{5*}**
Butajira local	b	34.0bcd^{e}	71.0^{abc}	41.1^{11}	62.7^{a}	53.4^{ab}	56.3^{12}	**53.1^{3}**
Cheffe	c	10.5^{g}	70.3^{abc}	46.8^{3}	58.1^{abc}	52.8^{b}	58.4^{6}	**49.5^{10}**
Ejeri	d	33.6^{bcde}	70.2^{abc}	46.3^{5}	61.6^{ab}	40.5^{e}	59.7^{5}	**52.0^{6}**
Habru	e	30.8^{ef}	68.7^{bcd}	42.9^{8}	55.4^{bcde}	47.9^{c}	60.3^{3}	**51.0^{8}**
Mastewal	f	34.2^{bcde}	70.9^{abc}	49.4^{1}	54.9^{bcde}	48.6^{c}	60.6^{2}	**53.1^{2}**
Naatolii	g	33.0^{de}	75.0^{a}	42.0^{9}	55.6^{bcde}	56.1^{a}	61.0^{1}	**53.8^{1}**
Shasho	h	37.8^{ab}	66.2^{bcde}	43.3^{7}	57.7^{abcd}	53.0^{b}	58.4^{8}	**52.7^{4}**
Wolayita local	i	35.9^{abcd}	70.4^{abc}	41.2^{10}	61.6^{ab}	40.5^{e}	57.4^{11}	**51.2^{7}**
FLIP03-53C	j	30.6^{ef}	61.6^{e}	41.0^{12}	50.5^{e}	44.8^{d}	57.5^{10}	**47.7^{12}**
FLIP03-102C	k	26.8^{f}	68.0^{bcd}	46.7^{1}	50.9d^{e}	30.5^{g}	54.9^{13}	**46.3^{14}**
FLIP03-128C	l	37.6^{abc}	67.2^{bcd}	37.0^{15}	54.6bcde	36.0^{f}	53.6^{15}	**47.7^{11}**
FLIP07-81C	m	38.6^{a}	69.0^{bcd}	47.4^{2}	56.6^{abcde}	32.8^{g}	57.9^{9}	**50.4^{9}**
FLIP08-60C	n	33.2^{cde}	66.1^{cde}	37.7^{14}	53.7cde	33.1^{g}	58.4^{7}	**47.0^{13}**
FLIP07-27C	o	33.8^{bcde}	64.4^{de}	38.1^{13}	55.7^{abcde}	19.2^{h}	54.3^{14}	**44.3^{15}**
Mean		**31.9**	**68.7**	**43.0**	**56.6**	**42.6**	**57.9**	**50.1**
LSD		**4.14**	**5.57**	**NS**	**7.00**	**2.79**	**NS**	**NS**

NS = not significant; * = Ranks of genotypes; E1 = Jolle Andegna 2012, E2= Jolle Andegna 2013, E3 =Taba 2012, E4 = Taba 2013, E5 = Huletegna Choroko 2012, and E6 = Huletegna Choroko 2013.

Genotype FLIP03-128C (l) for example ranked 3rd at E1, but its ranks were greater than 10 in the remaining environments. Entry Naatolii (g) was the highest yielding genotypes at E2, E5 and E6, respectively, but ranked 10th, 9th and 9th at E1, E3, and E4, respectively.

Although ANOVA is important in detecting the presence of GxE interaction, it is not capable to explain the type of the GxE interaction, the contribution of each genotype or each environment to the total GxE interaction and the relationship between the genotypes and the environments (which genotype is better adapted to which environment, whether there are genotypes adapted to all environments or to specific environments). Stability analysis sheds light to many of these questions.

Stability Analysis

The GxE (Linear) interactions in Eberhart and Russell's (1966) regression model were not significant (results not presented); the slopes (b_i), which are used as a measure of the responsiveness of the genotypes to change in environments, did not vary for the different genotypes included in the study; neither did the slope (b_i) of each genotype deviate from unity (Table 5), which indicates that all the tested genotypes had average responsiveness.

There was no correlation between yield and the bi values (r = -0.18; the rank correlation was -0.22 and were non-significant). The range of the slopes was narrow (0.75 to 1.35) and this may be the reason for the non-significant correlation between the slopes and grain yield.

On the other hand, the pooled deviation was highly significant (results not shown). It was also significant for 13 of the 15 genotypes (Table 5), which entails that the pattern of the highly significant GxE interaction could not be explained by regressing varietal means on environmental indices. Indeed, this model explained only 12.2% of the GxE interaction. This can also be observed from the very low R^2 values for each genotype (Table 5).

Wricke's ecovalence (Wi), Deviation from regression (S^2d_i) and AMMI Stability Value (ASV) assigned similar stability ranks to the 15 genotypes; the correlations between these ranks being 0.97^{***}, 0.87^{***} and 0.93^{***}, all very highly significant. If the whole range of stability by Wi, S^2d_i or ASV is divided into three categories, the lowest one-third, the middle one-third and the highest one-third, then genotypes can be classified into three corresponding stability groups; high, intermediate and low stability, respectively. All three assigned Ejeri (d), Habru (e), Wolayita local (i), Mastewal (f) and FLIP03-53C (j) into the high stability group. The genotypes assigned to medium and low stability groups were the same for W_i and S^2d_i; the two differing from ASV by assigning FLIP03-128C (m) in the Medium Stability and FLIP03-102C (k) in the low stability groups; these two genotypes were assigned into the opposite groups by ASV. We can, therefore, conclude that Cheffe (c), Naatolii (g), FLIP03-102C (k), FLIP07-81C (m), and FLIP07-27C (o), were the most unstable genotypes.

Table 5. Mean grain yield, Wricke's ecovalence (Wi), slope (bi), deviation from regression (S^2d_i) and AMMI Stability Values (ASV) of the 15 chickpea genotypes tested in 2012-2013 in southern Ethiopia

Genotypes	Mean	Wi	bi	S^2d_i	R^2	ASV	RY	RW	RD	RASV
Arerti	52.15	63^{***}	1.12	4.16^{***}	0.21	3.6869	5	6	6	8
Butajira local	53.06	117^{***}	0.96	9.91^{***}	0.01	3.7163	3	10	10	9
Cheffe	49.48	579^{***}	1.37	38.45^{***}	0.21	10.667	10	15	15	15
Ejeri	52.00	27	1.04	1.81	0.05	1.8277	6	1	1	2
Habru	51.01	32	0.99	2.78^{*}	0.00	2.4989	8	2	3	5
Mastewal	53.08	45^{*}	0.91	2.55	0.18	1.6122	2	4	2	1
Naatolii	53.78	156^{***}	1.02	11.55^{***}	0.00	5.1878	1	12	12	12
Shasho	52.71	110^{***}	0.75	4.58^{***}	0.51	3.0294	4	9	7	6
Wolayta local	51.16	44^{*}	1.02	3.69^{***}	0.01	2.2411	7	3	5	4
FLI P03-53C	47.65	62^{***}	0.83	2.93^{*}	0.43	1.8954	12	5	4	3
FLI P03-102C	46.27	139^{***}	1.09	10.83^{***}	0.06	3.606	14	11	11	7
FLI P03-128C	47.66	100^{***}	0.90	7.51^{***}	0.08	4.1896	11	8	9	11
FLI P07-81C	50.38	160^{***}	0.91	13.08^{***}	0.04	6.058	9	13	13	13
FLI P08-60C	47.02	78^{***}	1.02	6.59^{***}	0.01	3.9529	13	7	8	10
FLIP07-27C	44.26	401^{***}	1.07	33.61^{***}	0.01	9.7807	15	14	14	14

*significant at P<0.05; *** is significant at P<0.001; W_i=Wricke's Ecovalence; b_i=Slopes from regression; S^2d_i=Deviations from regression; R^2=Coefficient of Determination; ASV=AMMI Stability Value; RY=Ranks by Yield; RW=Ranks by Wricke's Ecovalence; RD=Ranks by Deviations from regression; RASV=Ranks by AMMI Stability Values.

There was no correlation between ranks by yield on one side and ranks by W_i, S^2d_i; and ASV on other side (r=0.25, 0.33, and 0.31, respectively; all statistically non-significant). Simultaneous selection for high yield and high stability is possible. The 15 genotypes are almost evenly distributed into all possible combinations of levels of yield and levels of stability (low, medium and high). For example, Mastewal (f) is a high yielding variety with high stability, while Natolii (g) which is also a high yielding variety has low stability. FLIP03-53C (j) is a low yielding genotype but with high stability while FLIP03-102C (k) and FLIP07-27C (o) were also low yielding but at the same time they had low stability.

Additive Main Effects and Multiplicative Interaction (AMMI)

The first two interaction principal component axes (IPCA 1 and IPCA 2) explained 65.8 and 21.3%, respectively, and together 87.1% of the interaction Sum of Squares (Table 6).

Table 6. Analysis of variance for AMMI model for grain yield of chickpea genotypes evaluated across six Environments

Source	D.f.	SS	MS	p-value	Percent of Gx E explained
Total	269	50714.8			
Treatments	89	48473.9	544.7	<0.001	
Genotypes	14	2130.7	152.2	0.08	
Environments	5	40004.2	8000.8	<0.001	
Block	12	297.4	24.8	0.02	
Interactions	70	6339.0	90.6	<0.001	
IPCA 1	18	4172.7	231.8	<0.001	65.8
IPCA 2	16	1351.8	84.5	<0.001	21.3
IPCA 3	14	498.9	35.6	<0.001	7.9
IPCA 4	12	182.1	15.2	0.218	2.9
IPCA 5	10	133.8	13.4	0.328	2.1
Error	168	1943.5	11.6		

Df=degree of freedom; SS =sum of squares; MS= mean squares

IPCA 3 accounted for only 7.9% of the interaction sum of squares. AMMI-II was, therefore, the most appropriate model. The first two IPCA divided the environments into four separate polygons. E1 and E5, each in separate polygon, were two environments with the highest contribution to the GxE interaction (32.6 and 45.9%, respectively and a total of 78.5%) (Fig. 2).Genotypes on or near the vertex of polygons, far from the center of the plot also contributed the most to the total GxE interaction and were therefore unstable. They had positive interaction (GE) with the environment nearest to their vertex and had the potential to give high yield (G+GE) at this environment, this being decided by their overall genotypic effect (G).

FlIP03-128C (l) had high positive interaction with E1. Butajira local (b), Cheffe (c) and Naatolii (g) had high positive interaction with Huletegna Cheroko-2012 (E5). Genotype Shasho (h) had large positive interaction with both E1 and E5. Cheffe (c) and FLIP03-102C (k) had positive interaction with E3 (Fig. 2).

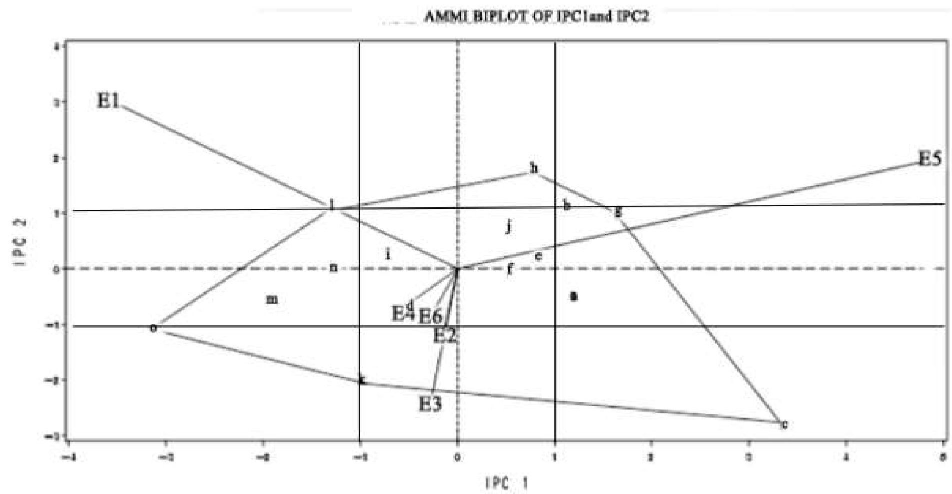
The genotypes at or near the vertex of polygons on Fig. 2, such as FlIP03-128C (l), Butajira local (b), Cheffe (c), Naatolii (g), Shasho (h), FLIP03-102C (k), FLIP08-60C (n), FLIP07-27C (o), FLIP07-81C (m), Arerti (a), manifested large interaction and were, therefore, unstable; they constituted 90% of the GxE Sum of Square.

Genotypes placed near the origin, such as Ejere (d), Habru (e), Mastewal (f), Wolayita local (i), and FLIP03-53C (j) contributed very little (10%) to the total GxE interaction and were therefore stable. Among these genotypes, Ejere (d), Habru (e), Mastewal (f), and Wolayita local (i) gave above average mean yield and can be recommended for wide adaptation. These were also identified by the univariate stability parameters, W_i, S^2d^i and ASV_i.

Genotype plus Genotype by Environment interaction (GGE) biplots

The first two components explained 83.3% of the total GGE variation with component 1 and 2 explaining 61.8

and 21.5%, respectively (Fig.3). E1 (Jolle 2012) and E5 (Huletegna Choroko-2012), two environments with the lowest mean yields, had the longest vectors, indicating that these are environments with high discriminating power (Fig.3). The yield range was very big at these two environments. Indeed the difference between the 15 genotypes was statistically non-significant at E3 (Taba, 2012) (p=0.08) and E6 (Huletegna Choroko, 2013 (p=0.06)), while at E1 and E5 the differences were very highly significant (p<0.0001); at E4 the difference was significant at p=0.03. E2, E3, E4 and E6 had short vectors and were badly modeled by the two components Genotype FLIP07-27C (o) had very large negative interaction with E5, small negative interaction with the remaining environments except E1 where it had a small positive interaction (Fig. 2).



E1=Jolle Andegna 2012, E2=Jolle Andegna, 2013; E3=Taba, 2012, E4=Taba, 2013, E5= Huletegna Choroko, 2012, E6=Huletegna Choroko, 2013

Figure 2. AMMI biplot for 15 chickpea genotypes tested at three locations in southern Ethiopia in 2012/13

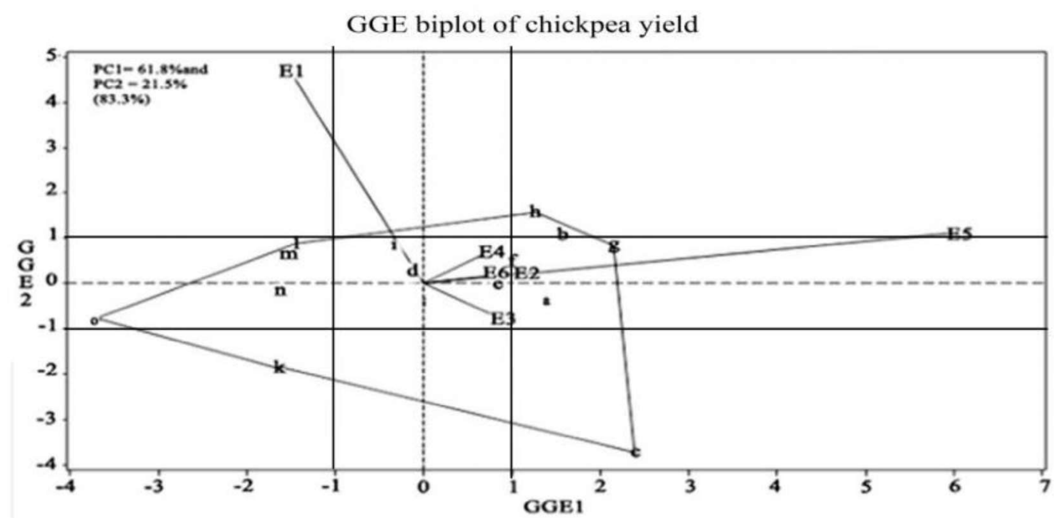


Figure 3. GGE bi-plot showing which cultivar yielded best in which environment

GGE biplot which used the first two components divided the six environments into three sectors; E1 (Jolle-2012) was separated from all other environments. Indeed the correlations between yields at this environment and yields at all other environments was negative; the largest negative correlation being that with E3 (-0.31) and with

E5 (-0.25). The remaining five environments were in the same cluster; the correlation between yields at these environments being positive. For example the rank correlations between yields at the highest yielding environment E2 and the remaining four environments E3, E4, E5 and E6 were 0.44, 0.57*, 0.61** and 0.52*, respectively. E3 had the weakest positive correlation with the remaining four environments and was in a separate polygon near the cluster of the four environments.

FLIP03-128C (l), and FLIP07-81C (m) are near the polygon of E1 and ranked 3rd, and 1st at this environment. Shasho (h) was also at the boundary between E1 and E5 where it ranked 2nd, and 3rd, respectively. E1 was the lowest yielding environments and the three genotypes can be classified as specifically adapted to low yielding environments.

E2 (Jolle-2013), E4 (Taba-2013), E5 (Choroko-2012) and E6 (Choroko-2013) were in the same sector very close to each other (Fig.3). They ranked the genotypes in a very similar manner. Although the mean yield at E5 was very similar to that at E3 (42.6 vs 43.0), it was closer to E2, E4 and E6 than to E3.

The winning genotypes in the sector of E2, E4, E5 and E6 were Butajira local (b) and Naatolii (g). Butajira local (b) ranked 3rd 1st 2nd and 12th at E2, E4, E5 and E6 while Naatolii (g) ranked 1st, 9th, 1st, and 1st, respectively at the four environments. The mean of these four environments, except E5, (Huletegna Cheroko 2012) (42.6) was much higher than the grand mean (50.1) and ranged from 56.7 to 68.7; the genotypes associated with them can, therefore, be considered as specifically adapted to high yielding environments. Cheffe (c) is specifically adapted to E3 where it ranked 3rd. Its rank in E2, E4, E5 and E6 was also less than 6, but it was ranked 15th in E1, giving the lowest yield. This genotype can also be considered as specifically adapted to high yielding environments. Genotype Arerti (a) was in the sector of E3. Although it was much nearer to the center of the plot than Cheffe (c), it can be considered as specifically adapted to high yielding environments and ranked 6th, 3rd, 5th, 4th and 6th at E2, E3, E4, E5, and E6, respectively, but 13th at E1.

Genotypes near the center of the plot, Ejeri (d), Habru (e), Mastewal (f), Wolayita local (i), and FLIP03-53C (j) were stable. All except FLIP03-53C (j), gave yields higher than the grand mean and can be considered as widely adapted genotypes. FLIP03-102C (k), FLIP08-60C (n) and FLIP07-27C (o), were not adapted to any of the environments, their mean yields were below the grand mean.

Based on stability analyses using three univariate and two multivariate (AMMI and GGE) stability parameters, the 15 chickpea genotypes can be categorized into the following four groups:

Group I: - Those specifically adapted to high yielding environments (E2, E4, E5 and E6); E3 was adjacent to this group and shared similar genotypes with the four environments. These were Arerti (a), Butajira local (b), Cheffe (c) and Naatolii (g).

Group II: -Those specifically adapted to low yielding environments (E1)-Shasho (h), FLIP03-128C(l) and FLIP07-81C (m).

Group III: - Genotypes adapted to all environments (wide adaptation) – Ejeri (d), Habru (e), Mastewal (f), Wolayita local (i), FLIP03-53C (j).

Group IV: - Those not adapted to any environment - FLIP03-102C (k), FLIP08-60C (n) and FLIP07-27C (o).

Various measures of drought tolerance have been calculated for the four groups and these are given in Table 7. For this analysis E1 (Jolle Andegna in 2012) was used as stress environment while E2 (Jolle Andegna in 2013) was used as non-stress environment.

Table 7. Drought Tolerance measures of three groups of chickpea genotypes grown in 2012/13 at three locations in southern Ethiopia

Type	YLDA	YLDB	MEAN	PYR	YSI	DSI	DRI	GM	MP
High yielding	5.08	62.00	26.63	91.88	0.08	0.91	0.07	17.37	33.54
Low yielding	8.81	48.33	22.17	81.73	0.18	0.79	0.24	20.63	28.57
Non adapted	6.16	44.22	18.79	85.83	0.14	0.84	0.14	16.37	25.19
Widely adapted	6.71	50.87	23.29	86.57	0.13	0.85	0.14	18.44	28.79

YLDA=Yield under moisture stress (at E1, Jolle Andegna, 2012); YLDB=Yield under no moisture stress (E2, Jolle Andegna, 2013); MEAN=Mean of the six environments; PYR=Percent Yield Reduction; YSI=Yield Stability Index; DSI=Drought Susceptibility Index; DRI=Drought Resistance Index; GM=Geometric Mean; MP=Mean Productivity.

Comparison of group I and II genotypes revealed that genotypes adapted to high yielding environments had the highest seed yield under no stress (YLDB) (62.0 vs 48.3; 28.4% yield advantage), the highest mean yield (MEAN) (26.6 vs 22.2) and mean productivity (MP) (33.5 vs 28.6), while genotypes adapted to low yielding environments had the highest mean yield under moisture stress (YLDA) (E1) (8.8 vs 5.1; 72.5% yield advantage), the highest geometric mean yield (GM) (20.6 vs 17.4), the highest Yield Stability Index (YSI) (0.18 vs 0.08), the highest Drought Resistance Index (DRI) (0.24 vs 0.07), the lowest Percent Yield Reduction (PYR) (81.7 vs 91.9), and the lowest Drought Susceptibility Index (DSI) (0.79vs 0.91). The other two groups had intermediate values for these parameters.

The genotypes specifically adapted to the most drought stressed environment might have been specifically bred for drought tolerance, and selection methods using some of the drought indices may have been used during evaluation. Two of these, FLIP03-128C (l) and FLIP07-81C (m), were indeed extra-early chickpea genotypes received in 2011 from ICARDA. They can be recommended for areas where the rainfall is low most of the years and the probability of high rains is very low. Most growing areas in the rift valley are of this type. Arerti (a), Butajira local (b), Cheffe (c) and Naatolii (g) are adapted to high yielding environments and should be grown in mid-altitude areas adjacent to the rift valley where rainfall is relatively high most of the years. Ejeri (d), Habru (e), Mastewal (f), and Wolayita local (i), are widely adapted genotypes and can be grown in most of the areas suitable for chickpea growing.

Modern methods of weather forecast can be used to predict the suitability of the coming season for chickpea production. If high rainfall is expected for the growing season even in areas with severe moisture stress, varieties with high potential yield can be distributed to farmers; at least the stable varieties can be substituted for those adapted to low yielding environments. Farmers can get some bonus from these relatively high yielding varieties.

DISCUSSION

Many authors have studied the performance of chickpea genotypes over many environments varying in degree of moisture stress (Getachew Tilahun *et al*., 2015; Farshadfar *et al*., 2011; Geletu Bejiga and Ketema Daba, 2003; Upadhyava *et al*., 2013; Yucel and Mart, 2014). In agreement with our results all these authors reported significant E, G and GxE effects. In these studies the environment constituted more than 80% of the treatment sum of squares, which is in agreement with our results (82.5%) and is the major determinant of the observed variability in grain yield of chickpea while the share of the GxE effects was higher than that of G. The contribution of E was smaller in the studies by Getachew Tilahun *et al*. (2015) (53%), Fekadu Gurmu *et al.* (2011) (69.7%) and Mulugeta Atnaf *et al.* (2013) (25.6%); GxE constituted 59.6% in this study). In most of these studies the most discriminating environments were the highest yielding environments, while in our study the two low yielding environments, E5 and E1, were the most discriminating environments.

Many studies on chickpeas showed that linear regression could not explain much of the significant GxE interaction; the GxE linear component was non-significant while the pooled deviation was significant (Fekadu Gurmu *et al*., 2011; Getachew Tilahun *et al.,* 2015; Kenga *et al.,* 2003) implying that there is either no relationship, or no simple relationship (the relation may be explained by fitting quadratic component or even log-linear regression may be appropriate) between the GxE interaction and the environmental values and hence no prediction can be made from linear regression (Perkins and Jinks, 1971). Linear regression explained only 15.4% of the GxE interaction of soybean yield in the investigation by Fekadu Gurmu *et al*. (2011), a little higher than the one in our study (13%).We found no relationship between yield and the stability parameters; the rank correlation between W_i, S^2d_i and bi on one side and grain yield on the other side was 0.25, 0.33 and -0.22, all statistically non-significant, contradicting the notion that varieties with $b_i < 1$ are adapted to low-yielding environments while those with b_i-values > 1 are adapted to high-yielding environments (Eberhart and Russel, 1966; Finlay and Wilkinson, 1971). In agreement with our results Astveit and Astveit, (1984) and Nurminiemi (1995), however found no correlation between yield and b_i-values. Getachew Tilahun *et al.* (2015) found positive correlation between Wricke's ecovalence (W_i) and seed yield; high yielding genotypes had higher ecovalence and were adapted to high yielding environments, which contradict our results.

The first two components of AMMI (IPC1 and IPC2) were used by Fekadu Gurmu *et al.* (2011), while the first two components of G+GE (GGE1 and GGE2) were used by Mulugeta Atnaf *et al.* (2013) to shed light on the significant GxE interaction of grain yield in soybean. Muhammad Amir *et al*., (2015), Upadhyava *et al*., (2013) and Farshadfar *et al*., (2011) also used the first two components of GGE to study GxE interaction in grain yield of chickpea. These two components explained more than 75% of the GxE interaction or of the GGE sum of square in these studies and the researchers were able to classify the environments into different groups depending on their potential yield and the pattern of their interaction with the genotypes included in the study. There was positive correlation between relatively high yielding environments, for example irrigated and rain fed environments, while the correlation between environments with severe stress and other environments (non-irrigated and irrigated) was not significant (Upadhyava *et al.*, 2013). In our study yields under the most severe drought stress environment (Jolle Andegna in 2012 (E1)) and yields at the highest yielding environment (the same site in 2013 (E2)), were negatively correlated.

Sometimes a large heterogeneous production area is classified into more homogenous mega-environments by AMMI or GGE analysis. Appropriate varieties could then be developed for each mega-environment (Farshadfar *et al.*, 2011) which enabled the exploitation of repeatable GxE interactions such as differences in soil types, altitude zones and the amount of annual rainfall. Genotypes could also be classified into various categories depending on their potential yield and the pattern of their interaction with the environments. High yielding and stable genotypes with wide adaptation, unstable genotypes that are specifically adapted to either high yielding or low yielding environments and those adapted to no environment and should be discarded from further investigation, could be identified. Mulugeta Atnaf *et al.* (2013) identified the most discriminating and most representative environments for soybean production in western Ethiopia.

Some physiological and drought tolerance characteristics such as Percent Yield Reduction (PYR), Drought Tolerance Index (DTI), Root Length Density (RLD) and the Maximum Root Depth (RDp) were also used to evaluate chickpea genotypes for drought tolerance (Geletu Bejiga and Ketema Daba, 2003; Gaur *et al.,* 2008;Ulemale *et al.*, 2013; Getachew Tilahun *et al.*, 2015;). Drought tolerant genotypes have minimum Percent Yield Reduction (PYR) and the highest Drought Tolerance Index (DTI). They also have the highest RLD and RDp. Gaur *et al.* (2008) have found high variability for such traits in collections of chickpea at ICRISAT. They suggested that selection of early flowering, early podding and early maturing (85-100 days) lines with vigorous early growth improves tolerance to terminal drought. Although we did not take data on RLD and RDp, the genotypes adapted to the low yielding environment (Jolle, 2012, E1) such as FLIP03-128C(l) and FLIP07-81C (m) had the tallest plants. Root length is believed to be proportional to plant height and these genotypes are believed to possess higher RLD and RDp values than genotypes adapted to non-stress environments such as Arerti (a), Butajira local (b), Cheffe (c) and Naatolii (g).

Ulemale *et al*. (2013) reported the lowest and highest PYR of 11.67 and 60.95% and the maximum and minimum DRI of 1.52 and 0.29. In our experiment these values were 80.7 and 96.8% and0.255 and 0.009 for Shasho (h) and Cheffe (c), respectively. Shasho (h) was adapted to low yielding environments while Cheffe (c) was adapted to high yielding environments. The mean PYR and DRI for the genotypes adapted to high yielding and low yielding environments were 91.9 vs 81.7 and 0.07 vs 0.24, respectively. Widely adapted genotypes had intermediate values (86.6 and 0.14, respectively). The very high values for PYR and very low values for DRI in our experiment might be due the high Drought Intensity Index (DII) of 0.873, which indicates severe drought stress. Yield under the most severe drought stress (E1) (31.89) was only 46.4% of that under the most favorable conditions (E2) (68.71) (12.7% in the original scale; 0.6584 vs 5.2 t ha^{-1}). In the study of Yucel and Mart (2014) grain yield was reduced by 43% due to drought stress. In our experiment seed yield was reduced due to moisture stress by 53.4% in the transformed scale and by 87.3% in the original scale (ton ha^{-1}).

CONCLUSIONS AND RECOMMENDATIONS

Long term climatic data reveals that the southern rift valley can be classified into mid-altitude chickpea growing areas with relatively higher annual rainfall and its better distribution and areas with lower altitude and lower amount of rainfall accompanied with uneven distribution in most of the years. Butajira (Jolle Andegna) and Taba belong to the first group while Halaba (Huletegna Choroko) belongs to the second group. This is repeatable GxE interaction which can be exploited by recommending genotypes adapted to high yielding environments such as Butajira local, Naatolii, Cheffe and Arerti for mid-altitude chickpea growing areas similar to Butajira and Taba and distributing genotypes adapted to low yielding environments such as FLIP03-1280, FLIP07-81C and Shasho in more moisture-stressed areas similar to Halaba (Huletegna Choroko). However the unrepeatable GxE patterns such as manifested through the big difference in the amount of rainfall between the 2012 and 2013 growing seasons at the same location, should also be taken into consideration. If the weather forecast indicates that severe moisture stress is anticipated for the coming growing season, then genotypes initially recommended for low-yielding areas such as FLIP03-1280, FLIP07-81C and Shasho may be recommended for the more favorable regions such as Butajira and Taba and the vice versa, if the anticipated growing season is a favorable one, genotypes initially recommended for more favorable zones such as Butajira local, Naatolii, Cheffe and Arerti can be distributed in areas like Halaba. The widely adapted genotypes such as Ejeri, Habru, Mastewal and Wolayita local can be made available to users as alternatives in both favorable and unfavorable moisture stress areas. The high yields during these rarely occurring favorable growing seasons are crucial for the food security of such areas; the surplus grain can be stored and used over a longer period.

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Does HIV Risk Perception Influence Voluntary HIV Counseling and Testing Service Utilization Among in-School Youth? Application of the Health Belief Model, Hawassa City, Southern Ethiopia

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Abstract
Despite its important role in the prevention and control of HIV/AIDS, voluntary counseling and testing (VCT) service is being utilized poorly by the youth. Identifying the role of HIV risk perception as a factor in the utilization of VCT service enables designing appropriate behavioral change interventions. This study was conducted in Hawassa city, Southern Nations, Nationalities and People's Region (SNNPR) to assess whether HIV risk perception influences the utilization of VCT service among in-school adolescents. The study used a cross-sectional quantitative study design applying the Health Belief Model (HBM) on a sample of 455 students selected using a two-stage stratified cluster sampling technique. Data were collected using a structured, self-administered questionnaire in Amharic language. Data analysis considered the complex sampling design. Results showed perceived susceptibility to HIV/AIDS among the students to be low (mean score = 3.12, standard error (SE)= 0.08—maximum expected score was 8). Conversely, perceived severity of HIV/AIDS was high (mean score = 7.16, SE = 0.16—maximum expected score was 10). Two hundred and twenty three (49.0%) of the students had used VCT service at least once in their life time. The reason given for not utilizing VCT service by many students (47.1%) who had never had VCT service was absence of any risk for HIV. HIV risk perception (perceived susceptibility and perceived severity) did not show a statistically significant association with VCT service utilization. Appropriate health information about the importance of VCT should be provided to in-school youth regardless of their level of risk perception.

Key Words: AIDS; Perceived susceptibility, Perceived severity, Perceived benefit, Perceived barrier, VCT service
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INTRODUCTION

More than three decades after its emergence, HIV/AIDS continues to be a major public health problem. By 2015, there were 36.5 million people living with HIV globally. People aged 15-24 years are most vulnerable accounting for 34% of all new HIV infections worldwide in 2015 (UNAIDS, 2016). According to the Ethiopian Demographic and Health Survey (EDHS) report of 2011, the prevalence of HIV among adults aged 15-49 years was 1.5% (1.9% among females and 1.0% among males) (CSA and ICF International, 2012).

In-school youths are at high risk of HIV. A study has shown nearly one-third of in-school youth to have started sex and that risky sexual behaviour is prevalent (Negeri 2014). However, it has been shown that as high as 48.2% of in-school youth engaged in risky sexual behaviors consider themselves to be at no or low risk of HIV infection (Mitikie et al, 2005).

In Ethiopia, HIV counseling and testing as a tool for HIV prevention and control began in the 1980s with services expanding throughout the 1990s. In the early 1990s, several national level training programs were conducted for nurses and social workers from all regional hospitals and those in Addis Ababa (The National AIDS Council Secretariat, 2000). Ethiopia has published its first VCT guideline in 1996. It has been revised and updated twice since then in light of the state-of-the-art evidence regarding counselling and testing for HIV/AIDS (FHAPCO, 2007).

The primary aim of VCT is preventive – to help people change their sexual behavior so as to avoid transmitting HIV to sexual partners if positive, and to remain seronegative if negative. VCT is a behavioral intervention, not a mere diagnostic procedure. As such, VCT is one of the components of the multifaceted HIV/AIDS prevention and control approaches. Despite many limitations and difficulties in the implementation of VCT in sub – Saharan Africa, many studies have shown that it is effective in reducing HIV infection (UNAIDS, 2001).

In one cross-sectional community based survey, which was under taken on adolescents of Harar town, Ethiopia in 2005, it was found that only 21.9% of adolescents reported that they had ever been tested for HIV. Fear of coping with the positive test results, low risk perception for HIV, fear of stigma and discrimination that follows positive test results, absence of community support, lack of perceived benefit of VCT, fear of partners' reaction were commonly cited reasons for not utilizing the VCT service (Oljira, 2005).

While it sounds logical to assume that a higher risk perception for HIV increases the likelihood of seeking VCT services, a qualitative study which was undertaken in Hawassa town in 2011 on youths identified HIV risk perception to be rather a debatable issue in that it was considered as enhancing factor by some participants and as inhibiting factor by others (Meshesha, 2011).

The important research question is, therefore "how does HIV risk perception affect VCT service utilization? Is it an enhancing factor, an inhibiting factor or not related to VCT service utilization at all?" Hence, the overall aim of this study was to assess the role of HIV risk perception as a factor in influencing VCT service utilization so that further behavioral change intervention programs can be undertaken considering perception-related factors.

MATERIALS AND METHODS

Study design
A cross-sectional quantitative study design was conducted applying the Health Belief Model (HBM).

Area and period
The Study was undertaken in Hawassa city, Southern Ethiopia, in January 2012. At the time of the study, Hawassa city had a total of nine secondary and preparatory schools of which two were public and 7 were private. The total number of students enrolled in all the nine schools was 12,982 of which 8,347 were in public schools and 4,635 were in private schools. (Information obtained from the Education Department of Hawassa City Administration, 2011.)

Population
The source population for this study comprised all regular day-time students of all secondary and preparatory schools of Hawassa city. The study population constituted secondary and preparatory school students in schools selected for the study.

Sample size and Sampling technique
The sample size for the study was determined by using the standard formula for estimating a single proportion $n = \frac{Z^2_{1-\alpha/2} P(1-P)}{d^2}$ where n is the minimum sample size required assuming a simple or systematic random sampling, Z is the confidence coefficient in each tail of the normal curve at 1-α level of confidence, α is the level of significance (type-I error) and P is an estimate of the proportion of VCT service use. Thus taking a z-value of 1.96 for a level of confidence of 95% (i.e., α of 5%) and estimating the proportion of youths who have undergone VCT to be 21.9% based on a study conducted at Harar, Eastern Ethiopia (Oljira, 2005), the sample size required was 263. However, the sampling design employed was complex (involving stratified and cluster sampling) and hence a design effect was taken into account. Yet design effect is determined based on actual data and it shall be obtained from studies carried out previously (Aday, 1996). Nevertheless, we couldn't get studies reporting design effect and we decided to use a design effect of 2. Thus considering a design effect of 2 and a response rate of 90%, the final estimated sample size was 585.

The sampling involved stratified two-stage cluster sampling technique. In the first stage, schools were stratified by ownership as public and private. From each stratum, one school was randomly selected using the lottery method. In the second stage, students were stratified by grade level (9^{th}, 10^{th}, 11^{th} & 12^{th}). Then sections (i.e., clusters) from each stratum were randomly selected. Accordingly, from the selected public high school, two sections were randomly selected from grade 9 and one section from grades 10 to 12 each. From the selected private high school, one section was randomly selected from each of the grades 9 to 12. In total, nine sections were randomly selected for the study. All students in the selected clusters were studied. We assume the assignment of students to different sections to be random and hence students across sections are considered homogeneous in relation to the variables addressed by the present study. The use of cluster sampling to select students is thus considered appropriate.

Data collection
Data were collected in the month of January 2012 using an Amharic-version structured, self-administered questionnaire. The questionnaire constituted information on socio-demographic background of the respondents, constructs of the HBM, VCT service use and other pertinent items. Data were collected in the students' classrooms. Two facilitators who were neither staff nor students of the selected schools facilitated the data collection process.

Measurement of the constructs of the HBM
To measure the four main construct of the HBM (Hayden, 2014), we designed items intended to tap information on each of the four constructs. The items were of Likert-type scales. Below, we briefly describe the items used and how scale scores were developed.

Perceived severity of HIV/AIDS was measured using two items: i) HIV/AIDS is a deadly disease; and ii) There is no cure once HIV/AIDS is contracted. Each item was measured on a five-point scale with scores of 1=strongly disagree, 2=disagree, 3=no opinion, 4=agree and 5=strongly agree. Then a composite summated score was constructed for each study participant by summing up the scores for the two items. Maximum expected score was 10 and minimum expected was 2. Higher scores indicate higher perceived severity. The reliability coefficient (Ordinal Coefficient alpha) was 0.534.

Perceived susceptibility to HIV/AIDS was also measured using two items: i) How do you rate your susceptibility to HIV infection? And ii) How do you see your chances of having a negative test result if you are tested for HIV? Both items were measured on a four-point scale. The scores for the first item were 1=none, 2=low, 3=medium and 4=high whereas the possible scores for item 2 were 1=high, 2=medium, 3=low and 4=none. Then a composite summated score was constructed for each study participant by summing up the scores for the two items. Maximum expected score was 8 and minimum expected was 2. Higher scores indicate higher perceived susceptibility. The reliability coefficient (Ordinal coefficient alpha) was 0.528.

Perceived benefit of VCT service use was measured using two items: i) Being tested for HIV and knowing one's status helps to take measures that prevent contracting the virus (if negative) and to limit progress of HIV/AIDS disease (if positive); and ii) Being tested for HIV and knowing one's status helps to take care not to transmit the virus to other people (if positive). Each item was measured on a five-point scale ranging from 1=strongly disagree to 5=strongly agree as for perceived severity. Expected maximum and minimum of the summated score were 10 and 2 respectively. Higher scores indicate higher perceived benefit. The reliability coefficient (Ordinal coefficient alpha) was 0.80.

Perceived barriers to VCT service use were measured using three items: i) Would your friends be unhappy if you get tested for HIV? ii) Would your parents/guardians be unhappy if you get tested for HIV? And iii) Are you afraid of being socially discriminated if your HIV-test result turns positive? Each item was measured on a three-point scale with scores of 1=never, 2=slightly and 3=so much. A composite summated score was calculated for each study participant by summing up the scores of the three items. Expected maximum and minimum of the summated score were 9 and 3 respectively. Higher scores indicate higher perceived barriers. The reliability coefficient (Ordinal coefficient alpha) was 0.66.

Though there are two other constructs (self-efficacy and cues to action) they are not yet well investigated and their performance in influencing health behaviour is not well established (Champion and Skinner, 2008). Hence, we did not include these two constructs in the present study.

Definition of HIV/AIDS risk perception

According to Brewer et al (2007), risk perception has three dimensions: perceived likelihood, perceived susceptibility and perceived severity. The HBM with which our study was guided doesn't have a "perceived likelihood" construct. Hence, in the present study two of the four constructs of the HBM (perceived susceptibility and perceived severity) were used as indicators of risk perception.

Study Variables

Dependent Variables: VCT service Utilization.
Independent variables: HIV/AIDS risk perception (perceived susceptibility and perceived severity).
Control variables: Perceived benefit and perceived barriers

Data analysis

Data were entered, cleaned and analyzed using IBM SPSS version 20 statistical software. Subsequently, reliability analysis was done to determine the internal consistency of the items used to measure the HBM constructs. All the items were not normally distributed. Hence, we did ordinal reliability analysis which is a recommended method for non-normal ordinal data (Gadermann et al 2012) using SPSS-R menu (Basto & Pereira, 2012). Ordinal coefficient alpha obtained from the ordinal reliability analysis was used to assess the internal consistency reliability.
Prior to further analysis, the data were prepared for complex sample survey data analysis as recommended in the literature (Heeringa et al., 2010). Briefly, we created strata and cluster identifiers for both stages of sampling. We also created an analysis weight variable. To determine the weight variable, the selection weight of schools in the first stage of sampling was calculated as the inverse of the probability of selection of schools. Then in the second stage, the selection weight of classrooms (sections) was calculated as the inverse of the selection probability of classrooms. The final selection weight was calculated as the product of the selection weight of schools and the selection weight of classrooms. A nonresponse adjustment weight was also estimated as the inverse of the response rate across the second stage strata (grade level) of the selected schools. Post-stratification weight was not considered as we didn't have an appropriate post-stratification factor. The final analysis weight was, therefore, calculated as the product of the final selection weight and the nonresponse

adjustment weight. Finally, a complex sample analysis plan file was created by declaring the strata, cluster and weight variable in IBM SPSS version 20.

Analysis of the data used the complex sample analysis plan file mentioned above. Appropriate summary statistics (means, standard deviations, proportions) were determined. Logistic regression analyses were carried out to determine the association between HIV/AIDS risk perception and VCT service utilization. Initially, we did crude logistic regression to see the crude association between the four HBM constructs and VCT service utilization. Then we entered all the four HBM constructs into a multiple logistic regression model to assess the association of perceived severity and perceived susceptibility with VCT service utilization adjusting for the other constructs. As students' background characteristics (such as age, sex, grade level, religion) did not qualify as confounders, they were not adjusted for in the logistic regression analysis. Model building and variable selection for the multivariable model proceeded as per the existing methodological recommendation (Heeringa et al., 2010). Assessment of the goodness-of-fit of the logistic regression model was done using Nagelkerke's psuodo-R^2 and model classification accuracy.

Odds ratios were used to assess the presence and extent of association between VCT service utilization and risk perception. The 95% confidence intervals of odds ratios not embracing 1 indicated statistically significant associations.

Ethical issues

The study was undertaken after ethical clearance was obtained from the Institutional Review Board at the College of Medicine and Health Sciences of Hawassa University. Letterer of permission was obtained from the officials of Hawassa City Administration Health Desk. Verbal informed consent was obtained from all study participants prior to taking part in the study. Besides, names or any other personal identifiers of the respondents were not documented in the questionnaires and confidentiality of responses provided by the respondents was kept strictly confidential.

RESULTS

Socio-demographic characteristics of the study participants

Details of the socio-demographic characteristics of the participants are given in Table 1. Out of the 585 proposed study participants, 476 study participants responded. Twenty one questionnaires were excluded because the participants did not respond to a considerable number of items. Thus, only data of 455 study participants were used for the analysis. The response rate was, therefore, 77.8%.

Based on the weighted analysis of the data, 305(67.1%) of the students who participated in this study were from public (governmental) schools while 150(32.9%) were from private schools. The male-to-female ratio was 1.14 to 1. In terms of age, the average (standard error (SE)) age of the study participants was 17.13 (0.14) years. One hundred and sixteen (26.0%) of the study participants had practiced sexual intercourse at least once in their life time.

Scores of the four constructs of the Health Belief Model (HBM)

The weighted mean score (±SE) of the perceived severity of HIV/AIDS as rated by the students who participated in this study was 7.09(±0.15)—expected maximum was 10. The corresponding score for perceived susceptibility to HIV/AIDS was 3.12 (±0.08)—maximum expected score was 8. In the same way, the scores for perceived benefit of VCT and perceived barriers for VCT service use were 8.44 (±0.15)—maximum expected score=10, and 4.70 (±0.05)—maximum expected score=9, respectively (Table 2).

Table 1. Socio-demographic characteristics of the students who participated in the present study, secondary and preparatory schools of Hawassa city, Jan. 2012

Characteristic	**Weighted frequency**	**Weighted percent**
School ownership(n=455)		
Public	305	67.1
Private	150	32.9
Grade level (n=455)		
9th	160	35.2
10th	101	22.1
11th	115	25.3
12th	79	17.4
Sex (n=442)		
Male	235	53.3
Female	206	46.7
Religion (n=453)		
Protestant	216	47.7
Orthodox	176	38.9
Muslim	24	5.3
Catholic	13	2.9
Other	24	5.3
Ever had sex (n=444)		
Yes	116	26.0
No	329	74.0

Table 2. Means of the summated scores on perceived severity of and perceived susceptibility to HIV/AIDS and perceived benefit and perceived barriers of VCT service use, secondary and preparatory schools of Hawassa city, January 2012

HBM Construct	Weighted mean (±SE)*
Perceived severity of HIV/AIDS	7.16(±0.16)
Perceived susceptibility to HIV/AIDS	3.13 (±0.08)
Perceived benefits of VCT	8.48 (±0.13)
Perceived barrier of VCT service use	4.69 (±0.06)

* SE = standard error

VCT service utilization

Of the 455 students who took part in this study, 49.0% (95% confidence interval [CI]: 26.3%, 72.1%) had had VCT service at least once in their life time. Of those who had ever had VCT service (excluding those with missing information), 51 (25.6%) had reportedly had the service once whereas 57 (28.7%) had had the service twice. Fifty (25.3%) of them had the service three times. Similarly, of those who had reportedly had the service, more than 70% had the service in the one year period prior to the survey (Table 3).

The reason given for not having so far had VCT service by a considerable proportion (47.1%) of the students who had never had VCT service was absence of any risk for HIV. Yet, the majority (85%) of the study participants had a desire (intention) to have VCT service in the future (Table 3).

Association between risk perception for HIV/AIDS and VCT service utilization

In the present study, HIV/AIDS risk perception (perceived severity of HIV/AIDS and perceived susceptibility to HIV/AIDS) did not show any statistically significant association with VCT service utilization both in the unadjusted logistic regression model and after adjustment for perceived benefit and perceived barriers (Table 4).

Table 3. VCT service utilization among students who participated in the present study, secondary and preparatory schools of Hawassa city, January 2012

Characteristic	Weighted frequency	Weighted percent
Ever got VCT service (n=455)		
Yes	223	49.0
No	232	51.0
Number of times VCT service received (unweighted n=194)		
Once	51	25.6
Twice	57	28.7
Three times	50	25.3
Four times	24	12.2
5 or more times	15	8.2
Last time VCT service received (unweighted n=210)		
Within the past 1 month	28	12.8
Within the past 3 months	45	20.6
Within the past 6 moths	38	17.5
Within the past 1 year	42	19.4
Before 1 year	65	29.7
Reason for not being ever tested (unweighted n=226)		
Absence of any risk to HIV	102	47.1
No reason	56	25.9
Peer discouragement	15	7.1
Fear of positive test result	9	4.4
Fear of stigma and discrimination if test result turns positive	8	3.8
Don't know where to get the service	7	3.0
Absence of parental (guardian) cooperation	6	2.6
Other reason	13	6.0
Intention to be tested in the future (unweighted n=443)		
Yes	377	85.0

Table 4. Association between HIV risk perception and VCT service use adjusted for other constructs of the Health Belief Model, secondary and preparatory schools of Hawassa city, January 2012

Explanatory variables[a]	COR (95% CI)[b]	AOR (95% CI)[c]
Perceived severity score	0.99 (0.77, 1.28)	0.98 (0.72, 1.34)
Perceived susceptibility score	1.13 (0.70, 1.84)	1.13 (0.72, 1.78)
Perceived benefit score	1.02 (0.66, 1.56)	1.01 (0.67, 1.53)
Perceived barrier score	1.00 (0.67, 1.51)	0.99 (0.57, 1.74)

Note: [a] All variables entered as continuous covariates; [b] COR, Crude odds ratio; [c] AOR, Adjusted odds ratio; Overall classification accuracy = 55.3%. Nagelkerke's psudo-R^2 = 9%

DISCUSSION

In this study we found perceived severity of HIV and perceived benefit of VCT service to be high among in-school youth in Hawassa city. Conversely, perceived susceptibility to HIV was low. Level of perceived barriers was also low. Less than half (49%) of the students have used VCT services at least once in their life time. The reason predominantly mentioned for not using VCT services was absence of any risk for HIV. On the other hand, intention to use VCT services in the future was very high (85%). Perceived risk perception was not associated with VCT service utilization.

Our finding that high school students perceive themselves to be less susceptible to HIV is consistent with the finding of a study in Cameroon (Haddison et al., 2012). Risk perception has also been shown to be low among university students in Ethiopia (Gebremedihin et al., 2013; Shiferaw et al., 2014). Such a low perception of self risk for HIV could emanate from failure to recognize one's own risk despite the presence of the risk. This calls for proper health information communication to students regarding what constitutes risk for HIV. On the other hand, reporting low self-risk perception could merely be denial of own risk despite recognition of its presence. Denial could result from a social desirability bias whereby students may feel reporting absence of risk for HIV as socially acceptable. Denial could also be an attempt to repress memory of one's own risky previous acts so as to avoid associated psychological impacts.

In the present study, it is found that less than half (49%) of high school students have utilized VCT service at least once in their lifetime. Other studies both from Ethiopia and other African countries have shown VCT service uptake among high school students to be generally much lower (Oljira, 2005; Abebe & Mitikie, 2009; Haddison et al., 2012; Sanga et al., 2015). The relatively higher VCT service utilization found by the current study could show the relatively better recognition of the importance of VCT among high school students in Hawassa city. This could be substantiated by the higher level of perceived benefit of VCT service among the students. However, the effect of social desirability bias could also not be fully precluded. In any case, considering the high risk of HIV among such populations, the VCT service utilization found even by the current study does not seem satisfactory.

On the other hand, intention to use VCT services in the present study is high (85%) which is consistent with studies conducted among high school students elsewhere (Abebe & Mitikie, 2009; Haddison et al., 2012). While such a finding on the one hand implies the discrepancy between intention and actual use, on the other hand, it may imply that with proper health information communication, the VCT service uptake among high school students could be increased because they seem to better recognize its importance.

In this study, students' perception of own risk for HIV did not show a significant association with VCT service utilization. This finding is consistent with the findings of previous studies (Negeri, 2014; Abebe & Mitikie, 2009). It appears that HIV risk perception does not affect the likelihood of VCT service uptake contrary to what we might think.

However, the following issues should be considered in the interpretation of the results of the present study. On the one hand, as the reliability of the scale we used to measure risk perception (perceived susceptibility and perceived severity) was about 0.53 (less than the recommended 0.7 cutoff), it might have threatened the validity of the measurement and hence the true association between risk perception and VCT service utilization could have been masked. On the other hand, as only daytime regular students were included in the present study, the results may not apply to night shift students. Furthermore, the response rate in the present study was relatively lower (77.8%) and could lead to bias. However, as a way of attenuating the effect of the relatively lower response rate, we have used non-response weighting as per existing methodological recommendations (Heeringa et al., 2010) and hence the likelihood of bias due to the low response rate is considered minimal.

CONCLUSIONS

The study showed the "perceived susceptibility" dimension of risk perception for HIV among in-school youth in Hawassa to be low. On the other hand, the "perceived severity" dimension of risk perception was high. Though the utilization of VCT service among the students is higher relative to the utilization reported by other studies, it can still be considered low as only less than half of the students utilized VCT service. Despite the mention of absence of any risk for HIV as a reason for not utilizing VCT services, HIV risk perception did not show a statistically significant association with VCT service utilization. Appropriate health information about the importance of VCT should be provided to in-school youth regardless of their level of risk perception.

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The Effect of Replacement of Maize with Kocho on Feed Intake, Growth Performance and Carcass Characteristics of Hubbard Broiler Chickens

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Abstarct

The replacement value of maize with *kocho* on feed intake, growth performance and carcass characteristics of growing Hubbard broiler chicken was evaluated. The four treatment diets contained 0% (T1), 33% (T2), 67% (T3) and 100% (T4) kocho as a replacement for maize in the concentrate mixture. The concentrate mixture was composed of noug (*Guizotia abyssinica*) seed cake, wheat bran, soybean, limestone, vitamin/mineral premix), dicalcium phosphate, lysine, methionine and common salt. Unsexed broiler (180) chickens were allocated to the dietary treatments with three replicates of 15 chickens each in a completely randomized design. Feed and water were provided *ad libitum*. The experiment lasted for 49 days. At the beginning of the experiment, eight unsexed chicks were selected and killed by dislocating the neck and kept in deep freezer (-20^0C) until chemical analysis to determine nutrient retention. At the end of the experiment, two chickens (1 male and 1 female) per replicate were randomly selected for measurement of carcass characteristics and nutrient retention. The dry matter intake was similar (P>0.05) among treatments. The crude protein intake of chicks fed on T1 diet were the highest (P<0.05) while the lowest was for T2. The metabolizable energy retention for T1 diet was greater (P<0.05) than those receiving T3 and T4 diets. There was an increasing trend in phosphorus retention with increasing levels of *kocho* in concentrate mixture. There were no significant difference in body weight gain, slaughter weight and edible carcass of chicks across treatments. The dressing percentage for chicks receiving T4 diet was higher than that of T2 diet. In conclusion due to the year round availability and easy access by smallholder farmers in the southern and south-western part of Ethiopia where enset is widely grown, *kocho* could be used as energy source as a substitute for maize.

Keywords: Broiler chicken, *Ensete ventricosum,* Feed intake, *Kocho*, Weight gain.

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INTRODUCTION

Inadequate feed supply and poor quality of the available feedstuffs are one of the major reasons for the poor performance of poultry sector in Ethiopia (Negussie and Alemu, 2005). The productivity of the sector in the tropics has been grossly limited by the scarcity and consequent high prices of the conventional protein and energy sources (Aberra *et al*., 2011). Poultry today has emerged as the fastest growing segment of the agricultural industry. Broiler farming is an important part of commercial poultry enterprise which provides a large part of increasing demand for animal protein, cash income and creates employment opportunities (Mahbub *et al*., 2011).

There are different types of locally available feed resources that are used for livestock feed among which enset (*Ensete ventricosum*) is widely used especially in the southern parts of Ethiopia. Cultivated enset grows in a wider area comprising the central, south and south-western parts of Ethiopia and it is used as a staple food by 7–10 million people and its use is expanding in other parts of the country (Admasu, 2002). In addition to its use as a source of carbohydrate rich human food, all parts of enset is utilized as animal feed. For example, the by-products of enset processing such as *furfurame* is used as poultry feed (Seyoum, 2013). According to Ajebu (2008) enset pseudostem (12 MJME/kg DM) and corm (13 MJME/kg DM) are rich in energy. According to the same author, these fractions are highly digestible. Mohammed et al. (2013) indicated that pseudostem (65% DM) and corm (71% DM) are rich in starch.

The major foods obtained from enset are *kocho*, *bulla* and *amicho*. *Kocho* is the most common one and it is the bulk of the fermented starch obtained from the mixture of the decorticated (scraped) leaf sheaths and grated corm. According to Admasu (2002), *kocho* yield of enset per unit of space and time, in terms of edible dry weight and energy, was much higher than the yields of any other crop cultivated in Ethiopia. It was also indicated that the starch content of *kocho* is similar to that of maize (Gebre-mariam and Schmidt, 1996). Yilma (2001) reported that *kocho* has high carbohydrate (96% DM) content than maize (83% DM). Ajebu *et al.* (2012) observed similar effect on intake, digestibility and growth performance when *kocho* partially replaced maize in sheep feeding. *Kocho* could be produced throughout the year and hence is available year round unlike that of maize which is seasonal. If that is the case, *kocho* could be used as a substitute to maize in poultry ration. However, there is no information which evaluated the replacement value of maize with *kocho* on the performance of broiler chickens. Therefore, the objective of this study was to assess feed intake, growth performance and carcass characteristics of Hubbard chickens fed with different proportion of maize and *kocho* in concentrate mixture.

MATERIALS AND METHODS

Experimental chicks and design

The experiment was carried out at the poultry farm of School of Animal and Range Sciences, Hawassa University, Hawassa, Ethiopia. Three hundred day-old unsexed broiler Hubbard chicks were used for the experiment. The experimental floor was covered with wood shavings of 4-5 cm depth. Experimental house and equipments were cleaned, disinfected with formalin and aerated before the transfer of chicks. The chicks were reared in the brooder for two weeks at the experimental site and during that phase they were provided with the starter ration. After brooding, the chicks were divided into four treatment groups of 45 chicks each and randomly assigned to the four treatment diets in a completely randomized design. Each treatment group was further sub divided in to three replicates of 15 chicks per replication and kept in a 1.50 m x 2.0 m wire mesh partitioned pens.

The chicks were vaccinated against Gumboro and Newcastle diseases using appropriate vaccine as per the recommendation of the manufactures. For coccidiosis prevention amprolium (20-40 g/100 liters of water) was provided for five consecutive days per week from first week to fourth week of age and oxytetracyline - 10% (20 g/100 liters) was given with drinking water whenever necessary. The chicks were administered with commercial anti stress (vitalyte) to prevent stress which could be associated with transportation. It was given in drinking water during the first three days upon arrival. Other poultry management routine procedures were maintained.

Experimental feed preparation and feeding management

Maize, wheat bran, noug seed cake and soybean were purchased from local market. Vitamin-mineral premix, lysine, methionine, dicalcium phosphate and limestone were purchased from Addis Ababa commercial market. Soybean was roasted for 5 minutes to deactivate trypsin inhibitor. The feed ingredients were milled and mixed well manually. The proportion of experimental diet is shown in Table 1. Wet *kocho* was purchased from Tula market and sun dried without squeezing the water part. The fibers of wet *kocho* were separated by hand and mesh. Then the flour of *kocho* was spread over mat to dry till it become safe for storage. All ingredients of the ration were mixed at required proportion for feeding of the chicks. The diet was formulated to be iso-nitrogenous and iso-caloric. Initially it was planned to offer diets which contain 21% CP and 13.2MJ ME/kg DM as recommended by Eekeren et al. (1997) for broiler chicks.

Table 1. Proportion of feed ingredients (% as feed basis)

Feed ingredients	Dietary level of the diet (%)			
	T1	T2	T3	T4
Maize	35	21	14	0
Kocho	0	14	21	35
Noug seed cake	23	29.5	32.25	41.75
Wheat bran	14	10	9	3
Soybean	24.5	22	20.25	16.75
Lime stone	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.5	0.5	0.5	0.5
Vitamin-mineral premix	0.5	0.5	0.5	0.5
Lysine	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25
Total	100	100	100	100

The feeds were offered once a day at 8:00 am. Water was provided ad libitum. The duration of feeding trial was 49 days excluding the adaptation period.

Measurement of chicks performance

Chicks were individually weighed at weekly intervals. Feed intake was calculated as the difference between the amount of feed offered to the chicks and the amount refused. Body weight gain was calculated as the difference between the final and initial chicks' weight. Nutrient efficiency ratio was determined from the amount of body weight gain of the chicks per unit of nutrient consumed.

Determination of carcass characteristics

For evaluation of carcass traits 24 chicks, two chicks from each replicate group (one male + one female) that represent the mean body weight were selected randomly at the end of the feeding trial. All chicks were deprived of feed and water over night to empty the gut content. Chicks were slaughtered by severing jugular vein and allowed to bleed completely and then plucked manually and weighed to determine blood and feather weight. Data on pre-slaughter live weight, weight of blood, weight of shank, neck, head, breast meat, drum stick, thigh, digestive tract, wing, gastrointestinal and reproductive organs, the visceral organs including heart, kidney, spleen, lung, and liver weight were recorded. The edible carcass weight was calculated by subtracting the non edible offal (shank, spleen, feather, pancreas, head, respiratory organs, reproductive organs, digestive tracts) from the total live body weight. Edible carcass weight was determined by summation of back, drumsticks, thighs, wings and breast including skin, gizzard and liver. Total edible (TE) offal was calculated by adding gizzard, liver and skin to commercial carcass (back bone, drumsticks, thighs, wings, breast muscle, breast bone and neck). Dressing percentage was calculated from carcass weight as a percentage of slaughter weight. DP = WC/SBW x 100, where DP = Dressing percentage, WC = Carcass weight, SBW = Slaughter body weight.

Determination of nutrient retention

At the beginning of the experiment 8 chicks representing all the treatment groups (two unsexed chicks that representing the average body weight of each treatment group) were selected, weighed and leg banded. Before slaughtering the chicks by cervical dislocation they were starved for 12 h to make empty stomach. After slaughtering, the chicks were placed into plastic bags and frozen (-20^{0}C) for determination of nutrient retention. In the same manner, at the end of the experiment two chicks (one male and one female) from each replicate (6 chicks / treatment), whose body weight was closest to the mean body weight of their respective groups were selected. The chicks were identified by means of a leg band and were starved for 12 h, weighed and killed by cervical dislocation. The frozen whole body was then cut up into small sections by using machetes and minced thoroughly using meat mincer. After uniform mixing of the minced meat samples were taken and dried at 65^{o}C for 100 h and finely milled to pass through 1mm mesh screen. The absolute dry matter of the carcass sample was determined by drying the sample at 105^{0}C overnight.

After determination of each nutrient in the sample, the amount of each nutrient deposited in the whole body were determined by multiplying the obtained values with their respective slaughter weight. The amount of each nutrient retained during the experimental period was calculated by the difference of the initial and final nutrient composition of the chick. The amount of nutrient retained daily was also determined by dividing the nutrients retained by the total experimental duration. The percent of nutrient retained in the whole body were calculated as amount of nutrient in the whole body/ Amount of nutrient consumed × 100. Crude protein intake (PI) was determined following the method of Sevier *et al*., (2000) using the formula: PI = Total DM intake × % crude protein in the diet. Protein efficiency ratio (PER), as a measure of nutritive value of dietary protein, was determined according to Wilson (1989): PER = Mean weight gain (g)/ Mean protein intake.

Chemical analysis of the experimental feeds and minced carcass

Experimental feed offered and refusals were weighed and sampled daily for each treatment. Sub samples were dried in a dry oven at 65^{o}C for 48 h and ground to pass through 1mm mesh screen and the dry matter (DM), ether extract (EE), crude fiber (CF) and ash were determined according to the procedures of AOAC (1995) and nitrogen free extract (NFE) was calculated by difference. A micro-Kjeldahl procedure of nitrogen analysis was employed to determine the nitrogen content. The crude protein (CP) was then determined as nitrogen content x 6.25. Calcium was determined by atomic absorption spectrophotometer and phosphorus calorimetrically as described by AOAC (1995). The metabolizable energy (ME) was estimated by the formula: ME (Kcal/kg DM) = 3951 + 54.4 EE - 88.7 CF - 40.8 ash (Wiseman, 1987).

Statistical analysis

The data were subjected to Analysis of Variance, using the Statistical Analysis System (SAS, 2004). A significant level of differences among means was determined by using the Duncan Multiple Range Test. Difference between treatment group were considered statically significant at P<0.05.

The following statistical models were employed to analyze the data: $Y_{ij} = \mu_i + T_j + E_{ij}$, Where, Y_{ij} = the response variable: μ_i = over all mean: T_i = the effect of treatment: E_{ij} = random error.

RESULTS

Chemical composition of the feed ingredients

Chemical composition of *kocho* and maize are presented in Table 2. *Kocho* had low crude protein, low ether extracts and high nitrogen free extract content when compared with maize that had high CP, high EE and low NFE. The highest CP content was for soybean while the lowest was for k*ocho*.

Nutrient intake

The daily nutrient intakes of broiler chicks are presented in Table 4. The DM intake was not significantly different among the treatments. The CP intake of chicks fed on T1diet was the highest (P<0.05) whereas T2 had the lowest intake. The CF intake was highest in T4 and lowest for T1. Chicks fed T3 diets had the highest (P<0.05) ME intake followed by T2 while those fed T4 had the least. The Ca and P intake increased with increasing level of *kocho* in the diet. Similarly, there was a trend of increasing ash intakes with increasing levels of *kocho*.

Table 2. Chemical composition (% dry matter, unless specified) of the feed ingredients

Nutrients	Feed ingredients				
	Maize	Soybean	Noug cake	Wheat bran	*Kocho*
Dry matter (%)	94.7	95.6	94.5	93.7	96.2
Crude protein	8.1	30.8	29.9	17.0	3.8
Crude fiber	2.0	13.1	19.4	5.2	4.1
Ether extract	8.7	16.6	12.1	9.4	5.8
Ash	1.0	1.0	1.0	0.9	1.0
Nitrogen free extract	75.0	34.1	32.2	61.1	81.4
Calcium	0.63	0.68	0.54	0.59	0.62
Phosphorus	0.28	0.22	0.29	0.25	0.31
ME (kcal/kg DM)	4209	3651	2856	3962	3857

ME =metabolizable energy, Kcal= kilo calories, NFE = DM-(CP + CF + EE + Ash). Metabolizable energy (Kcal/Kg DM) = 3951+ 54.40 Crude fat – 88.70 Crude fiber – 40.80 Ash (Wiseman, 1987).

Table 3. Chemical composition (% DM, unless specified) of the treatment diets

Chemical component	Treatments			
	T1	T2	T3	T4
Dry matter (%)	97.7	96.0	95.0	93.4
Crude protein	23.0	18.7	18.0	18.0
Crude fiber	7.2	7.5	7.1	8.5
Ether extract	10.8	13.0	12.4	10.4
NFE	55.7	55.9	56.5	55.5
ME (kcal/kg DM)	3864	3953	3957	3722
Ash	1.0	1.0	1.0	1.1
Calcium	0.64	0.65	0.67	0.69
Phosphorus	0.23	0.21	0.24	0.26

DM = dry matter; NFE = nitrogen free extract; ME = metabolizable energy; Kcal = kilo calories; NFE= DM-(CP + CF + EE + Ash). T1= 0%*kocho:* 100% maize, T2= 33% *kocho* = 67% maize, T3= 67% *kocho*=33% maize, T4= 100% *kocho*: 0% maize in concentrate mixture

Table 4. Daily nutrient intake (g/day) of chicks fed different levels of *kocho* and maize in concentrate mixture

Intake	Treatments				Mean	SEM
	T1	T2	T3	T4		
Dry matter	160^{ab}	155^{b}	167^{ab}	161^{ab}	161	4.45
Crude protein	37.7^{a}	29.0^{c}	32.3^{b}	32.7^{b}	32.9	0.87
Crude fiber	11.5^{c}	12.8^{b}	13.1^{b}	16.2^{a}	13.4	0.29
Ether extract	16.9^{c}	22.6^{b}	23.9^{a}	17.1^{c}	20.1	0.49
Nitrogen free extract	88.0^{b}	87.6^{b}	96.8^{a}	92.1^{ab}	91.1	2.49
Metabolizable energy (kcal)	3761^{c}	3950^{b}	3999^{a}	3348^{d}	3765	5.53
Ash	2.17^{b}	2.20^{b}	2.30^{a}	2.27^{a}	2.26	0.04
Calcium	1.27^{b}	1.20^{b}	1.53^{a}	1.50^{a}	1.35	0.04
Phosphorus	0.60^{b}	0.67^{ab}	0.73^{a}	0.72^{a}	0.68	0.06

$^{abc:}$ Means in the same row with different superscript are significantly different at p< 0.05). Kcal, kilo calories. Treatment descriptions are as given under Table 3.

The dry matter and nutrient efficiency ratio

The DM and nutrient efficiency ratio of chicks fed on different levels of *kocho* and maize based diet are shown in Table 5. The efficiency ratio for DM and NFE were similar (P>0.05) among treatments. The highest (P<0.05) CP efficiency ratio was observed for chicks fed T2 diets while the lowest was for those fed T1 diet. The Ca efficiency ratio for T1 and T2 was higher (P<0.05) than that of T3 and T4. The highest (P<0.05) ME efficiency ratio was for T4.

Table 5. Nutrient efficiency ratio of chicks fed different levels of *kocho* and maize in concentrate mixture

Intake	Treatments				Mean	SEM
	T1	T2	T3	T4		
Dry matter	0.30	0.33	0.33	0.26	0.30	0.03
Crude protein	1.30^{d}	1.70^{a}	1.60^{b}	1.46^{c}	1.51	0.05
Ether extract	2.86^{a}	2.23^{b}	2.13^{b}	2.76^{a}	2.50	0.12
Nitrogen free extract	0.53	0.56	0.50	0.50	0.52	0.03
Metabolizable energy (kcal)	0.012^{b}	0.011^{b}	0.011^{b}	0.013^{a}	0.012	0.0003
Ash	0.10^{a}	0.10^{a}	0.10^{a}	0.08^{b}	0.09	0.003
Calcium	1.93^{a}	1.83^{a}	1.53^{b}	1.46^{b}	1.69	0.07
Phosphorus	4.0^{a}	3.66^{b}	3.50^{b}	3.13^{c}	3.57	0.11

$^{abc:}$ Means in the same row with different superscript are significantly different at p< 0.05). Kcal, kilo calories. NFE = DM-(CP + CF + EE + Ash). Treatment descriptions were as given under Table 3. Treatment descriptions are as given under Table 3.

Table 6. Daily nutrient retention (g/day) of chicks fed different levels of *kocho* and maize in concentrate mixture

Intake	Treatments				Mean	SEM
	T1	T2	T3	T4		
Dry matter	39.33^{a}	36.61^{a}	32.46^{b}	32.98^{ab}	36.35	4.99
Crude protein	22.60	25.31	23.00	23.16	23.53	3.44
Ether extract	7.26^{a}	3.91^{b}	3.46^{b}	4.10^{b}	4.68	1.39
Nitrogen free extract	9.10^{a}	7.05^{a}	5.91^{b}	5.85^{b}	6.97	1.79
Metabolizable energy (kcal)	1957^{a}	1660^{ab}	1465^{b}	1537^{b}	1655	252
Calcium	0.75	0.69	0.72	0.80	0.74	0.08
Phosphorus	0.29^{b}	0.33^{ab}	0.36^{a}	0.38^{a}	0.34	0.04

^{abc} :Means in the same row with different superscript are significantly different (P< 0.05). SEM =standard mean error. Treatment descriptions are given under Table 3.

Both Ca and P efficiency ratio declined with increasing dietary level of *kocho*. The amount of Ca and P required per unit of body weight gain increased with increasing levels of *kocho*.

Nutrient retention

The nutrient retention of chicks fed different levels of *kocho* and maize in concentrate mixture is shown in Table 6. The DM retention for T1 and T2 was higher (P<0.05) than that of T3 whereas T4 had an intermediate value. The ME retention for T1 was higher (P<0.05) than that of T3 and T4. There was an increasing trend in P retention with increasing levels of *kocho* in the concentrate mixture

Body weight gain

Initial body weight, final body weight, average daily body weight and total body weight gain of chicks are presented in Table 7. There were no significance differences in body weight gain of chicks among the treatments.

Carcass characteristics

Carcass characteristics of chicks fed with different levels of *kocho* and maize in concentrate mixture is shown in Table 8. The result indicated that the slaughter weight of chicks did not vary across the treatments. There was no significant difference (P>0.05) among treatments in edible carcass weight. The chicks that received ration containing different levels of *kocho* (T2-T4) performed similarly (p>0.05) in terms of wings and thigh weight with the highest value for T1. The highest (P<0.05) total edible offal was obtained from T1 and the lowest for chicks fed T3 diet. The dressing percentage for T4 was higher than that of T2 whereas T1 and T3 had an intermediate value.

Table 7. Body weight change (g) of chicks fed different levels of *kocho* and maize in concentrate mixture

Weight change	Treatments				SEM
	T1	T2	T3	T4	
Initial weight	247	247	251	254	8.57
Final weight	2442	2370	2302	2339	162.2
Total weight gain	2195	2123	2050	2085	158.5
Average daily gain	44.8	43.3	41.1	42.6	3.21

[abc:] Means in the same row with different superscript are significantly different at $p < 0.05$, SEM standard mean error. Treatment descriptions are as given under Table 3.

Table 8. Effect of feeding different levels of *kocho* and maize in concentrate mixture carcass characteristics of chicks

Parameters (g)	Treatments				Means	SEM
	T1	T2	T3	T4		
Slaughter weight	2231	2062	1978	2019	2073	197
Commercial carcass:						
Neck	80.4^{a}	69.5^{b}	58.2^{c}	67.7^{b}	69.0	5.5
Wing	102^{a}	82.7^{b}	80.3^{b}	82.1^{b}	86.9	6.39
Drumstick	231^{a}	211^{b}	205^{bc}	187^{c}	208	15.7
Thigh	256^{a}	217^{b}	210^{b}	231^{b}	229	17.6
Breast muscle	396^{a}	339^{b}	268^{c}	337^{b}	335	39.5
Breast bone	196^{a}	172^{b}	181^{ab}	180^{ab}	182	12.4
Back bone	150^{ab}	159^{a}	137^{b}	144^{ab}	148	16.6
Liver	47.5^{b}	53.2^{a}	58.0^{a}	53.2^{a}	53.0	4.37
Gizzard	56.1^{ab}	55.3^{bc}	60.3^{a}	51.4^{b}	55.8	5.22
Skin	149^{a}	111^{abc}	105^{c}	123^{b}	122	12.1
[1]TEO	1665^{a}	1470^{b}	1363^{c}	1450^{b}	1487	71.0
[2]Edible carcass	1649	1501	1475	1527	1538	186
Dressing percentage	73.8^{ab}	72.7^{b}	74.3^{ab}	75.4^{a}	74.1	20.5

[abc]: Means within the same category with different superscripts across the row are significantly different ($P<0.05$) , , SEM standard mean error, g gram,, [1]TEO = total edible offal = (calculation included skin, gizzard and liver and edible part of carcass), [2]Edible carcass weight = (slaughter weight – TNEO), Dressing % = (Weight of carcass/slaughter weight)*100. Treatment descriptions are as given under Table 3.

DISCUSSION

Nutrient and metabolizable energy contents of the experimental diets and ingredients

The analyzed CP values for all treatment diets were comparable and within the recommended levels suggested by Scanes *et al*. (2004), 20% and 18.5% CP for grower and finisher broilers, respectively, and is above the minimum CP requirement (16%) for broiler breed suggested by NRC (1994). The ME content of treatment diets were between 3722 to 3957 kcal/kg DM which were higher than the minimum values of ME requirement (2801 kcal/kg DM) recommended by NRC (1994) for broiler chickens.

The decreasing trend of EE with an increase in the proportion of *kocho* in diets may be explained by the increasing contribution of soybean oil due to the use of full fat soybean. This, together with CF and ash values contributed to differences in ME content of diets. The CF content of the diets varied between 7.1 and 8.5%. A crude fiber level above 7% has negative effect by reducing production as well as chicken growth (Varastegani and Dahlan, 2014). However, chickens fed on this diet showed significantly a good appetite, which suggests that the level of CF in *kocho* is still below the upper critical fibre level that can negatively affect feed intake and performance of chicks. The composition of calcium increased with the incorporation of *kocho* in the diets, as might be expected which could be due to high calcium content of *kocho* (Ajebu, 2008). All the treatment diets were in accordance with the recommended levels of calcium (0.8 to 1%) and phosphorus (0.35 to 0.45%) in terms of quantity and proportion (Ca: P ratio) in grower chicken diets under tropical conditions (Smith, 1990). The nutrient contents of *kocho* revealed that it is rich in energy (3857 kcal/kg DM), Ca (0.81%) and P (0.37%). The CP content of *kocho* (3.8%) in the present study was higher than the values (2.7%, 2.6%, 1.78 %; 1.5) reported by Ajebu *et al.* (2012), Yilma (2001), Kalekristos (2010) and Yewelsew et al. (2006), respectively. This difference may be due to the variation of enset varieties from which *kocho* is produced. Ajebu (2008) observed varietal differences in CP content of unprocessed corm and pseudostem from which *kocho* is produced.

The CP content of *kocho* in the present study is lower (38 g/kg DM) compared with maize (81 g/kg DM) which agrees with the result reported by Ajebu et al. (2012). The current study showed that *kocho* could be rich source of energy. Moreover, the high ME content of *kocho* noted in this study is indicative of its potential as a substitute to energy rich feed such as maize in the diet of broilers. The low CP content of *kocho* in the present study clearly suggested that by improving its CP content through mixing with high protein sources (like noug cake and soybeans) in ration formulation, it is possible to increase the efficiency of nutrient utilization. The EE content of *kocho* (5.8%) found in this study was higher than *furfurame* (4.1%), the by-product of *kocho* processing, as reported by Seyoum (2013). The CF content of *kocho* (4.1%) obtained from the present work was lower than the value of CF of *furfurame* (10%) reported by Seyoum (2013). The CP content of the noug cake used in this study (299 g/kg DM) was similar to the value (301 g/kg DM) reported by Ajebu et al. (2012) but it is higher than the value (253 g/kg DM) reported by Abebe (2011). The variation observed in CP content may be due to the difference in efficiency of extraction while extracting oil and other factors such as stage of maturity, time of harvesting, storage, soil type and environmental condition (Adugna, 2008). The CP content of wheat bran recorded in the present study (170 g/kg DM) was slightly lower than the value (180 g/kg DM) reported by Abebe (2011) and but greater than the value (128 g/kg DM) reported by Ajebu et al. (2012).

Nutrient intakes

The present result has shown that DM and nutrient intake was not affected by replacement of *kocho* with maize. The similarity in total DM intake among treatments indicates that feeding *kocho* as a replacement to maize in diet of broiler chicks had no negative effect on intake. The result of the present study agreed with Etalem *et al.* (2013) who observed similar intake and performance in chicken fed cassava root chips as a replacement to corn grain. The similarity among treatments in DM intake indicated the comparable feeding value of *kocho* and maize as an energy source. Similar to the current experiment, Seyoum (2013) has shown that *furfurame*, a by-product of *kocho* processing, has been shown to have similar feeding value with that of maize. As reported by Ochetim (1991), complete replacement of maize with cassava root resulted in reduction of feed intake which is not consistent with the current experiment. However, Hossain et al. (2013) and Ngiki et al (2014) reported increased feed intake with increasing level of cassava root meal in the diet of chicken in maize based diets. There was an increasing trend in the intake of phosphorus with increasing level of *kocho* in the diet. Ajebu et al. (2008) indicated that pseudotem is rich in phosphorus.

Effect of replacement of maize with *kocho* on weight gain of chicks

The similarity in average daily weight gain of the chicks could be due to the similarities in DM intake, DM conversion ratio and DM efficiency ratio. This once again indicates the comparable feeding value of *kocko* and maize as an energy source. Similar to the current experiment, Etalem *et al*. (2013); Hossain et al. (2013) and Ngiki et al. (2014) indicated that the replacement of cassava meal with maize grain at different levels did not influence daily weight gain in broiler chickens. Contrary to the current experiment, Seyoum (2013) observed a decrease in body weight gain with increasing levels of *furfurame*. The reason for decreased weight with increasing level of *furfurame* may be due to its fibrous nature compared with *kocho*. Similarly, loss of body weight was observed when cassava meal totally replaced maize in the diet of poultry (Ochetim, 1991).

The current result implies that due to the year round availability and easy access by smallholder farmers in the southern and south-western part of Ethiopia where enset is widely grown, *kocho* could be used as an energy source as a substitute for maize.

Nutrient retention of chicks

The high CP intake for T1 could be due to the high CP content of this nutrient in that treatment group. Chicks fed T1 diets had higher CP intake than the remaining treatment groups but in the case of CP retention, it was similar among the treatments. The result is not consistent with that of Seyoum (2013) where there was a tendency of decreased CP retention with increasing level of *furfurame.* The decreased protein retention could be due to lower protein efficiency ratio in this treatment. As it has been indicated by Jackson *et al.* (1982), the carcass moisture, protein, fat and ash content of broiler depend upon the protein concentration in a diet. Accordingly, in the present experiment chicks which were fed T3 diet had the lowest DM retention which could be due to lower content of fat, protein and ash as compared to other experimental groups.

The body composition of the chicken is affected by many factors such as strains, sex, age, quantity and quality of the dietary CP and ME, slaughter and sampling methods and environmental conditions. Among the different nutritional components, proteins (amino acids) are fundamental because they are related with synthesis of structural tissues, for instance in growing animals amino acids deposition in the skeletal muscle represent 65% of whole daily protein intake.

Carcass characteristics of chicks

Carcass yield is an indication of the quality and utilization of the ration (Bambgbose and Niba, 1998). The present information indicated that the slaughter weight of chicks in all treatment diets was not affected by the inclusion of *kocho*. However, there was a tendency of decreased slaughter weight with the increasing levels of *kocho*. This is in agreement with the previous finding of Seyoum (2013) for broiler chickens fed *furfurame*.

The weight of chicks fed T1 diet was relatively higher in edible carcass weight, drumstick, thighs, breast muscle, back and wing than the remaining treatment which is consistent with the work of Seyoum (2013) in chicks fed *furfurame* and Ocheiim (1992) in those chicks fed cassava meal as a replacement to maize. High carcass yield suggests more nutrient bioavailability for anabolic processes, perhaps more so, in protein synthesis than other diets (Tegene and Asrat, 2010) since the true muscle development is an accumulation of protein. From this it can be deduced that chicks fed on *kocho* based diets had low carcass yield than T1 diet, which might be due to poor bioavailability of nutrients in *kocho* diet which resulted in poor tissue growth. This indicated that protein and energy deposition depends to a great extent on the quality and quantity (biological value) of dietary protein and energy.

A progressive decrease in weights of edible carcass and the carcass components (drumsticks, thighs, breast, back and wings) were observed with increasing levels of *kocho*. Similarly, a decrease in weight of total edible offal was also noted with increasing level of *kocho* in the treatment diets. Similar results were reported by Seyoum (2013) where broilers were fed *furfurame* as a replacement to maize and Ochetim (1991) in chicks fed increasing levels of maize as a replacement to cassava meal. Thus, the lower weights of these carcass parts of the experimental groups compared to those fed T1 fed diets might be due to less deposition of protein in the former group. A non-significant result on dressing percentage of chickens fed different levels of *furfuram*e, a by-product of *kocho* processing, was reported by Seyoum (2013) which is not consistent with the current experiment. The difference might be attributed to the difference in fiber content between *furfurame* (10%) and *kocho* (4.1%) The value of dressing percentage obtained in the current experiment is more or less similar to the value (70%) reported by Scanes *et al*. (2004) and Maigualema and Gernat (2003) for broiler breeds regardless of diets. Seyoum (2013) also reported a dressing percentage of 72.7% where f*urfurame* replaced maize in concentrate mixture which is similar with the current experiment

CONCLUSIONS

The replacement of maize with *kocho* in the diet of growing Hubbard chicks had no negative impact on the performance (live body weight, daily weight gain, slaughter weight, carcass yield), DM intake, and efficiency ratio of the chicks compared to T1, which indicates that *kocho* could partially or totally replace maize in broiler diets as energy feed ingredient. Thus, in areas where maize grain feeding is not common, *kocho* could be used as a source of energy. In fact a source of protein is required since *kocho* is very poor in CP content.

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Mange Mites Infestation on Small Ruminants in and around Bale Robe, South Eastern Ethiopia

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ABSTRACT

The study was carried out between November, 2013 and March, 2014 to estimate the prevalence of sheep and goat mange mite infestation and identify the dominant mange mites in and around Bale Robe town, South Eastern Ethiopia. Skin scraping was the method employed to collect mange mites for identification. A total of 470 animals were examined and only 8 (1.7%) of them were infested with mange mites. From 350 sheep and 120 goats examined for mange mites infestation, 5 (1.4%) and 3 (2.5%) were found positive, respectively. The difference in the prevalence between the two host species was not statistically significant (P>0.05). Likewise age, body condition status and sex of the animals had no significant (P>0.05) effect on the prevalence of mange mite infestation. The genera of mange mites infesting the animals were *Demodex* (0.86%), *Sarcoptes* (0.62%) and *Psoroptes* (0.21%). Of these genera, *Demodex* was the most prevalent in the study area. In conclusion, the prevalence of mange mite in the current study is low. Extensive epidemiological investigations that considers agro-ecology and other non-host factors are required to further minimize the prevalence of infestation and design appropriate control strategies.

Keywords: Bale Robe, Ethiopia, mange mite, sheep, goat

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INTRODUCTION

Live stock production is an important sector of Ethiopia agriculture economy, providing a significant contribution to gross domestic and export products and raw materials for industries. The estimated Ethiopian sheep and goats population is approximately 24.2 and 22.6 million, respectively (CSA, 2012). Owing to their high fertility, short generation interval and adaptation even in harsh environment, sheep and goats are considered as investments and insurance that provide income to purchase food during season of crop failure and to meet seasonal purchase such as improved seed, fertilizers and medicine for rural households (Demissie et al., 2000).

The quality of hides and skins deteriorates due to pre and post slaughter defects by lice, ticks and mange mites that cause downgraded and rejection of hide and skin (Bayou, 1988). Among the diseases of sheep and goats, infestation by mange mites and ticks as well as dermatophilosis causes a considerable economic loss particularly to the skin and hides export due to various defects (Woldemeskel, 2000). Mites are active in keratin layer and cause direct damage to the skin, also cause indirect economic loss by decreasing reproduction and production performance (Soulsby, 1982). According to tannery reports, skin disease due to external parasites causes 35% and 56% sheep and goat skin rejection, respectively. In Ethiopia 56% of goat and 35% of sheep skin are rejected annually due to various factors, of which mange infestation accounts for 33% in sheep and 21% in goats (Bayou, 1998). Mange, a contagious disease of animals, is characterized by a variety of clinical signs depending on the species of mites. Four genera of parasitic mites can cause mange in sheep and goats, namely: *Chorioptes* species, *Demodex* species, *Psoroptes* species and *Sarcoptes* species (Urquhart, et al., 1996). Though the magnitude of the problem created by mange mite is believed to be huge, studies conducted in this regard in different parts of the country and information available are little in general. Moreover, no studies on the subject have been conducted in and around Bale Robe area. Hence, it would be essential to have a base line data on the prevalence of mange mites of small ruminants, the species of mites circulating and potential risk factors in the study area. Therefore, the objectives of the study were to estimate the prevalence of mange mites of sheep and goats, and identify the major risk factors in and around Bale-Robe.

MATERIALS AND METHODS

Study area and study animals

The study was conducted in and around Bale-Robe, South East of Oromia Region, Ethiopia. Geographically, Bale-Robe is located around 7°7′ N and 40°E. The annual mean temperature of the area ranges from 5^{o}c to 23.5^{o}C. It is characterized by bimodal rainfall and annually receives rainfall greater than 1150 mm. The short rainy season is from March to May, while the long rain season is from July to October. The study animals were sheep and goats managed under extensive husbandry system, which were grazed freely. Sheep and goats presented to Bale-Robe Veterinary clinic and in kebeles' around the clinic were included in the study. The age of the study sheep and goats was determined as described by Steel (1996) and Gatenby (2002), respectively.

Study design, sample size and sampling methods

A cross- sectional study was employed to estimate the prevalence of mange mite infestation and to identify the genera of mange mites prevalent in sheep and goats. A systematic random sampling method was used to select the study animals. The sample size needed for the study was calculated by using the formula given by Thrusfield (2005). The study considered 50% expected prevalence, 95% confidence level and 5% level of precision. Accordingly the sample size calculated, both for sheep and goats, was 384. Therefore, by taking in to account the proportion of study animals' 350 sheep and120 Goats were sampled from the study area.

Selected animals, sheep and goats, were thoroughly examined by palpation and observation for any skin lesions. Animals suspected for mange mite were isolated and clinically examined for presence of skin lesions such as erythema, pruritis and scales. Then samples of skin scrapping were collected from the edge of a visible lesions and its surrounding as described by Chauhan and Agrwal (2006) in to a clean universal bottle. The samples were labeled and then transported to Bale Robe Veterinary Clinic. In the clinic a few drop of 10% KOH was added to the samples and allowed to stand for 25 minutes. Finally, the samples were examined under stereomicroscope for mange mites. The genera of mange mites were identified as described by Kaufmann (1996), Wall and Shearer (2001) and Taylor et al. (2007).

Data analysis

The data were summarized by descriptive statistics such as proportion and mean using Microsoft Office Excel software. The summarized data were analyzed using Chi-square test and different risk factors compared. All analyses were performed using STATA 11 software.

RESULTS AND DISCUSSION

From a total of 470 small ruminants (350 sheep and 120 goats) examined 8 animals (1.7%) were positive for mange mite infestation, of which sheep and goats accounted for 5 (1.4%) and 3 (2.5%), respectively. The analysis for the risk factors considered during the study and species of mange mites have been identified shown in table 1 and 2.

Table 1. Prevalence of mange mite infestation and presumed risk factors

Risk factors	Level	Number examined	Prevalence number positive (%)	χ^2	p-value
Species	Sheep	350	5 (1.4)		
	Goat	120	3 (2.5)	0.61	0.40
Age	Young	160	3 (1.9)	0.04	0.84
	Adult	310	5 (1.6)		
Sex	Female	327	4 (1.2)		
	Male	143	4 (2.8)	1.47	0.23
Body condition	Good	124	0		
	Medium	239	5 (2.1)		
	Poor	107	3 (2.8)	3.14	0.21
Overall		470	8 (1.7)		

Table 2. Genera of mange mites infesting sheep and goats in the study area

Genera of mange mites	Species of Animals		Overall Prevalence	Std. Er	χ^2	p-value
	Sheep	Goat				
Demodex	3 (0.86%)	1 (0.83%)	4 (0.85%)	0.004	470	0.000
Sarcoptes	1 (0.29%)	2 (1.7%)	3 (0.64%)	0.004		
Psoroptes	1 (0.29%)	-	1 (0.21%)	0.002		

This study revealed an overall mange mite prevalence of 1.7%, of which 1.4% and 2.5% were in sheep and goats, respectively. This finding is in a general agreement with reports from Eastern Amhara Region (Sertse and Wossene, 2007), Central Ethiopia (Haffize, 2001; Yacob et al., 2008), Kombolcha (Numery, 2001), in and around Mekelle (Habte, 1994; Kassaye and Kebede, 2010) and Sidama (Teshome, 2002). In contrast, the current study finding was considerably lower than the prevalence reported from the Southern range land of Oromia: 14.64% in sheep and 16.45% in goats (Molu, 2002), Hararghe: 7.85% in sheep and 11.8% in goats (Takele, 1986), Robe areas: 6.7% in sheep (Shenkutie, 1987) and Wolaita zone: 5.85% and 8.11% (Sheferaw et al., 2010). The discrepancy in prevalence between the present and other studies is likely attributed to difference in management, the prevailing ecological factor, breed of the study animals and the awareness of farmers to use of acaricide and related control practices. The other reason for the difference could be the intervention made by Oromia Regional State i.e. application of acaricide to control small ruminant ectoparasites. According to Asmare et al. (2016) the prevalence of mange mite is higher in lowland and lower in highland. This is possibly associated with differences in the optimum climatic conditions required for the breeding and survival of mites (Pangui, 1994). The review done by Asmare et al. (2016) revealed that some studies done in Ethiopia reported as low as 0.2% apparent prevalence both in sheep and goats.

During the current study three genera of mange mites, namely *Sarcoptes*, *Demodex* and *Psoroptes,* were detected in the study area. These genera of mange mites were also commonly reported from different parts of Ethiopia (Numery, 2001; Yacob et al., 2008; Kassaye and Kebede, 2010; Sheferaw et al., 2010; Yasine et al., 2015; Seid et al., 2016). The overall prevalence of *Sarcoptes*, *Demodex* and *Psoroptes* was 0.62 %, 0.86% and 0.21%, respectively. This study showed that goats (1.7%) were predominantly infested by *Sarcoptes* species than sheep (0.29%) as similar results were also reported previously from various parts of country (Numerry, 2001; Kassaye and Kebede, 2010, Sheferaw et al., 2010; Yasine et al., 2015). There was no significant difference in mange mites prevalence between age group, species and body condition status of studied animals. This finding is in a general agreement with the report of Sheferaw et al. (2010) and Seid et al. (2014). Therefore, sex and age of the host animals are not contributing factors for the differences in the prevalence of mange in the study area. It has been stated that mange mite infestation is independent of age and sex (Soulsby, 1982). *Demodex* was the most dominant mange mite that was followed by *Sarcoptes* in the current study area. It was also reported as the dominant genera in earlier studies conducted in various parts of the country (Sertse and Wossene, 2007; Sheferaw et al., 2010 and Fentahun et al., 2012).

CONCLUSIONS AND RECOMMENDATIONS

The present study revealed low level of mange mite infestation in sheep and goats in and around Bale Robe, South Eastern Ethiopia. Three genera of mange mites, namely: *Demodex, Sarcoptes* and *Psoroptes* were found in the area. *Demodex* and *Sarcoptes* are burrowing mites, which affect sheep and goats; and cause skin damage (Urquhart et al., 1996). Taking in to consideration the importance of sheep and goats skin as one of the most important source of foreign currency to Ethiopia, the infestation of mange mites recorded in the study area deserves due attention to all levels in order to further minimize the spread of infestation. Hence, strategic control has a great contribution to minimize the infestation and to prevent the spread. Awareness creation among animal breeders and/or farmers through planned animal health extension program is recommended on treating sick animals, reducing transmission from animal to animal and avoiding the associated economic losses.

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Spatial Erosion Hazard Assessment for Conservation Planning in the Gibe-III Dam Catchment, Southwest Ethiopia

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Abstract

Soil erosion is one of the biggest global environmental problems resulting in both on-site and off-site effects. Sedimentation as off-site effect is considered to be critical in reservoirs and water bodies, both in reducing capacity and loss of value. Soil erosion hazard was assessed using adapted USLE (Universal Soil Loss Equation) model to spatially identify and prioritize areas for conservation planning in Gibe –III dam catchment, southwest Ethiopia. Rainfall, soil map, a 30x30 m DEM, and satellite images were used to determine the USLE variables. Individual Geographic Information System (GIS) files (thematic layers) were built for each USLE factor and these layers were spatially overlaid and combined by a cell by cell-grid modeling procedure to predict the mean annual soil loss and develop erosion hazard intensity map of the study area. The mean annual soil loss rate ranges from 0 - 51.57 tons $ha^{-1}yr^{1}$ with an estimated average of 7.47 tons $ha^{-1}yr^{-1}$. Based on the level of soil erosion rates, the study area was classified into five priority categories for conservation interventions. The analysis showed that 53% of the study area suffers from a moderate to very high erosion risk (>6.25 tons $ha^{-1}yr^{-1}$). These areas are located around the steeper slope banks of Gojeb and Gibe Rivers. However, Woreda level prioritization indicate that Menjiwo, Merka Gena, Loma Bosa, Esara Tocha, Gimbo, and Kindo Koysha Woredas were the largest sediment producer Woredas; together they cover 43% of the study area but they produce 53% of the total annual soil loss. Moreover, the total potential soil movement in the study area was estimated 9,700,823 tons yr^{-1} from 1,298,402 ha. Thus, any intervention designed to reduce the sediment load reaching to Gibe –III dam should start from these prioritized Woredas.

Key words: Soil erosion, USLE, GIS, Gibe –III dam catchment, Prioritization, Ethiopia.
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INTRODUCTION

Soil erosion is the process of detachment, transportation, and accumulation of surface soil by erosive agents. Various human activities disturb the land surface, and thereby induce significant alteration of natural erosion rates. Rapid population growth, cultivation on steep slopes, clearing of vegetation and overgrazing are the main anthropogenic factors that accelerate soil erosion in Ethiopia (Reusing *et al.,* 2000). In Ethiopia, accelerated soil erosion by water constitutes a severe treat to the national economy (Sutcliffe, 1993; Hurni, 1993). On the average, Ethiopia losses 12 tons of soil per hectare per year, or an estimate of 1493 million tons of soil per year due to water erosion. On the other hand, the soil formation rate for Ethiopia is in the range of 2-22 tons per hectare per year (Mahmud *et al.,* 2005; Hurni, 1988).

The effects of erosion are both on-site and off-site. Sedimentation as off-site effect is considered to be critical in reservoirs and water bodies, both in reducing capacity as well as loss of value. According to World Commission on Dams (2000) about 25% of the world's existing fresh water storage capacity may be lost in the absence of measures to control sedimentation. The study also indicated that the problem is more severe in developing countries. Soil erosion reported to be a serious problem in Ethiopia through increasing sedimentation of reservoirs and lakes (Bezuayehu, 2006). Specific studies indicated that sediment concentration of 16.7 kg m^{-3} in Bilate river (Sileshi, 2001); accumulation about 3.5 million m^3 of silt in just 23 years for Koka dam (Gizaw *et al.,* 2004) and 50% of the studied reservoirs in Tigray have lost their economic life before half of the design period because of siltation (Haregeweyn *et al.,* 2005).

Soil erosion risk assessment and mapping of erosion prone areas under various land use/land cover helps to prioritize where in the watershed action to be taken and for overall soil conservation planning. This is important in order to encourage effective natural resource conservation and sustainable development. Therefore, the need for soil erosion assessment is not merely quantifying the erosion rate but spatial assessment of erosion can be core of any decision making and supportive in policy formulation for sustaining the environment as a whole (Kalpana and Bhaware, 2006)

Soil conservation activities do require planning and prioritizing locations for intervention. In reality due to various required resources (E.g. financial constraints), it is difficult to conserve all areas under the risk of erosion. Therefore, in practice, areas at high risk have to be prioritized first than other areas for management and conservation of soil and water resources. However, a critical element to the success and sustainability of any watershed management program is the ability to utilize limited time and funds most effectively to address priority areas, particularly in large watersheds. In fact, a range of sophisticated assessment tools currently exists to assist decision-makers and managers to identify key areas for the implementation and application of watershed management programs (Heidi *et al.,* 2011). For example, the hydrologic models that provide detailed assessments of hydrologic processes and calculate sediment loads, as well as providing information on the efficiency of alternative control practices and land-use changes applied at the field, farm, and sub-watershed scale. Recently, application of erosion models tend to favour the process based types in many parts of the world; like WEPP (Water Prediction Program); CREAMS (chemical, runoff and erosion from agricultural management systems). Process-based models provide an ideal tool for facilitating water resources management at small scale level. However, the accuracy and reliability of process-based hydrologic models decreases with the increasing complexity and size of the system being modeled (Novotny and Olem, 1994). These models however, do require large datasets as well as more variables than the simple model like USLE. Given the high erosion rate in Ethiopia and scarcity of detailed input data the USLE is considered to be the best option. Moreover; very large watersheds, like Gibe – III dam catchment, exhibit a high landscape variability that cannot be easily or accurately characterized at a minimal expense with process-based hydrologic models. This is also an added reason for using USLE utilizing remotely sensed data and Geographic Information Systems (GIS). Thus for large watershed areas; a coarser level of data can be used to provide an initial identification of areas exhibiting considerable soil loss.

The adapted USLE for Ethiopian condition has got great attention and application in many parts of Ethiopia; Bobe (2004) applied USLE in Harerghe; Gebreyesus and Kirubel (2009) estimated the amount of soil loss in different landforms and land uses using USLE in Medego watershed Tigray region. Habtamu et al. (2013) used it in Choko Mountain Northern Ethiopia. Using the adapted USLE Abate (2011) estimate the soil loss to establish priority categories for conservation interventions in south Wello. Most recently Beshir and Awdenegest (2015) applied USLE for predicting soil loss to identify hotspots in the Gibe catchment, Jimma zone western Ethiopia, while Meshesha et al., (2012) and Syed and Hamelmal (2016) applied adapted USLE for soil loss estimation in the Awassa catchment.

However the USLE model is not without limitations, it is developed to estimate long term average annual soil loss from sheet and rill erosion (Wischmeier and smith, 1978). Thus gully erosion rates, stream bank erosion and erosion in urban areas cannot be estimated. Moreover storm event soil loss rates could not be done unless modified as MUSLE (Modified Universal Soil Loss Equation) (Williams, 1975)

Determining the location of priority areas for Gibe III dam catchment is important and timely exercise to provide a management and decision tool for natural resource managers. This is critically important for the reduction of siltation in the reservoir (such like Gibe III dam) by developing and implementing successful and cost-effective erosion prevention programs. Thus the objective of this study was to assess spatial erosion hazard for Gibe III dam catchment using USLE model in a GIS environment and prioritizing erosion prone areas for soil conservation planning at woreda level.

MATERIALS AND METHODS

Description of the Study Area

The study area, Gibe-III dam catchment, is located at the central part of the Omo Gibe Basin, southwestern part of Ethiopia (Fig.1). Geographically the catchment area extends between 6.748° – 7.815°N latitude and 35.655° – 37.919° E longitude and has a total area of 12,984 km^2. Most parts of the study area lies in the Ethiopian highlands >1500masl (FAO, 1984). It lies in two regional states, namely: Southern Nations Nationalities and People Regional State in its southern part composed of twenty three Woredas covering about 71 % of the total area, and the Oromia Regional State in the north, crossing six Woredas which cover 29 % of the area. The average annual rainfall and air temperature of the study area is 1,499 mm and 20.4°C, respectively (EEPCo, 2009). According to FAO classification, soils of the study area are classified as Humic Nitosols (43%), Humic Alisols (24%), Lithic Leptosols (23%), Chromic Luvisols (7%) and Eutric Vertisols (3%).

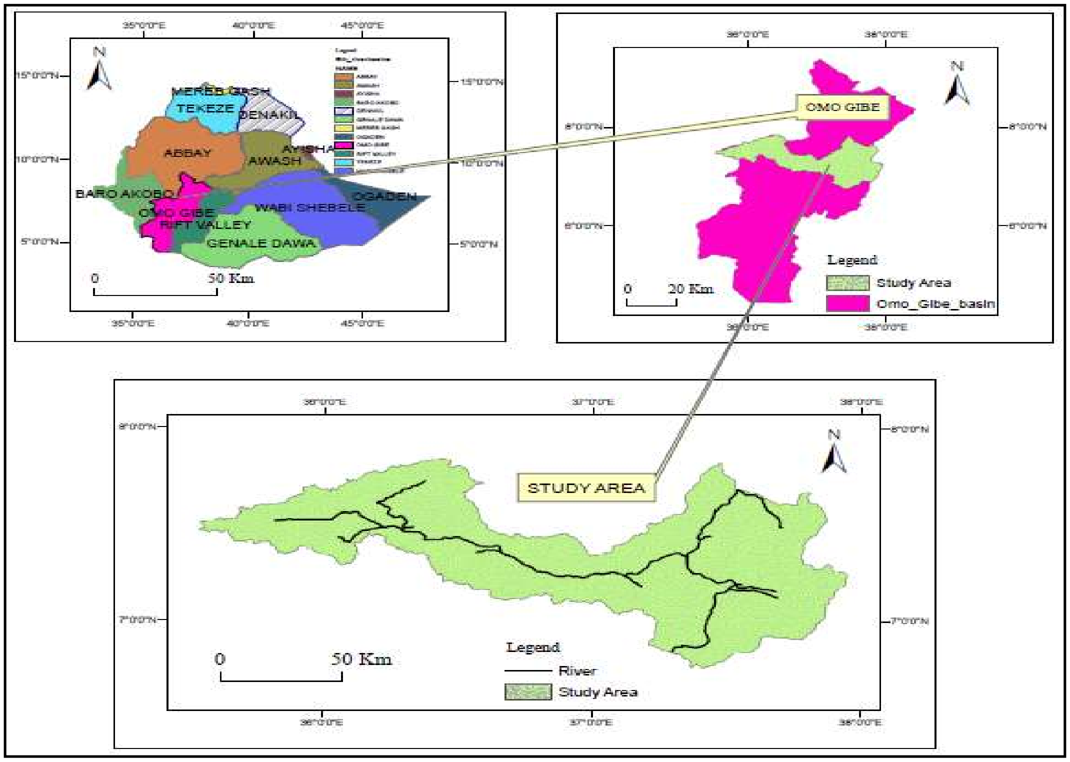

Figure 1. Location of the study area (Gibe-III Dam Catchment)

Data Generation and Data Analysis

The rainfall data was collected from Ethiopian Meteorological Agency and Omo – Gibe Basin master plan, Ethiopia. Monthly rainfall data for the period from 1980 to 2012 was used to compute rainfall erosivity (R) factor from 35 metrological stations that found within and around the study area. The soil data for this study were obtained from FAO soils and the soil map of Omo - Gibe basin master plan from Ministry of Water Resources, Ethiopia. ASTER; NASA source DEM with a spatial resolution of 30m was obtained from Ethiopian Geological Survey office and was used to prepare slope map, LS factor map and DEM based analysis. The LANDSAT 2013 ETM+ image for the study area was downloaded via FTP (http://glovis.usgs.gov). This image was used to prepare land use land cover map of the study area for C_factor and P_factor estimations.

ERDAS Imagine 10 was used for satellite image processing and land use land cover classification whereas Global Mapper 11 and Arc SWAT for delineation of the study area and ArcGIS9.3 was used for DEM processing and raster based overlay analysis.

The data analysis involved the use of adapted USLE model in a GIS environment. Individual GIS files were built for each factor in the USLE. Each factor is considered as a thematic layer. These layers were spatially overlaid and combined by a cell by cell-grid modeling procedure in ArcGIS 9.3 to predict the mean annual soil loss and develop erosion hazard intensity map of the study area. However, the various layers of data were brought to common coordinates before being processed together. The resulting mean annual soil loss map was then classified into different priority classes based on WBISPP (2001) classification of soil loss classes and simple algorithms were used to classify the area into different erosion hazard zones.

The Universal Soil Loss Equation (USLE) model could be written as:

$$A = R \times K \times (LS) \times C \times P \quad (1)$$

where: A: soil loss in $t \cdot ha^{-1}$ $year^{-1}$; R: rainfall erosivity factor in $MJ \cdot mm \cdot ha^{-1} \cdot hr^{-1}$ $year^{-1}$; K: soil erodability factor in $t \cdot hr \cdot MJ^{-1} \cdot mm^{-1}$; LS: slope steepness-length factor; C: cover and management factor; and P: conservation practices factor. LS, C and P are dimensionless.

The USLE parameters are location specific and need to be calibrated to the specific area to enable reasonable prediction of the rate of soil loss. Hence, in this study the Universal Soil Loss Equation (USLE) model adapted for Ethiopian condition was considered (Hurni, 1985; Hellden, 1987; SCRP, 1996; Kaltenreider, 2007).

The parameters/factors that participate in the model were processed with 30m by 30m cell size and while the final model output was set to 100m by 100m to obtain the annual soil loss per hectare per year. All layers were projected with UTM Zone 37N using the WGS 1984 datum; these correspond to standards used by the Ethiopia Mapping Agency. The figure below show the steps followed in the analysis.

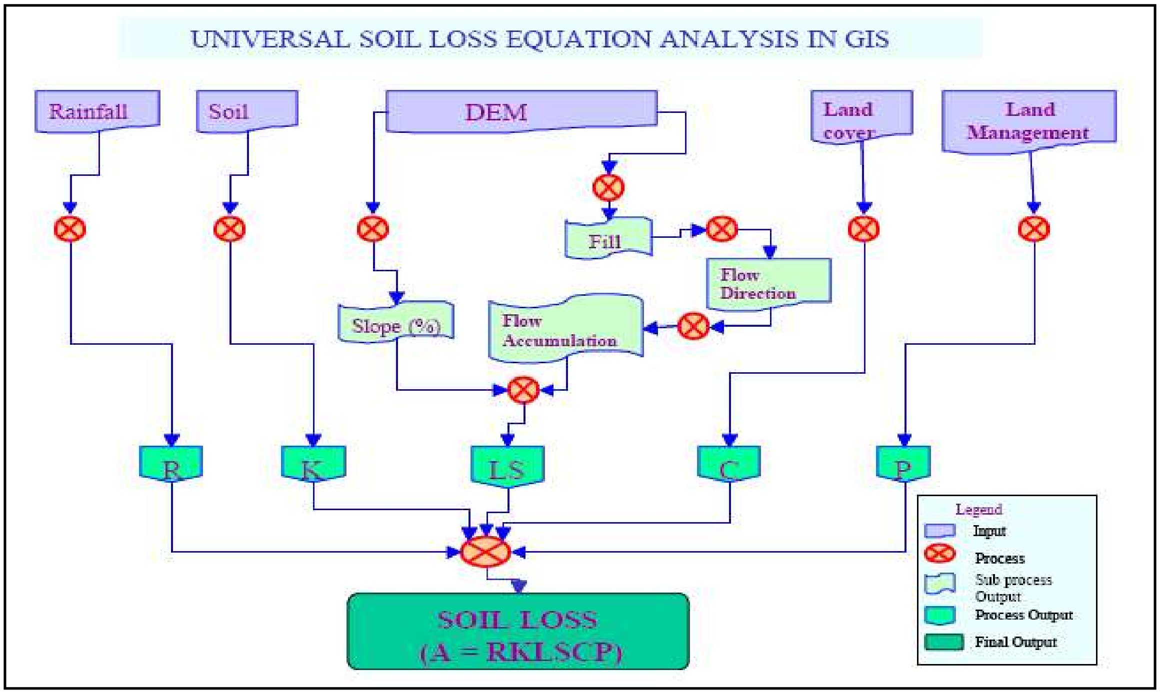

Figure 2. Flow Chart showing analysis of annual soil loss based on GIS application (adapted from Atesmachew et al., 2012)

In this study the analysis of each process factors was derived as follow:

Rainfall Erosivity /R_Factor/ Estimation:-The rainfall erosivity factor in USLE is estimated from the total storm energy and maximum 30min intensity (Renard et al., 1997). However, this relationship is limited in Ethiopia because of mainly the absence of rainfall kinetic energy and rainfall intensity data. The estimation of rainfall erosivity here used the modified method for Ethiopian condition by Kaltenrieder (2007) (Eq. 2).

$$R = 0.729*P - 376.2 \quad (2)$$

Where; R is the rainfall erosivity factor ($J \cdot m^{-1} \cdot hr^{-1}\ year^{-1}$) and P is the mean annual rainfall (mm).

Monthly precipitation data of over 30 years (1980 - 2012) from 35 meteorological stations were used and the calculated R_factor values for each station are given in Table 1 and this was then transferred to ArcGIS9.3 and an attribute table was created.

The R factor value map (using the point theme) was produced using the nearest neighbor Kriging interpolation technique, with 12 neighborhoods in spatial analyst tool (Figure 3).

Soil Erodibility /K_Factor/ Estimation:-The soil data for this study were obtained from the soil map of Omo - Gibe river basin master plan and FAO soils and used for analyzing the soil erodibility factor (K_factor). The basic soil data set was found in vector format which changed to raster grid and re-classified in ArcGIS 9.3 Spatial Analyst Tool. The K_factor estimations for different soil types of Gibe-III dam catchment are shown in Table 2. Figure 4 shows the resulting K_factor value map.

Table 1: Mean Annual Rainfall (32-year average) and Calculated R_factor Value for 35 Stations

No	Station Name	Mean Annual RF (mm)	Calculated R_factor	No	Station Name	Mean Annual RF (mm)	Calculated R_factor
1	Agaro	1527	737.0	19	Gojeb	1523	734.1
2	Ambay School	1720	877.7	20	Hosaina	1194	494.2
3	Areka	1333	595.6	21	Jima	1495	713.7
4	Asendabo	1254	538.0	22	Metseso	2106	1159.1
5	Bele	1273	551.8	23	Morka	1128	446.1
6	Bilate	1101	426.4	24	Omonada	1205	502.2
7	Bonga	1784	924.3	25	Saja	1506	721.7
8	Chekorsa	1614	800.4	26	Sekoru	1430	666.3
9	Chena	1877	992.1	27	Serbo	1318	584.6
10	Chida	1690	855.8	28	Shebe	1622	806.2
11	Chira	2092	1148.9	29	Sodo	1199	497.9
12	Dedo Sheki	1898	1007.4	30	Wishwish	1768	912.7
13	Deneba	1031	375.4	31	Worancho	1074	406.7
14	Dimbira	1287	562.0	32	Woshi	1463	690.3
15	Dimtu	1425	662.6	33	Yebu	1963	1054.8
16	Durame	1083	413.3	34	Mizan Teferi	2071	1133.6
17	Gera	1789	928.0	35	Tepi	1561	761.8
18	Gesuba	1086	415.5				

Source: Ethiopian Meteorological Agency (1980 – 2012) (Computed)

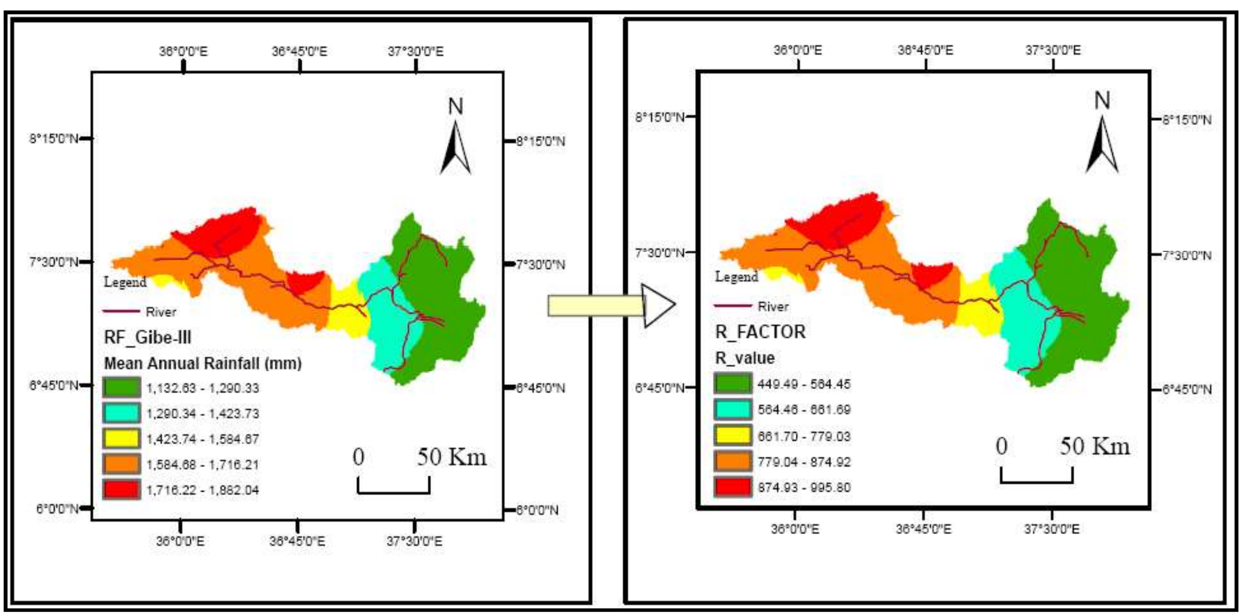

Figure 3. Rainfall erosivity /R_Factor/ map of the study area

Table 2. Soil Erodibility /K_Factor/ Value Estimated

No	Soil type	K_Factor value	No	Soil type	K_Factor value
1	Chromic Luvisols	0.14	4	Eutric Vertisols	0.19
2	Humic Nitosols	0.32	5	Humic Alisols	0.22
3	Lithic Leptosols	0.24			

Source: Adapted from Kaltenrieder (2007) and Ali and Hagos (2016)

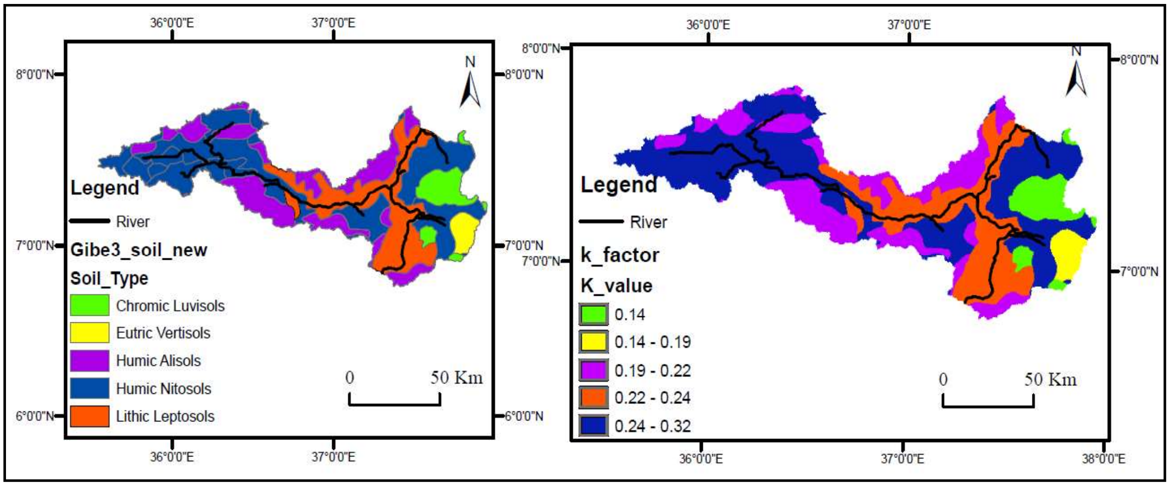

Figure 4. Soil erodibility /K_Factor/ map of the study area

Topographic (L and S) Factors Estimation:-The LS factor grid was estimated with the following equation (Eq. 3) proposed by Wischmeier and Smith (1978); Moore and Burch (1986a and 1986b); and Abate (2011).

$$LS = (\text{Flow Accumulation} * \text{Cell value} /22.13)^{m} * (0.065 + 0.045\,S + 0.0065\,S^2) \quad (3)$$

where: LS is slope length- steepness factor, S is slope gradient (%), cell value is 30m contributing area and m is as in Table 3 (Wischmeier and Smith, 1978). The values of flow accumulation and slope gradient were derived from DEM after conducting FILL and Flow Direction processes in ArcGIS 9.3. Figure 5 shows the derivation process and the resulting topographic factor (LS) map of the study area.

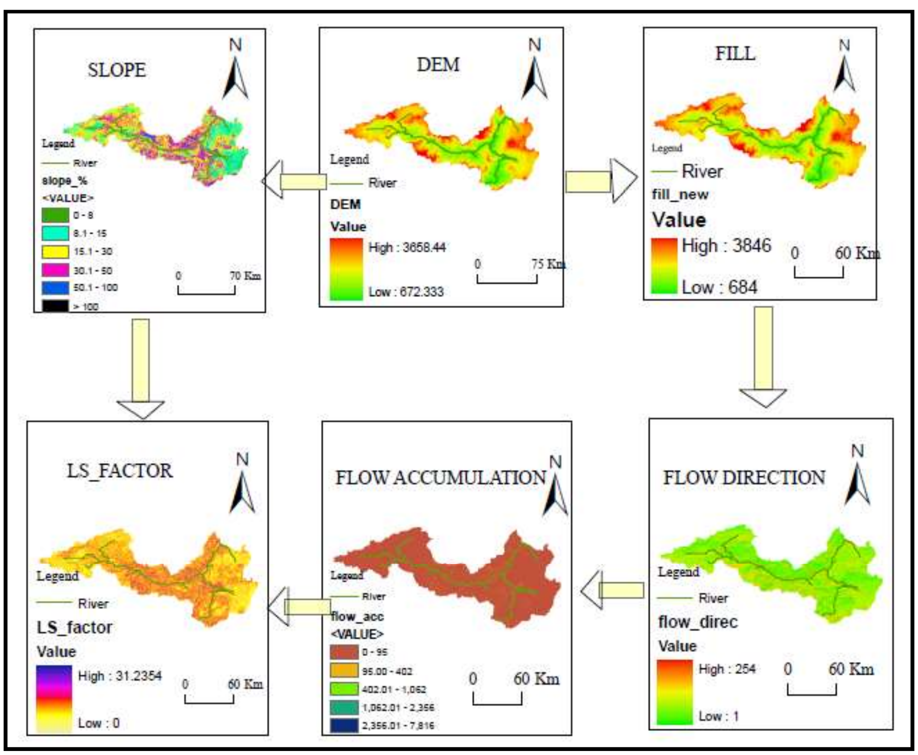

Figure 5. Topographic (LS_Factor) map of the study area

Table 3: **m**-value

m - value	Slope (%)
0.5	> 5
0.4	3 - 5
0.3	1 – 3
0.2	< 1

Source: Adapted from Wischmeier and Smith (1978)

Cover and Management /C_Factor/ Estimation:- Seven major land use land cover (LULC) maps were produced from Landsat7 ETM+ (Dec.3, 2013), by a hybrid classification procedure (figure 6). *C*_factor values corresponding to each crop/vegetation condition were identified. In cultivated lands C_factor value were estimated based on the weighted average of the dominant crop types. Table 4 lists the average *C*_factor values for the different land use categories identified and these values were used to re-classify and obtain the *C*_factor map of the study area (Figure 6).

Table 4 Estimated C_factor values for the derived land use land cover classes

Land use Land cover type	Average C_Factor value	% Land Area
Cultivated Land; Rainfed; Cereal Land Cover System; lightly stocked	0.30	24.36
Cultivated Land; Rainfed; Cereal Land Cover System; moderately stocked	0.30	30.93
Forest; Open (20-50% crown cover)	0.05	17.57
Grassland; moderately stocked	0.05	14.57
Grassland; unstocked (woody plant)	0.01	1.58
Shrub land; Open (20-50% woody cover)	0.001	0.32
Woodland; Open (20-50% tree cover)	0.001	10.66

Source: Adapted from Kaltenrieder (2007)

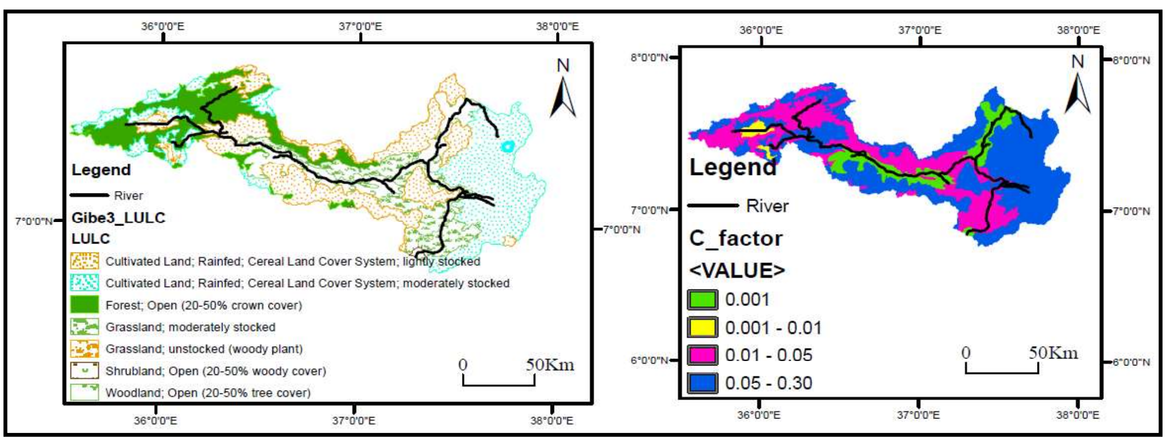

Figure 6. LULC and C factor map of the study area

Supporting Practice /P_Factor/ Estimation: - It depends on the type of conservation measures implemented in the area, with value ranges from 0 to 1. However, in the study area, as data were lacking the P-values suggested by Shi *et al.* (2002) and Abate (2011) was used (Table 5). The assumption here is the grass or forest lands are not treated with any conservation practice while the agricultural lands are treated and the effect of which is high in gentle slopes. Thus, the agricultural lands are classified into six slope categories and their respective P-values were assigned (Table 5).

In ArcGIS9.3, the original land use land cover map in a vector format was first re-classified in to two categories (i.e. Agricultural land and other land) then it was converted in to raster format. In Spatial Analyst Tool extension Local the new raster land use was combined with slope map (%) derived from DEM to get a combined land use - slope map of the study area and the P_factor values listed under Table 5 were assigned to each land use - slope combination grid. Finally the assigned P_factor values were looked up in Spatial

Analyst Tool extension Re-class to produce the resulting P_factor map (Figure 7).

Table 5 Conservation practices factor (P-Value)

Land use type	Slope (%)	P_factor value
Agricultural Land	0 – 5	0.11
	5 – 10	0.12
	10 – 20	0.14
	20 – 30	0.22
	30 – 50	0.31
	50 – 100	0.43
Other Land	All	1.00

Source: Adapted from Shi *et al.* (2002) and Abate (2011)

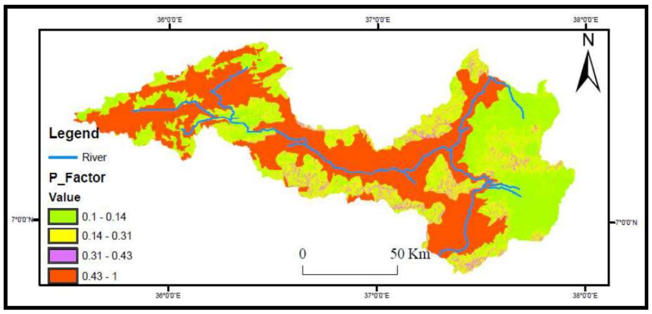

Figure 7. Supporting practice /P_Factor/ map of the study area

Analysis Based on Woreda and Kebele

In Ethiopia, resources, for conservation activities, are allocated by the government through political administrative boundaries (Region, Zone, Woreda, and Kebele) not through watershed or sub-watershed boundaries. Therefore, in order to effectively and efficiently utilize these limited resources and extracting meaningful priority locations, the catchment wise annual soil loss estimation has been considered as a better option. These estimations were further classified and prioritized, for conservation planning purpose, based on political administrative boundaries viz; Woreda and Kebele.

Hence, the catchment wise soil loss map of the study area was overlaid on the administrative Woreda and Kebele shape file map to extract Woreda and Kebele level average annual soil loss. This was done in ArcGIS9.3 using the command Spatial Analyst extension Extract by Mask. The average annual soil loss rate (t/ha/yr) of each Woreda and Kebele was then estimated as total soil loss (t/yr) of ith Woreda and Kebele per total geographical area (ha) of ith Woreda and Kebele.

RESULTS AND DISCUSSION

Erosion Hazard Assessment

The annual soil loss rate was determined in cell-by-cell analysis by multiplying the respective USLE factor values interactively in ArcGIS 9.3 Spatial Analyst extension Raster Calculator. Figure 8 shows the resulting soil loss rate map of the study area. The estimated annual soil loss rate ranged from 0 tons ha^{-1}yr^{-1} (in the plain areas) to over 12 tons ha^{-1}yr^{-1} (in much of the steeper slope banks of the main Rivers-*Gibe* and *Gojeb* and their tributaries). In few areas extreme values reaching to over 50 tons ha^{-1}yr^{-1} was also estimated.

Acceptable soil loss rate of < 6.25 tons ha^{-1}yr^{-1} was considered as a boundary (WBISPP, 2001) for evaluation of our estimate the study area. Accordingly, the soil loss rates (>6.25 tons ha^{-1}yr^{-1}) are particularly associated with high erosivity (R_value), large values of LS (especially of high slope, S), and lack of permanent supporting practice (P) (Fig. 3, 5, and 7). These areas are dominantly found at the steeper slope banks of *Gojeb* and *Gibe* Rivers at the western and northern parts of the study area respectively and at their tributaries. High soil loss rate was also found in randomly distributed cultivated lands having rugged topography (high LS_factor value) and high erodibility.

On the other hand, relatively the lower soil erosion rates (i.e. below 6.25 tons ha^{-1}yr^{-1}) were registered in forest cover areas (~17%; < 3.125 tons ha^{-1}yr^{-1}) and where most agricultural practices are carried out (~30%; <6.25 tons ha^{-1}yr^{-1}). With respect to areas of natural shrubs (11%), and grass lands (16%) had most of the highest soil losses (>12.5 tons ha^{-1}yr^{-1}); it appeared that the areas have a serious problem that should be dealt with conservation measures. This is attributed to the fact that the type of cover occurred on the steep slope area with high value of LS_factor and a higher K value ranges between 0.22 - 0.24. In the agricultural land, soil erosion was not as critical as in these areas, due to the fact that, although they had relatively higher C values (0.3 *vs* 0.001 and 0.05, respectively), mostly the land used for agricultural crops was located in areas where the least LS value was observed.

The total annual soil loss or movement in the study area was estimated 9,700,823 tons from 1,298,402 ha (Table 7). The largest size among soil loss categories was that of 6.25 -12.5 tons ha^{-1}yr^{-1} which accounts for 40.28% of the study area (Figure 8 and Table 6). The average annual soil loss for the entire catchment was estimated at 7.47 tons ha^{-1}yr^{-1}.

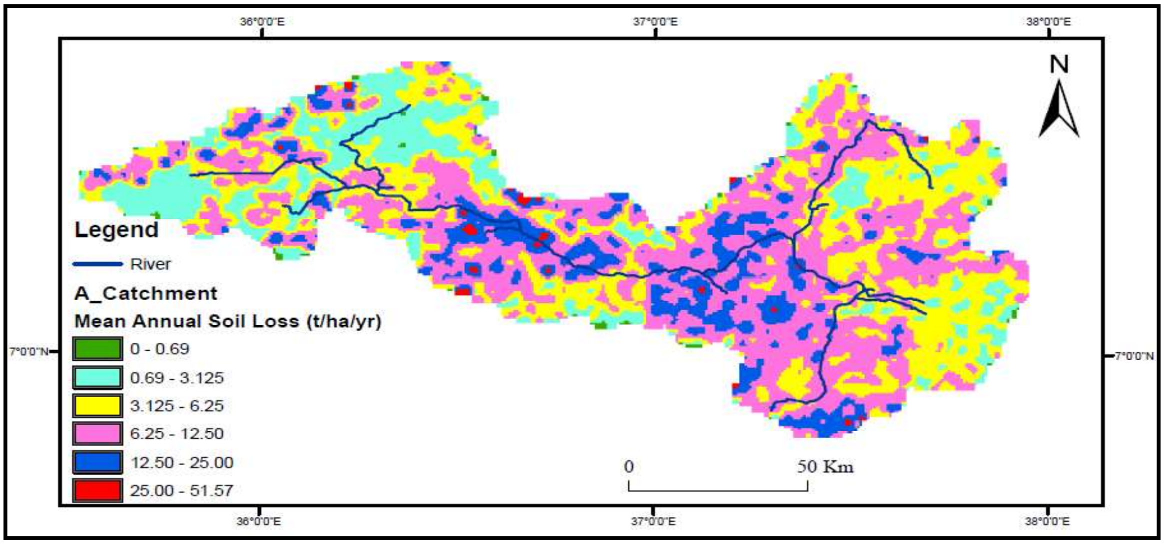

Figure 8. Spatial distribution of mean annual soil loss in the study area

The estimated soil loss rate and the spatial patterns are generally realistic compared to what can be observed in the field as well as results from previous studies. For instance, the results of this study falls within the ranges of the estimated soil loss for Ethiopia, which was ranging from 0 to 300 tons $ha^{-1}yr^{-1}$ with an estimated national average of 12 tons $ha^{-1}yr^{-1}$ Hurni (1985). Similarly the average annual soil loss for the entire Lake Hawassa catchment in the Rift Valley Basin, Ethiopia was estimated at about 5 tons $ha^{-1}yr^{-1}$ (Ali and Hagos, 2016 and Tigneh, 2009).

Prioritization for Soil Conservation Planning

The USLE model result was re-classified or prioritized in to different erosion hazard classes for conservation planning purpose. Prioritization of these areas means ranking in terms of conservation urgency. Studies have shown that the USLE model is more appropriate to show areas with differing degree of erosion hazard rather than their qualitative soil loss (Van Remortel, 2001). Soil loss tolerance (SLT) denotes the maximum allowable soil loss that will sustain an economic and a high level of productivity (Gebreyesus and Kirubel, 2009; FAO and UNEP., 1984). According to Renard *et al.* (1996), the common SLT values range from 5 to 11 tons $ha^{-1}yr^{-1}$. Morgan (1995) also argues that 10 ton $ha^{-1}yr^{-1}$is an appropriate boundary measure of soil loss over which agriculturists should be concerned. The assignment of a range depended on the judgment of how much erosion would be harmful to the soil. Accordingly, for this study WBISPP (2001) classification of soil loss classes were used and the extent of soil erosion was classified into five erosion hazard classes (Table 6). The least soil loss rate (less than 0.69 tons $ha^{-1}yr^{-1}$) category is considered as negligible and a severity class of no erosion is given. Area coverage in (ha) and percent proportion were also tabulated for each of the soil erosion potential categories.

Table 6. Erosion hazard classes and area coverage in Gibe-III catchment

Soil loss ($t\ ha^{-1}\ y^{-1}$)	Equivalent top soil removal (mm)	Severity Classes	Conservation Priority classes	Area (ha)	Per cent of total area
<0.69	-	No erosion	-	5,231	0.40
0.69 - 3.125	< 0.25	Very Less	V	214,412	16.51
3.125 - 6.25	0.25 – 0.5	Less	IV	391,583	30.16
6.25 - 12.50	0.50 – 1.0	Moderate	III	523,018	40.28
12.50 - 25.00	1.00 – 2.0	High	II	156,584	12.06
>25.00	>2.0	Very High	I	7,574	0.58

Source: Adapted from WBISPP (2001) classification of soil loss classes

The total area with a soil loss potential higher than the SLT, i.e. > 6.25 tons $ha^{-1}yr^{-1}$, was 687,176 ha which comprises 53% of the total study area. Around 40% of the study area fall under the moderate erosion category while high severity class account for 12% of the area. The spatial locations of the areas highly affected by soil erosion, with a soil loss potential higher than the SLT, i.e. > 6.25 tons $ha^{-1}yr^{-1}$, are dispersed throughout the catchment mostly on the steeper slope banks of the *Gojeb* and *Gibe* rivers and their tributaries (Figure 8). These areas are under erosion severity classes of very high, high and moderate, where accordingly conservation priorities of the first, second and third level respectively. A closer look on the individual USLE factors output (Figure 3, 4, 5, and 7) revealed these areas are characterized by high rainfall erosivity, high soil erodibility, topographic ruggedness, and inadequate / poor vegetation cover during critical periods of the year.

The plane or relatively flat parts of the study area, which account for 47 percent of the total area fail in the least vulnerable to soil erosion category compared to other areas, as they are in the very less and less soil erosion severity classes. As can be seen from Figure 8, most of the least vulnerable areas to soil erosion (at the eastern part) are mainly found in gentle to flat topography but cultivated lands. This implies that topography seems dominant than cover. The other section of this category are under the natural forest and shrub lands at the upper western part in which good ground cover have multiple benefits in protecting the land from erosion (Morgan, 1995). In general, presumably rainfall, topography and cover were the dominant variables which determined the spatial distribution of erosion in the study area.

The soil loss rate map (Figure 8) and erosion hazard class (Table 6) clearly shows that nearly 53% of the total study area requires implementation of different types of soil and water conservation measures for a sustainable land use and reduction of both on site and off site effects of erosion. Where resources are limited, implementing conservation measures in only selected areas that are highly affected by erosion can significantly reduce great soil loss in the study area. Thus, it is necessary to identify and prioritize highly affected areas (i.e. administrative Woreda and Kebele) for treatment with appropriate soil and water conservation measures.

Annual Soil Loss Assessment by Woreda

The average annual soil loss rate of the study area Woredas ranges from 3.37 – 11.91 tons/ha/yr (Figure 9 and Table 7). Table 7 clearly shows that out of the total 29 Woredas, 18 Woredas fall under moderate to high soil loss rate category (>6.25 tons/ha/yr) and the rest 11 Woredas below the maximum soil loss tolerable limit (<6.25 tons/ha/yr). However prioritization was done considering the potential sediment generation capacity of Woredas. This is because the main intension of this research was to reduce the total sediment load reaching to Gibe –III dam through spatially identifying and prioritizing areas producing large sediment load for conservation planning. Here the sediment yield is considered as an index to judge the relative erosion rate across the study area, assuming sediment delivery ration of the whole catchment the same. This approach enabled us to make comparison and prioritize spatially for conservation intervention.

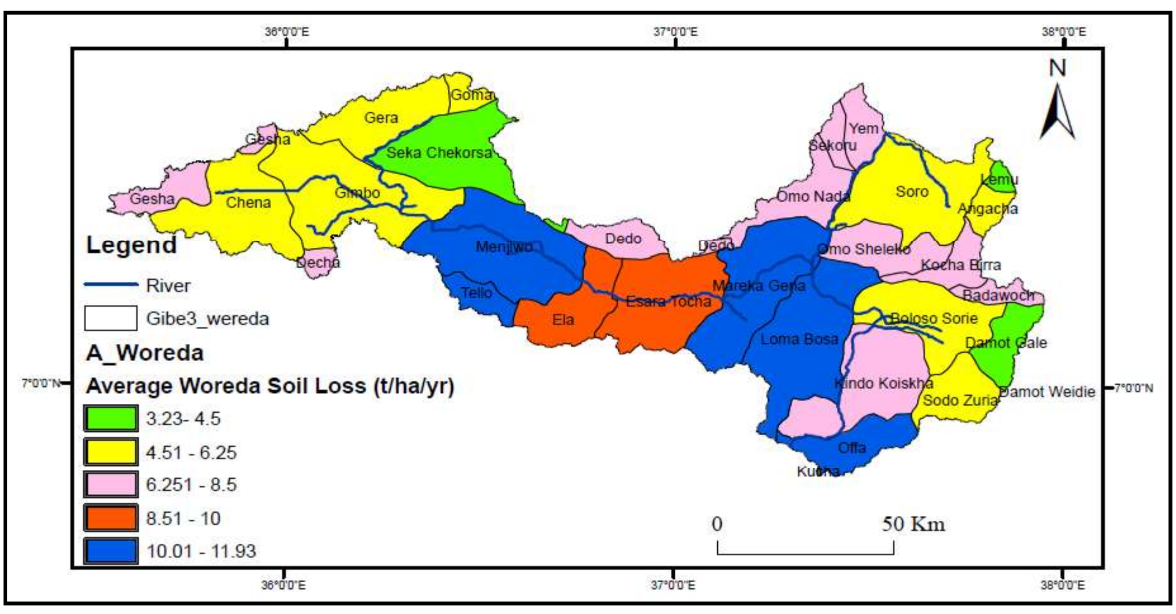

Figure 9. Average annual soil loss analysis based on Woreda

Table 7. Annual soil loss result of Gibe –III Dam catchment Woredas

Woreda	Average Annual erosion loss (ton/ha/yr)	Area (ha)	Total Annual soil loss (ton/yr)	Percent of soil loss
Menjiwo	10.61	105334	1117470	11.52
Merka Gena	11.91	88302	1051820	10.84
Loma Bosa	10.28	100614	1033790	10.66
Esara Tocha	8.48	78167	662933	6.83
Gimbo	6.07	107202	650534	6.71
Kindo Koysha	7.49	79428	594552	6.13
Soro	5.42	90049	488063	5.03
Ela	8.66	46169	399700	4.12
Chena	5.02	75307	377919	3.90
Boloso Sorie	5.87	64349	377909	3.90
Offa	10.38	35414	367719	3.79
Omo Nada	7.49	38450	287820	2.97
Omo Sheleko	7.03	38485	270662	2.79
Gera	4.93	51519	254012	2.62
Seka Chekorsa	3.37	71012	239003	2.46
Dedo	8.07	25624	206688	2.13
Gesha	6.84	28551	195136	2.01
Tello	11.02	16205	178506	1.84
Kacha Bira	8.03	21362	171431	1.77
Sodo Zuria	4.96	33315	165079	1.70
Yem	7.18	20632	148051	1.53
Badawoch	7.45	12420	92575.3	0.95
Damot Gale	3.52	25550	89878.1	0.93
Sekoru	7.98	10088	80536.5	0.83
Angecha	4.85	12207	59202.3	0.61
Goma	5.67	10355	58755.9	0.61
Decha	8.23	6950	57206.1	0.59
Lemu	4.32	5126	22153.8	0.23
Kucha	7.98	215	1714.87	0.02
TOTAL		**1,298,402**	**9,700,823.45**	**100.00**

Based on the analysis Menjiwo, Merka Gena, Loma Bosa, Esara Tocha, Gimbo, and Kindo Koysha Woredas are the first largest sediment producer groups and soil erosion sensitive Woredas in the study area (Table 7). In terms of the total annual soil loss Menjiwo Woreda generates the highest sediment load 1,117,470 t/yr which comprises 11.52% of the total annual soil loss of the entire study area followed by Merka Gena Woreda 1,051,820 t/yr (10.84%) and the remaining Loma Bosa, Esara Tocha, Gimbo, and Kindo Koysha Woredas produce the annual soil loss of 1,033,790 t/yr (10.66%), 662,933 t/yr (6.83%), 650,534 t/yr (6.71%), and 594,552 t/yr (6.13%) respectively. These six Woredas only covers 43% of the total catchment area but they contribute 53% of the annual soil loss of the entire catchment. Besides their area coverage the topographic ruggedness, insufficient permanent supporting practice, and poor vegetation cover during critical periods of the year coupled with erosive rainfall contributes to the high rate of soil erosion in the above prioritized Woredas.

Generally, as shown in Figure 9 and Table 7, the least annual soil loss rate was exhibited in Seka Chekorsa Woreda (3.37 ton/ha/yr) followed by Lemu Woreda (4.32 ton/ha/yr) whereas the maximum were estimated for Merka Gena Woreda (11.91 ton/ha/yr) and Menjiwo Woreda (10.61 ton/ha/yr). The main reason for higher soil loss rate in the study area was due to rugged topography, lack of permanent conservation practices, and high rainfall erosivity. While the probable reason for the least soil loss rate was observed as due to relatively a good forest cover with a lower C_factor value and plane topography with little LS_value.

Woreda level soil loss result was further analyzed by Kebele level to identify and prioritize the highest sediment producer Kebeles for intervention purpose.

Annual Soil Loss Assessment by Kebele

The study area consists of 29 political administrative Woredas and around 710 Kebeles. Kebele is the smallest political administrative boundary in Ethiopia, where a single Woreda consists of a number of Kebeles. Kebele level prioritization was done to identify the highest sediment generating Kebeles in the study area for conservation planning. Hence, Kebele level annual soil loss was extracted from the catchment wise soil loss map using Kebele shape file. Figure 10 shows the resulting Kebele level average annual soil loss map.

The average annual soil loss rate at Kebele level for the entire catchment ranges from 1.05 t/ha/yr to 30.97 t/ha/yr (Fig. 10). However, here prioritizing Kebeles for intervention was done based on previous determination of highest sediment producing six Woredas (Fig. 11). Table 8 shows the prioritized Woredas with their total number of Kebeles and the highest sediment producing Kebeles. The analysis result reveals that, for the prioritized six Woredas, the majority of the sediment was generated by less than half of their total Kebeles.

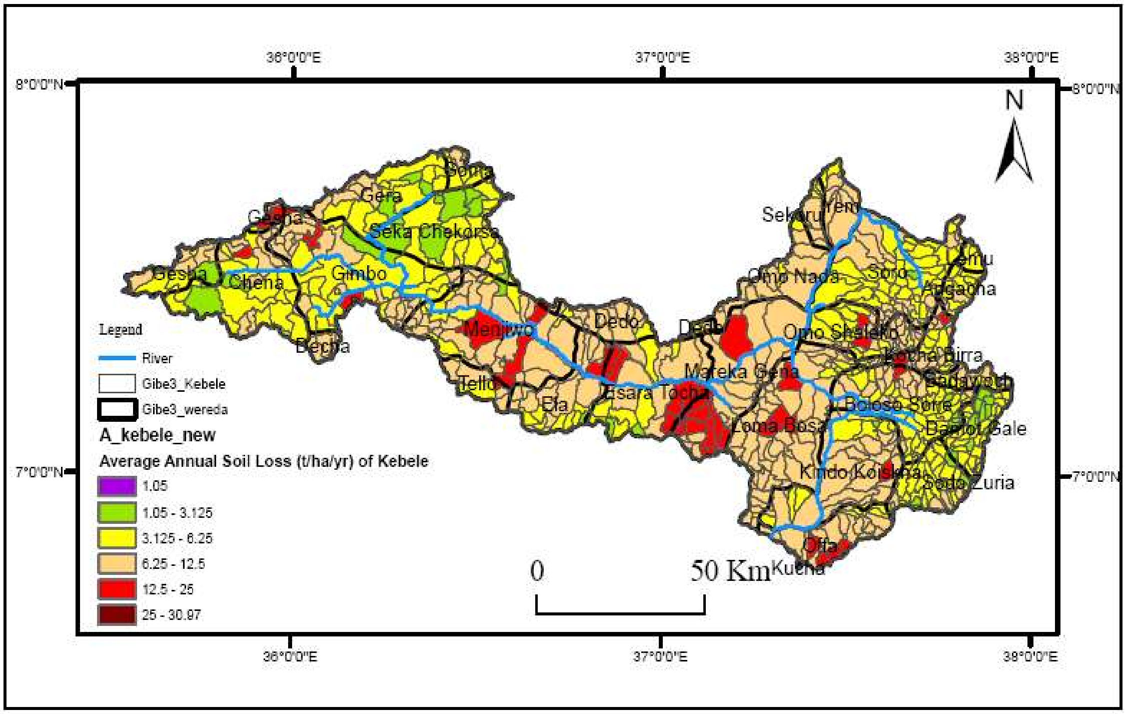

Figure 10. Average annual soil loss analysis based on Kebele

Table 8. Summary of kebele level soil loss analysis result for the prioritized six Woreda

Woreda Name	Woreda total sediment (ton/yr)	Total Kebele	Prioritized Kebele (total sediment in [ton/yr])	Percent proportion of sediment produced
Menjiwo	1,117,470	46	20 (943,630)	85
Merka Gena	1,051,820	47	20 (922,991)	88
Loma Bosa	1,033,790	71	25 (805,824)	78
Esara Tocha	662,933	26	13 (564,669)	85
Gimbo	650,534	56	19 (454,704)	70
Kindo Koyisha	594,552	54	18 (457,789)	77

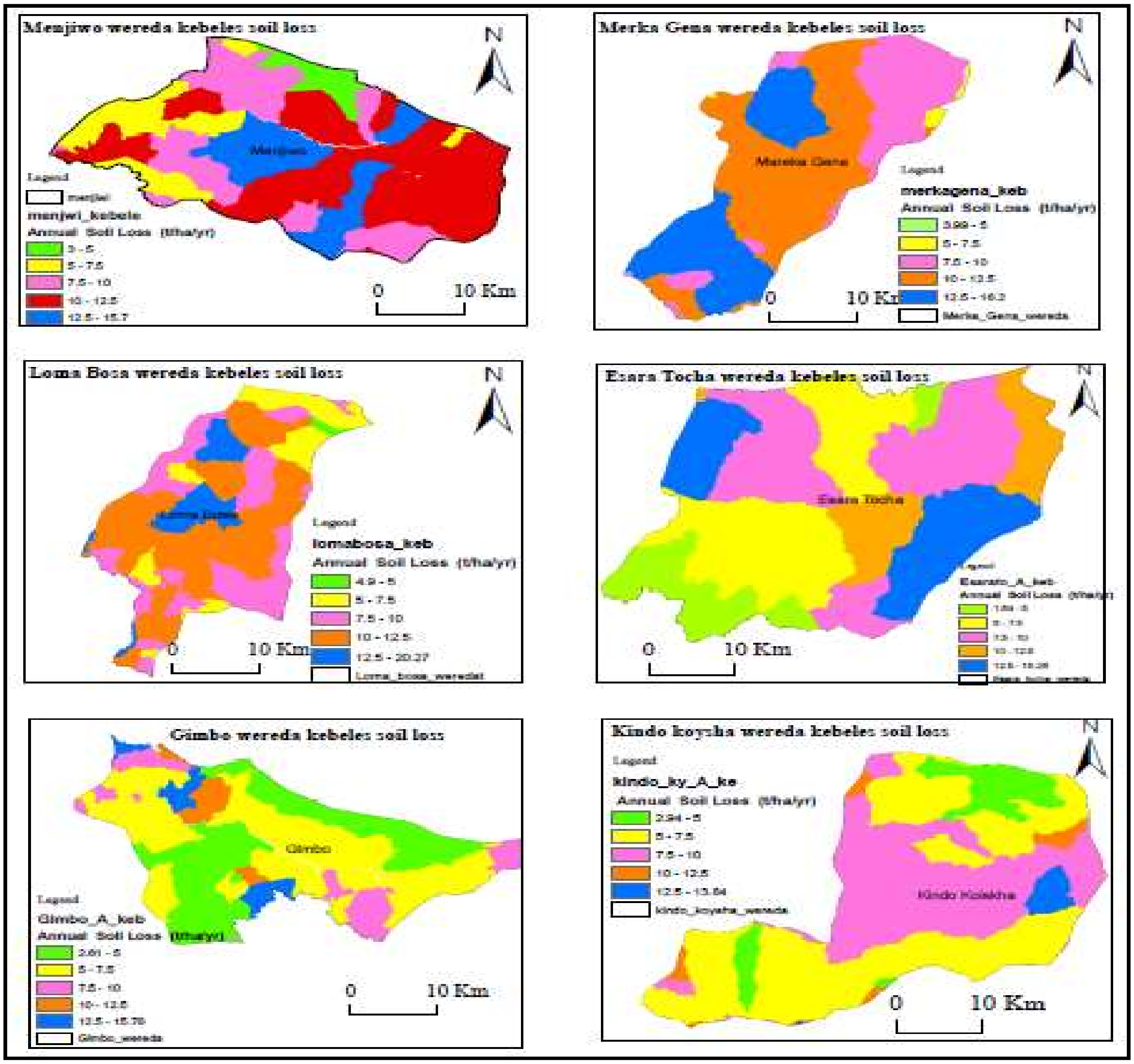

Figure 11. Total annual soil loss of the prioritized six woreda Kebeles

The largest sediment producer Woreda in the study area (i.e. Menjiwo) comprised of 46 Kebeles but 85% of its sediment was produced only by its 20 Kebeles (<50%). Similarly 88% of the total annual sediment of Merka Gena Woreda was generated only by 20 Kebeles (<50%) out of 47. Only one third of the kebeles (33%) produces 78% of the total annual sediment in Loma Bosa Woreda. A similar trend was observed in all of the six analyzed Woredas. Therefore, in terms of mobilizing the limited resources (i.e. material, human, and financial) and implementing appropriate soil and water conservation measures, authorities should focus on these prioritized Kebeles producing the large sediment load reaching to Gibe-III Dam.

CONCLUSIONS

A quantitative assessment annual soil loss was conducted to identify erosion hazard levels and prioritizing erosion prone areas for conservation planning purpose in Gibe – III dam catchment. The general approach involves estimation of individual USLE factors in ArcGIS9.3, preparation of erosion intensity map, and finally identifying and prioritizing erosion prone administrative Woredas and finally Kebeles for conservation planning. The estimated annual soil loss of the study area ranged from 0 – 51.57 tons $ha^{-1}yr^{-1}$ with an annual average of 7.47 tons $ha^{-1}yr^{-1}$. USLE is applied to estimate annual erosion rate integrating the spatially varying erosion rates. Given the study site covers vast area (over $1200km^2$) it is impractical to quantitatively validate it based on field measured data. Previous results of soil loss measured in the study area are not available. However, to avoid applying the model without evaluation, we evaluated the model's performance by comparing its output with results from other research of similar nature and the national average. The national average soil loss is 12 tons $ha^{-1}yr^{-1}$ (Hurni, 1985), estimates in the rift valley (ranging from 5 -50 tons $ha^{-1}yr^{-1}$) (Ali and Hagos, 2016; Meshesha et al., 2012) which all justify our estimated soil erosion rate is acceptable. This approach is reasonable and valid under the circumstances prevailing in our study area.

The potential total annual soil loss of the study area was 9,700,823 tons from 1,298,402 ha. Administrative Woreda level soil loss analysis indicated that out of the total 29 Woredas, 18 Woredas fall under moderate to high priority class. However, Menjiwo, Merka Gena, Loma Bosa, Esara Tocha, Gimbo, and Kindo Koysha were identified as the first largest sediment producers and soil erosion sensitive Woredas which requires immediate attention for soil conservation intervention. The highest sediment producing Kebeles of these Woredas were also identified. Thus, to utilize the limited resources in effective and efficient manner, any soil and water conservation intervention designed should focus these prioritized Kebeles which are at high risk of soil erosion and producing high sediment. Hence, the study demonstrates that the adapted USLE model useful tool to estimate mean annual soil loss over large areas with coarser data. Its use to facilitate sustainable land management through conservation planning is paramount importance.

The sustainability of Gibe - III dam may be depends on the management of its catchment area which provides both water and sediment. Hence, to alleviate the problem of siltation and increase the life span of the dam, proper design and urgent implementation of best management practices in the prioritized Woredas and their Kebeles are proposed. The proposed best management practice includes: in steep slope areas of cultivated lands: introduction of agro-forestry practices, properly designed cutoff drains, waterways, soil bunds, *fanya juu* bunds, and stone bunds; in gentle slope cultivated lands contour farming, grass strips, and multiple cropping systems; and at communal lands and or degraded remote areas: tree planting and area closure in conjunction with moisture improving structures like water collection trenches and micro-basins.

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Upon submission of a manuscript, the authors are required to state that the paper has not been submitted for publication to any other journal or will not be submitted to any other journal. Manuscript submission implies that the author or authors agree to assign copyright to *JSD*. Manuscripts should be written in English, with spelling according to recent editions of the Advanced Learner's Dictionary of Current English (OUP). The font size for the text is 11-point Times New Roman, at exactly 1.5 point line spacing throughout (TNR 11/1.5).

Types of article

Research articles

Research articles should report original research. They should not exceed 6000 words in length, including title, abstract and references; 3-4 tables and 5-6 figures are permitted.

Review articles

Review articles cover recent advances in an area in which an author has been actively engaged. Maximum permissible length is 6000 words, including title, abstract and bibliography, or proportionately shorter if the review includes illustrations.

Short communications

Short communications contain news of interest to researchers, including progress reports on ongoing research, records of observations, short comments, correction and reinterpretation of articles previously published in JSD, *etc*. Maximum permissible length is 1500 words, including title, abstract and references; they may contain not more than two figures and/or two tables.

Book reviews

A critical evaluation of recently published books in all areas of science and development will be published under this column. The maximum permissible length of a book review is 1500 words, including any references.

Format of manuscripts

Research articles intended for submission to the Journal of Science and Development (JSD) should have the following basic structure.

Research articles

Title: The title of the paper, the name (s) and affiliated institutions. Full postal, telephone and email address of the corresponding author should be clearly indicated.

Abstract: The abstract must contain (a) the author's or authors' name(s), (b) the full title of the manuscript, (c) an abstract of not more than 250 words indicating the major aims and findings of the paper.

Keywords: 3-6 keywords should be set below the abstract, arranged in alphabetical order and separated by commas.
Introduction: A brief background of the subject, statement of the problem and the aims of the paper.

Materials and methods: Describe the materials and sites used in the study, the procedures, methods or tools used in data collection and analysis.

Results: Describe the results obtained, cross-referencing between text, tables and figures. When applicable, describe the statistical significance of the results.

Discussion: Give interpretations and implications of the results obtained. Compare your findings with related previous studies. The results and discussion sections may be presented together or separately.

Conclusions: Describe the contribution of the study to knowledge, and indicate future research needs (if any). The conclusion may also be included in the discussion.

References: All literature referred to in the text should be cited as exemplified below.
Acknowledgements: (if required). These should be brief, *e.g.* five lines of text.

Short communications

Short communications should essentially follow the structure given for research articles.

Review articles, book reviews

The structure of these articles will largely be determined by their subject-matter. However, they should be clearly divided into sections by an appropriate choice of headings.

Methods of submission

1. Electronic submission

Manuscripts should be prepared by means of Microsoft Word or an equivalent word-processing program. They should preferably be submitted electronically, by means of the style sheet **JSD_stylesheet.doc**, which can be downloaded from the journal's website. This style sheet consists of two sections:

(1) an *Input section,* into which your final manuscript is pasted from another Word document, and
(2) a *Help section*.

The Help section contains detailed instructions for preparing a manuscript for *JSD*. Please read it before you begin to prepare your manuscript.
Electronic files containing manuscripts should be named according to the following convention:

Authorname_Brief_title.doc, *e.g.* Bloggs_Podocarps_in_southern_Ethiopia.doc,

Where Brief_title is the first 4-5 words of the manuscript's title.

Diagrams should be lettered in a sans-serif font (Arial or Helvetica-at least 12-point), for final reduction to single-column (6.9 cm) or double-column (14.3 cm) width. Single column figures are preferred. Black-and-white diagrams should be submitted as uncompressed TIFF (.tif) files or as .jpg files, at a resolution of 300 dpi. Diagrams created in the default mode of Microsoft Excel (frame, colored background, *etc*.) are not acceptable for publication in *JSD.*

Files containing diagrams should be named according to the following convention: Author name _Figure No xxx.tif, *e.g.* Bloggs_Figure 006.tif

Photographs should be submitted as high-resolution (at least 600 dpi) greyscale (8-bit).jpg or uncompressed .tif files. The desired final size ('1-col', '2-col' or 'landscape') should be indicated. Always send photographs as separate files, using the same filename convention as above.
Photographs as described above are preferred, but clear, glossy black and white photographs (100×70 mm) on photographic paper may also be submitted. They should be clearly numbered on the back in **soft** pencil.

Tables should be prepared in MS Word's Table Editor, using (as far as possible) 'Simple1' as the model:

(Table … Insert … Table … Auto format …Simple 1),

(see JSD_stylesheet.doc for illustration). Tables taken directly from Microsoft Excel are not generally acceptable for publication in *JSD*.

Use Arabic (1, 2, 3 …), not Roman (I, II, III …), numerals for tables. Footnotes in tables should be indicated by superscript letters beginning with 'a' in each table. Descriptive material not designated as a footnote maybe placed under a table as a Note.

Footnotes should be avoided. Wherever possible, incorporate such material in the text, within parentheses.

2. Submission in paper form

Manuscripts may also be submitted on A4paper, subject to the same limits regarding number of words, tables and figures as above. Separate the manuscript into three sections:

(1) **text section**, with figure and table texts at the end;

(2) **figure section** (one figure per page, for reduction to 6.9-cm and 14.3-cmcolumn width); and

(3) **table section** (one table per page). Type the text itself at double line-spacing on one side of the paper only, with top, left and bottom margins set at 2.5 cm. The right margin should, however, be set at 7.5cm, to leave space for reviewers' and editors' comments. Number all pages in sequence, including figures and tables.

The order of headings and sub-headings should be indicated as shown in the style sheet JSD_stylesheet.doc. Keep all levels of heading as short as possible.

Tables, figures and illustrations should be submitted each on a separate page. When a manuscript is submitted in paper form, a CD containing all sections of the paper, including diagrams, is also required. Diskettes ('floppy disks') are not admissible.

Conventions

Scientific names must be italicized. At first mention, the author (*e.g.* (L.)) should be given, but must not be italicized. Use single quotation marks ' ', unless you are giving a quotation within a quotation, in which case use " ' ' " .

Insert … Symbol … Special characters

All data should be given in the metric system, using SI units of measurement.

Use '.' (point) as the decimal symbol. Thousands are shown spaced, thus: 1 000 000.Use a leading zero with all numbers <1, including probability values (*e.g.* $p< 0.001$).

Numbers from one to nine should be written out in the text, except when used with units or in percentages (*e.g.* two occasions, 10 samples, 5 seconds, 3.5%). At the beginning of a sentence, always spell out numbers (*e.g.* 'Twenty-one trees were sampled...').

Use the 24-hour time format, with a colon'**:**' as separator (*e.g.* 12:15 h). Use day/month/year as the full date format (*e.g.* 12 August2001, or 12/08/01 for brevity in tables or figures).Give years in full (*e.g.* '1994–2001', never '94–01'). Use the form '1990s', not'1990's' or '1990ies'.

Use the en-dash – for ranges, as in '1994–2001'

(Insert … Symbol … Special characters En dash).

In stating temperatures, use the degree symbol ' º ', thus ' ºC', **not** a superscript zero ' 0 '.(Insert … Symbol … Normal text),

Define all symbols, abbreviations and acronyms the first time they are used, *e.g.* diameter at breast height (DBH), meters above sea-level (m asl). In the text, use negative exponents, *e.g.* g m-2, g m-2 sec-1, m3 ha-1 as appropriate. Use 'h' for hours; do not abbreviate 'day'.

If possible, format mathematical expressions in their final version (*e.g.* by means of Equation Editor in MS Word or its equivalent in Word Perfect or Open Office); otherwise, make them understandable enough to be formatted during typesetting (*e.g.* use underlining for fractions and type the numerator and denominator on different lines).

References

Please inspect the examples below carefully, and adhere to the styles and punctuation shown. Capitalize only proper names ('Miocene', 'Afar', 'The Netherlands') and the initial letter of the title of papers and books, *e.g.* write 'Principles and procedures of statistics', **not** 'Principles and Procedures of Statistics'. Do not italicize Latin abbreviations: write 'et al.', **not** '*et al.*'

References in the text should use the 'author-year' (Harvard) format:

(Darwin and Morgan, 1993) or, if more than two authors, (Anderson et al., 1993)

(Hartman and Kester, 1975; Anderson et al., 1993; Darwin and Morgan, 1994) chronologically.

References in the list should be in alphabetical order, in the following formats:

Journal article

Kalb J.E. 1978. Miocene to Pleistocene deposits in the Afar depression, Ethiopia. *SINET: Ethiop. J. Sci*. 1: 87-98.

Books

Whitmore T.C. 1996. *An introduction to tropical rain forests*. Clarendon Press, Oxford, 226pp.

Steel R.G.D. and Torrie J.H. 1980. *Principles and procedures of statistics*. 2nd ed. McGraw-Hill Book Co., New York. 633 pp.

Contribution as a chapter in books (Book chapter)

Dubin H.J. and Grinkel M. 1991.The status of wheat disease and disease research in warmer areas. In: Lange L.O., Nose1 P.S. and Zeigler H. (eds.) *Encyclopedia of plant physiology. Vol. 2A Physiological plant ecology*. Springer-Verlag, Berlin. pp. 57-107.

Conference/workshop/seminar proceedings

Demel Teketay 2001. Ecological effects of eucalyptus: ground for making wise and informed decision. Proceedings of a national workshop on the eucalyptus dilemma, 15 November 2000, Part II: 1-45, Addis Ababa.

Daniel L.E. and Stubbs R.W. 1992.Virulenceof yellow rust races and types of resistance in wheat cultivars in Kenya. In: Tanner D.G. and Mwangi W. (eds.). Seventh regional wheat workshop for eastern, central and southern Africa. September 16-19, 1991. Nakuru, Kenya: CIMMYT. pp. 165-175.

Publications of organizations

WHO (World Health Organization) 2005. Make every mother and child count: The 2005 World Health Report. WHO, Geneva, Switzerland.

CSA (Central Statistical Authority) 1991. Agricultural Statistics. 1991. Addis Ababa, CTA Publications. 250 pp.

Thesis

Roumen E.C.1991. *Partial resistance to blast and how to select for it*. PhD Thesis. Agricultural University, Wageningen, The Netherlands. 108 pp.

Gatluak Gatkuoth 2008. *Agroforestry potentials of under-exploited multipurpose trees and shrubs (MPTS) in Lare district of Gambella region.* MSc. Thesis, College of Agriculture, Hawassa University, Hawassa. 92 pp.

Publications from websites (URLs)

FAO 2000. Crop and Food Supply Assessment Mission to Ethiopia. FAOIWFP. Rome. (http://www. fao.or~/GIE WS). (Accessed on 21 July 2000).

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Although proofs are checked before they are sent to the author(s), it is the responsibility of the author(s) to review page proofs carefully, and to check for correctness of citations, formulae, omissions from the text, *etc*. Author(s) should return their corrections within seven (7) working days from the date on which the proofs were sent to them. Failure to do so will cause the paper to be printed as in the page proofs.

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