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EFFECT OF VERMICOMPOST APPLICATION ON POTATO TUBER YIELD AT BULE DISTRICT, HIGHLAND OF GEDEO ZONE, SOUTHERN ETHIOPIA

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Abstract

Ethiopia is known for its high potato production potential though the average productivity compared to other countries is low. Various factors were contributed for its low productivity including soil acidity and unbalanced soil nutrient concentrations which are serious challenges to small scale farmers for crop production in the highlands of Ethiopia. Therefore, the objective of this study was to investigate the effect of vermicompost on potato tuber yield at Bule District, Highland of Gedio Zone, Southern Ethiopia. The treatment consisted of four treatment levels of vermicompost (0 $t.ha^{-1}$, 2.5 $t.ha^{-1}$, 5 $t.ha^{-1}$, and 7.5 $t.ha^{-1}$) laid out in a randomized complete block design with three replications. The following data was collected and discussed. The highest and significant days of maturity (121.67 days), leaf number (78.33), plant height (78.78cm), tuber number (11.12), total tuber yield (33.23 $t.ha^{-1}$, and tuber dry matter percentage (30.26%) were recorded at maximum level application of vermicompost (7.5 $t.ha^{-1}$) in this study. Therefore, 7.5 $t.ha^{-1}$ of vermicompost should be considered for potato production at the study area as it was effective on potato yield particularly highest tuber dry matter percentage.

Keywords: Lime, Potato tuber, Vermicompost, Yield

1 Introduction

Potato (*Solanum tuberosum* L.) is one of the most productive food crops in the world. In volume of world crop production, it ranks fourth following wheat, maize, and rice (Adane *et al*., 2010). The production of potato is expanding at a faster rate than other food crops in developing countries, including Ethiopia. Currently, potato is one of the most common and important horticultural crops in the highlands of Ethiopia both as food and cash crop (Gildemacher *et al*., 2009). The crop has also proved that it has great potential for adaptation to the diverse growing conditions of the tropics where the majority of the developing countries are located. It is an important crop in Ethiopia and plays a major role in national food and nutritional security, poverty alleviation, and income generation. With increasing urbanization in Ethiopia, the use of potato is not only as fresh tubers but also as processed products such as chips, French fries and crisps is rising (Abebe *et al*., 2012). In Ethiopia, the area coverage is reached 66,923.33 *ha* and harvesting 921,403.185 tons with involving of 1,197,018 householders (CSA, 2016/17). But national average yield of potato is 13.7 $t.h^{-1}$ (CSA, 2016/17), which is below the world average production 17.7 $t.ha^{-1}$ (FAO, 2010). Among African countries, Ethiopia has possibly the greatest potential for potato production but average productivity is low compare to other country. Some of the

challenge includes: narrow genetic basis of potato varieties, inappropriate agronomic practices, soil nutrient depletion and soil acidity, moisture stresses, diseases, insect pests, poor seed quality, shortage of seed tubers of improved potato varieties, and susceptibility to diseases. Among others soil acidity is the major constraints of potato production in the country (Alemayehu *et al*., 2015).

Acid soils limit crop production on 30 to 40% of the world's cultivated land and up to 70% of the world's potentially arable land (Haug, 1983). It is becoming a serious challenge to small scale farmers for crop production in the highlands of Ethiopia (Kiflu *et al*., 2016). Currently, it is estimated that about 40% of the arable lands of Ethiopia are affected by soil acidity (Taye, 2007).

Vermicompost (VC) was reported to increase the pH of acid soils and improve soil fertility by supplying essential plant nutrients (Materechera, 2012). Similarly, Wael *et al*. (2011) reported that VC can be used to increase the pH in acidic soils and reduce Al and Mn toxicity due to its alkalinity properties. It has been reported that application of VC increases the supply of easily assimilated as well as micronutrients to plants besides mobilizing unavailable nutrients into available form (Zeinab *et al*., 2014). Vermicompost contains high levels of total and available N, P, K (Tesfaye, 2017), stimulates microbial activities and growth regulators (Chaoui *et al*., 2003). Generally, VC can improve seed germination, growth and yield of crops (Nagavallemma *et al*., 2004). There is an increasing interest in the potential use of VC as soil amendment, where the addition of VC improves the soil physical and chemical properties (Angin *et al*., 2013; Lordan *et al*., 2013). Continuous and adequate use of VC with proper management can increase soil organic carbon (OC), soil water retention and permeability (Mahdavi *et al*., 2007) and increase yield of potato. Abdullah (2008) also figured out increased levels of vermicompost reclaim the soil and increase the yield of potato in South America. With continuing consumer concerns related to food quality and safety, as well as the chemicals used in food production, the demand for organic products is gradually increasing all over the world (Gaurilcikiene *et al*., 2008). For organic potato producers one of the main challenges is nutrient management.

Soil acidity limits or reduces crop production primarily by impairing root growth as a result of the toxicity to roots of high concentrations of soluble aluminum (Tisdale *et al*., 1985). Moreover, low pH enhances the fixation of P through sorption by forming compounds with Al and irons. Hence, it is a serious threat to crop production in most highlands and a major crop production constraint in the small-scale farmers of the country. Based on the problem that soil acidity causes on a larger areas in Ethiopia, it needs due attention to be addressed by different coping mechanisms (Mesfin, 2007).

In Ethiopia there is limited research finding on effect of vermicompost on growth and yield of potato. Therefore, it is time to apply this golden in the garbage (vermicompost) to solve soil problems and increase yield of potato at study site as well as elsewhere similar environment in Ethiopia. Therefore, the objective of this research was to investigate the effect of vermicompost on potato tuber yield of potato at Gubato village of Bule District, Highland of Gedio Zone, Southern Ethiopia.

2 Materials and Methods

2.1 Description of the Study Area

The experiment was conducted under rain fed condition during the rainy season of 2019 cropping season at Gedeo zone, Bule District. Bule District is among the six Districts in the Gedeo Zone of SNNPR. It is located at 117 *km* from the region's capital and 27 *km* from the Zone's capital Dilla. Bule District is bordered on the south, East and west by Oromia region and on the north by Sidama zone. The District has a total area of 27,300 *ha*, with its altitude ranging between 2,001–3,000 meters above sea level (masl). It comprises 32 villages (three town administration village), of which 70% have a dega agro-ecology, while the remaining 30% can be characterized as woyina dega (mid altitude) agro-ecology. The area lies between 6°04′16″ and 6°23′50″ N latitude and

from 38°16′20″ to 38°26′11″ E longitude. Mean annual rainfall of the wereda is 1600mm, with minimum and maximum temperature of 12.6 °*C* - 20 °*C*. (Bule woreda BOA, 2017). The dominant soil type of the study area is Nitisols (Tarekegn, 2008).The land use system of the study area is a mixture of crop farming and agroforestry system.

2.2 Soil Sampling and Analysis

Soil sampling was done before sowing. The sampling was done on farmer's lands of Gubato village of Bule district for evaluation of some physicochemical properties in 2019. The villages were selected on the basis of crop produced there. Before investigation of this research, a soil sample was taken and analyzed. Soil samples were collected by auger from 0 to 30 cm depth in zigzag pattern and a composite sample were done. All the soil analysis was undertaken according to standard laboratory procedures.

Soil particle size distribution was analyzed by the Bouyoucus hydrometer method (Bouyoucos, 1951). Soil bulk density (ρ_b) was measured from undisturbed soil samples collected using a core sampler as per the procedure described by Jamison *et al*. (1950), while particle density (ρ_s) was measured using pycnometer (Barauah and Barthakulh, 1997). Total porosity (ϕ) was calculated from the values of ρ_b and ρ_s (Brady and Weil, 1996) as:

$$\phi = (1 - \frac{\rho_b}{\rho_s}) * 100$$

Soil p*H* was measured potentiometrically in 1:2.5 soils: H_2O solution using a combined glass electrode p*H* meter (Chopra and Kanwar, 1976).

Total exchangeable acidity was determined by saturating the soil samples with 1 M *KCl* solution as described by Rowell (1994). From the same extract, exchangeable *Al* in the soil samples was determined by application of 1 M *NaF*. Acid saturation (AS) was calculated from exchangeable acidity and CEC Rowell (1994).

$$\text{AS} = \frac{Exchangeable\ acidity\ (cmol\ c\ kg^{-1})}{CEC\ (cmol\ c\ kg^{-1})} * 100$$

Where: AS = Acid saturation, CEC = Cation exchange capacity

Organic carbon (O*C*) content of the soil was determined by the wet combustion procedure of Walkley and Black (1934) and OM% was obtained by multiplying O*C*% by 1.724. The total nitrogen (*N*) content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Available *P* was extracted by the Bray II method (Bray and Kurtz, 1945). Potassium (*K*) was determined by saturating the soil samples with 1M NH_4OAc solution at p*H* 7.0 and was measured by flame photometer from the same extract. The cation exchange capacity (CEC) of the soil was determined from the NH_4^+ saturated samples that was subsequently replaced by *K* from a percolated *KCl* solution (Chapman, 1965).

2.3 Vermicompost Analysis

Vermicompost was brought from Hawassa Research Center. It was prepared from raw materials such as cow dung, sheep and goat feces, dried chopped maize residues and chopped grasses by using red worm (*Eisenia fetida*). Selected parameters of VC was determined using dried samples which was ground to pass through a 2 mm sieve as described by Pisa and Wuta (2013).

p*H* was determined from a suspension of 1:10 VC: H_2O as described by Ndegwa and Thompson (2001). The total O*C* was estimated by wet combustion procedure of Walkey and Black (1934). Total OM% was obtained by multiplying total O*C*% by 1.724 (Emeterio and Victor, 1992). The total *N* content of the VC was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Total *Ca*, *Mg*, *K*, and *Na* was extracted by wet digestion using concentrated sulphuric acid (H_2SO_4), selenium (*Se*) powder, lithium sulphate (Li_2SO_4), and hydrogen peroxide (H_2O_2) mixture (Okalebo *et al*., 2002). Total *Ca* and *Mg* were determined from the wet digested samples by AAS while *K* and *Na* were estimated by flame photometer. Total *P* was extracted using concentrated H_2SO_4, *Se* powder, salicylic acid ($C_7H_6O_3$), and H_2O_2 mixture (Okalebo *et al*., 2002).

2.4 Treatments, Experimental Design, and Procedures

This article was emanated from the main effect of vermicompost of the following treatments of the research implemented. The research was carried out on farmer's land of Gubato village, Bule District.

Land preparation was carried out well in advance before planting the potato tuber. The experimental field was prepared following the conventional farmers' practices. The field was oxen ploughed three times before sowing.

The seed bed was prepared by ploughing and harrowing using oxen and then was leveled manually. The experiment was laid out in factorial randomized complete block design with three replications; the plot size was 4.25m by 2.6m (11.05m^2).

Four rates of vermicompost (0, 2.5, 5, and 7.5) were used as treatment. Potato variety of Gudene was used with intra and inters row spacing of 35cm and 70cm, respectively. The distance between adjust plots and blocks were 0.6m and 1m respectively.

Each plot had 6 rows and each row had 7 potato plants. There were a total of 42 potatoes per plot. The potato was purchased from the farmers produce Gudane variety. One month prior to planting, vermicompost was applied in the plots and thoroughly incorporated into the soil. All agronomic practices such as weed control, earthing up and disease and insect inspection were done regularly.

2.5 Data Collections and Measurements

The data collected were crop phenology, growth parameters, tuber yield and yield components of potato.

a. Crop phenology

Days to maturity: days to maturity was recorded when 75% of the plants in plots are ready for harvest as indicated by senescence of leaves and haulms. The days were counted from date of planting to maturity of the crop.

b. Growth parameters

Plant height (cm): refers to the height from the base to the apex of the plant. It was measured using a measuring tape at 50% flowering from the main stem originating directly from mother tubers to the apex of the plant by taking five sample plants from each plot. Mean value of height measurements was then taken.

Leaf number: It was determined by counting from five plants at 50% flowering. Mean number of leaves was then used.

c. The tuber yield and yield component of potato

Tuber number per hill: refers to the number of tubers per plant and it was taken from five plants during harvest in each plot. Mean number of tubers was then taken for the analysis.

Total tuber yield: This was recorded from the weight (in kg) of total tuber per plot. The data were taken from plants in the net plot area at harvest.

Dry matter Content (%): Five fresh tubers were randomly selected from each plot and weighed. The tubers was sliced and dried in oven at 70 $^{\circ}C$ until a constant weight was obtained. The dry matter percent was calculated using the following formula (Tekalign, 2011)

$$\text{Dry matter content } (\%) = \frac{\textit{Dried tuber yield}}{\textit{Fresh tuber yield}} * 100$$

2.6 Statistical Analysis

Data on soil physicochemical properties, growth and yield components of potato tuber were subjected to analysis of variance (ANOVA) (SAS, 2009). Significant differences between treatment means were separated using the Least Significance Difference test at 5% level of significance for the parameters showed significance difference between treatments.

3 Results and Discussions

3.1 Soil Physico-chemical Characteristics of the Study Sites

The result of textural class determination of composite soil sample taken before treatment with vermicompost showed that the study site was clay soil as presented in Table 1. The bulk density of the soil was high which could limit plant growth due to restriction of root penetration in clay soil (Jones, 2003). Due to the high bulk density value, the total porosity of the soil was relatively high. The percent of O*C* and T*N* were 1.47 and 0.50, respectively. As per rating of Tekalign (1991), soil samples percent of O*C* of the study area qualified in the range of 0.5-1.5% which is low organic carbon. Hence, the present study revealed low soil organic carbon. In comparing with the rating of Murphy (1968), the percent of T*N* qualified as medium in soil total nitrogen. Long term cultivation without organic fertilizers leads to a decrease in soil O*C* and total *N* contents (Alexandra, *et al.* 2013).

Table 1 Soil physical and chemical characteristics of experimental site before sowing potato tuber

Soil Properties	Value	Status	Remarks
Physical property			
Sand (%)	25	Low	
Clay (%)	45	High	
Silt (%)	30	Moderate	
Textural class	Clay		
Bulk density ($g\,cm^{-3}$)	1.36		
Particle density ($g\,cm^{-3}$)	2.35		
Total Porosity	42.13		
Chemical property			
Soil pH H_2O	4.80	Strongly acidic	Marx *et al*., 1999
OC (%)	1.47	Low	Tekalign, 1991
TN (%)	0.50	Medium	Murphy, 1968
Av. K *cmol* (+) kg^{-1}	1.04	Low	Marx *et al*., 1999
C:N	2.49		
Av. P ($mg.kg^{-1}$)	13.75	Low	Marx *et al*., 1999
CEC *cmol* (+) kg^{-1}	14.80		
Ex. Acidity ($meq\ 100g^{-1}$)	5.72		
Ex. H^+ ($meq\ 100g^{-1}$)	1.90		
Ex. Al^{3+} ($meq\ 100g^{-1}$)	3.01	High	

Where: OC, organic carbon; TN, total Nitrogen; Av. K, Available Potassium; C, Carbon; N, Nitrogen; Av. P, Available Phosphorus; CEC, Cation Exchange Capacity; Ex. H^+, exchangeable Hydrogen ion; Ex. Al^{3+}, exchangeable Aluminium ion.

The measured soil pH of the study site was 4.8. This indicated that the soils are strongly acidic. The available phosphorus content was 13.75 $mg\,kg^{-1}$. Based on the rating of so available Phosphorus suggested by Ethio SIS (2014), the study site qualified (< 15 $mg\,kg^{-1}$) as very low. The low content of available P is common characteristic in most of the cultivated and acidic soils of Ethiopia (Tekalign, 1991). The available K of the study site was 1.04 *cmol* (+) kg^{-1}. As per rating suggested by Marx *et al*., (1999), the

study site qualified as low in available K. The CEC, Ex. H^+, Ex. Al_3^+ and Ex. acidity of soil of the study site was 14.8 $cmol$ (+) kg^{-1}, 5.27, 1.9 and 3.46 meq 100 g^{-1}, respectively. In general, from the results of soil analysis before treatment of lime and vermicompost clearly indicated that the soil of the study site had soil fertility problems and soil acidity that limited successful growth and production of tubers or crops. This calls for development of appropriate management practices that enhance tuber or crop production.

3.2 Vermicompost Analysis

The analyzed chemical character of VC was pH: 7.26, OC: 13.69%, OM: 23.60, total N: 1.40%, available P: 4.78 $mg\,Kg^{-1}$, and exchangeable K: 9.12 $cmol$ (+) kg^{-1} (Table 2). This indicated as VC had high nutrient that can increase soil fertility and create suitable environment for beneficial soil micro-organisms that suit plant growth. These VC also increases soil fertility without polluting the soil, as well as the quantity and quality of crops. Similarly, Singh *et al*., 2011 indicated as VC is used as a soil activator, soil conditioner, and soil fertility booster with all required plant nutrient, Vitamins, enzymes, growth hormones and beneficial micro-organisms.

Table 2 Chemical properties of Vermicompost (VC)

	Chemical Properties of Vermicompost						
	p$H\ H_2O$	OC (%)	OM (%)	TN (%)	Exc. K $cmol$ (+) kg^{-1}	C:N ratio	Av. P ($mg.kg^{-1}$)
Value	7.26	13.69	23.60	1.40	9.12	9.78:1	4.78

Where: OC, organic carbon; OM, organic matter; TN, total nitrogen; Exc. K, exchangeable potassium; C, Carbon; N, Nitrogen; Av. P, available phosphorus

3.3 Effect of Vermicompost on Phenology and Growth of Potato

Analysis of variance showed that vermicompost treatments had significant effect on the 75% day's to maturity. As indicated in table 3, minimum days (110.44) and maximum days (120.67) to maturity was recorded. The minimum days to maturity were due to lack of enough nutrient supply that leads a crop to senescence. Prolonged maturity in response to increasing rate of vermicompost may be ascribed to the availability of optimum nutrients contained in vermicompost contribution through enhanced leaf growth and photosynthetic activities, thereby increasing in synthesis of photoassimilate, which was further utilized in building up of new cells, and prolonged maturity of potato. This is because of application of vermicompost makes the plant to use more environmental factors during the growth period and thus obtain optimal conditions for the photosynthesis process (Jayanthi *et al*. 2002).

Significant variation was obtained among different vermicompost level on leaf number of potato. The lowest leaf number (63.48) was recorded with nil applications of vermicompost, while the highest leaf number (78.33) at the maximum levels of vermicompost (7.5 $t.ha^{-1}$) application was recorded. In agreement with this, Mohamed *et al*., (2017) reported that increased levels of vermicompost increased the leaf number of potato. This is due to the ability of humic substances (HS) found in mineral-organic materials stimulates growth of numerous plants part by encouraged nutrient and water uptake (Theunissen *et al*., 2010; Chen *et al*., 2004; Nardi *et al*., 2002). Because of vermicompost contains essential nutrients in plant-available forms, enzymes, vitamins and plant growth hormones (Borah *et al*., 2007), leaf number is increased.

Table 3 Effect of vermicompost on 75% day's to maturity, leaf number, and plant height of potato

Factors	Treatment	75% day's to maturity	Leaf number	Plant height (cm)
Vermicompost	0	110.44^{d}	63.48^{d}	49.78^{d}
($t.ha^{-1}$)	2.5	114.00^{c}	70.33^{c}	62.40^{c}
	5	117.78^{b}	74.71^{b}	70.62^{b}
	7.5	121.67^{a}	78.33^{a}	78.78^{a}
LSD (0.05)		1.09	2.93	2.21
CV		0.96	4.18	3.46

3.4 Effect of Vermicompost on Tuber Yield and Yield Components

The number of potato tuber per hill was significantly increased due to the application of vermicompost (Table 4). Increasing vermicompost is improving the physical conditions and vital processes of the soil which makes the nutrients such as nitrogen, phosphorus and potassium, and plant growth promoters and vitamins (Vitamin B12) more accessible to the plants, which will increase the number of tubers and yield of the plant (Monaghesh *et al*,. 2015). Ajudan *et al*. (2005) showed that with increasing of organic fertilizer up to 20 tons per hectare, potato yield increased. This indicates the importance of using organic fertilizers in increasing potato tuber yield and also the sensitivity of this plant to improvements of the physical properties of the soil.

A significant difference was found on potato tuber yield. This implies how total tuber yield was affected by vermicompost (Table 4). The maximum total tuber yield (33.23 $t.ha^{-1}$) was recorded with application of maximum level of vermicompost (7.5 $t.ha^{-1}$), while the minimum total tuber yield (27.31 $t.ha^{-1}$) was recorded without application of vermicompost. In line with this, Joshi *et al*., (2015) also figured out the increased tuber yield of potato due to increased rate of vermicompost application that have high porosity, aeration drainage and water-holding capacity which had positive effects on tuber development and total yield. Similarly, Osvalde *et al*. (2016) reported that using peat and vermicompost in organic potato production system enhanced *P* uptake that contribute for the tuber yield of potato. In acidic soils with high levels of exchangeable *Al*, organic matter (OM) in vermicomposts plays a significant role in the reduction of *P* adsorption site of soil and increased *P* availability due to cumulative effects of several mechanisms (Opala *et al*., 2010). These include release of organic *P* from decaying residues, blockage of *P* adsorption sites by organic molecules released from the residues, a rise in soil p*H* and complexation of soluble *Al* and *Fe* by organic molecules (Iyamuremye and Dick, 1996). These contribute for the increment of potato yield and yield components.

Dry matter percentage revealed significant differences between the various vermicompost treatments (Table 4). The lowest tuber dry percentage (28.03) was recorded in the control treatment (0 $t.ha^{-1}$). The mean dry matter percentage ranged between 28.03 to 30.26%.The highest tuber dry percentage (30.26%) was obtained with the application of 7.5 $t.ha^{-1}$ which was followed by the application of 5 $t.ha^{-1}$, and 2.5 $t.ha^{-1}$. The vermicompost may have essential nutrients that increase tuber dry matter. This revealed that quality produce of potato was recorded. Similarly, Mohamed *et al*. (2017) reported that increased levels of vermicompost increase dry matter content of potato tuber. Stimulation of root growth (initiation and proliferation of root hair), increased root biomass, enhanced plant growth and development have been reported with the application of vermicompost, because of the presence of humic acids (Suh *et al*., 2014).

Table 4 Effect of vermicompost on tuber number, tuber yield, and tuber dry matter percentage of potato

Factor	Treatment (level of vermicompost)	Tuber number per hill (No.)	Total tuber yield ($t.ha^{-1}$)	Dry matter (%)
Vermicompost	0	9.54^{d}	27.31^{c}	28.03^{d}
($t.ha^{-1}$)	2.5	10.01^{c}	29.76^{b}	28.70^{c}
	5	10.57^{b}	32.04^{a}	29.50^{b}
	7.5	11.12^{a}	33.23^{a}	30.26^{a}
LSD (0.05)		0.25		0.23
CV		2.49	5.09	0.81

4 Conclusion

At highland of Ethiopia, potato productivity is low due to unbalanced nutrient and soil acidity. The objective of this research was to investigate the effect of vermicompost on potato tuber yield at Gubato village, Bule Wereda, Gedio Zone, Southern Highland of Ethiopia. The result of soil sample taken before plough showed as the study area had the problem of low soil fertility and strong acidity. The treatments used for this study were four rates of vermicompost (0, 2.5, 5, and 7.5 $t.ha^{-1}$) that laid out in randomized complete block design with three replications. Increased levels of vermicompost had significantly a stimulating effect on days to maturity and, growth, tuber yield and dry matter percentage of potato. The result of analysis indicated that the highest and significant days of maturity (121.67 days), leaf number (78.33), plant height (78.78cm), tuber number (11.12), total tuber yield (33.23 $t.ha^{-1}$, and tuber dry matter percentage (30.26%) were recorded at maximum level application of vermicompost (7.5 $t.ha^{-1}$) in this research. Though the result of potato tuber yield at application of 5tha-1 was not significantly different from the result obtained due to 7.5 $t.ha^{-1}$ of vermicompost application, the tuber dry matter percentage was significantly different. From this study, it was concluded that vermicompost is good organic fertilizer to obtain good yield of potato tuber. Therefore, 7.5 $t.ha^{-1}$ of vermicompost should be considered for potato production at the study area as it was effective on potato tuber dry matter percentage and soil amendment.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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E J E D

DETERMINANTS OF ADOPTION OF INTRODUCED LAND MANAGEMENT PRACTICES IN SANA WATERSHED, SOUTHERN ETHIOPIA

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Abstract

In Ethiopia, soil erosion is a severe problem and a major cause of the decline of land productivity. A number of soil and water conservation practices were introduced in south central highlands of Ethiopia to combat land degradation and for sustainable land management. However, the adoption of these practices is far below the expectation. The objective of this study was to examine factors affecting adoption of introduced land management practices in Sana watershed, Southern Ethiopia. Mixed research design methods were employed in order to conduct this study. Questionnaires, focus group discussion, in-depth interview and field observation were used to collect data. A binary logistic regression model was employed to analyze the collected data and to interpret the result. The result showed that sex of house hold heads, education status of house hold heads, access to extension services and training were positively correlated at significant level with the adoption of the introduced land management practices. On the other hand, the age of house hold heads, and distance of farmlands from home steads influenced the adoption of introduced soil and water conservation practices negatively. The finding showed that the identified environmental, demographic, economic, and institutional factors influence the adoption of land management practices. This implies that the regional and local administrates should consider these factors to improve farmers' acceptance of introduced land management practices and to promote agricultural productivity and environmental quality. Extension and training services on the introduced land management practices for the farmers and agricultural extension service workers should also considered by the regional and local administrates.

Keywords: Adoption, Land management, Sana Watershed, Soil Erosion

1 Introduction

The primary development goal, which is sustainable economic development of the Ethiopian government, is to achieve food security and eradicate poverty (Kharioet *al.*, 2016). While the agricultural sector has to provide commodities for domestic food consumption, supply raw materials for agro-industries and export, increase income of farm households and create expanded demand for manufactured products; the performance of Ethiopian agriculture has remained weak. Despite its importance, the performance of agricultural sector in Ethiopia has been unsatisfactory compared to the rapid population growth, for instance, the average growth rate of agricultural sector from 1982-1996 was 2.27%. This probably leads the country to have considerable food insecurity (Getaye, 2020).

Soil erosion is a global problem and considered

as one of the major issues in many countries (Berberoglu *et al*., 2020) and is a serious problem in Ethiopia (Dabi *et al*., 2017). Different soil and water conservation technologies were implemented for combating soil erosion and nutrient depletion, improving water conservation and enhancing soil and water productivity and rehabilitating degraded areas (Berberoglu *et al*., 2020). The Ethiopian farmers have long been aware of soil erosion problems and devised techniques to halt soil erosion and to conserve land resources, as part and parcel of agricultural systems (Assefa and Hanns, 2014). However, soil and water conservation practices have not been adopted and sustainably used by the farmers (Betru, 2002; Fitsum *et al*., 2002; Yeraswork, 2000).

The common land and soil degradation problems are observed in south central highlands of Ethiopia especially in the highlands of Kambata Tambaro, Wolaita and Hydiya zones. This study is undertaken to assess farmers' use of introduced and indigenous soil and water conservation interventions in the Sana middle watershed in the SNNPR. This area is among the most densely populated areas in the country with 573 persons per square kilometer (PCC-FDRE, 2008) and has steep slope topography that leads high run off during intense precipitation. Furthermore, due to long historic agricultural practices and lack of appropriate soil and water conservation practices, a number of agricultural lands, forest area, range lands, sloppy areas and grazing lands are seriously damaged.

Currently, the Ministry of Agriculture of Ethiopia has Growth and Transformation program to involve rural communities living in highly degraded and drought prone areas in soil and water conservation and afforestation practices (MoA, 2003). These practices were also implemented in the study area. In addition to government efforts, local NGO, namely KMG (Kambati Menti Gezima) has made different conservation measures like fanya juu, soil bunds, area closures, and planting different types of trees on farmlands.

Most of farmers of the study area were involved in the implementation of the soil and water conservation programs. However, the programs have not been successful in a meaningful and sustainable manner due to low adoption of farmers to the practices to alleviate soil erosion problem on their farmlands and degraded lands. Moreover, the implementation rate of the soil conservation practices was very low since the farmers resist accepting and applying the introduced land management practices effectively and continuously. Hence it is very important to study the main factors and problems related with the application of introduced land management programs. Therefore, this study is to explore demographic, economic, institutional, and environmental factors that influence households' introduced land management practices.

2 Materials and Methods

2.1 Description of the Study Area

The study watershed is located in SNNPR; in *Kambata Tambaro zone HaderoTunto zuria Wereda*. Astronomically, the study area is located between 7°9′00″N - 7°19′30″N latitude and 37°34′30″E - 37°43′30″E longitude (Figure 1).

According to south nation nationalities Bureau of Finance and Economic Development (SNNPR BFED, 2019) the study area has three agro ecological zones - *Dega, Weyna Dega*, and *kola*, which cover 17.39% and 57% and 13.04%, respectively. The Watershed is characterized by rugged topography, which comprises mountains, plains, and plateaus and its altitude ranges from 782m to 2810m above mean sea level (Figure 1). Its mean annual temperature and total annual rainfall is about 26°*C* and 850-1400mm respectively (SNNPR BFED, 2019). The main rainy season in the area is summer (*Kiremt*) that ranges from June to August with maximum rain fall and two minimum rainy seasons spring (*Tsedy*) and Authomn (*Mekar*) with little rain fall. The dry season (*Bega*) in the area is mostly from October to February (Hadero Tunto Zuria wereda agricultural and Rural Development office (HTZWARDO), 2019).

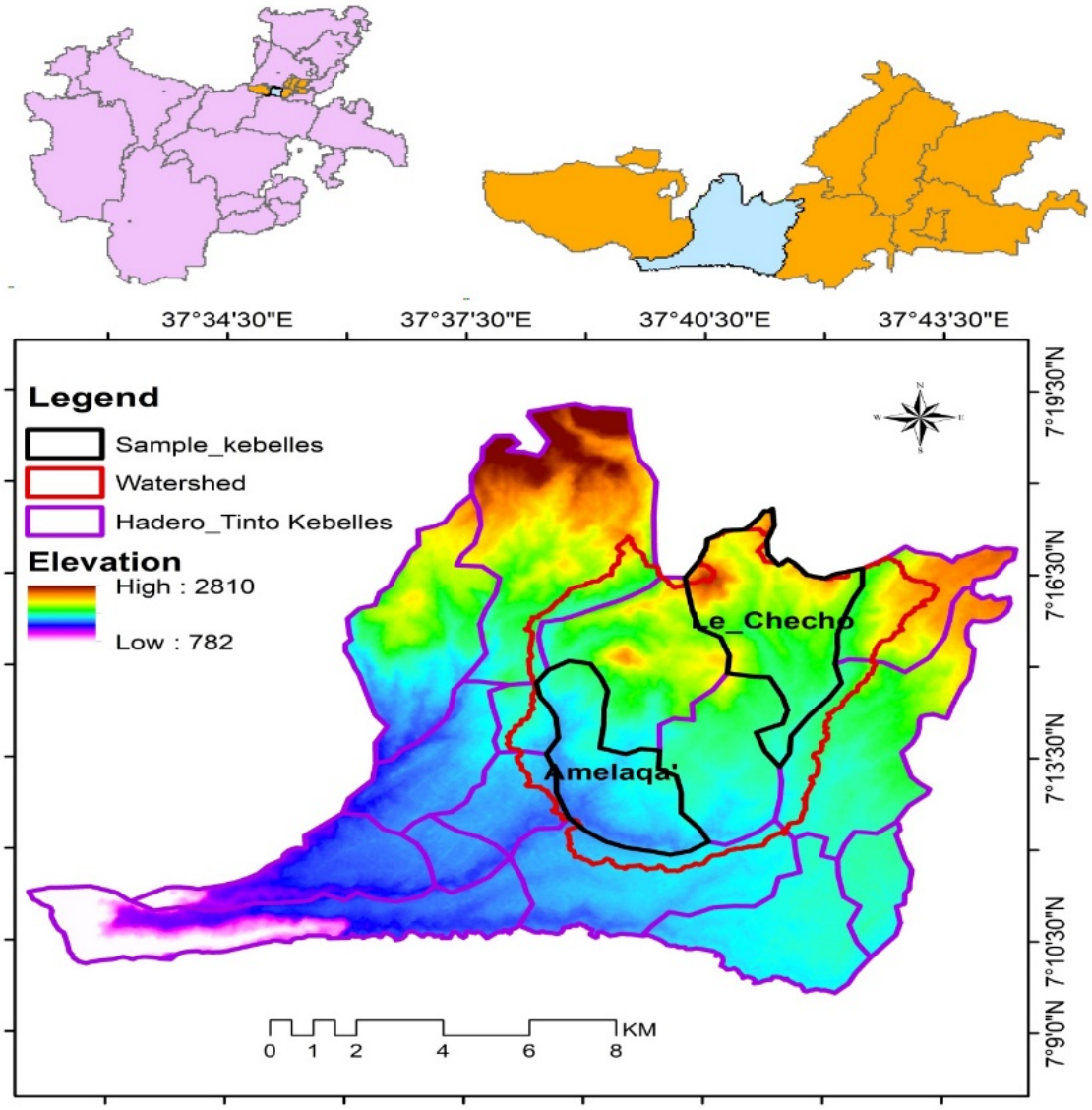

Figure 1 Map of the Study Area

2.2 Research Design and Methodology

Mixed research design approach was employed in this study. Among the different types of mixed research methods, concurrent or parallel approach was implemented. The quantitative research method enabled the researchers to collect data on all quantified relationships between adoption of introduced soil and water conservation practices and factors (household characteristics, and socioeconomic, institutional, and physical factors) affecting it. Qualitative research method was used to collect and analyze qualitative data which were used to strengthen and bridge the gap in quantitative research method.

2.3 Data Source and Data Collection Techniques

Questionnaires, in-depth interview, focus group discussion and field observation were used as the foremost primary data collection methods. The questionnaire included both closed and open-ended ques-

tions. It enabled the researchers to collect data from representative sample household farmers. In-depth interview was conducted with key informants who were considered knowledgeable about the general situation of soil and water conservation practices. In addition, the secondary data were gathered from the annual report of the related offices such as Soil and Water Conservation manuals, different written documents, books, and statistical data about the physical and socio-economic conditions of the study area.

2.4 Sampling Technique and the Sample Size

Getting representative and reliable information and drawing important conclusions about the study employing sound methodologies are a pre-requisite. Thus, the researchers used both probability and non-probability (purposive) sampling techniques. Simple random sampling technique was used to select farmers from the Sana watershed who adopted the introduced land management practices. Out of the total six *kebeles* of the watershed, two of them were purposively selected; namely *Le-checho* kebele and Amelaqe *kebele*. These kebeles were selected because they are relatively considered more degraded areas than the rest of the *kebele's* of the watershed due to their higher slope range. As a result, intensive land management intervention practices were exercised by local NGO, namely *KMG* and the government to rehabilitate degraded lands. The farmers in the areas were selected proportionately based on population size of the Kebele and their practice of adopted introduced land management.

The sample size of the respondents was determined by (Yamane, 1967) sample size determination formula. From the total 1830 household heads in the sample kebeles, 95 respondents constituted the sample size. Finally, proportional numbers of sample respondents were taken from each sample Kebeles. Key informants were selected purposively from the woreda agricultural experts, agricultural extension workers, local NGO (KMG) and kebele administrators. Based on data saturation, 7 key informants were employed. Ten knowledgeable participants were purposely selected for focus group discussion.

2.5 Data analysis and Interpretation Methods

There are different factors that determine the application of introduced land management practices. These factors can be categorized under demographic, economic, institutional, and environmental factors. In this study such factors as educational level, age, sex, households' contact with development agents, land holding size, household size, and training, distance of farmland from home, slope, annual income and access to credit are assumed to be potential determinants of application of introduced land management practices.

An attempt is, therefore, made to find out the relationship between these factors and introduced land management practices in the study area. Binary logistic regression model was applied to analyze the relationship between independent and dependent variables using SPSS 20.0. The dependent variables predict the presence or absence of characteristics or outcomes based on the value of a set of predictors or independent variables.

Before proceeding to the analysis, model fitness was considered for introduced land management practices. The fitness of the model for application of soil bund was Cox and Snell (R^2 = 0.652) and the Nagelkerke (R^2 = 0.946). The Nagelkerke value (R^2) explained that 94.6% of soil bund application has relationship with the independent variables in the model.

3 Results and Discussions

The major factors that influenced adoption of soil bund practices in Sana watershed were identified by analyzing the dependent variable (adoption of introduced land management practices) against 11 explanatory variables and the results were presented as hereunder.

Household characteristics and adoption of introduced land management practices

Among house hold characteristics, the age of the household head influenced the adoption of intro-

duced land management practices. One-unit increase in the age of farmers is found to have decreased odds of introduced land management practices by the factor of 0.233 and the result is statistically significant ($p < 0.05$) (Table 1). The negative and significant relationship could be explained that older farmers are influenced by labor shortage which can be a hindrance to practicing introduced land management. This is inconsistent with previous study conducted by Chomba (2004) which showed the age of farmers to have positive and significant influence on implementation of introduced soil and water practices.

Educational status of farmers has a predictive power in explaining implementation of introduced land management practices. Holding other repressors constant, a change in household head education level by one unit, say one grade, increases the probability of introduced land management practices by the factor of 3.017. This result is statistically highly significant ($p < 0.05$) (Table 1). The finding of positive association between household heads educational status and introduced land management practices is similar to the findings by Habtamu (2006), which identified educational status of farmers has positive influence on farmers' decision to retain introduced soil and water conservation structures. And also another study carried out by Krishna *et al.* (2008) indicate that education of the household head was found to have a positive and significant influence on the application of soil and water conservation strategies. This indicated that the higher educate level of household head increase their ability to find information.

Sex of the household heads is positively correlated with the adoption of introduced land management practices. Most of the land management practices require more labor force. Hence, male headed households are expected to spend much more time and labor in engaging on land management practices than female headed households. As logistic regression analyses indicated, the sex of the household head is positively and significantly affects the decision to use land management practices. Taking female headed households as a reference group, the odds of implementing introduced land management practices among male headed households was 2.625 times or more likely greater than that of the female headed households. This result is statistically highly significant ($p < 0.05$) (Table 1). The finding is in conformity with the assumption that male headed households are more likely to practice land management than female headed households. The result is consistent with (Krishna *et al.* 2008) that showed that male headed households have a higher chance to be involved in the use of SWC technologies than women. This might be due to the fact that Physical structures that were constructed are highly labor intensive and cannot be undertaken by women alone.

The household with larger size are supposed to be better in undertaking different land management practices since they are less likely to have shortage of labor which is required to do land conservation activities. Consistent with this expectation, logistic regression analysis indicates that there is significant relationship between number of household sizes and application land management. This implies that, as family size increases by one person, the likely for land management practices increases by a factor of 4.367. This result is statistically highly significant ($p < 0.05$) (Table1). This shows that the presence of sufficient size of labor force in a household is an important requirement for the application of land management practices. This result is similar with the survey result of Eleni (2008) that was conducted at Tulla District, Ethiopia, which state that household size could have a positive and significant relation with implementation of soil and water conservation structures. However, this result is not consistent with Bekele and Drake (2003), a study conducted in the eastern highlands of the Ethiopia and noted that in a family with a large number of mouths to feed, immediate food need is given priority and labor is diverted to off-farm activities that generate food.

Environmental factors and adoption of introduced land management practices

The distance of farm land from the home determines the application of introduced land management practices. The analysis indicates that the distance of farm land from the home is negatively associated with ap-

plication of introduced land management practices. With one-unit increase in the distance of farm land from the home the probability of introduced land management application decreases by a factor of 0.475 and the result is statistically significant at $p < 0.05$ (Table 1). The result is consistent with Berhanu and Swinton (2003) studied about investment in soil conservation in Northern Ethiopia. They found that plots distant from homesteads discouraged investment in soil conservation. Similar, study conducted by Habtamu (2006) also showed that farmers residing close to their cultivated land invest more on soil conservation measures than their counterparts living at distance. This is because cultivated lands closer to the residences receive more attention and supervision than land that is situated at the farthest distance.

A positive relationship was observed between slope gradient and application of introduced land management practices. This means sloppy land had significantly more soil bund terraces than flat fields. It indicates that a one-unit increase in the gradient of slope (from flat to very steep slope), the probability for introduced land management practices increases by a factor of 4.314. This result is statistically significant ($p < 0.05$) (Table 1.). This finding is similar to the findings of Eleni (2008) who found out that farmers cultivating steep slopes are constructing soil bunds and fanya juu on their farmland to prevent soil erosion.

Economic factors

A positive relationship was observed between income level of households and application of introduced land management practices. It indicates that when household income level increases by one birr, the probability of a household practice of applying introduced land management practices increases by the factor of 4.260. This result is statistically significant ($p < 0.05$) (Table 1). Positive relationship indicates that high income levels of households help them to be involved in the maintenance and construction of introduced land management practices than households with low income levels. This is in line with the findings of Kessler (2006), who reported that households with a higher income became interested to invest more in soil and water conservation measures than households with low income group.

Households with larger land sizes are expected to be better in introduced land management practices. This is because when households have larger farm sizes, they can plan different land management technologies due to the large land size. In this study, there is also positive significant relationship observed between farm size and introduced land management practices. It shows that an increase in a unit of landholding size leads to an increase of the odds of introduced land management by a factor of 2.192. This result is statistically significant at $p < 0.05$ (Table 1). This result is consistent with studies conducted by Habtamu (2006) who identified that farmers with large farm size were less likely to retain conservation structures. Similarly, the survey result by Eleni (2008) reported that farmers with larger farm size are more likely to invest in soil conservation measures.

Households' livestock size could be considered as one indicator for better availability of resources. On the other hand, better availability of resources is assumed to have positive impact in households' land Management practices. Hence, greater livestock holding is expected to have positive influence in households' involvement in improving their introduced land management practices. But, in this study, negative but significant relationship was observed between livestock holding and introduced land management practices.

A one-unit increase in livestock holding is found to lead to decreased odd of introduced land management practices by a factor of 0.271 and the result is statistically highly significant ($p < 0.05$) (Table 1).

The inverse relationship might be explained in terms of specialization. As a farmer specialized more in livestock production, he/she gives less focus to crop production and hence invests less in introduced land management practices. This is consistent with a previous study which indicated farmers' livestock holding size to have significant negative influence on the adoption of stone terraces (Aklilu, 2006).

Institutional factors

Access to extension services is assumed to improve farmers' attitude towards introduced land management practices. This is because farmers with access to extension services are expected to have better access to information which could play a significant role in introduced land management practices. The analysis indicated that farmers' contact with development agents have predictive power in implementing introduced land management practices. Using the odds of introduced land management practices among farmers' no contact with development agents as a reference, farmers contact with development agents have much higher chance of applying introduced land management practices. Farmers contact with development agents are found to have increased odds of applying introduced land management practices by a factor of 3.130 higher when compared to farmers of no contact with development agents and the result is statistically significant ($p < 0.05$) (Table 1). Wagayehu and Lars (2003) obtained similar result in eastern highland of Ethiopia indicating that if a farmer receives better information or advice from extension agents, the farmer will be willing to construct new conservation measures and maintain the existing ones. Contrary result was obtained by Chomba (2004) which showed that a large proportion of farmers who had contact with agricultural support programs did not continue the improved practices.

Household s' training is observed to have predictive power in introduced land management practices. By taking odds of introduced land management practices among households with no training as a reference, households with training have higher chance of implementing introduced land management practices. Households with training are found to have increased odds of introduced land management practices by a factor of 3. 4 higher when compared to households with no training and the result is statistically significant ($p < 0.05$) (Table 1.). Conversion factor used for TLU was: 0.1 for Sheep and goats; 0.8 for Horse and Mules; 0.5 for Donkeys and 0.7 for all cattle (Jahnke, 1982).

Table 1 Binary logistic regression for application of introduced land management practices

Independent Variables	Estimated Coefficient (*B*)	S.E	Wald	*P* (Sig).	Odds ratio Ex (*B*)
Age category	-2.016	0.492	4.097	0.035	0.233
Educational status	0.702	0.341	4.117	0.040	3.017
Sex	2.453	0.555	8.839	0.0013	2.625
Household size	1.474	0.551	5.350	0.008	4.367
Distance of farm land from home	-0.981	0.418	4.693	0.019	0.475
Annual income	2.111	0.487	8.669	0.0021	4.260
Land holding size	1.433	0.251	11.418	0.0041	2.192
Slope	1.198	0.469	5.108	0.011	4.314
Farmers' contact with dev't agents	2.315	0.577	8.024	0.0014	3.130
Farmers' Training	2.007	0.686	5.851	0.0033	3.400
Livestock(TLU) *	-1.305	0.344	7.587	0.0027	0.271

Notes: Significant at $P < 0.05$ confidences, Cox and Snell R^2 =0.652; Nagelderke R^2 = 0.946 (94.6%).

4 Conclusion

The study shows that majority of farmers in the watershed adopted introduced land management practices. The factors such as educational level, age, sex, households' contact with development agents, land holding size, household size and training, distance of farmland from home, slope and annual income influenced farmers to adopt introduced land man-

agement application. This implies that the regional and local administrates should provide extension and training services on the introduced land management practices for the farmers and agricultural extension service workers. These measures encourage farmers to take introduced land management practices on their farmlands. Moreover, in order to make trainings more successful, trainings should be provided with field works and field observations.

Conflict of Interest

The authors declare that there is no conflict of interest.

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E J E D

ETHNOBOTANICAL STUDY OF MEDICINAL PLANTS IN ALE SPECIAL DISTRICT, SOUTHERN ETHIOPIA

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Abstract

An Ethno-botanical study was carried out to investigate the type, associated knowledge and practices of medicinal plants used by the local people in Ale Special District, SNNPR, Ethiopia. Ninety informants were selected by preferential sampling technique. Ethnobotanical data about traditional medicinal plant names and associated knowledge such as use, remedy preparation, administration, and others were collected using semi-structured interview, field observation, and focus group discussion. Informant consensus, preference ranking, direct matrix ranking, informant consensus factor and fidelity level were computed. A total of 72 medicinal plant species belonging to 68 genera and 39 families were documented. Among the plant families, Lamiaceae was found to be the richest plant family with 11 species followed by Asteraceae (5 species). From medicinal plants recorded in the study area 80.56% were used only to treat human ailments, 8.33% were used only to treat livestock ailments, and 11.11% were used to treat both human and livestock ailments. Regarding plant habits, herbs accounted for 51.39% followed by shrubs for 20.83%, trees accounted for 19.44%, and climbers accounted for 8.33%. The most frequently utilized medicinal plant part was leaf. The most widely used method of preparation was crushing followed by chopping, and powdering. The common route of administration was oral followed by dermal application. From the plants in the study area, Plumbago zeylanica, Cucumis ficifolius and Hypoestes forskaolii are popular in the area and some medicinal plants are more effective in curing ailments like snake bite and malaria (ICF=0.93). Agricultural expansion, over grazing, over harvesting of plants for different household utensils and other human induced problems were the major threats of natural habitat in general and medicinal plants in particular. The area is known for its diverse medicinal plant utilized for curing various ailments in the study area. There was little practice of medicinal plants conservation in the area. The local government and other concerned groups shall give emphasis on the conservation of medicinal plants used for treating various types of human and livestock ailments in the area.

Keywords: Ale Special District, Ethnobotany, Indigenous knowledge, Medicinal plants

1 Introduction

Plants provide various benefits for peoples including food, shelter, clothing, cosmetics, dyes, and medicine. People categorize plants based on their growth form or plant habit, value or use they provide for the people, location, *etc.* (Cotton, 1996). Traditional medicines are used to explain the traditional practice that has been in existence, even before the advancement of modern medicine (Getachew Addis

et al., 2002). It is widely used in among societies for prevention and treatment of physical and mental disorders (Tesfaye Awas and Sebsebe Demissew, 2009). It is reported that more than 3.5 billion people in the developing countries depend on traditional medicines of plants for the treatment of both human and livestock diseases (FAO, 1997). 70 to 80% of people in Africa consult traditional practitioners for their health care. According to Cotton (1996), over centuries, indigenous people have developed their own locality specific knowledge on plant use, management, and conservation. Conservation of ethnobotanical knowledge as part of living cultural knowledge and practices between communities and the environment is essential for biodiversity conservation (Martin, 1995; Balick and Cox, 1996).

In Ethiopia, though there were some ethnomedicinal studies carried out by various scholars, there is limited development of therapeutic products. Knowledge about the use of plants is transferred for one generation to another (Fiseha Mesfin *et al*., 2014). In most places of the country, knowledge on medicinal plant's use has been passed verbally from one generation to the next through traditional healers (Haile Yineger and Delenasaw Yewhalaw, 2007; Tesfaye Awas and Sebsebe Demissew, 2009; Gidey Yirga, 2010a; Gidey Yirga, 2010b; Fiseha Mesfin *et al*., 2014). In this course of knowledge transfer, valuable information can be lost whenever a traditional medical practitioner or healer passes away without transferring his/her traditional medicinal plant knowledge and its practice to others.

Indigenous knowledge on usage of medicinal plants as folk remedies are getting lost owing to migration from rural to urban areas, industrialization, rapid loss of natural habitats and changes in life style (Gidey Yirga, 2010c). Population pressure, environmental degradation, agricultural expansion, loss of forests and woodlands, overharvesting, fire, cultivation of marginal lands, overgrazing and urbanization appeared to be the major threats to the medicinal plants in the country (Abebe Demissie, 2001). Endemic medicinal species restricted to Ethiopia are of primary concern to Ethiopia and to the world as well and thus need serious attention (Endashaw Bekele, 2007).

Even though the country has high potential of traditional plants and associated indigenous knowledge, the effort to use this available resource and knowledge scientifically is less. The knowledge and technical skills regarding preparation of remedies from traditional medicinal plants are fragile and may easily be forgotten as most of the medicinal plants are kept secret (Gidey Yirga, 2010a). Documentation of medicinal and other ethno-botanical uses of medicinal plants in the country is an urgent task to rescue the rapid loss of the natural habitat of these plants and the knowledge and practice of medicinal plants use. Thus, this study was conducted with the aim of investigating medicinal plants used by the Ale people for the treatment of various ailments and documenting the indigenous knowledge of the community on use and conservation of various medicinal plants in Ale District.

2 Material and Methods

2.1 Description of the Study Area

Ale Special District is situated between of 05°20′ - 05°4′ N latitude and 37°00′ - 37°25′ E longitude (Figure 1). The Special District was one of the five former Districts of the Segen Area People's Zone in SNNPRS. Kolango was the administrative town of the Special District which is located at a distance of 645 *km* south of Addis Ababa.

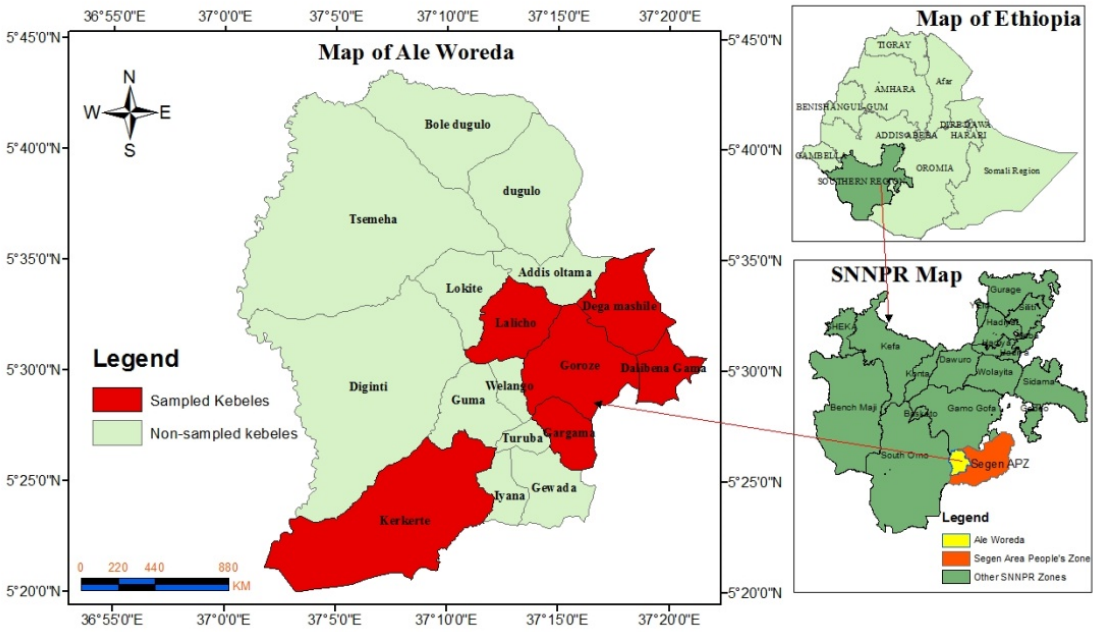

Figure 1 Map of the Study Area

Elevation of the study area ranges from 500 meter above sea level (*masl*.) at '*Datane*' to 2800 *masl*. at '*Tosho*'. Based on the data obtained from National Meteorology Agency (2020), the monthly mean temperature of the study area was at the range of 16 $^{\circ}C$ to 26.8 $^{\circ}C$, whereas the mean annual rainfall of the area was 860 *mm*. and had a bimodal rainfall pattern. From the total 1039 km^2 area of the District, 35.2% was characterized by arid ('*kola*') agroecology, 47.2% was characterized by sub-humid ('*woina-dega*'), 17.6% of the area of the Special District was characterized by humid ('*dega*') agroecology (AWOFED, 2020).

2.2 Research Methods

Data Collection Sites and Informants Selection

Six *kebeles* were randomly selected from the 17 *kebeles*of Ale Special District. Traditional healers in these six *kebeles* were considered as target population. Yamane's formula of sample size determination (Yamane, 1967) was used to determine the sample for this study at 95% confidence level (*Equation 1*). At 95% confidence coefficient, the degree of variability was 0.5 with the level of precision or sampling error of 5%.

$$n = \frac{N}{(1+Ne^2)} \tag{1}$$

Where,
n is the required sample size; N is the traditional healers in the selected six *kebeles*; and e is the level of precision, which is 0.05.

$$\text{Thus, } n = \frac{N}{(1+Ne^2)}$$

$$n = \frac{116}{(1+116^*.05^2)} = \frac{116}{1.29} = 90$$

90 traditional healers (hereafter, named as informants) whose age was over 20 years were used as samples from the 116 traditional healers existing in the selected six *kebeles*. Proportional sample of informants from each sampled *kebele* was taken purposively based on experience on the medicinal plants usage and practice of treating ailments. The sampled *kebeles*, their respective elevation, and proportional sample size is given in Table 1. Moreover, 12 informants (2 from each *kebele*) were taken for the Focus Group Discussion (FGD), where one of the two informants selected in each *kebele* was participated in FGD only.

Table 1 Sampled *kebeles* for data collection and their proportional sample size

Sampled *Kebeles*	**Elevation range** (in $masl.$)	**Number of traditional healers**	**Proportional Sample Size**
Dega-Mashille	2000 – 2800	12	9
Delbena-Gama	1600 – 1900	22	17
Gargama	1700 – 1800	19	15
Goroze	1650 – 2100	21	16
Lalicho	1900 – 2300	16	13
Qerqerte	500 – 1500	26	20
Total		116	90

2.3 Data Collection and Analysis

Types of Data Collected and Method of Collection

In the study area, relevant primary data regarding the medicinal plants used to treat human and livestock ailments and the associated knowledge such as plant parts used, plant habits or growth forms, remedy preparation methods, route of administration of remedies, dosage, disease treated, threat to medicinal plants, and conservation practice were gathered. Semi-structured questionnaire and FGD guide were developed and utilized for data collection. Moreover, guided field observation was taken place as a means of data collection methods. Medicinal plants mentioned by the local healers were observed and recorded.

Voucher specimens were collected pressed, dried, and taken to the National Herbarium (ETH) for taxonomic characterization and identification. Plant identification was made using published volumes of Flora of Ethiopia and Eritrea and comparing with the existing plant specimens in the Herbarium.

Preference Ranking

Preference ranking, one of the techniques used for ethno-botanical and ethno-medicinal studies data collection (Martin, 1995) was applied in this study during the FGD. During the preference ranking exercise, five medicinal plants that were reported in the study area for their potential to cure tonsillitis (the most frequently reported ailment in the study area) were ranked by ten randomly selected members of FGD participants using the scale of 1 (least preferred) to 5 (most preferred).

The medicinal plants that were used for preference ranking were *Acmella caulirhiza*, *Crabbea velutina*, *Encostema axillare*, *Plumbago zeylanca*, and *Rhaminus prinoides*. Each informant was undertaken the ranking independent of the other informants.

The overall ranking of the medicinal plants presented for this particular ranking exercise was then made by taking the sum of all rank values given for each medicinal plant. Similarly, ranking was done in a similar manner for threats to the existing medicinal plants in the study area.

Direct Matrix Ranking

Direct matrix ranking was undertaken to compare medicinal plants commonly reported for their multipurpose use (Martin, 1995; Cotton, 1996) in the study area. Besides the medicinal value, medicinal plants in the study area was categorized based on their use value as fodder, edible, construction materials and farm implements, firewood, charcoal, live fence, and timber. Six medicinal plants were presented for ten randomly selected FGD participants to independently give a score of 0 to 5 (0=not used, 1=less used, 2= moderate, 3= good, 4= very good, and 5= the best) for each medicinal plant based on its use category. The overall ranking of the multipurpose plants under investigation was made by comparing the sum of all use values given to each plant.

Informant Consensus Factor

The Informant Consensus Factor (*ICF*) is the factor used to calculate the level of homogeneity between information provided by different informants (Trotter and Logan, 1986). Accordingly, ICF was calculated using *Equation 2* for each category of ailments in the study area showing agreement of informants on the reported use of medicinal plants for curing group of ailments (Heinerich *et al*., 1998).

$$ICF = \frac{n_{ur} - n_r}{n_{ur} - 1} \quad (2)$$

Where, ICF= informant consensus factor; n_{ur}= number of use citation in each category; and n_t = number of species used

Fidelity Level

Fidelity Level (FL) was used to indicate the use of a given medicinal plant for a particular purpose in a given cultural group or area (Friedman *et a*l., 1986). Relative healing capacity of each medicinal plant in the study area was analyzed by FL index (*Equation 3*).

$$ICF = \frac{I_p}{I_u} * 100 \quad (3)$$

Where, I_p is the number of informants who independently indicate the use of a species for the same major ailments and I_u is the total number of informants who indicate the plant for any major ailment.

2.4 Data Presentation and Analysis

Data collected for this study was summarized and presented in tables and charts. Ethno-botanical data analysis methods such as preference ranking and direct matrix ranking for selected medicinal plants Martin (1995) and Cotton (1996) were used for data analysis in addition to percentage and frequency, which are descriptive statistical methods. Moreover, narrative statements were given for some qualitative data gathered through questionnaires.

3 Results

Ethnomedicinal Plant Species Composition in the Study Area

A total of 72 medicinal plants belonging to 68 Generas and 39 Families were documented in Ale Special District (Annex). Of the top five species rich plant families, Lamiaceae had 11 species, Asteraceae contained 5 species, and the remaining three families – Acanthaceae, Fabaceae, and Solanaceae each represented by 4 species of medicinal plants.

Among the medicinal plants documented in the study area, 88.89% were used to treat human ailments and 19.44% were used to treat livestock ailments. 51.39% of the medicinal plants recorded in the study area were herbs and the remaining medicinal plants are shrubs, trees, and climbers (Table 2).

Table 2 Number of medicinal plant categorized in their growth forms and target of application

Ailments treated	Herbs	Shrubs	Trees	Climbers	Total	Percentage
Human's only	30	11	12	5	58	80.56
Livestock's only	4	0	1	1	6	8.33
Both Human's and Livestock's	3	3	2	0	8	11.11
Total	37	14	15	6	72	
Percentage	51.39	19.44	20.83	8.33		

Detail description regarding the name of medicinal plant species documented at study area, plant growth form or habit, plant parts used to prepare remedies, disease treated, mode of preparation of remedies, and mode of application is given in Annex.

According to the information gathered from the study area, different plant parts are used as medicines by the local people. From the parts reported, the most frequently utilized plant part was leaf. Roots of medicinal plants were the second widely used for medicinal purpose next to leaves (Figure 2).

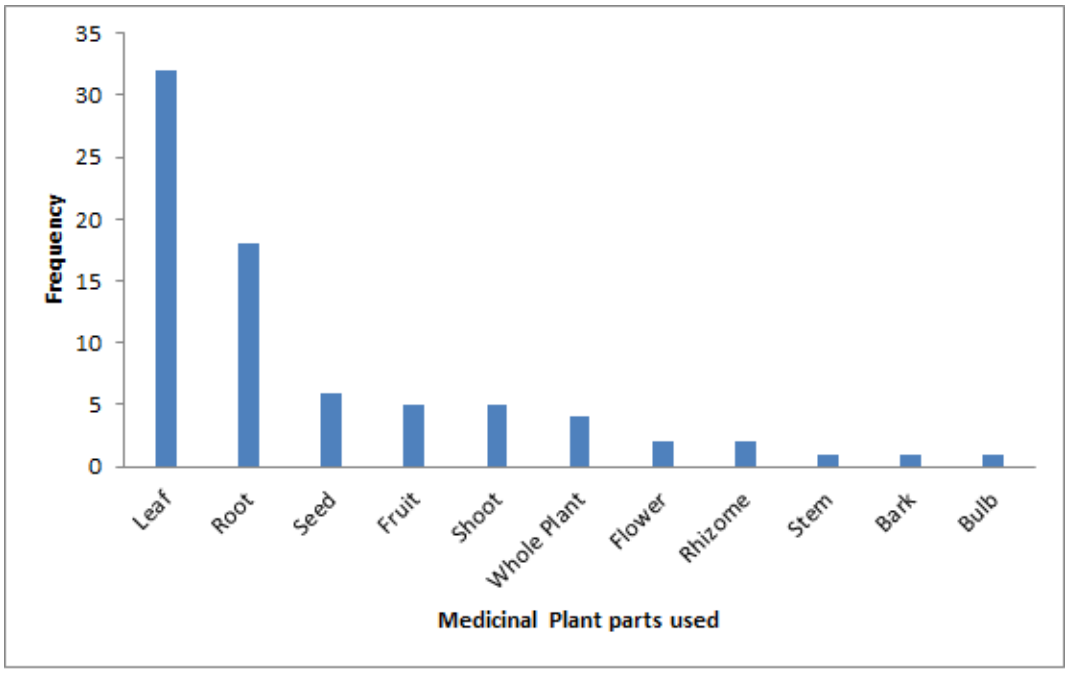

Figure 2 Medicinal plant parts used for remedy preparation in the study area

Methods of Remedy Preparation

Though higher number of herbaceous medicinal plants documented in the study area, majority of the remedies were prepared from dry plant materials than the fresh ones.

On the course of remedy preparation to treat human and livestock ailments, the local community employed number of methods of remedy preparation for various ailments. A total of 99 remedies were reported to be prepared from the 72 medicinal plants in the study area. The preparations of remedies vary based on type of disease treated and the actual site of the illness.

The primary method of remedy preparation in the study area was reported to be crushing of plant parts, and was accounted for 32.32% of the reported remedy preparation methods in the study area. Whereas, chopping, powdering, and pounding were accounted for 16.16%, 13.13%, and 10.10% respectively (Figure 3).

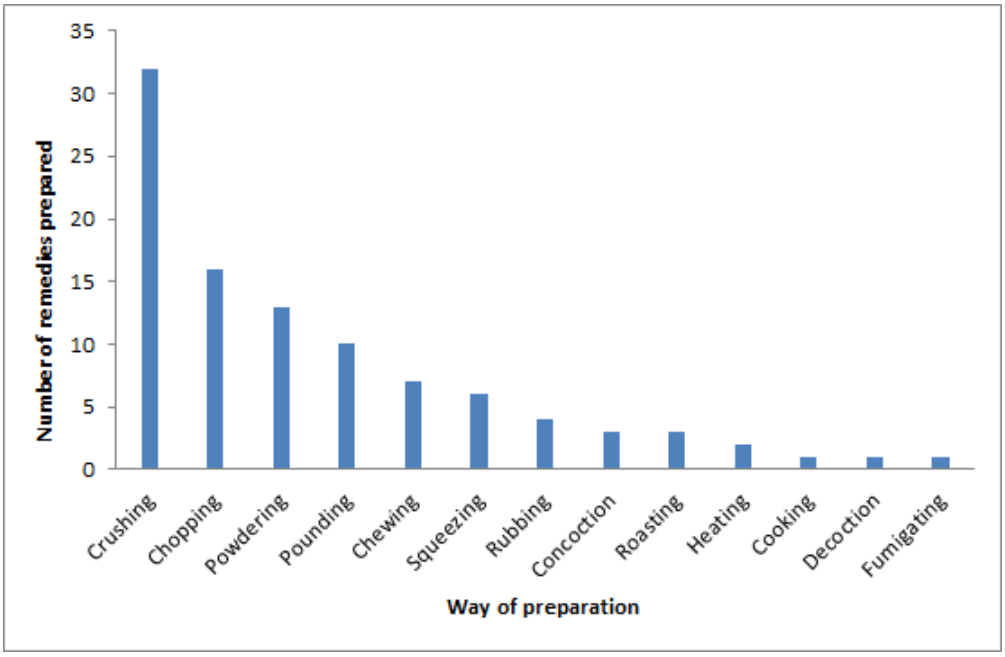

Figure 3 Percent of mode of administration of remedies

Modes of Administrations and Dosage of Remedies

The mode of administration of the traditional remedies by traditional healers in Ale District depends on the nature of remedy and the type of disease to be treated. Accordingly, ailments that require oral application of remedies were reported to frequent. As a result, oral application was a primary mode of administration accounted for 59% which is followed by external (dermal) and ocular applications accounted for 24% and 7% respectively (Figure 4).

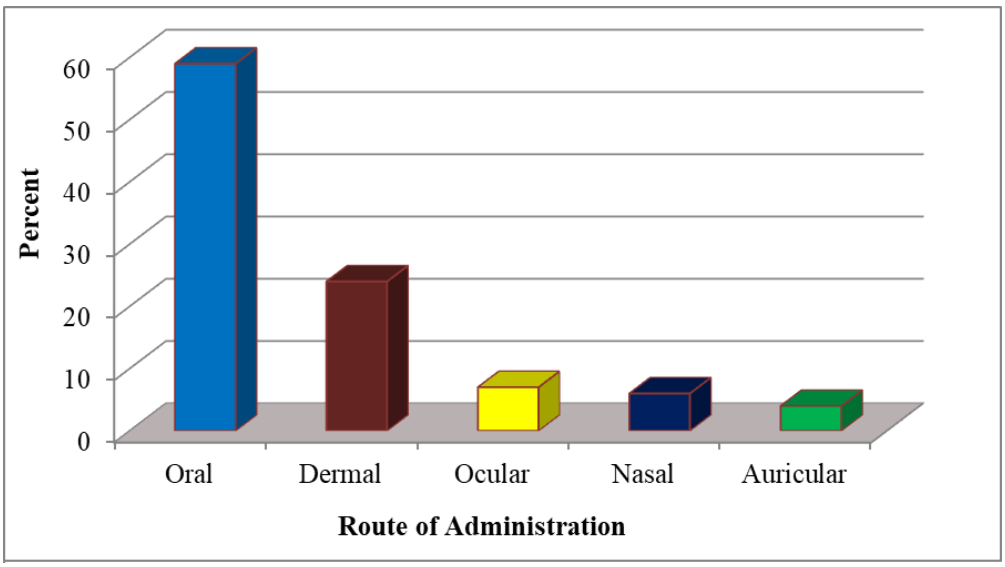

Figure 4 Percent of mode of administration of remedies

Preference Ranking

In this study, tonsillitis was reported as the most frequently occurring disease for which several patients in the study area visited traditional healers. Among the medicinal plants reported to cure tonsillitis in the study area, *Plumbago zeylanica* was found to be the most effective medicinal plant against tonsillitis and ranked the first, followed by *Encostema axillare*, and *Crabbea velutina* (Table 3).

According to interview from informants, some medicinal plants were most effective to cure frequently occurring and known ailments than others. This revealed that some medicinal plants were considered to be most effective and used frequently than others.

Table 3 Preference ranking of five medicinal plants for treating tonsillitis

Medicinal Plants used to Treat Tonsillitis	Respondents										Total Scores	Rank
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}		
Acmella caulirhiza	3	1	2	2	1	3	1	4	2	3	22	4^{fh}
Crabbea velutina	2	4	5	4	5	1	3	2	3	4	33	3^{rd}
Enicostema axillare	5	3	3	5	2	4	4	5	5	2	38	2^{nd}
Plumbago zeylanica	4	5	4	3	3	5	5	3	4	5	41	1^{st}
Rhamnus prinoides	1	2	1	1	4	2	2	1	1	1	16	5^{th}

Direct matrix ranking

In additional to their medicinal value, some medicinal plants were used for other purpose. Accordingly, *Cordia africana* ranked 1st as multiuse medicinal plant followed by *Eucalyptus globulus* and *Moringa stenopetalla* which ranked 2^{nd} and 3^{rd} respectively. On the other hand, the selected plants were used for firewood, which was ranked the 1^{st}, followed by their values for medicinal purpose and source of construction materials and farm implements as 2^{nd} and 3^{rd} respectively. The total score of data matrix from informants is given in Table 4.

Table 4 Direct matrix ranking of six medicinal plants (The numbers under each use category are the sum of all scores given by the ten informants)

Multipurpose Medicinal Plants	Use Category/Source of								Total Score	Rank
	Medicine	Fodder	Edible Part	Construction	Firewood	Charcoal	Live Fence	Timber		
Cordia africana	32	4	30	50	46	20	21	50	253	1^{st}
Croton macrostachyus	37	0	0	26	46	0	40	6	155	5^{th}
Eucalyptus globulus	24	0	0	47	50	19	50	47	237	2^{nd}
Moringa stenopetalla	44	50	50	0	14	0	30	0	188	3^{rd}
Rhamnus prinoides	32	32	13	0	0	0	8	0	85	6^{th}
Terminalia browni	24	0	0	45	50	50	11	3	183	4^{th}
Sum	193	86	93	168	206	89	160	106		
Rank	2^{nd}	8^{th}	5^{th}	3^{rd}	1^{st}	6^{th}	4^{th}	7^{th}		

Informant Consensus

From the total medicinal plants documented, *Plumbago zeylanica* was cited by 39 in informants and ranked the 1^{st} accounting for 43.3%. The top ten plants that had higher citation are given in Table 5.

Table 5 Informant consensus on 10 medicinal plants cited by informants

Medicinal Plant Species Cited by Informants	Number of Citations	%	Rank on Citation
Acmella caulirhiza	31	34.4	6^{th}
Allium sativum	32	35.6	5^{th}
Cucumis ficifolius	35	38.9	2^{nd}
Cyphostemma adenocaule	30	33.3	7^{th}
Dicrocephala integrifolia	29	32.2	8^{th}
Hypoestes forskaolii	34	37.8	3^{rd}
Enicostema axillare	28	31.1	9^{th}
Jasminum abyssinicum	27	30.0	10^{th}
Nepeta azurea	33	36.7	4^{th}
Plumbago zeylanica	39	43.3	1^{st}

Fidelity Level

The result of the study showed that the effectiveness of medicinal plants against a given ailment was varying from one plant to another. Medicinal plants that had the capability of treating a number of specific diseases had given a high *ICF* value. Therefore, the highest *ICF* value (0.93) was obtained from category of problems where snake bite and malaria were contained in. Whereas the least *ICF* value (0.76) was obtained for category consisting muscular rigidity at the neck, swelling around neck region, breast swelling, and mumps. *ICF* or human disease categories in the study area is given in Table 6.

Table 6 Informant consensus for category of human diseases

Category	n_t	n_{ur}	*ICF*
Tonsillitis, Headache	13	75	0.84
Diarrhea, Blood dysentery, Shigellosis	10	59	0.84
Eye illness, Ear pain, Cataract,	7	70	0.91
Intestinal parasites, Tapeworm	3	16	0.87
Abdominal pain, Gastritis	9	52	0.84
Snake bite, Malaria	4	45	0.93
Wound, Cut surface, Fire burn, Skin rush	11	60	0.83
Muscular rigidity of the neck, Swelling around neck region, Breast swelling, Mumps	7	26	0.76
Febrile illness, '*Mich*', Dizziness, Rheumatism	9	35	0.77

Fidelity level indicates that the comparison of relative healing capacity of medicinal plant species for particular disease. Fidelity levels of top ten medicinal plants are given in Table 7. These medicinal plants were observed to be with high fidelity level indicated that they had good healing capacity from which *Cucumis ficifolius* and *Plumbago zeylanica* both ranked 1^{st} with respect to their relative healing capacity of specific ailments.

Table 7 Top nine medicinal plants with their respective Fidelity level values

Medicinal Plants Used to Treat Ailments	Ailment Treated	I_p	I_u	FL %	Rank
Acmella caulirhiza	Tonsillitis	28	31	90.3	5^{th}
Allium sativum	Leech	30	32	93.8	4^{th}
Cucumis ficifolius	Blackleg	35	35	100	1^{st}
Cyphostemma adenocaule	Fire burn	27	30	90	6^{th}
Dicrocephala integrifolia	Headache	25	29	86.2	8^{th}
Jasminum abyssinicum	Diarrhea	24	27	88.9	7^{th}
Moringa stenopetalla	Hypertension	24	28	85.7	9^{th}
Nepeta azurea	Liver problem	32	33	97	3^{nd}
Plumbago zeylanica	Toothache	39	39	100	1^{st}

Key: I_p is the number of informants who independently indicate the use of a species for the same major ailments and I_u is the total number of informants who indicate the plant for any major ailments.

Threats to Medicinal Plants and Conservation Practices

Different anthropogenic factors were threatening medicinal plants in the study area. The information from informants showed the most mentioned threats to medicinal plants include agricultural expansion, wood cutting for different purpose, overgrazing, charcoal making, firewood, timber, and drought. The result of preference ranking of threats to medicinal plants in the study area is given in Table 8. According to the informants and personal observation of the researcher, the natural vegetation in the entire study sites were cleared from the area for the contest of agricultural expansion. Overutilization of plant resources by the local communities were also seen except for some remnant patches in midlands and highlands as well as Afromontane forest of Deneko high lands. These areas were covered by densely populated bushes, shrubs, herbs and trees.

Table 8 Preference ranking of threats to medicinal plants in the study area

Threatening Factors	Respondents										Total Score	Rank
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}		
Agricultural expansion	5	4	4	5	4	3	5	5	4	5	44	1^{st}
Overgrazing	4	3	5	3	5	4	4	4	5	3	40	2^{nd}
Firewood	2	2	3	1	2	1	3	1	3	2	20	4^{th}
Cut for various purpose	3	5	2	4	3	5	2	3	1	4	32	3^{rd}
Drought	1	1	1	2	1	2	1	2	2	1	14	5^{th}

4 Discussion

4.1 Ethnomedicinal Plants Composition, Indigenous Knowledge, and Application of Traditional Medicine

Though medical services in the District are improving, number of peoples in the study area was reported to visit local healers in search for traditional remedies that would cure or provide relief from their illness. The result indicated that there was more number of medicinal plants used to treat human ailment than livestock ailment. This might be due to existence of fewer livestock ailments in the study area and/or limited knowledge and skill about animal health. Similar findings were obtained by Mirutse Gidey *et al*., (2009) and Tesfaye Awas and Sebsebe Demisew (2009).

The result showed that leaf is predominantly used for remedy preparation than any other plant part in the study area. The common use of the leaf might be due to the relative ease of finding this plant part which agrees with similar work of Panghal *et al*. (2010). Many studies that were carried out in Ethiopia and other parts of the world showed leaf is the dominant part to prepare the remedy (Haile Yineger and Delenasaw Yewhalaw, 2007; Tesfaye Hailemariam *et al*., 2009; Mirutse Gidey *et al*., 2009; Panghal *et al*., 2010; Fiseha Mesfin *et al*., 2014). The advantage of using leaf for remedy preparation over roots, stem, or the whole plant is that it helps the whole plant not to disappear from the study area and allow the plant to sustain for continuous use.

Remedy Preparation, Modes of Administration, and Dosage

It was indicated in the result section that remedies to treat human and livestock ailments in the study area were prepared by crushing followed by chopping, powdering, and pounding of parts or the whole medicinal plant. It agreed with the findings of Gidey Yirga (2010a) in which they mentioned crushing is the dominant method of preparation. Predominant practice of crushing exercise over other methods of extracting remedies is an indication of utilizing most medicinal plants in dry form. The use of medicinal plants in dry form has an advantage over the fresh one in that it can be used any time even in drought seasons in which annual herbs were not accessible.

The result of the study indicated that most of the medicinal plant remedies prepared for the specific ailment were taken orally. This is because majority of diseases treated was internal problems and the remedies were more efficient with their potential efficacy when taken orally. This situation coincides with the findings of Haile Yineger and Delenasaw Yewhalaw (2007) and Tesfaye Hailemariam *et al*. (2009) that oral application was reported to be the dominant route of administration of remedies.

Though the concentrations of locally prepared remedies were not scientifically known, the dosage of administered remedies depends mainly on age and body weight of the patient, type of disease, and nature of the remedy. Prescriptions with respect to frequency and duration of application of remedies for a particular ailment vary from healer to healer. However, healers use similar practice of administering remedies for some health problems. For example, to treat a person with abdominal pain in the study area, most healers used to prescribe one coffee cup of remedy prepared from crushed *Thunbergia alata* mixed with butter to be taken orally twice a day until the patient gets recovered. Frequency of the treatment might depend on severity of effect of a disease.

To determine the dosage of remedies, local healers in study area use coffee cup, tea glass, or water glass to measure volume of the administered remedies. Tea spoon and bottle stopper were also used in some cases when the remedies are administered in dry form. A local drink called as '*Warshe*' was used to be mixed with some remedies. Some remedies were prepared from the mix of coffee leaf extract and need to be taken orally with empty stomach early in the morning.

One of the drawbacks of traditional health care system in Ethiopia was that it does not use standard measurement units to determine the concentration

and dosage of remedies administered to treat human and livestock ailments. Variation on the measurement of most remedy administered for particular ailments in the study area was documented from one locality to another as well as healer to healer.

Values of Medicinal Plants and Preference by the Local Community

Some medicinal plants such as *Cordia africana*, *Terminalia browni*, *Cupressus lustanica*, *Eucalyptus globulus*, *etc*. have had high use value than others and used for various purpose by the local community beside their medicinal value. It was observed that these plants were highly threatened in the area except *Terminalia browni*, which is highly adaptive in the area and kept as agroforestry tree in the farm lands and fallow lands. The use of these multipurpose medicinal plants for other purpose may contribute for the loss of medicinal plant in the study area since they were frequently used for purposes other than medicine.

Results from informant consensus factor showed that medicinal plants that were used frequently are chosen in advance by the local healers to treat particular problems for which the local people need potential cure. It also implied that these medicinal plants are effective in treating particular ailments and have high importance since they are applied by many people and have been utilized for a long time.

Based on the findings, the *ICF* of some categories of diseases was high and it showed there was a good indicator for a high rate of informant consensus on the frequent use of some medicinal plants for the health problems occurring in the area. This would be due to poor socio-economic as well as personal and environmental hygiene of the people in the study area, indicating that category with high *ICF* was prevalent and that with low *ICF* was relatively rare.

The result of Fidelity level showed that some medicinal plants had high healing potential compared to others according to their *FL* computed. This revealed that some medicinal plants were essential on which local people rely on to cure human and livestock problems that frequently occur in their respective locality and the choice of the informant is mainly depends on the efficacy of the medicinal plants utilized. This indicated that the medicinal value of some plants in the study area was high in relation to other medicinal plants investigated.

Acquisition and Transfer of Knowledge of Traditional Medicine

Traditional healers were found to play an important role in the primary health care system of the local people as they treat people who have little access to- and unable to afford the cost of- modern medication (Gidey Yirga, 2010a). The transfer of knowledge takes place only along family line mostly from parents to one of their respective family members verbally. As they indicated this transfer of knowledge takes place when the healer is getting older. This transfer may not take place if the healer passes away suddenly prior to the transfer of the knowledge to his family members. This phenomenon limited the spread of ethno-medicinal knowledge in the study area.

According to information documented from informants and other local elders, most of the traditional healers were not volunteered to show the type of the plant used as a remedy rather they kept as secret and said that knowledge of medicinal plant is one of the income source. They also believe that when the medicinal plants are disclosed, the healing capacity of the plant diminishes. Several similar studies have indicated that traditional healers or local practitioners of traditional medicinal plants were not interested to disclose and publicize their medicinal plants knowledge and practice (Haile Yineger and Delenasaw Yewhalaw, 2007; Mirutse Giday *et al*., 2009; Gidey Yirga, 2010b).

4.2 Threats to Medicinal Plants and Conservation Practices

The result showed that the loss of medicinal plants has occurred by anthropogenic and natural conditions. Agricultural expansion was the main threats to medicinal plants in the study area followed by

over grazing and cutting of trees used in household activities. In lowland areas, shortage of rain due to seasonal drought was also considered as threat to medicinal plants in the study area and ranked the least. These threatening factors might be resulted from population increase and the demand for farmlands and grazing lands.

The degree of threats in the study area varies from place to place and species to species. These major factors were perceived as predominant threats that contributed to loss of biodiversity in general and medicinal plants in particular in the study area. This finding is in congruence with the finding of Zemede Asfaw (2001) and Kebu Baleme *et al*. (2004).

The result of the information revealed that some of the medicinal plants such as *Cordia africana*, *Croton macrostachyus*, *Cupressus lustanica*, *Moringa stenpetalla*, *Terminalia browni*, and *Rhamnus prinoides* have been over used and are being highly vulnerable and threatened than other medicinal plants in the area. These medicinal plants were relatively known for their greater multipurpose values than the other medicinal plants.

Some medicinal plants in places of low and erratic distribution of rain fall mainly in the low lands of the District were threatened by drought. This finding is in agreement with the finding of Kebu Balemie *et al*. (2004)

Another threat to medicinal plants might be careless collection of medicinal plants in the area. Some informants harvest the medicinal plants by uprooting, stem cutting or bark pealing. Even though this careless harvesting was carried out by few traditional healers, it contributed to the threatening factor of medicinal plants in the study area.

The medicinal plants existing in homegardens of the study area were not been intentionally cultivated for medicinal purpose except by some traditional healers rather they were cultivated for their primary purpose such as food or spice other than medicinal value. There are no plant parts sold directly in the market purposefully as medicine in the District but those healers who know the plant type as medicine buy the parts from the market to heal others. Consequently, this helped in conservation of medicinal plants indirectly in the area.

Wild medicinal plants were kept in the nearby patches of forest remnants, fallow lands, agroforestry areas, in the farmlands for different purpose but not only for medicinal determination because medicinal values of those plants were known only by the corresponding healers. However, most of informants reported that people in the study area have awareness problem to conserve biodiversity in general. This revealed that there was no considerable conservation practice for medicinal plants in the study area rather they were conserved indirectly when cultivated in home gardens and farm lands for other purposes. Therefore, according to Gidey Yirga (2010a) encouraging the local people to cultivate some medicinal plants in their home gardens, or grow together with other crops in their farmlands, and planting as live fences is greatly important for the conservation of medicinal plants in the study area.

5 Conclusion

The study carried out in the area showed that Ale Special District is relatively endowed with wide range of medicinal plant along with its use, practice, and associated indigenous knowledge. These medicinal plants were used for the treatment of both human and livestock ailments in the area.

Utilization of traditional medicines extracted from medicinal plants and the practice was the day to day experience of the local community. The natural vegetation in the study area was a potential source for medicinal plants as most of the medicinal plants were obtained from wild and some were obtained from home gardens that are cultivated for different purposes besides medicinal value. Some medicinal plants were used for other different purposes like firewood, charcoal, construction and others in addition to medicinal purpose. Though the indigenous knowledge of the local people to sustainably use the medicinal plants for their need has contributed to bet-

ter manage and conserve this resource in the area, usage of some medicinal plants for other purpose was threatening the medicinal plants in the study area. Moreover, agricultural expansion, and over grazing were the major threats to the medicinal plants in the study area and in the future, it may affect indigenous knowledge associated with those medicinal plants.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Annex

List of Medicinal Plants Used to Treat Human and Livestock Diseases in Ale Special District

Key to Abbreviations: Plant habit (T-Tree, Sh-Shrub, H-Herb, and Cl-Climber), Applied to (Hu-Human, Ls-Livestock, and Bo-Both)

Scientific Name	Family	Plant Habit	Disease treated	Applied to
Acmella caulirhiza Del.	Asteraceae	H	Tonsillitis	Hu
Allium sativum L.	Alliaceae	H	Tonsillitis	Hu
			Leech & Blackleg	Ls
Amaranthus caudatus L.	Amaranthaceae	H	Diarrhea	Hu
Becium grandifolorum (Lam) Pic. Serm*	Lamiaceae	Sh	Cataract	Hu
			Cut surface	Bo
Calotropis procera (Ait.) Ait. f.	Asclepiadaceae	Sh	Blackleg	Ls
Catha edulis (Vahl) Forssk. ex Endl.	Celastraceae	T	Tonsillitis	Hu
Clerodendrum myricoides (Hochst.) V.	Lamiaceae	Sh	Abdominal pain	Hu
			Internal parasites	Hu
Coffea arabica L.	Rubiaceae	Sh	Diarrhea	Hu
			Wound	Hu
Cordia africana Lam.	Boraginaceae	T	Diarrhea	Hu
Coriandrum sativum L.	Apiaceae	H	Hemorrhage during birth	Hu
Crabbea velutina S. Moore	Acanthaceae	H	Tonsillitis	Hu
Crotalaria spinosa Hochst. ex Benth.	Fabaceae	H	Blackleg	Ls
Croton macrostachyus Del.	Euphorbiaceae	T	Blackleg	Ls
			Eye illness	Hu
Cucumis ficifolius A. Rich.	Cucurbitaceae	Cl	Blackleg	Ls
			Snake bite	Hu
Cucurbita pepo L.	Cucurbitaceae	Cl	Tapeworm	Hu
Cupressus lustanica Mill.	Cupressaceae	T	Thinness	Ls
Cyphostemma adenocaule (Steud. ex A.Rich) Desc. ex Wild & Dr.	Vitaceae	Cl	Fire burn	Bo
			Blood dysentery	Hu
Datura stramonium L.	Solanaceae	H	Pain or '*Waransa*'	Ls
			Blood dysentery	Hu
			Ear pain	Hu
Delphinium dasycaulon Fresen.	Ranunculaceae	H	Shigellosis & Swelling	Hu
Dicrocephala integrifolia (L. f) Kuntze	Asteraceae	H	Headache	Hu

*Endemic plants

Scientific Name	Family	Plant Habit	Disease treated	Applied to
Dodonea angustifolia L. f.	Sapidaceae	Sh	Mumps	Hu
Eclipta prostrate (L.) L.	Asteraceae	H	Blackleg	Ls
Eleusine coracana (L.) Geartn.	Poaceae	H	Diarrhea	Hu
Enicostema axillare (Poir. ex Lam) A. Raynal.	Gentianaceae	H	Tonsillitis	Hu
Ensete ventricosum (Welw.) Cheesman	Musaceae	H	Abdominal pain	Hu
Erythrina brucei Schwein f.*	Fabaceae	T	Abdominal pain	Hu
Eucalyptus globulus Labill.	Myrtaceae	T	Cough	Hu
Foeniculum vulgare Miller	Apiaceae	H	Urine retention	Hu
			Cough	Hu
Gardenia ternifolia Schumach. & Thonn.	Rubiaceae	T	Skin disease & Abdominal pain	Hu
Gossypium barbadense L.	Malvaceae	Sh	Wound	Hu
Guizotia scabra (Vis) Chiov.	Asteraceae	H	Abdominal pain	Hu
Hagenia abyssinica (Bruce) J. F. Gmel.	Rosaceae	T	Tapeworm	Hu
Hypoestes forskaolii (Vahl.) R. Br.	Acanthaceae	H	Snake bite	Hu
Hyptis pectinata (L.) Poit.	Lamiaceae	H	Blackleg	Ls
			Malaria & Rheumatism	Hu
Indigofera vohemarensis Baill.	Fabaceae	H	Toothache	Hu
Ipomea kituiensis Vatke	Convolvulaceae	H	Eye illness	Hu
Jasminum abyssinicum Hochst. ex DC.	Oleaceae	Cl	Diarrhea	Hu
Justicia schimperiana (Hochst. ex Nees) T. Anders.	Acanthaceae	H	Febrile illness	Hu
Lagenaria siceraria (Molina) Standl.	Cucurbitaceae	Cl	Muscular rigidity of neck	Hu
Mimosa pigra L.	Fabaceae	Sh	Blackleg	Ls
Monopsis stellarioides (Presl) Urb.	Lobeliaceae	H	Abdominal pain & Swelling around neck	Hu
Moringa stenopetalla (Bak. F) Cuf.	Moringaceae	T	Hypertension	Hu
			Cough	Ls
Nepeta azurea R. Br. ex Benth	Lamiaceae	H	Eye illness, Kidney Problem, Liver problem, & Skin rash	Hu
Nicotiana tobacum L.	Solanaceae	H	Eye illness	Hu
			Leech	Ls

*Endemic plants

Scientific Name	Family	Plant Habit	Disease treated	Applied to
Ocimum basilcum L.	Lamiaceae	H	Headache	Hu
Ruta chalepensis L.	Rutaceae	H	Tonsillitis	Hu
Searsia rosmarinifolia (Vakl) F. A. Barkley	Anacardiaceae	H	Blackleg	Ls
Solanum incanum L.	Solanaceae	Sh	Wound	Hu
Stachys jijigaensis Sebsebe*	Lamiaceae	H	Tonsillitis	Hu
Syzygium guineense (Willd.) DC. Subsp. *afromontanum*	Myrtaceae	T	Diarrhea	Hu
Terminalia browni Fresen.	Combretaceae	T	Eye illness	Ls
Thunbergia alata Boj. ex Sims	Acanthaceae	Cl	Abdominal pain & Swelling around neck	Hu
Verbena officinalis L.	Verbenaceae	H	Febrile illness	Hu
Vernonia amygdalina Del.	Asteraceae	T	Gastritis	Hu
Withania somnifera (L.) Dunal in DC	Solanaceae	Sh	Blackleg	Ls
Zanthoxylum chalybeum Engl.	Rutaceae	T	Cough & Sneeze	Ls
Zingiber officinale Roscoe	Zingiberaceae	H	Abdominal pain	Hu
Pentas schimperiana (A. Rich.) Vatke	Rubiaceae	Sh	Swelling	Hu
Plumbago zeylanica L.	Plumbaginaceae	H	Breast Swelling, Tonsillitis, & Toothache	Hu
Polygala erioptera DC.	Polygalaceae	H	Snake bite	Hu
Pouzolzia parasitica (Forssk.) Schweinf	Urticaceae	H	Wound	Hu
Ocimum lamifolium Hochst.ex Benth	Lamiaceae	H	Febrile illness	Hu
Ocimum suave Willd.	Lamiaceae	H	Rheumatism & '*Mich*'	Hu
Ocimum urticifolium Roth	Lamiaceae	H	Headache	Hu
Olea europaea L. subsp. *cuspidata*	Oleaceae	T	Blackleg	Ls
Pelargonium multibracteatum Hochst. ex A. Rich	Geraniaceae	H	Eye illness	Hu
Premna schimperi Engl.	Lamiaceae	Sh	Diarrhea	Hu
Premna oligotricha Baker	Lamiaceae	Sh	Tonsillitis, Toothache, & Skin rush	Hu
Pterocephalus frutescens Hochst. ex A. Rich.	Dipsacaceae	H	Wound	Hu
Rhamnus prinoides L. Herit.	Rhamnaceae	Sh	Tonsillitis	Hu
Rhus natalensis Krauss	Anacardiaceae	T	Dizziness	Hu
Ricinus communis L.	Euphorbiaceae	Sh	Wound	Hu
			Rabies	Bo

*Endemic plants

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E J E D

PUBLIC SPACE OCCUPATION AND UTILIZATION AMONG STREET CHILDREN OF DILLA TOWN

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Abstract

The problem of street children is a global concern and an increasing number of children are being forced to the streets driven by poverty, abuse, loss of parent, divorce, and torture. Most of these children are deprived of basic needs such as shelter, food and cloth. There is a widespread perception among the children and the public in large that public space is a free space for street children to enjoy. This paper explores public space occupation and utilization by street children using GIS and RS techniques. The study explores the movement of street children from one place to another; and analyse public perception towards street children. The study draws on a multiple methods fieldwork, which lasted for three weeks using focus group discussions, semi-structured interviews, in depth interview, and participant observation together with participatory mapping. Researchers' field notes and reflections over field observations were also included as one data collection method. Data for this study were obtained from both primary and secondary sources. Primary data were collected from street children, key informants; while secondary data such as reports from official documents were consulted to supplement the primary data. In order to generate spatial data of the occupation and utilization of public space, 1:50, 000 topographic maps, and orthophoto were used. Based on the analysis made, it was identified that the children are abandoned to the public spaces without fulfilling any of their basic needs. Majority of the children don't have safe place to live. Our investigation attested that street children developed the feeling that they are only entitled to live in a place which is not claimed by the public. Our spatial data have shown that public space such as market places, bus station, different business areas and street corners, ditches, bridges are among the spaces claimed by the children. They don't have the courage to live close to residential areas as they are considered a 'threat' by the public in general. This makes the children the most marginalized, ignored part of the population, facing many human rights violations. Thus, it is imperative to improve perception of the public and street children in order to reduce the challenges that children of the street have been facing.

Keywords: GIS and RS, Public space, Street children

1 Introduction

Children have been compared to flowers often as the similarities are evident - they are beautiful, they are unique, they require tender, loving care, they bloom in their own time. Often we focus on changing our children rather than changing their environment, but changing the environment has a big impact on how our children grow. If we consciously tend to our gardens, our flowers will blossom (Eanes, 2014) the

same logic works for the children as well.

Families, especially parents play a fundamental role in forming the values of children. The ability to cope with and adjust to life problems and demands is based upon the psychological foundations of early family experiences. Children receive care for their dependency and attention for their sociability. The kind of care and attention children receive during their early years of life affect their handling of important issues, such as trust vs. distrust. This ability equips children for establishing later ties with people outside the family (Aptekar,1993; Aptekar, 1994; Aptekar and Behailu, 2015) Nowadays, most children are forced to live on the streets without due care and support from their family. Street children are children who struggle for the challenges of life on the street. For Thomas (2001), the term “street children” is demeaning by itself, because it depersonalizes each child and makes him/her a problem to be solved. The term street involved children rather than street children (Kobayashi, 2004).

Though finding the exact number of street children is difficult, in 2011 the UN reported there are estimated to be 120 million children living on the streets in the world (30 million in Africa, 30 million in Asia, and 60 million in South America). The UN in 2017 reported the number of street children increased to 150 million throughout the world (UNDP, 2017).

According to UNICEF report, in Ethiopia 150,000 children live on the streets and 60,000 of them are found in the capital of the country. However, aid agencies estimate that the problem may be far more serious, with nearly 600,000 street children countrywide and over 100,000 in Addis Ababa (Shimelis, 2015).

Children are at risk of abuse, exploitation and vigilante or police violence, but the most vulnerable are those who actually sleep and live on the streets, hiding under bridges, in gutters, in railway stations. They also suffer from absence of parental protection and security due to the missing connection with their families (Ibrahim, 2012). While they may have small jobs such as shoe-shining or market-selling to pull through, many also end up dying on the pavement, Hunger, victims of drugs, gang rivalry and at risk from rape and other sexual abuse as well as sexual exploitation and live at great risk of contracting HIV/AIDS. Without some form of basic education and economic training, the future is bleak for these street children and their life expectancy terrifyingly low (UNICEF, 2017).

The issue of street children is an alarming and an escalating problem worldwide; and for many street children, capital cities and urban centres of the world have become places of survival (Kaleab, 2016). The emergence of street children is bound up with the totality of urban problems that the phenomenon is exclusively urban: there are no "rural street children." The migration of children from rural areas to urban public places proves this problem as an outcome of urbanization (Ennew& Swart-Kruger, 2003).

A public space is a social space that is generally open and accessible to people. Public spaces including high streets, street markets, shopping precincts, community centers, parks, playgrounds, and neighbourhood spaces in residential areas play a vital role in the social and economic life of the communities (Jan & Anne, 2009; Pancholi *et al*., 2015).

Urban public spaces are acting as a home for street children, a place where they can do their day to day activities. It is also a place where they form their own norms and values, and build a strong friendship which serve as a family. Public spaces should be considered a basic service, with the same priority as transport, water and sanitation which communities often primarily focus their resource on (Sangmo, 2015). Yet the dimensions and limits of what is “public” differs markedly from city to city, region to region, acted on and altered by economic, political, social, and cultural forces (Igor, 2017)

Obviously, the public see them as threat to the community thus to avoid them not to work and live close to their residence or commercial areas. The children also feel that they are not entitled to claim a safe place to work and sleep. A public place such as market places, bus station, main road, ditch, bridge, and

waste dumping site are among the places claimed by street children to live and enjoy.

Street children are seen as a problem, and a threat to society instead of viewed as children with problems who need help from society (Corsaro, 2011). Children perceive that they have no ultimate right to move freely everywhere to work and to sleep. Their movement is limited and their place of residence is also very limited. That limits their interaction with the public. Thus, it is important to make analysis of where children in the street spend their time and find their daily bread. Geospatial technology plays pivotal roles in this regard, particularly in terms of identifying the space that is claimed by street children and the space the public deny the children (Baui, 2008).

In this study a geospatial data were collected by using a GPS tool in order to show the occupation and movement of street children. Geospatial data is information about a physical object that can be represented by numerical values in a geographic coordinate system. Generally speaking, spatial data represents the location, size and shape of an object on planet, earth such as a building, lake, mountain or township. GIS was used to access, visualize, manipulate and analyze geospatial data.

As it indicated earlier, the study focuses on children of the streets, who live on public spaces by involving in different activities for their survival. For this matter GIS and remote sensing techniques is applicable to map their territory and movement through place to place.

2 Materials and Research Methods

2.1 Description of the Study Area

The study was conducted in Gedeo zone which is one of 14 administrative zones found in Southern Nations Nationalities and Peoples Regional State (SNNPR) of Ethiopia (Figure 1).

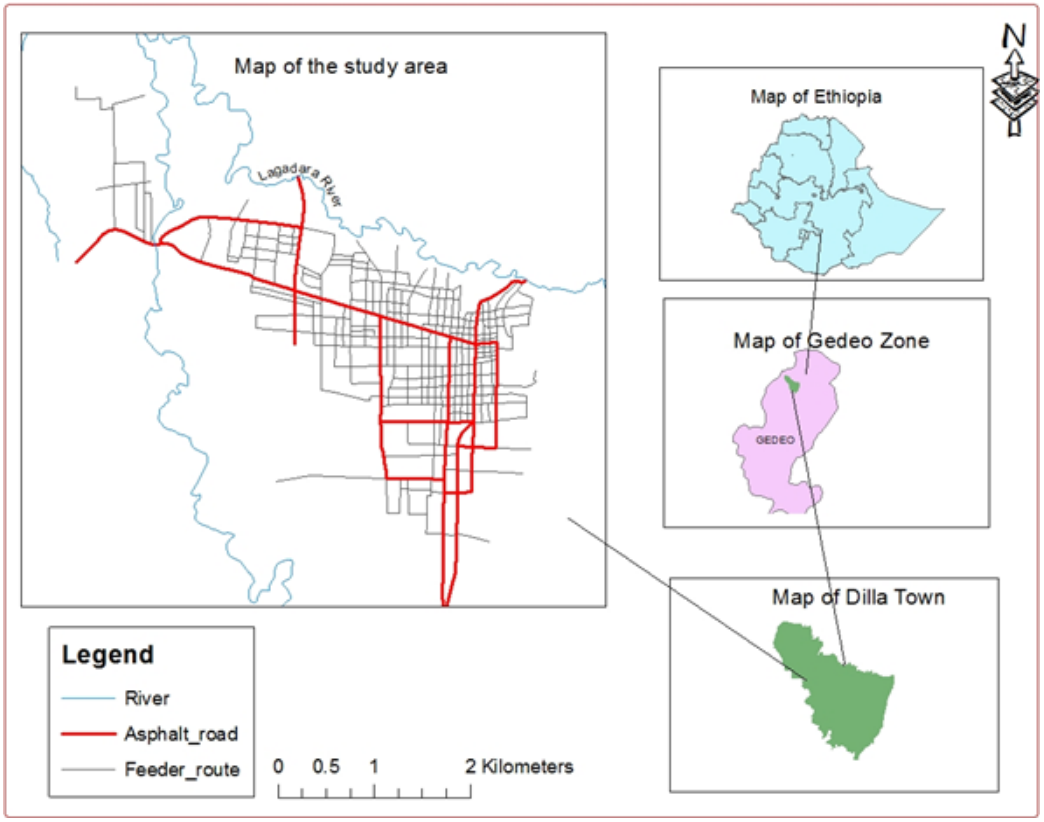

Figure 1 Location map of the study area

There are six Woreda Administrations (districts) and two town administrations under Gedeo zone administration. The administrative capital of Gedeo zone, Dilla Town, is located at 369 kilometers south of Addis Ababa. The zone lies approximately between 6°09′60.00″ N lat, 38°19′60.00′ E longitude (Legesse, 2013). The same authors indicated that it is situated at eastern escarpment of the Great Ethiopian Rift Valley bordering Sidama Zone in the North and, Oromia Regional State in the south, east and west.

According to the recent projection, the total population of the zone was estimated to be 1,079,771 in 2011 E.C., out of which 865,906 were rural inhabitants. With the total land area of 1353 km^2, Gedeo zone has a population density of 853 persons per km^2 and with a population growth rate of 2.9% in the year 2008 E.C (GZFED, 2017). The most densely populated Woreda in the regional state and the country - Wenago- with 1039 persons per square kilometers, is located in this zone.

Nowadays the life style of societies in urban centers is highly interrelated with the use of technologies. In order to fulfil their needs, the development of infrastructure service like road, electricity, water, telecommunication, and postal service plays a vital role.

In the study area, Dilla town, road construction is growing in slow rate. The main asphalt road which connects Ethiopia to Kenya passes through the town. In general, the service of asphalt road covers 21.5 *km*, gravel road 100.8 *km*, coble stone 30.32 *km* and granular sub-base road 67.3 *km*, it constructed by the collaboration of government and the community (Figure 2).

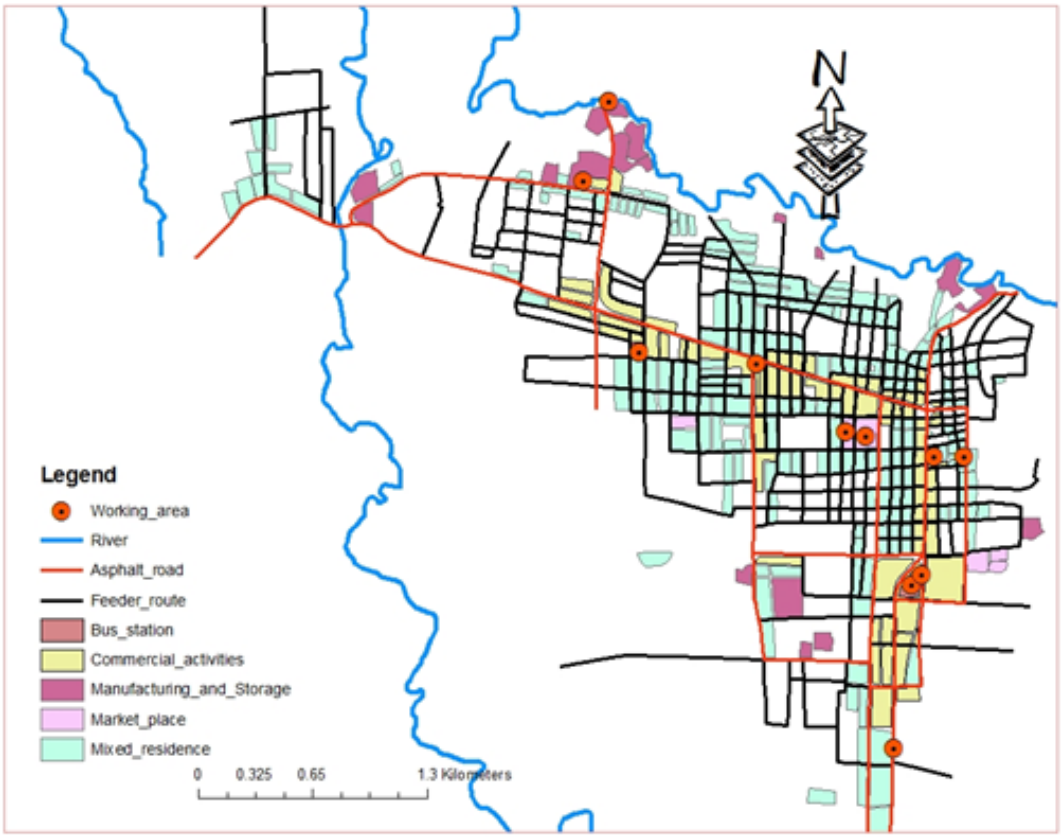

Figure 2 Distribution of road infrastructure in the study area

In Dilla town, there are 20 kindergarten and 30 primary and secondary schools which are owned by both government and private sectors. Upper level Education is also given in Dilla University with two campus OdaYaa and Main campus. In addition, technical, vocational and educational training college (TVET) and teachers training college (TTC) are found in the town giving service to the whole trainers in Gedeo zone (Figure 3).

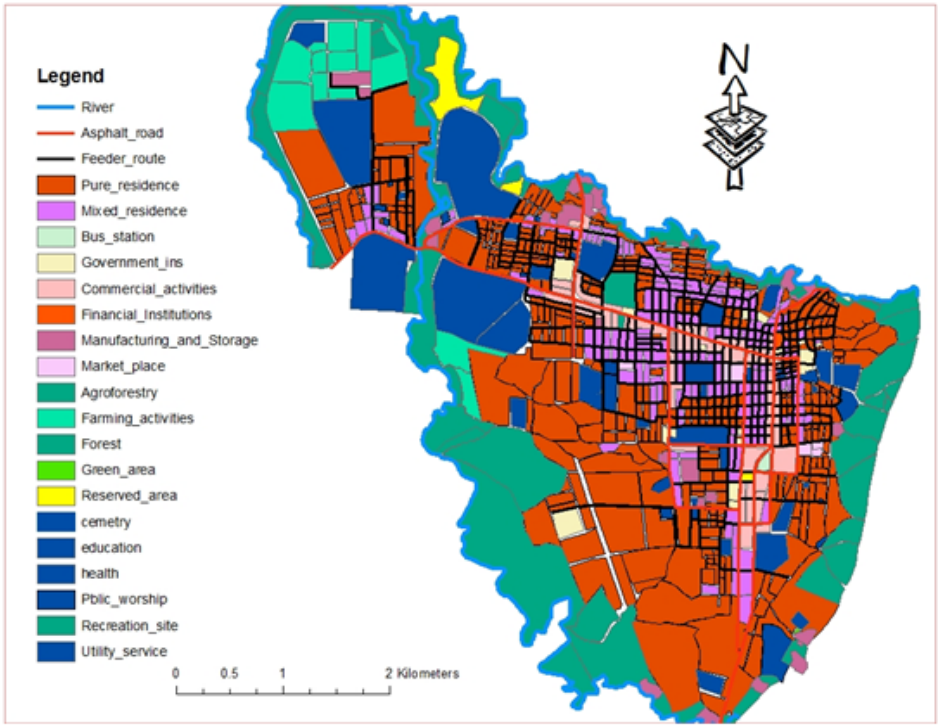

Figure 3 Map of Dilla town with its major function

2.2 Research approach

This sub-section of the article outlines the overall research approach of the study including the research design, specific methods employed in the recruitment of research participants, methods of data collection and analysis of data and reporting and dissemination of the study findings.

The study employed a mixed research approach due to the fact that the study calls for quantitative data and qualitative data as well. The spatial aspect is more covered through the collection and analysis of quantitative data; however, some aspect of the research such as soliciting important data from the children was conducted using qualitative methods. Thus, the study used a mixed research approach.

2.2.1 Research Design

Among the design found under mixed approach, this study employed a concurrent triangulation research design as the research requires gathering of both quantitative and qualitative data simultaneously. For the qualitative aspect, we employed case study to explore and examine in-depth analysis of public space occupation and utilization among street children of Dilla town. For the quantitative the research used a descriptive research.

2.2.2 Data Sources and preparation

Data for this study were obtained from both primary and secondary sources. Primary data were collected directly from street children and key informants. The

secondary data such as reports from official documents were consulted to supplement the primary data. In order to generate spatial data, the Dilla town existing 1:50, 000 topographic maps, and orthophoto were used.

Hardcopy 1:50,000 topographic maps were bought from Ethiopia Geospatial institute the then Ethiopian mapping agency. The maps were scanned and converted to image after which geo-referencing was done. The scanned images were registered to WGS 1984 spheroid and datum and projected using UTM zone 37 N. Geo-referencing was conducted using ERDAS IMAGIN software. Once the images were geo-referenced, an attempt was made to identify and digitize different geographic features.

The other datasets used was orthophoto of 2013 and high resolution images downloaded using SAS Planet application. SAS planet application helps to download images similar to Google earth. The images downloaded from SAS Planet were used to facilitate identification of different geographic features and map the distribution of the different infrastructure based on their functionalities. ARC GIS 10.4 was used to digitize and prepare the required thematic maps. The preparation was supported by collection of ground control points based on the function of different place with respect to street children public space utilization. Garmin GPS was used to collect the ground control points from the different parts of the study area.

The thematic maps necessary to examine utilization of public space by street children were prepared for two major purposes. The first is to carryout participatory mapping with the children, while the other is to show the interaction between the children and the public at large. Different maps were prepared and given to the children to identify and mark place at which they eat, sleep, work, play, bath, wash their cloths, and learn. The maps were printed in A4 size paper.

2.2.3 Methods of Data Collection

To undertake this study different data collection methods were used. The following are the specific data collection methods employed in this study.

2.2.3.1 In-depth Interviews

In this study, we used an in-depth interview as a method of data collection so as to gather first-hand information. Accordingly, in-depth interviews were held with street children in the study area. About 50 street children were interviewed to get a general condition of their life on the street. Furthermore, in-depth interview was held with officials of Dilla town municipality, children, youth and women office and others.

2.2.3.2 Key Informant Interviews

Key informant interview was also conducted with officials who work in Women, youth and Children affairs. Key informant interviews were selected based on their experience and knowledge about the issue under investigation. Accordingly, 9 informants were selected from two offices to reflect on the utilization of public space by children on the street.

2.2.3.3 Focus Group Discussions

Focus group discussions were conducted with street children to let them reflect their view on the perception they have about themselves and also the public at large. Some of street children who took part in the focus group discussions were selected purposively on the basis of their willingness. Actually, it was somehow difficult to manage the discussion as the children were not stable to stay with us for a while. Each group was composed of 7 participants. A focus group discussion guide containing a list of questions that are thought to explore the topic under study was prepared and used for this purpose. During discussions, the researchers played the role of moderator.

2.2.3.4 Participatory mapping

The process of participatory mapping can contribute to building community cohesion, help to engage

participants to be involved in resource and land-related decision-making, raising awareness about pressing land-related issues and ultimately contribute to empowering local communities and their members (IFAD ,2009; Juri, 2009).

In order to examine the way children use public spaces, an attempt was made to let children identify and map the different public spaces that children of the streets have been using. The children were given a draft map with marker so that they can easily identify where they live, eat, sleep, and bath, learn and *etc*. The children enjoyed doing identification and marking of different places using the maps provided. The children were able to produce different drawing by themselves without giving the already prepared draft map for participatory mapping. Based on the drawings and the maps produced, an attempt was made to prepare the actual maps showing the places where children claim and vice versa.

2.2.4 Sampling Techniques

This study employed a non-probability sampling techniques mainly, purposive and snow ball sampling to choose the participants. The target population for this study was street children living in the town disregard of their age, gender, where they come from, and their stay in the street. Some of these children are already registered and their number is known while others were not. This makes the process of sample determination somehow difficult. However, for sake of making the sample respondents representative, we decided to take sample from different sites where the children supposed to spend majority of their time. Accordingly, we have chosen Ginbi gebeya*, main bus station, near to Ethiopian telecommunication, main office, Dilla Branch, Molla Golja† area, and Misrke Tsehay Hotel‡.

In this study, we have used a purposive sampling technique to select the study area as well as study participants. We purposively selected Dilla town because the problem of street children is prevalent in this area. In the same manner, key informants were purposively selected.

Thus, only participants who are perceived knowledgeable about street children were included in the study from concerning government offices like Women and Children Affair Office.

We also used a purposive sampling technique to select street children. We purposively selected street children for in-depth interview. Snowball sampling technique was used as a back up to purposive sampling. Accordingly, we used some street children to get other children and to identify where they live. Thus, this sampling technique helped the researcher to get street children during the study. The sample size of the study was determined by the principle of data saturation theory due to the nature of the study.

2.2.5 Methods of Data Analysis

Once the necessary data were collected, an attempt was made to analyse using appropriate methods. Qualitative datasets were analysed thematically based on the research objectives and emerging issues in the process.

The spatial data generated to examine utilization of public space by children were analysed through visual interpretation. The maps that the children work on were used to compare with the actual space utilization identified through field survey and mapped using orthophoto. Comparison was made between the maps worked out by the children and the maps generated through collection ground control points from field.

* Ginbi Gebeya is a large market center where majority of the inhabitants of the two buy food and other items for home consumption and other purposes.

† Molla Golja area is known for its high concentration of people as it is a junction place and taxi stop. It is also a place where petty trading is very common. The children mostly prefer that area as it provides them access to job and cheap food.

‡ Misrake Tsehay Hotel is a hot spot area for concentration of street chidern due to that fact that it serve as Bajaj transportation stop. Petty trading is also common in the area

3 Results and Discussion

3.1 Demographic characteristics of the street children

The age of total respondents ranges from 9-19 years with higher proportion of sample respondents in the age group of 9-12, followed by 13-16, and the remaining 3 children are with the age group of 17-19. During the data collection phase, we couldn't find girls, all the respondents were boys. Finding street girls was difficult because most girls are not exposed to street life like boys and even those girls who are exposed to street life are in most cases involved in prostitution than staying on the street. As a result, street girls are less available than boys in the street. According to Lalor (1999) the reason as to why numbers of female street children are small in comparison to male street children as follows: The true incidence of working girls may be hidden by the nature of their work, which tends to be less visible than the work of street boys. For example, females may work as maids in bars, back street hotels and private houses. Street boys, on the other hand, typically engaged in more visible activities such as car washing, shoe shining and peddle (Shimelis, 2015).

Table 1 Age-sex distribution of the respondents

Age group	Male	Female	Percentage
9-12	27	0	54
13-16	20	0	40
17-19	3	0	6
Total	50	0	100

3.2 Major drivers that leads children to live on the street

Street is not a preferable place to live on. There are different reasons that can push or pull children to the street. Poverty, is the main cause followed by child abuse, divorce of parents, death of parents, attraction of the city, addiction of drugs, in need of job, *etc*.

In the study area, most children left their home due to the disagreement with parents. Other reasons like the need of job, family breakdown and others followed after it. In general, poverty is the main factor to bring those causes and finally lead the children to the streets.

Table 2 Major drivers for street children to live on the street

No.	Drivers that lead to the streets	Frequency	Percentage
1	Death of parents	1	2
2	Conflict with parents	18	36
3	Family breakdown	14	28
4	In need of job	15	30
5	Peer influence	2	4
	Total	50	100

As it indicated in Table 2, more than half of the children left their home due to the uncomfortable conditions at home, and many of them lost their mother due to death/ divorce and do not have smooth relation with their parents mostly with their father. One of the respondents who came from *Gedeb woreda* says the following

"My father was my only reason to leave my home. He always gets drunk and bit my mother. When I was about 8 years my mom died; so I shouldered all the responsibility to take care of my younger sister. I did any work to afford our daily meal. Year after the death of my mother, my father gave my sister to my Aunt. Then I became angry and accidentally hit one of his eyes to left him blind. That moment I run away from him when I see one of his eyes bleeding and came to Dilla town to lead this kind of life".

This kind of reasons/ disagreement between children and their step or real parents/ cannot be solved with a short time orientation or a promise of change; rather it needs a continuous assessment till a permanent change is observed. Mostly reuniting children to alcoholic parents is like putting them to the fire.

3.3 Public space occupation and utilization by street children

This section of the study tries to view the occupation, movement and utilization of public space by street children. There exist different locations by which street children are found: public space such as market places, bus station, different business areas and street corners, ditches, bridges and others. They don't occupy space which they assume is claimed by urban dwellers. For instance, they assume that they have no right to occupy any spaces which is close to residential area, governmental offices, commercial areas and other public spaces. According to their perception, their space is an open space which is not claimed by anyone such as ditch, bridge, along the roadside, and market place. An attempt was made to identify and map the space occupied by the children by categorizing into working place/space, sleeping space, bathing and washing space and space in which they eat food. Detail of the space used by the children is presented in the sub-sequent sub-sections.

3.3.1 Working areas of street children

Street children are daily workers though they are too young to perform different activities as they supposed to earn income for their survival. In every crowded public business spot, it is possible to find street children. In Dilla town public business centers like bus station, market center, grain mill areas, shopping centers, 15^{th} street and also local market areas are the main hot spot areas where they look for jobs. They perform different jobs like fetching water, carrying luggage for passengers, carrying different item, washing dishes, *etc*.

The children have a specific place of work depending on their age, living area and also their sociability. For instance in *Ginb Gebeya*; it is possible to find several children, whose age is less than 16 as compared to other areas. In this area, we interviewed 15 children; all of them are below the age of 16. This is because of the wide range of access for job without any exclusion. In addition, this place is not much preferable by older children, because the income is very less. This happens for two reasons one for their age and the second is the availability of extra human power.

In the contrary children of bus station area and *Asra amestegna menged* (15^{th} street) get better income relatively to those who spend around market area; due to the lesser number of street children and lot of job options like carrying luggage, washing dishes; fetching water. Sometimes they help passengers to find accommodation; in return the owner of the hotel gives them a tip. Comparatively, children of the 15^{th} street get much better income from the bus station. They are much older, stronger, and also with a better experience of urban life. They fetch water, carry items, give a delivery service and works in flour factories to load quintals of flour to the loader and deliver it to different branches. In general, it is also common to see them in the ditches and around waste disposal sites to search for any sort of unused iron materials and sell it to trash collector.

As it is indicated on the figure 4, street children are looking for job at crowded areas where the need of man power is high. General market area, bus station, grain mills area and also factories are the best sites for street children to generate income. On contrary, these crowded areas create suitable condition for theft. Some other children with families generate income via begging at street junction area and also around religious institutions.

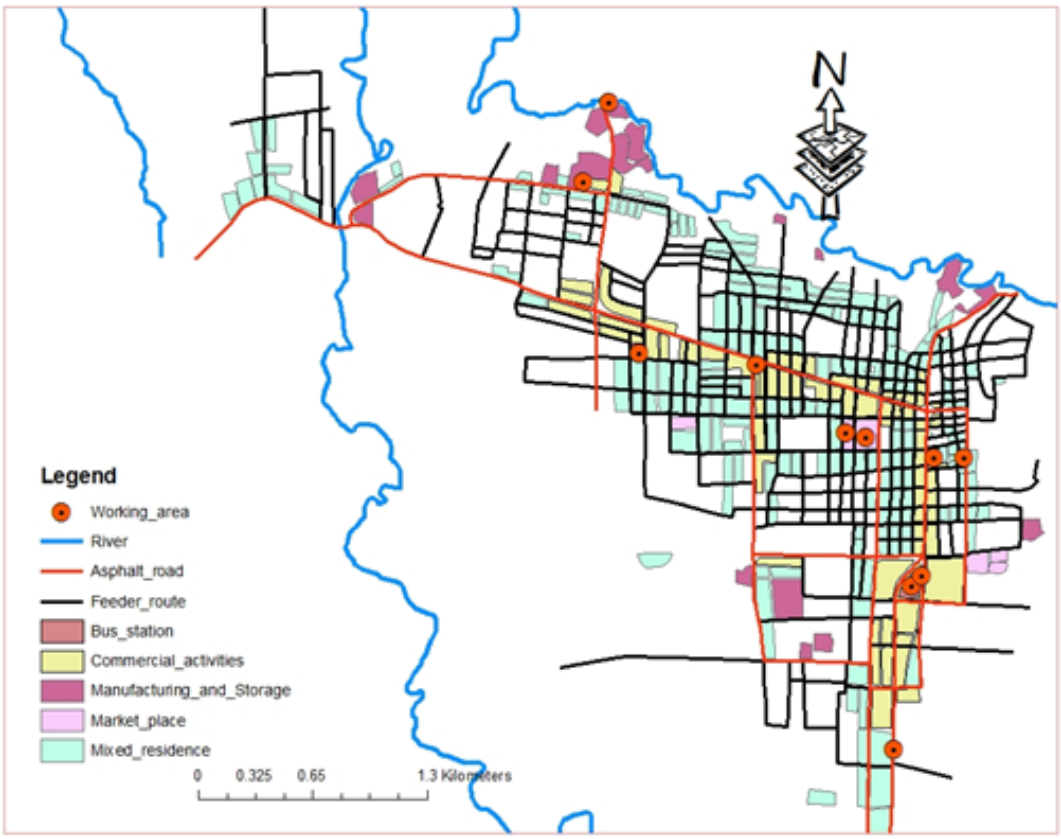

Figure 4 Working areas of street children

3.3.2 Where do they eat?

Food is one of the basic needs of human beings. Street children purchase their food at public spaces. There are some common and known areas that give service for street children and other daily workers. As it is shown on figure 5, those places are found at the back yard of telecommunication, at the left side of *Misrake Thsehay* hotel, at the surrounding area of bus station, at the ending street of general market and on the corners of the main asphalt road. The places are found nearby their working areas and food is being sold at a very fair price. Telecommunication is found in Bedecha sub-city and workers of this area can easily get their meal three times in a day since the area has a lot of road side vendors who sell food items. The same is true for bus station and market area street meal services. The site selection of meal service at *Misrake tsehay* hotel is slightly different. In that area only few street children are found; it is also not their working area. It is found at the main road which takes to *Kebado* and *Odolla kebeles* (areas found in Sidama Regional State). It gives service only after evening because it is a time for children on the street and other daily workers to return to their home; so they have their dinner along on their way.

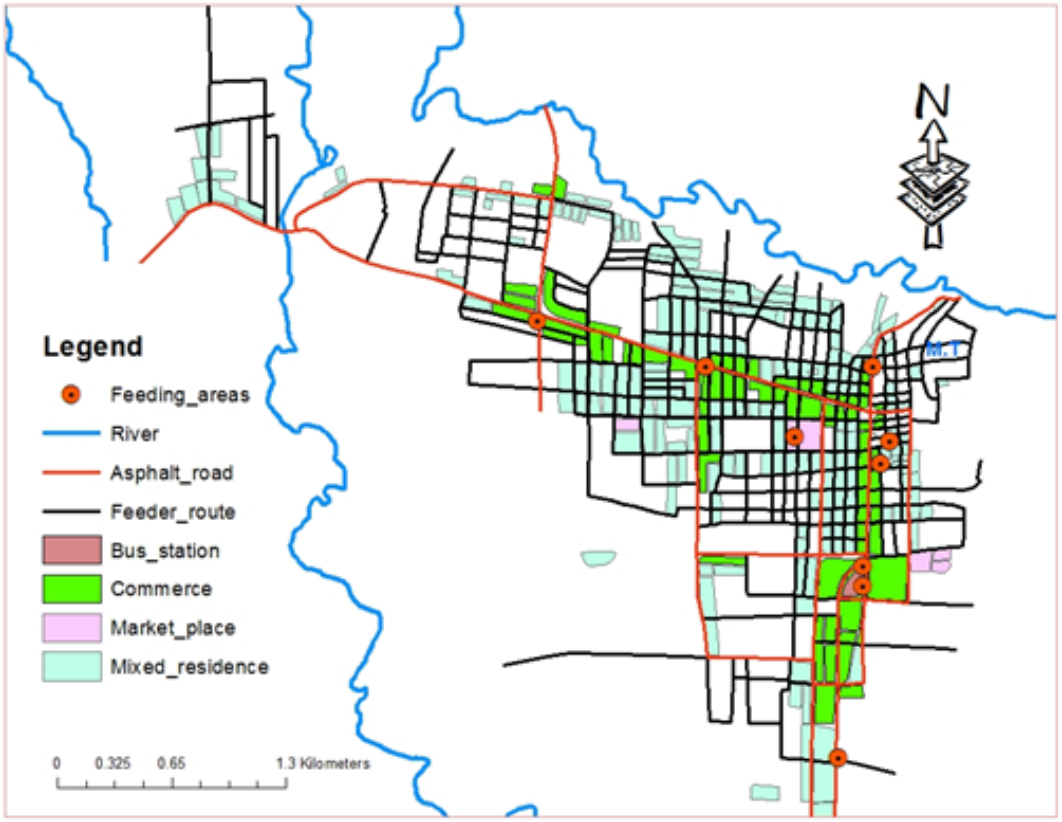

Figure 5 Feeding areas of street children

3.3.3 Where do they sleep?

For children of the street, night time is their worst moment because they are beaten, stolen, raped, face dangerous animals like hyena at their early age. In order to minimize these problems, they prefer to sleep at the main road under the street lights; around some governmental organizations like Gedeo zone administration, Dilla town municipality, and police station, *etc*. and also around schools where they can get the protection of the guard. Most of the time, they prefer to sleep by forming groups and they do not allow any one from other groups to join their group because they feel secured when they sleep with their friends.

As it is indicated in figure 6, a large number of street children sleep at the corners of the main Asphalt road. Some others sleep at Sesa sub-city mixed residence areas locally named (*Mariyam Sefer*) and *Bedecha* sub-city mixed residence area and a few numbers of children sleep at *kirinchaf* primary school and Dilla high school surroundings. It is clear that they do not sleep on pure residential areas because the community's perception towards them isn't good. They are perceived as thief. They stated that:

The community does not accept them as a child; they even do not allow us to sleep around their residence because for them we are thieves and source of violence. Beside this, at residence areas it is difficult to get a shelter at rainy seasons while at commercial areas it is possible to use the shades and verandas of shops.

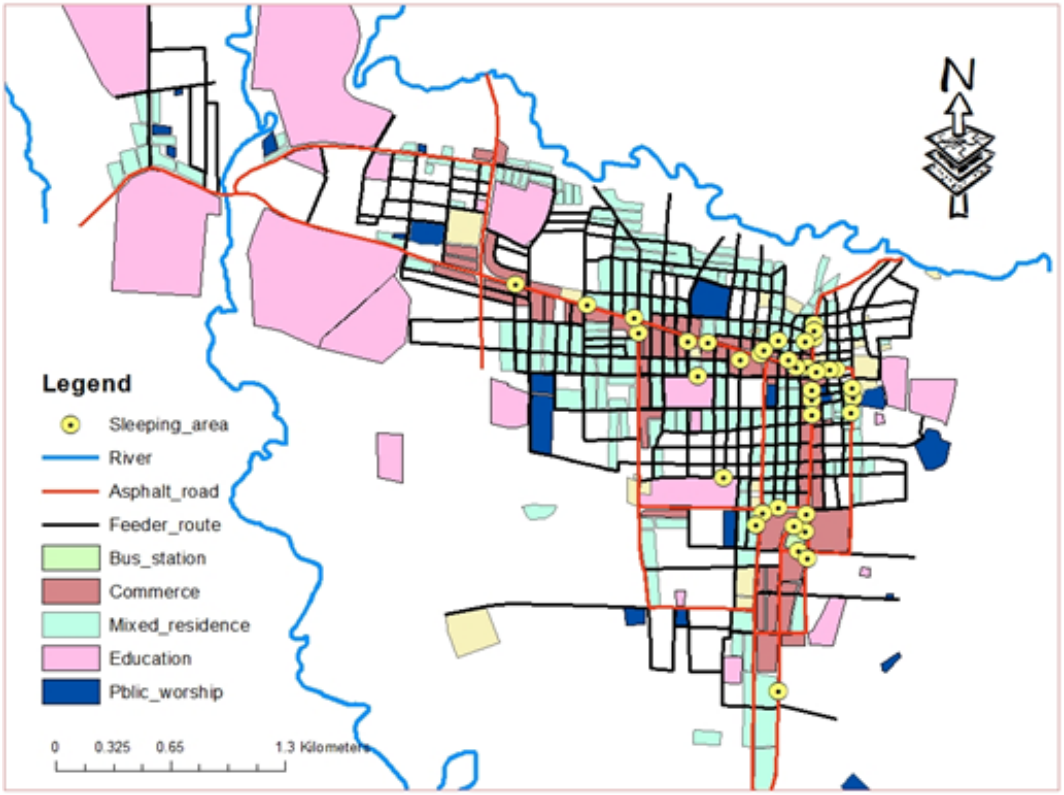

Figure 6 Sleeping areas of street children

There are some individuals who rent house for some street children with low cost for sleeping purpose. These houses are locally named '*Kesha Bet* '. Therefore, some children who do not prefer to sleep on the street have an option to sleep at *Kesha bet* (Figure 7).

For some children, even if it is crowded and some of the boys can get drunk and violent, it is better than to sleep at the streets, while some others do not prefer the houses because it is full of bug. So everywhere it is common to see street children who sniff kerosene gas with plastics, to stifle hunger and numb the cold at night.

Figure 7 A *Kesha Bet* at 5^{th} street

3.3.4 Access to public toilets

Greater access to toilets means greater access to the community as well as the world. Free toilet provision in public places, such as city centers, squares, stations, parks and at every crowded areas is necessary to build a healthy and clean environment.

In Dilla town, there are five public toilets which give service to the communities. These toilets are found within general market area, two local market areas and also at bus station areas. In comparison to the past years, the trend of using public toilets is increasing. But still our public spaces ditches and other open land areas are abolished with the waste of street children.

As it is indicated on figure 8, the children used to pee within the ditches, at the corners of the schools, within hidden areas. One of the children around general market area says "we have to go to the toilet early in the morning, before the streets are crowded. People say, "There are public toilets," but people have to pay to use them and we don't have the money."

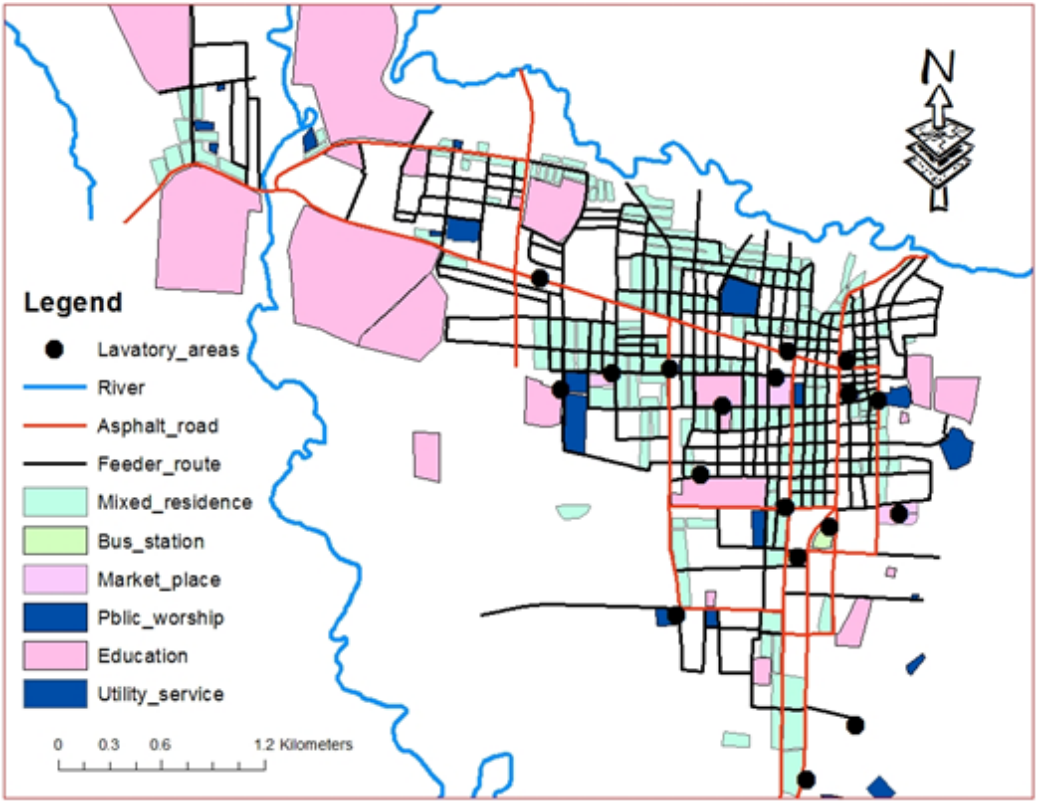

Figure 8 Lavatory areas of street children

In addition, the availability of the public toilet is not enough to the community including street children. The children are not well informed about the benefit of using public toilet and also have no awareness as how they use it. Also the concerned body do not give attention to decommission the full one. Due to the reason the problem of public toilet is acute and serious problem in Dilla town.

3.3.5 Playground/ Where do they play?

Like any child a street child needs to play and have a fun. And whenever they need to play; they play with a hand playing games. Figure 9 indicates areas where their playground resides on. These playing instruments found nearby to telecommunication meal service area, at the areas of market area and at bus station. They paid to play it. In addition, they watch

movie at a house which is found in market area. As all other services, the play grounds of street children are found far from pure residence areas; they play with their street friends at similar social status, this indicates that they are not only stigmatized by adults but also with children at the same age at them. In addition, they played games at a very low price comparing to the home children.

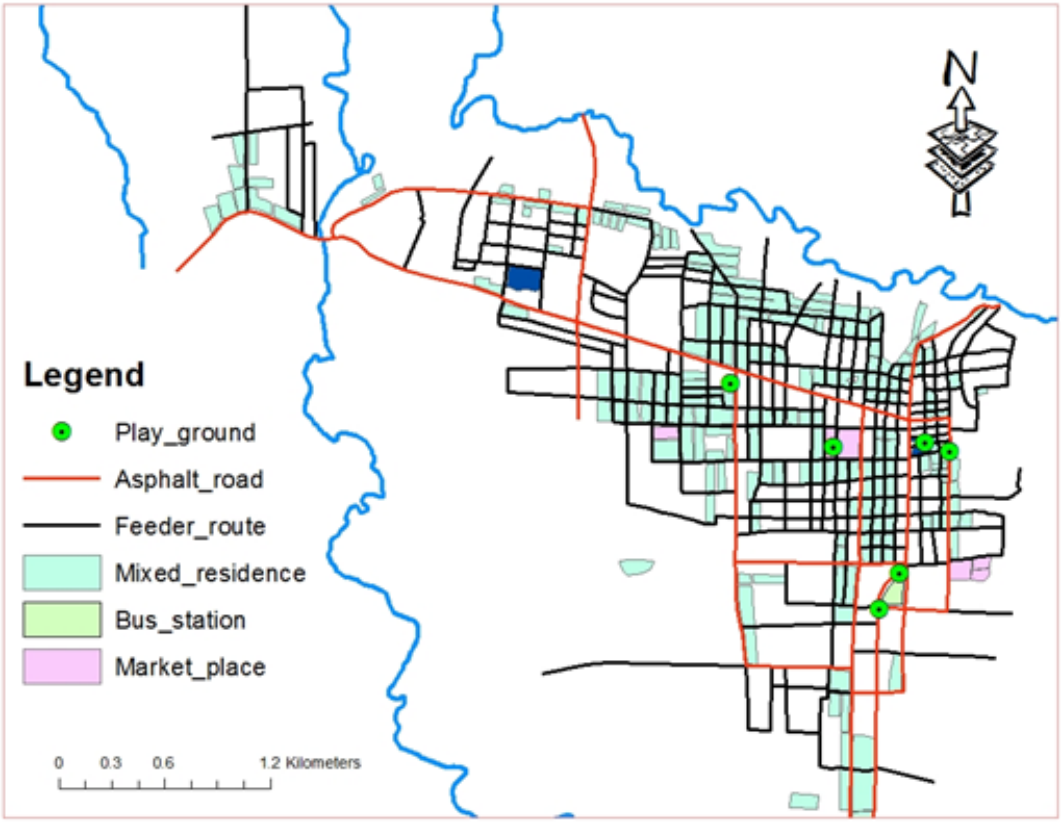

Figure 9 Playground of street children

3.3.6 Sanitation areas

In order to get clean up the children has to walk far to the Lagadara River. But due to its distance and their lack of knowledge for health, they do not wash their body and clothes for more than a month. So, by creating easy access for bathrooms it is possible to minimize skin and other related diseases.

As it is shown in figure 10, street children should walk more than 1km to the river to get cleaned up. This is due to river is a common property for all residents, no one can limit them and also it is for free. But currently, one public bathroom at the general market area is opened, so the health sanitation officers and the town municipality together should give attention to the health situation of the children and also to create conducive environment for all. Therefore, it would be better to open more public bathrooms and letting them use it for free.

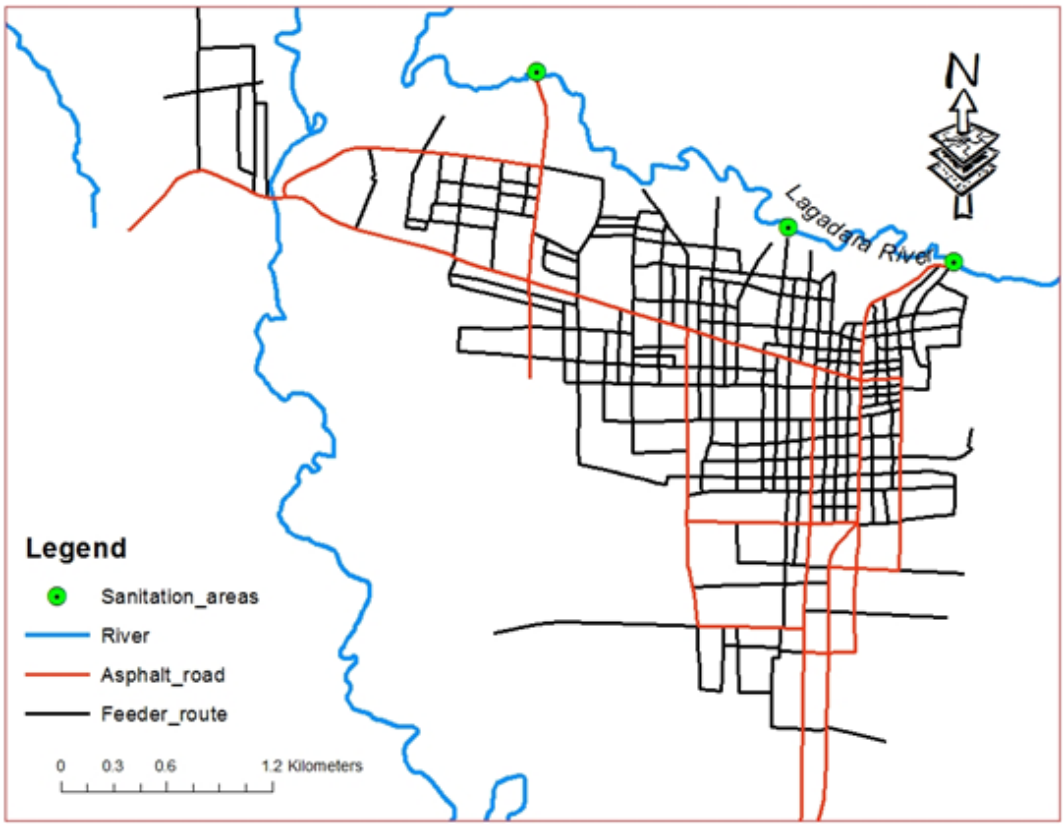

Figure 10 Sanitation areas for the street children

3.3.7 Perception of the public/ community about street children

Street children are assumed to be not part of the larger community; they form small community on their own; a sub-culture, which grows within a larger culture. The children have built a lower self-esteem for themselves; for this matter they feel like they belong to the street. They are ruled by their own norms and values which is different from the social norm of the larger community. So, due to their way of living and inability to cope up with the environment, societal and economic difference, they isolate themselves from the pure residence areas and bound stick to the public spaces.

The society also threatens them as outsiders rather than as children to be nurtured and protected. Thus, they are both spatially and socially oppressed, through multiple forms of social control, marginalization, and powerlessness. Due to their way of dressing, sanitation problem, and also deviant behaviour the community reject them to share their pure residence area with them. For instance, due to the existence of street children, *Bedecha* sub-city mixed residence area is known as a criminal zone.

The interaction between the community and street children differed through places and with time. At working areas, they are perceived as daily workers, around churches and road junction, they are treated as beggars, and while during the night, they have the image of thieves. Hence, in our town standard and even as a whole country except a few cities, public spaces are not clean, and attractive to use it as a recreation center for the community.

4 Conclusion

During the study, the researchers have explored the critical life conditions of street children. They do not have any access to the basic necessities like shelter, drinking water, food, bathroom. . . and so on. They are living in hunger; they do not have shelter at the rainy or sunny days; they do not have access to education, they are drug abused, raped, neglected, and also they do not get medical treatment. These are children who do not live their childhood as a child.

The English philosopher Harbert spencer talked about the survival of the fittest in his principle of sociology, I do agree with his quotes. In our view of street children, the one who works harder has a better access to buy his daily meal, while others who keep looking for food in trashes may end up in sniffing motor gases. For instance, a child who lives and works in bus station area has a better access to job and gain income, while others who work in Market areas are highly starved.

Street children are not found in pure residence areas because they are sources of fear to the communities. The mixed residence areas where street children sleep are known for criminal activities. Therefore, the communities as well as the younger street children are the victims of the criminal acts. As a result of this fear, street children prefer to sleep at the corners of the main Asphalt road, around schools, also at governmental institutions like EEPCO and Telecommunication.

In addition, their behavior is shaped by their environment they live on. Therefore, a street child who lives in *Bedecha* sub city becomes violent because it is a local alcohol trading center; others who live in *Molla-Golja* areas are drug abused because they have a higher tendency to get empty plastics of motor gas; others who live in first street junction areas are beggers because most of them are children of street family. On the other hand, children of Bus station areas are comparatively lead a better life. Finally, street children of 15^{th} street are responsible for their actions because they live in the town center for a very long time and adopted the environment.

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E J E D

WATER HYACINTH INVASION IN THE RIFT VALLEY LAKES BASIN—AN EMERGING ENVIRONMENTAL AND SOCIO-ECONOMIC CHALLENGES: A REVIEW PAPER

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Abstract

Water hyacinth (Eichhornia crassipes) occurs almost throughout wetlands of Africa and poses serious socio-economic and environmental problems of people in riparian communities, which added constraints on the sluggish development process. This review aims to show the spatial distribution, characteristic and impacts of water hyacinth to initiate urgent policy attention and amelioration mechanisms in Rift Valley Lakes Basin (RVLB). This invasive weed has spread quickly from Amazon to many tropical and sub-tropical countries and known to cause major ecological, environmental, and socioeconomic challenges. In Ethiopia, water hyacinth was officially reported from Awash basin, Koka Lake in 1962. Then, the plant had succeeded in infesting wetlands in western and north western Ethiopia, and recently lakes of RVLB mainly Lake Ziway and Lake Abaya. Lake Ziway – the shallow freshwater ecosystem reputed for its prolific birdlife, rich fish fauna and home to hippos population, islands of ancient monasteries and engine (irrigation water source) of mechanized to smallholder farms, is a corridor of employment, industrialization, and socioeconomic development. On top of these all development led pressures, invasion of water hyacinth has conveyed competition in water demand and enhanced immense ecological and environmental challenges. Lake Abaya – the second largest lake next to Lake Tana, has recently been overrun by water hyacinth mainly sourced from the eastern side of the lake. Researchers reported that water hyacinth in Lake Abaya affects the macrophyte community composition, abundance and diversity negatively. This affirms its wider impact on Ethiopian aquatic ecosystems. A comprehensive look at the short and long term consequences of its expanding invasion within the framework of specific local environmental, ecological and societal conditions is long-overdue. Proper policy attention and interventions would reduce invasion of water hyacinth and limit water depletion to enhance water resource potential. It also reduces eutrophication, improves water ecosystem health and the livelihood of the local community and other water users.

Keywords: Abaya Lake, Ethiopia, invasive species, Rift Valley Lakes Basin, Water hyacinth, Ziway Lake

1 Introduction

Invasive species are widely accepted as one of the leading causes of biodiversity loss and can have significant effects on resource availability and can suppress the relative abundance of native species (Bhattacharya *et al*., 2015; Patel, 2012). In Ethiopia, close to 35 invasive alien plant species are posing negative impacts on native biodiversity, agricultural lands, rangelands, national parks, waterways, lakes, rivers, power dams, roadsides, urban green spaces with

great economy and social consequences (Rezene and Taye, 2014). They may also alter biological communities and ecosystem structure and processes in terms of food web structure and energy flow (Wondie, 2013).

Water hyacinth (*Eichhornia crassipes* [Mart.] Solms), is a perennial, herbaceous, free floating aquatic plant originating in the Amazon Basin, South America (Hill and Coetzee, 2008). Since the late 1800s, the plant has spread in large areas of the World (Van Driesche *et al*., 2002; Tellez *et al*., 2008). The invasive weed has spread quickly from Amazon to many tropical and subtropical countries of Latin America, the Caribbean, Africa, Southeast Asia, and the Pacific (Julien, 2001; Navarro and Phiri, 2000). This free-floating vascular plant is known to cause major ecological and socioeconomic changes. It commonly forms dense, interlocking mats due to its rapid reproductive rate and complex root structure (Mitchell, 1985). Water hyacinth reproduces both sexually and asexually. Seeds generally germinate within six months, with dry conditions promoting germination (Ueki and Oki, 1979).

According to Navarro and Phiri (2000), significant freshwater bodies, marsh and wetland areas of Africa and the Middle East have been infested by this invasive weed. It also causes serious environmental and socioeconomic problems for millions of riparian communities whose livelihoods are dependent on water bodies and it has become an additional limiting factor of development. This is because the weed affects hydropower generation, irrigation, transportation, fishing, water level, access to water supply, and rapid reproduction of diseases causing organisms like Bilharzia and Malaria (Dersseh *et al*., 2019).

In Ethiopia, this weed was officially reported in 1962 in Koka Lake of the Awash Basin (Stroud, 1994) and it has been recognized as the most damaging aquatic weed in Ethiopia since 1965 (Wondie, 2013; Tegene and Ayele, 2014; Firehun *et al*., 2014). Water hyacinth infestation in Ethiopia has been manifested on a large scale in many water bodies of the country. The introduction and rapid spread of this weed in the Awash River Basin, Abbay River Basin, Baro-Akobo Basin and Rift Valley Lakes Basins (Lake Ellen, Lake Abaya, Lake Elltoke, Lake Ziway), has created serious problems for the water ecosystem services (Stroud, 1994; Rezene, 2005; Taye *et al*., 2009, Dersseh *et al*., 2019). For Ethiopia, having an economy highly dependent on agriculture and high population growth, it is prudent to effectively manage its water resources and the services to be provided. Research and intervention gaps related to water hyacinth and other invasive species impacts on hydrology and ecosystem services are well understood so as to plan and manage intervention projects in the rift valley lakes basin. Therefore, this review aims to show the spatial distribution, characteristic and adverse impacts of water hyacinth to initiate urgent policy attention and amelioration mechanisms in Rift Valley Lakes Basin (Figure 1).

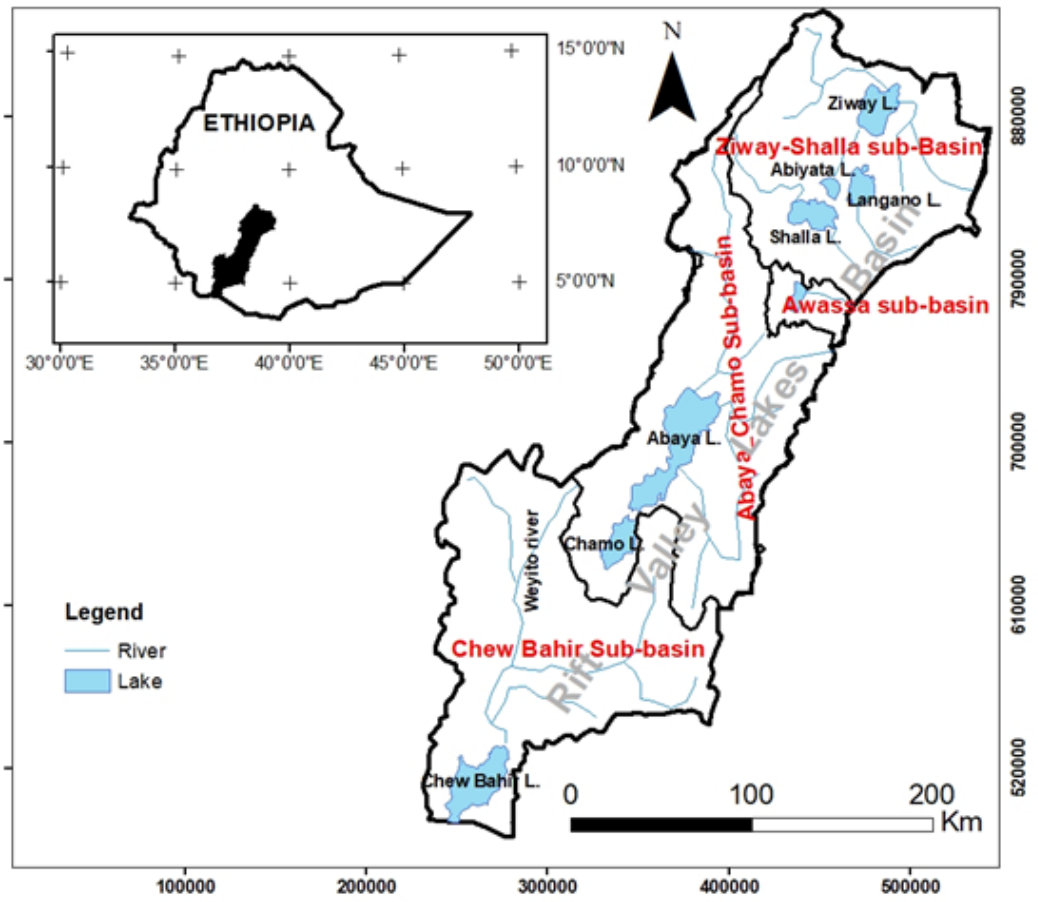

Figure 1 Rift Valley Lakes Basin (RVLB); (Source: *RVLB planning draft document*)

2 Water Hyacinth—existing situation in RVLB

Water hyacinth occurs almost throughout wet lands of Africa and poses serious socioeconomic and environmental problems on millions of people in riparian communities which added constraints on development (Howard and Matindi, 2003). Distribution modalities of water hyacinth have been different in some parts of Africa. In Egypt, Nile Delta, it has been distributed as an ornamental plant for Public gardens between the 1890s and 1900s (Gopal, 1987). In Sudan, the source of the weed was the Congo River where the infestation was since 1952. In Nigeria, the weed came from Benin (Navarro and Phiri, 2000).

In Ethiopia, the harmful water hyacinth, locally called *Emboch* had succeeded in infesting wetlands in western and north western as well as lakes of rift valley basin in Ethiopia. At that time, although authorities were notified, no subsequent action was taken. Since 1962, the plant had succeeded in infesting the whole stretch of the White Nile from Juba to Baro and Gillo Rivers in Ethiopia and Southwards up to Pibo River to Akobo. The Baro River is the main transportation route and difficulties experienced by steamers and boats have been frequently reported since the advent of water hyacinth (Rezene, 2005). Coupled with inability of communities and government authorities to respond to its infestations, connectivity among diverse water bodies during the peak rainy season has further facilitated the spread of water hyacinth (Taye, 2006).

Infestation of water hyacinth in Ethiopia has been manifested on a large scale in many water bodies of

the upper rift valley; Awash River and Lake Koka (Figure 2). Before a decade, except Lake Ellen, most Lakes of the Rift Valley Lakes Basin, such as Lake Ziway, Langano, Abiyata, Shalla, Awassa, Abaya and Chamo are proved to be free from Water hyacinth (Senayit *et al*., 2004; Rezene, 2005). However, according to RVLB Office (the then authority) assessment report (2018), showed Lake Ziway and Lake Abaya have recent been infested rapidly.

Figure 2 Koka side infestation (*Photo credit; Habtamu Temesgen, March 2021*)

Lake Ziway

Lake Ziway (or known as Batu Dembel), is the third-largest of the seven Ethiopian Rift Valley lakes and its total area is 434 sq km. It is characterized by relatively shallow freshwater ecosystem fed by the Meki and Ketar rivers and reputed for its prolific birdlife and rich fish fauna. It is also home to a small resident population of hippos. Five volcanic islands dot Lake Ziway's surface, with hiking trails, forests, and ancient monasteries to discover (Petra *et al*., 2009). Also important to mention is the irrigated agriculture which is found predominantly in the vicinity of Lake Ziway where small and medium-sized pumps draw water from the lake. Water for irrigation is abstracted by smallholder farmers, the floriculture industry, and several large investors like wineries and alfalfa. These developments are supported by the Ethiopian Government, as they are key for (youth) employment and socioeconomic development. Horticulture (vegetable-farming) has increased and irrigated agriculture now dominates even along the shore of the Lake. The growing Irrigated agriculture around Lake Ziway has conveyed competition in water demand and enhanced eutrophication (Temesgen *et al*., 2013). According to RVLBO (the then authority) assessment report (2018), more than 78 hectars of the shore of Lake ziway (in Dugda woreda) and 24 hectares in part of Ziway town are infested with this weed. Local people witnessed that water hyacinth has been recently introduced in to Lake Ziway from the neighboring Koka Lake through excavator.

Lake Ziway and its shore are of immense ecological value and provide the means of existence for millions of people. Continuous human encroachment, which enhance rapid invasion of water hyacinth (Figure 3) in this sensitive habitat is increasing environmental danger and creating harms. Intensive agriculture has caused heavy soil erosion and silting up of the Lake due to destruction of the wetland. Several species of animals and plants have already disappeared while the last wetlands and forests are still shrinking. In addition to small holder farming, the government has declared the region as an Economic Growth Corridor. The development of irrigation and other infrastructure and of export-oriented farming will lead to a further intensification of agriculture, an influx of migrants, and a deterioration of water quality. Unless mitigation measures will be enforced, these changes bear considerable risks for the downstream communities and decline of Lake Abiyata (Temesgen *et al*., 2013). The livelihoods of people living in, or along the borders of lakes and rivers depend partially or entirely on ecosystem services. Loss or degradation of the wetlands harms them directly and indirectly as ecosystems play a critical role in their daily life and in maintaining the quality of the environment.

Lake Abaya – is the second largest lake in Ethiopia with a total area of 1108.9 km2, including its islands (Sileshi, 2007). The lake is characterized by unusual reddish color, due to the presence of a large amount of iron sediment. Economically, Abaya Lake is used for fish harvesting, Roof tacking and Crocodile farming (Janko, 2014; Mengesha, 2017). The Lake has recently been overrun by water hyacinth, which is mainly sourced from the eastern side of the lake (Gelana River and Gidabo River catchments). A research conducted on Abaya Lake by Mengistu and his research group (2017) revealed that water hyacinth affects the macrophyte community composition, abundance and diversity negatively. The invasive species has reduced macrophyte abundance and diversity and in some cases changed the community to nearly monotypic flora showing its wider impact on Ethiopian aquatic ecosystems. A broad & closer, systematic and comprehensive look at the short and long term consequences of its expanding invasion within the framework of specific local environmental, ecological and societal conditions is long-overdue (Figure 3).

Figure 3 fast vanishing of water hyacinth in rift valley lakes; Lake Ziway (left), Lake Abaya (right); (*Source, Public media*)

3 Drivers of Rapid Water Hyacinth Expansion

Though the triggering factors are accumulated from activities of remotest watershed points, the rapid expansion and reproduction rate of water hyacinth is because of two major conditions: climatic and water body conditions. Temperature (which ranges from 28 $^{\circ}C$ – 30 $^{\circ}C$), sunlight shading, salinity, disturbance, eutrophication, pH, and reproduction systems are the main determinant factors for the optimum growth of water hyacinth (Gaikwad and Gavande, 2017). The most favorable conditions are quiescent water, shallow water depth ($< 6m$), bed surface covered with deposited sediment which is rich in organic matters and availability of vital elements such

as nitrogen and phosphorous in nutrients (Makhanu, 1997). Sunlight is important for photosynthesis because the nutrient uptake from the water by its root is not enough for its overall optimum growth. Optimum salinity condition for water hyacinth is $< 2\%$ salt in the water. Flooding, wave and currents are the main disturbances of the stability of the weed because high flooding, wave, and currents can flush out the weed to downstream. The favorite nutrients are nitrates, phosphates, and sulfates in dissolved form. The source of these nutrients could be polluted water by nutrients from agricultural fields, industrial zones, and residential areas. Runoff from agricultural fields contains phosphorus (P) and nitrogen (N) because of the application of chemical fertilizers and pesticides). The minimum requirement for the survival of water hyacinth is 5.5 $mg/L\,N$ and 1.66 $mg/L\,P$. For maximum growth of water hyacinth, 20 $mg/L\,N$, 3 $mg/L\,P$, 53 $mg/L\,K$ (potassium) and between 6.5 and 8.5 pH value are required (Gaikwad and Gavande, 2017; Khan and Ansari, 2005; Dersseh *et al*., 2019).

4 Environmental and Socioeconomic Impacts of Water Hyacinth

Invasion of aquatic habitats by non-native species like water hyacinth is a global environmental challenge with serious ecological, social and economic development consequences (Williamson, 1999; Villamagna and Murphy, 2010; Dersseh *et al*., 2019). They do this by altering soil and water chemistry, nutrient cycling, hydrology and disturbance regime of the infested ecosystem. Besides, they affect seedling recruitment blocking seed dispersal through their thick mat growth of stem, root and rhizome (Dersseh *et al*., 2019). As a result, they often out compete native plant species and establish a monotypic community as can be seen in Figure 1.

The social impacts include lack of clean water, increase in the prevalence of waterborne diseases, community migration, conflict among community and difficulty of getting access to water points. In some areas it can provide excessive surface area for intermediate hosts such as snails that transmit waterborne diseases such as schistosomiasis (Mengesha, 2017). The economic impacts of water hyacinth include a reduction in fish quantity and quality, blocking of waterways and impede water transportation, blocking of tunnels and turbines, and reduced hydropower generation, blockage of irrigation canals, reduction of aesthetic value of Lakes and tourism. Literatures testified that the most important environmental impacts are water quality decline, water loss due to high evapotranspiration, siltation, flooding, and aquatic life decline (Ouma *et al*., 2005; Janko, 2014; Mengesha, 2017). Water hyacinth can create an impenetrable fortress in shallow areas making it difficult to access deeper parts of water bodies for recreation, fishing, transportation etc. The mat can even hamper water flow to hydro-electric dams (Dersseh *et al*., 2019). Sedimentation, turbidity, eutrophication, deoxygenation, and proliferation of aquatic weeds are the major causes for loss of fish habitats.

Important to mention is the substantial impacts that water hyacinth have on water ecosystem service potential. It alters clarity of the water, reduction of dissolved oxygen, nitrogen, phosphorous, heavy metals, and other contaminants (Villamagna and Murphy, 2010). Water bodies infested by water hyacinth are characterized by higher turbidity, a higher level of chlorophyll, a higher level of chemical oxygen demand (COD), lower dissolved oxygen (DO), lower pH, and lower nitrates than non-infested areas (Brendonck *et al*., 2003). Hydrologic balance of water bodies is also affected by such infestation as it increases the evapotranspiration rate. Many scholars have reported a wide range of evapotranspiration rates from water hyacinth as compared to open water bodies.

5 Mitigation Framework

Water hyacinth removal campaigns have been done annually since 2012 for Lake Tana (Figure 4) and since couple of years for L. Ziway and L. Abaya. The local farmers and youths are playing a great role in these campaigns. Though, regional governments and Basin Development Authority have been working with great commitment to eradicate the water hyacinth, the expansion of the weed is far from con-

trol. The removal of the invasive weed by hand is becoming difficult and the expansion rate of the weed is extremely rapid. Thus, eradication seems to be difficult which indicates the need for integrated and sustainable management. The integration requires investigating and employing machinery, biological and chemical controls in addition to manual removal by farmers (Dersseh *et al*., 2019). Sustainable management is the focus of this mitigation framework which includes a number of intervention categories such as watershed (landscape) restoration, gulley rehabilitation, buffer zonation of water bodies, enhancing stakeholders commitment, improving harmony through reduced resources use conflict, policy issues, legal and institutional aspects etc. However, this framework is summarized under three categories: (1) *landscape functionality restoration via green-infrastructure*, (2) *stakeholder engagement*, and (3) *legal and institutional arrangements*.

Figure 4 Community taskforce trying mechanical removal from Tana Lake, (*source: public media*)

5.1 Landscape functionality restoration via green-infrastructure

Landscape restoration can have diverse targets; however, most restoration projects aim few ecosystem services with limited attention to immediate societal benefits. Restoration projects particularly in the Ethiopian Rift Valley Lakes Basin should focus on ecological restoration which eventually enhances hydrological balance and aquatic ecosystem health (Temesgen and Wu, 2018). Ecological restoration refers to the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Temesgen *et al*., 2013; Belete, 2017).

Ecosystem services that are potentially derived from restoration efforts are those benefits that are directly enjoyed, consumed, or used to yield human wellbeing. The notion of ecosystem qual¬ity and integrity as well as landscape functionality advocate conservation and use of soil, water, nutrients, and organic matters (collectively called "resources") within a landscape system through integration with development interventions. Many development goals are likely underpinned by the delivery of one or more ecosystem services. On the contrary, many ecosystem services depend on water and are affected by changes in water (quality) flows and gaining multiple ecosystem services through landscape restoration need to be targeted. This requires fundamental understanding

and management of the hydrologic mechanisms that underlie ecologic patterns and processes. This combined approach is termed as 'ecohydrology'. In a broader sense, targeted efforts to increase ecosystem carrying capacity and enhance the resilience and functionality of ecosystems at basin scale (Belete, 2017).

In the last few years, green infrastructure has become a popular concept to guide planning toward sustainable land use. It is a multifunctional tool which appropriates to realize objectives related to nature conservation, rural development, and sustainable agriculture and water resources use. It is an ecological technology application which has a spectrum functions that provide ecosystem services benefits of social, economy and environmental nature. The green infrastructure mainly focuses on providing multi-functional biogeochemical barriers that primarily regulate the hydrology (water cycle) and trap sediments (physical process) and nutrient cycling (chemical) that in turn enhance vegetation growth (biological process) and operates vice versa (ecohydrology) to limit eutrophication and hence aquatic weed invasions. Available literatures (Belete, 2017; Temesgen *et al*., 2018) shared the importance of multi-functionality of intervention; connectivity of upstream-downstream along the landscape continuum; restoration of ecological functionality of the landscape; and the role of hydrology and its feedback in terms of biota (dual regulation).

5.2 Stakeholder engagement

A stakeholder engagement is arguably the most important ingredients for successful project delivery and yet is often regarded as a fringe activity. Project managers depend on people to respond to the outputs and benefits that they deliver. People will only respond if they are engaged. Designing a course of action for addressing alterations to priority issues requires a thorough understanding of the stakeholders within the system boundary of the project landscape and how these stakeholders are affected by changes to the primary issues identified (Mathews *et al*., 2019). Within source-to-sea framework, Granit *et al*. (2017) suggests the following categories of stakeholders to frame stakeholders in relation to their interests in the highlighted flow (Box 1):

Box 1: Categories of stakeholders as a mapping approach

1. *Primary stakeholders* – are individuals or groups that are affected by the altered conditions, primary flows (issues), and will directly benefit from basin development strategies;
2. *Targeted stakeholders* – are actors or sectors whose practices are contributing to the altered condition and whose behaviors intervention strategies are aimed at changing;
3. *Enabling stakeholders* – are institutions providing or should provide enabling conditions for behavioral changes and benefits to occur and be sustained over time;
4. *Supporting stakeholders* – are development partners or financiers whose strategies are aligned with prevention of the altered condition;
5. *External stakeholders* – are individuals or groups outside the system boundary who share an interest in the altered condition.

Accordingly, water hyacinth and other related invasive species intervention projects in the RVLB are recommended to follow a source-to-Lake approach of stakeholders mapping and engagement (Box 1). Considering the inconsistency of stakeholders' interest and influence levels, the table below presents the diverse stakeholders categories, their role, position, interest, and concern.

Table 1 Stakeholders categories and roles for water hyacinth intervention projects in the RVLB

SN.	Categories	Role/position/interest/concern
	Primary stakeholders	
1	Farmers -particularly small-scale irrigators	Lost their irrigation site and cattle water and fodder supply due to water supply shortage and lake shore infestation as a result of invasion
2	Agri-business firms	Medium & large-scale firms may collapse as a result of water resources depletion and weed obstacles on irrigation infrastructures
3	Fishermen	Ecosystem alteration due to alien species and subsequent water resources depletion affects the livelihoods affecting the stakeholders
4	Resorts/Lodge/Hotel owners	Those hotels and resorts around the lakes and Rivers sides affected by the water resources depletion in the rift valley Lakes basin
5	Boat renters and lakeside enterprises	Owners and operators of tourist boat and other lakeside businesses that depend on the lake for attracting customers
6	Fish sellers and consumers	Small businesses of fish selling as well as the consumers
	Targeted stakeholder	
7	Agri-business firms	Most medium & large-scale firms may participate in overpumping and generally mismanagement of water resources
8	Farmers	Upstream farmers whose improper cultivation enhance nutrient laden erosion and those who cultivate lake shores
9	Firewood & charcoal traders	Retailers and wholesalers in the cities/towns are indirectly encouraging deforestation
10	Contractors in the construction industry	Transport construction materials from mountains at the upstream of the gully network, heavy trucks are adversely drive through the gully system that in turn triggers further erosion.
11	Municipalities	Whose system may loosely contribute to proper water use, allocation & management
	Enabling stakeholder	
12	Ministry of water, energy, and irrigation	Enable the community to use water and alternative energy sources
13	Basin development authority	Enable institution to implement IWRM in the basin at country level
14	Rift Valley Lakes Basin Office	Mandated institution to implement IWRM in the Rift Valley basin
15	Agriculture, land, and natural resources offices	Mandated institution to manage the natural resources in the basin
16	Environmental authority & CFEP	Mandated institution to protect the lakes and other resources from pollution
17	Municipality	Mandated for solid waste management and lakes and other parts of the rift valley basin
18	Tourism sector	Lakes and River sides used for an attraction for tourists
19	Investment bureau	Governing the investments around the water bodies (Lakes, Rivers)

Table 1 Contd.

SN.	Categories	Role/position/interest/concern
20	Universities	Higher institution (research, technology transfer, capacity building, and community services) in the rift valley
21	Alliance of friends of Lakes	Volunteer group who work in Lakes region
	Supporting stakeholder	
22	Industry parks	Social responsibility of the institutions in the water bodies
23	Hotels and resorts	Social responsibility of the Hotels and resorts in the water bodies
24	Universities	Research, technology transfer, university-industry linkage, and community service in the main Ethiopian rift valley basin
25	SIWI, IWMI	Support projects implementations to improve basin development & local communities
26	GIZ	Support projects implementations to improve basin development & local communities
	External stakeholder	
27	SIWI; GIZ; SIDA; GEF; US-AID; EU	These organizations and their network are the potential donors for source-to-lake system management of the rift valley basins

5.3 Legal and Institutional Arrangements

Analyzing the gaps in the existing governance system and the practices that are impacting the priority issues determine the success of source-to-lake* implementation. This is the way how to establish the enabling conditions that support the transition to behaviors and practices that result in the desired long-term impact (Mathews *et al*., 2019). Identifying relevant governance instruments and the institutions responsible for intervention projects implementation provides a general picture of the governance system. Further analysis of gaps in the enabling conditions, implementation barriers, conflicts or overlaps and challenges to coordination can help define where the governance system needs to be strengthened, and how much support it provides for interventions.

Instruments that influence governance range from "core" national legislation such as environment rights and obligations enshrined in the Constitution of Ethiopia or the Environmental Policy of Ethiopia, through to more specific obligations on rural land use found in regional state proclamations. Institutions can include Federal ministries and local councils. Governance institutions comprise most of the Enabling Stakeholders identified in stakeholders mapping.

Invasion trend of water hyacinth and other alien species in RVLB is the result of practices and behaviors relating to land use systems, dynamics and gaps in cultivation land management efficiency. Marginal land cultivation is also among those potential factors exacerbate erosion and transport favorite nutrients in dissolved form to water bodies and enhance weed invasion. The source of these nutrients could be polluted water by nutrients from agricultural fields, forest clearance; and also from industrial zones and residential areas. This means that instruments and institutions concerned with rural land use, agriculture, forestry, environmental protection, mining, and urban development were included within the analysis. Table 2 below provides several examples of important institutions and instruments, but is not exhaustive.

* A source-to-sea/lake system is the land area that is drained by a river system, its lakes and tributaries (the river basin), connected aquifers and downstream recipients including deltas and estuaries, coastlines and near-shore waters, the adjoining sea and continental shelf as well as the open ocean (Mathews *et al*., 2019).

Table 2 Examples of institutions and instruments

SN.	Institutions	Reason for Inclusion
1	Ministry of Agriculture & Natural Resources (MoA)	Using its hierarchical levels, the ministry supports the implementation of proclamations and regulations relating to agriculture and natural resources management. As part of its role, it administers sustainable land and watershed management and marginal land cultivation, and therefore is connected from the upper catchment to the endpoint of the system. In terms of erosion hazardous, the conversion of forest and marginal lands to agriculture as well as the increase in intensity of land uses has been a significant driver in sediment flows that increase its offsite impacts.
2	Ministry of Water, Irrigation & Energy (MoWIE)	Is a federal organization responsible for the management of water resources, water supply and sanitation, large and medium scale irrigation and electricity? The Ministry is a regulatory body, which involves the planning, development and management of resources, preparation and implementation of guidelines, strategies, polices programs, and sectoral laws and regulations. It also conducts study and research activities, provides technical support to regional water and energy bureaus.
3	Basin Development Authority (BDA)	Is housed within the MoWIE and responsible for policy development, surveys and research needed for the implementation of integrated water resource management and activities within the basins as well as developing plans for protection and sustainable uses of basins; follow-up implementation of various projects. It administers measures that should be taken against water resources depletion, pollution in the basin, working in collaboration with Regional Governments organs and other relevant bodies by setting up a forum for effective networking.
4	Commission for Forestry & Environmental Protection (CFEP)	This regional bureau is responsible for the management of the environmental impact of new activities, controlling pollution as well as monitoring the state of the environment. This Bureau is responsible for developing, conserving, and utilizing forests, which is one of the key components in the land-to-lake continuum, supporting policies and strategies from MEFCC at the Federal level. Wetlands identification, delineation, and implementation of community-based management are also done by this bureau. In terms of sediment in the sub-basin, its chief influence will be through managing activities that impact on water quality from point sources such as new development or sand-mining.
5	River Basin Councils & Basin Development Authority Proclamation (Proclamation No. 1097/2010)	This proclamation enhance decentralization of water resources planning and management functions to River Basin Organizations (RBOs) at the basin level so that most of the functions of the Federal government delegated to such a two-tier organizational set-up of RBO, Basin High Councils (BHC) and River (Lakes) Basin Authorities (RVLBA). Following this proclamation, the Council of Ministers has established by regulations the RVLBA for Abay and Awash and Rift valley lakes basin authority and basin councils.

Table 2 Contd.

SN.	Institutions	Reason for Inclusion
6	Ethiopia's Constitution of 1994	The Constitution underpins all legislation in Ethiopia and provides a basis for the development and inaction of legislation, regulation and proclamations, mainly at Federal and State levels. In addition to the rights, it also notes obligations on Governments and citizens that underpin provisions found in other Proclamations (e.g. relating to rural land use or forestry) in terms of providing or removing access to land).
7	Environmental Impact Assessment Proclamation No. 2991/2002	This Proclamation is concerned with managing activities that have an environmental impact on receiving environments but is generally focused on managing new or more significant activities and projects as opposed to managing land use. In terms of sediment, the Proclamation may be relevant for managing sediment flow from development activities across the Hawassa Sub-Basin as well as managing sand mining occurring in both lower and upper catchments.
8	Forest Development, Conservation & Utilization Proclamation No. 1065/2018	The Proclamation notes importance of Forests and Forestry to Ethiopia, and includes provisions for managing state forests, community forests, protected forests, preserved forests, private forest developers, amongst others. Given the key role of deforestation and afforestation in managing sediment flows, the implementation of this provision by regional agencies is an important part of governance.
9	E.F.D.R – Rural Land Administration & Land Use Proclamation No. 456/2005	The Proclamation provides for the rights and obligations around land use across Ethiopia, including the development of rural land use plans, use of degraded or marginal lands, and the various roles of Federal and Regional State authorities. It sets the basic conditions of rural land use across Ethiopia, and the responsibilities of various agencies and institutions. Whilst it is primarily interested in the appropriate distribution of land, it still outlines why certain lands may or may not be available for use.

6 Summary

This review aims to show the spatial distribution, characteristic and adverse impacts of water hyacinth to initiate urgent policy attention and amelioration mechanisms in Rift Valley Lakes Basin (RVLB). It also provides mitigation framework and approaches mainly for the sustainable management of the invasion. Water hyacinth has spread quickly and known to cause major ecological, environmental, and socioeconomic changes. In Ethiopia, it was officially reported from Awash basin, Koka Lake and had succeeded in infesting wetlands in Ethiopia. Recently, Lake Ziway and Lake Abaya had been under rapid infestation. On top of all development led pressures, invasion of water hyacinth has conveyed competition in water demand and enhanced immense ecological and environmental challenges in L. Ziway. Similarly, researchers reported that water hyacinth in Lake Abaya affects the macrophyte community composition, abundance and diversity negatively. This affirms its wider impact on Ethiopian aquatic ecosystems. A comprehensive look at the short and long term consequences of its expanding invasion within the framework of specific local environmental, ecological and societal conditions requires proper attention. Experiences shown that proper policy attention and interventions would reduce invasion of water

hyacinth and limit water depletion to enhance water resource potential as it reduces eutrophication, improves water ecosystem health and the livelihood of the local community and other water users. In addition to integrations that require employing machinery, biological and chemical controls and manual removal by farmers, this review also recommends a mitigation framework for sustainable management interventions such as landscape functionality restoration via green-infrastructure, stakeholder engagement, and legal and institutional arrangements.

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