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IDENTIFICATION OF SEED SOURCES THROUGH GERMINATION AND SEEDLING VIGOR FOR SOME WOODLAND TREE SPECIES AT ARBA MINCH ZURIA WOREDA, SOUTHERN ETHIOPIA

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ABSTRACT: Ethiopia is one of the most important centers of biodiversity that include high forests, woodlands, bushlands, plantations and trees outside forests. The diversity in these resources is threatened because of mismanagement and environmental degradation which have caused selective and total loss of genetic diversity. Understanding the variation among provenances and progenies during cultivation is essential in tree improvement programmes. Effect of provenance on seed germination and seedling vigor of *Balanites aegyptiaca*, *Ficus sur*, *Terminalia brownii*, *Tamarindus indica* and *Acacia abyssinica* were evaluated at Arba Minch Agricultural Research Center nursery by using Complete Randomized Design. Provenances were considered as treatments for all studied tree species. Data on germination rate, root collar diameter, leaf number, shoot height, fresh biomass and dry biomass weight were collected and analyzed by using ANOVA while Least Significance Difference (LSD) was employed for mean separation. In terms of seedling vigor, significant difference was not observed among provenances for *T. brownii*. Except shoot length, the same holds true for seedling vigor of *F. sur*. For *T. indica* and *A. abyssinica*, all studied parameters, except root collar diameter, showed significant variation among the provenances. Shoot length and leaf number significantly varied among provenance of *B. aegyptiaca* seedlings. Significantly higher *A. abyssinica* and *T. indica* seedling vigor was measured for Gununo and Arba Minch provenances, respectively. The present study concluded that the best seed source for *B. aegyptiaca*, *F. sur* and *T. indica* is Arba Minch area. Similarly, Gununo and Gofa provenances were identified as the best seed sources for *A. abyssinica* and *T. brownii* respectively.

Keywords: Biomass, Provenance, Seed germination, Seedling vigor.

INTRODUCTION

Ethiopia is one of the most important centers of biodiversity, that include high forests, woodlands, bush lands, plantations and trees outside forests (Zegeye et al., 2011). The share of woodland, shrubs and bushland contribute about 45% of the landmass, indicating quite extensive areas and ecosystems (FAO,

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2010). Out of twelve group of vegetation resource of Ethiopia (Friis et al., 2010), seven of these vegetation types are encountered in drier lowland areas of the country and are commonly referred to as dry forests. These forests are the most important forest types both in terms of area coverage and their contribution for livelihoods and economic development (Lemenih and Kass, 2011). Dry forests contain unique native biodiversity (Awas, 2007) and provide divers goods and services such as gum and resins, fodder, fuel, honey, hand crafts and construction materials (Fikir et al., 2016). However, the diversity in these resources is threatened because of mismanagement and environmental degradation that have caused selective and total loss of genetic diversity (PGRC, 1996; Lemenih and Bongers, 2011; Worku et al., 2012).

The cultivation of plantations as a source of forest product and using the protected forests only as seed source could be an appropriate option to reduce the pressure on the natural stand and improving rural livelihood of local communities (Apetorgbor et al., 2004). However, before large-scale plantations, efficient selection of reliable seed sources is required.

Differences among geographic sources in forest tree species are often substantial and economic improvement can be made by an appropriate provenance selection (Falconer and Mackay, 1996; Schmidt, 2000). Information on variation among provenances of indigenous woodland tree species on seed germination and seed vigor is sparse. Seed germination, the emergence of the embryo from the seed, is triggered by a variety of anabolic and catalytic activities (Bewley and Black, 1983). Seed vigor refers to ‘the sum total of those properties of the seed that determine the potential level of activity and performance of the seed during germination and seedling emergence’ (Perry, 1978). According to ISTA, (2015) seed vigor is not a single measurable character but a concept associated with various aspects of seed performance which include rate and uniformity of seed germination and seedling growth, emergence ability of seeds under unfavorable environmental conditions and performance after storage (ISTA, 2015).

In Ethiopia, only few studies look in to the effect of provenance on seed germination (Mebrate and Belachew, 2004; Bahru et al., 2014). These studies reported significant growth differences among provenances. However, only some indigenous species were considered in these studies. Thus, additional studies on variation among provenances of indigenous trees, particularly tree species that are economically and ecologically important are essential for improving quality of plantation, produced to get a higher quality product thereby supporting the conservation by utilization strategy. Therefore, the present study aimed at investigating the effect of provenances on seed germination and seedling performance of some selected woodland tree species namely: *B. aegyptiaca*, *T. brownii*, *T. indica, F. sur* and *A. abyssinica* in Arba Minch Zuria woreda and identifying the best seed source for these species.

MATERIALS AND METHODS

Site description

The study was conducted at Arba Minch Agricultural Research Center which is found in Arba Minch Zuria District of Gamo zone, Ethiopia. Arba Minch Zuria District is geographically located between 37˚26'02"E to 37˚39'49"E and 5˚43'03"N to 6˚08'39"N. The elevation of the district ranges from 1126 to 2100 meters above sea level. Meteorological records reveal that rainfall pattern in Arba Minch Zuria is bimodal with mean annual rainfall ranges from 1100 to 1600 mm, whereas the minimum and maximum temperature varying between 17^{o}C and 35^{o}C. The soil texture of the study site is characterized by clay loam texture and landscape of gentle slope. Seeds were collected from different geographical areas in Arba Minch Zuria woreda (Figure 1).

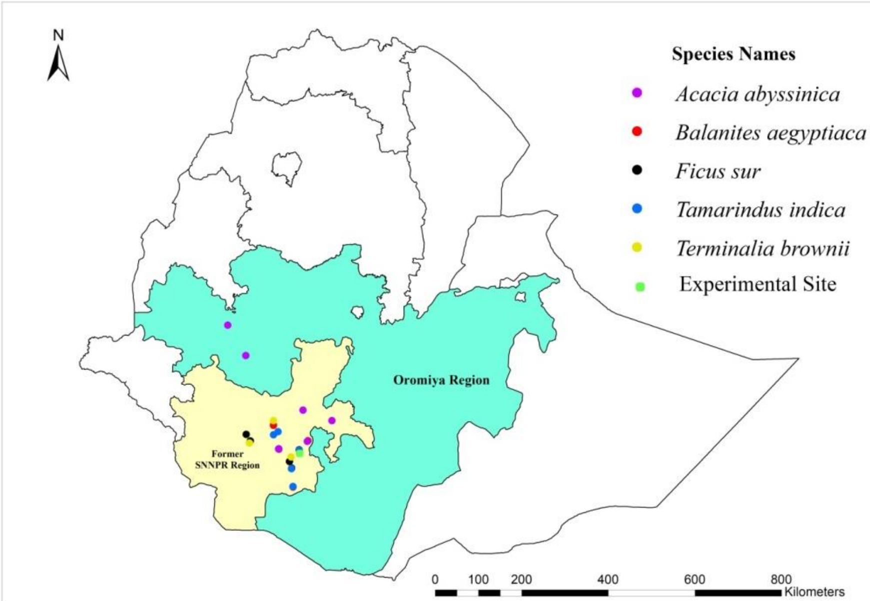

Figure 1. Distribution map of studied tree species.

Research design and management

Seeds of *B. aegyptiaca*, *T. brownii, T. indica, F. sur* and *A. abyssinica* were collected from different locations. During seed collection, healthy, vigorous and mature trees were selected as source of seed for all the species under the study. Isolated trees of cross-pollinating species or border trees were not selected because of risk of self-pollination (*i.e.* low productivity and viability).

Seeds were pretreated according to the recommendation of Tessema (2007). For *A. abyssinica*, seeds were soaked in hot water for one minute, allowed to cool and soaked for 36-48 hours. Damaged seeds that floated were discarded. For *B. aegyptiaca,* seeds were soaked in cold water for 24 hours, and then the water was changed and soaked for another 24 hours. For *T. indica,* seeds were soaked in cold water for 12 hours. *T. brownii* seeds were pretreated by removing wings and soaking in cold water overnight. No pretreatment was applied for seeds of *F. sur*.

Table 1. Locations and geographic coordinate data of the studied tree species.

Tree Species	Provenance	Altitude (m.a.s.l)	Latitude (N)	Longitude (E)
Balanites aegyptiaca	Arba Minch	1176	6°02'288"	37°34'431"
	Mirab Abaya	1196	6°17!597"	37°45'915"
	Konso	1535	5°20'118"	37°26'255"
	Humbo	1432	6°71'375"	37°85'818"
	Derashe	1325	5°43'579"	37°24'517"
	Gofa	1164	6°37'79"	37°02'69"
Ficus sur	Arba Minch	1185	6°62'040"	37°34'778"
	Basketo	963	6°17'387"	36°33'106"
	Bonke	1519	5°52'729"	37°22'784
	Derashe	1320	5°43'529"	37°24'390"
	Humbo	1434	6°71'208"	37°86'891"
	Melokoza	835	6°25'059"	36°28'074"
Terminalia brownii	Basketo	908	6°15'623"	36°32'915"
	Bonke	1305	5°57'565"	37°24'623"
	Derashe	1319	5°43'219"	37°24'710"
	Gofa	1130	6°43'3"	37°02'71"
	Konso	1384	5°20'542"	37°26'905"
Tamarindus indica	Arba Minch	1190	6°62'101"	37°34'895"
	Derashe	1324	5°43'719"	37°24'413"
	Gofa	1195	6°25'21"	37°02'68"
	Humbo	1384	6°71'545"	37°87'883"
	Konso	1304	5°21'657"	37°26'291"
	MirabAbya	1222	6°29'099"	37°76'835"
Acacia abyssinica	Gununo	1708	6°56'1"	37°39'03"
	Humbo	1597	6°71'375"	37°85'818"
	Loka Abaya	1760	6°43'69"	38°15'825"
	Mirab Abaya	1481	6°17'196"	37°44'19”
	Dabena	1917	8°42'07.91"	36°05'12.48”
	Dembi	1926	8°04'15.22"	36°27'34.27”

Polyethylene pots having 20 cm height and 12 cm diameter were filled with two parts of forest soil one parts of compost and one parts of sand soil to raise seedlings. Twenty polyethylene pots with four replications (5×4) in Complete Randomized Design (CRD) were used for each provenance. Treated seeds were directly sown in the polyethylene pots. The polythene pots were placed in nursery on an open ground and seedlings were maintained in the nursery until they grow. Metrological data of the seed development season compared to the previous year is given in Table 2. Seedlings survival was also monitored until the end of the work. All the necessary nursery operations were done during the entire period of experiment.

Table 2. Monthly maximum (Max) and minimum (Min) mean temperature, rainfall and relative humidity (RH) of Arba Minch area during 2018 and 2019 (trial seasons).

	2018				2019			
Month	Max temp. (^oC)	Min temp.(^oC)	Rainfall (mm)	RH (%)	Max temp. (^oC)	Min temp. (^oC)	Rainfall (mm)	RH (%)
January	29.84	15.81	2.46	38.84	28.11	15.62	3.44	36.12
February	30.70	18.85	47.60	39.32	28.64	18.62	38.56	35.75
March	28.66	17.94	35.50	58.77	27.35	17.17	53.94	55.34
April	26.75	17.34	250.70	66.12	26.32	16.59	261.27	64.18
May	26.42	17.86	165.00	64.13	26.01	16.44	189.11	60.26
June	24.78	17.04	89.00	50.56	25.16	16.31	63.41	44.63
July	25.52	18.44	12.80	44.12	26.34	16.64	16.35	44.96
August	26.84	18.26	94.40	63.35	26.11	15.74	101.02	56.89
September	28.68	17.73	159.40	69.11	25.45	15.96	201.11	61.09
October	27.86	17.95	102.60	60.34	26.72	16.17	111.01	60.54
November	28.62	16.75	81.00	57.45	27.58	16.03	76.48	54.75
December	28.94	17.35	17.76	16.34	28.01	17.14	13.16	26.35

Source: National Meteorological Agency, Hawassa Branch (2019).

Data collection and analysis

There are a number of factors that affect seed viability, longevity, germination and seedling vigor. The parameters selected for this experiment were germination, leaf number, shoots length, root collar diameter, and fresh and dry biomass. Data on growth rates of seedlings were taken regularly at every 15 days interval starting from the first germination. Shoot length of each species was measured using ruler in centimeter (cm), while root-collar diameter (RCD) was measured using caliper. The number of leaves in pairs of each seedling was counted. Fresh and dry biomass weight of a seedling was measured on five randomly selected seedlings (destructive sampling). The measurement of dry weight was done after drying the seedling in an oven for 24 hours at 65°C. The germination percentage data was first arcsine transformed before statistical analysis to fulfill normality (Gomez and Gomez, 1984). Collected data was analyzed and evaluated by using a descriptive statistic. The statistical significance differences among the treatments were determined by using ANOVA and SAS Computer Software Program was used for multiple comparison of Least Significance Difference (LSD).

RESULTS

Acacia abyssinca, Ficus sur, Balanites aegyptiaca, Tamarindus indica and *Terminalia brownii* started germination at 22, 24, 15, 18, 14 days after sowing respectively. Each germinated seedlings produced its first pair of leaves in the first week of germination. Germination and seedling vigor of *B. aegyptiaca, F. sur, T. brownii, T. indica,* and *A. abyssinica* in Arba Minch Zuria woreda are presented in Tables 3 to 7 respectively.

The experimental result for *B. aegyptiaca* showed significant differences among provenances ($p \leq 0.05$) in seed germination, leaf number and shoot length (Table 3).

Table 3. Mean seedling growth performances of *B. aegyptiaca* provenance in Southern Ethiopia.

Provenance	Germination (%)	Leaf number	Shoot length (cm)	RCD	Fresh biomass (gm)	Dry biomass (gm)
Arba Minch	79.47^{a}	35.94^{a}	44.25^{a}	0.18	40.75	15.5
Mirab Abaya	71.62^{b}	$31.88a^{b}$	37.16^{b}	0.17	41.75	15.3
Konso	69.10^{c}	30.62^{b}	$32.94b^{c}$	0.26	32	11.82
Humbo	67.65^{d}	29.94^{b}	39.25^{ab}	0.15	34.5	13.45
Derashe	64.32^{e}	29.62^{b}	35.53^{bc}	0.15	34	12.7
Gofa	60.15^{f}	22.38^{c}	29.88^{c}	0.13	32.5	12.43
CV (%)	1.4	9.5	12.4	52.2	20.1	22.7
LSD (5%)	1.44	4.2	6.7	NS	NS	NS

Means value with different superscript letters are significantly different ($P \leq 0.05$).Whereas; RCD= root collar diameter, CV= coefficient of variation, LSD= least significant difference NS= not significant.

The seeding performance of *F. sur* between provenances showed significant difference ($p \leq 0.05$). Germination and shoot length significantly varied but other parameters were not statistically different (Table 4).

Table 4. Mean seedling growth performances of *F. sur* provenance in Southern Ethiopia.

Provenance	Germination (%)	Leaf number	Shoot length (cm)	RCD	Fresh biomass (gm)	Dry biomass (gm)
Arba Minch	89.1[a]	12.81	24.75[a]	0.46	176	36.98
Basketo	76.45[c]	10.81	17.25[b]	0.35	131	32.05
Bonke	77.38b[c]	10.19	13.62[b]	0.36	113.8	24.55
Derashe	78.62[b]	11.25	16.38[b]	0.31	153.2	30.95
Humbo	79.00[b]	10.5	13.34[b]	0.32	105.5	26.25
Melokoza	74.30[c]	10.06	12b	0.28	70.5	18.25
CV (%)	3.3	15.3	26.1	30.8	39.3	39.7
LSD (5%)	3.96	NS	6.3	NS	NS	NS

Means value with different superscript letters are significantly different ($P \leq 0.05$).Whereas; RCD= root collar diameter, CV= coefficient of variation, LSD= least significant difference NS= not significant.

The experimental result of *T. brownii* showed significant difference among the different provenances ($p \leq 0.05$) with regards to seed germination. However, the other parameters did not show significant difference among the provenances. Even though no significant variation was observed in early growth parameters, the provenances of Gofa and Derashe performed well compared to the others (Table 5).

Table 5. Mean seedling growth performances of *T. brownii* provenance in Southern Ethiopia.

Provenance	Germination (%)	Leaf number	Shoot length (cm)	RCD	Fresh biomass (gm)	Dry biomass (gm)
Basketo	71.95[c]	14.81	18.85	0.22	54.25	18.48
Bonke	68.6[d]	14.69	17.75	0.23	51.75	17
Derashe	80.8[b]	15.38	21.44	0.21	63.5	18.93
Gofa	85.9[a]	14.25	21.98	0.38	60	19.65
Konso	71.35[c]	14.75	19.8	0.21	56.25	17.10
CV (%)	1.4	6.5	13.8	40.8	27.7	25.9
LSD (5%)	1.63	NS	NS	NS	NS	NS

Means value with different superscript letters are significantly different ($P \leq 0.05$).Whereas; RCD= root collar diameter, CV= coefficient of variation, LSD= least significant difference NS= not significant.

For *T. indica*, significant ($p<0.05$) differences were detected in most of the parameters except root collar diameter. Arba Minch provenance recorded the highest mean value of fresh biomass weight and dry biomass weight than the other provenances. Konso and Mirab Abaya provenances recorded the least mean value of shoot length (Table 6).

Table 6. Mean seedling growth performances of *T. indica* provenance in Southern Ethiopia.

Provenance	Germination (%)	Leaf number	Shoot length (cm)	RCD	Fresh biomass (gm)	Dry biomass (gm)
Arba Minch	87.9^{a}	15.19^{a}	20.91^{ab}	0.16	24.00^{a}	8.47^{a}
Derashe	72.3^{c}	13.75^{ab}	21.25^{ab}	0.15	17.25^{b}	5.82^{bc}
Gofa	76^{c}	12.56^{b}	20.75^{ab}	0.29	16.5^{b}	6.2^{b}
Humbo	81.1^{b}	14.81^{a}	22.19^{a}	0.11	17.25^{b}	6.15^{b}
Konso	82.1^{b}	13.13^{b}	18.44^{c}	0.22	15.00^{b}	4.85^{c}
Mirab Abaya	71.2^{c}	14.00^{ab}	19.69b^{c}	0.27	16.5^{b}	5.42b^{c}
CV (%)	4.2	7.1	6.9	15.7	14.3	14
LSD (5%)	4.92	1.5	2.1	NS	3.76	1.28

Means value with different superscript letters are significantly different ($P \leq 0.05$). Whereas; RCD= root collar diameter, CV= coefficient of variation, LSD= least significant difference NS= not significant.

The statistical test of *A. abyssinica* indicated that there was significant difference ($p \leq 0.05$) among provenances in most studied parameters. Generally, Gununo provenance recorded highest seed germination percentage and fresh biomass than the rest five provenances and the same provenance showed significantly higher mean value of shoot length than Debena, Denbi, Humbo and Loka Abaya provenances (Table 7).

Table 7. Mean seedling growth performances of *A. abyssinica* provenance in Southern Ethiopia.

Provenance	Germination (%)	Leaf number	Shoot length (cm)	RCD	Fresh biomass (gm)	Dry biomass (gm)
Dabena	70.73^{b}	18.79^{ab}	22.22^{b}	0.17	37.5^{bc}	9.9^{bc}
Denbi	65.25^{d}	17.12^{b}	20.88^{b}	0.16	17.75^{c}	5.12^{c}
Gununo	79.35^{a}	24.12^{a}	34.19^{a}	0.22	128.75^{a}	38.8^{a}
Humbo	67.98^{c}	15.06^{b}	22.88^{b}	0.14	51b^{c}	15.62^{bc}
Lokaabaya	64.25^{d}	14.81^{b}	22.25^{b}	0.11	45.5^{bc}	15.28^{bc}
Mirab	63.33^{d}	17.79^{b}	26.35^{ab}	0.19	66^{b}	20.88^{b}
CV (%)	2.4	19.1	21.8	32.3	46.9	47.7
LSD (5%)	2.47	5.075	8.04	NS	40.22	12.7

Means value with different superscript letters are significantly different ($P \leq 0.05$). Whereas; RCD= root collar diameter, CV= coefficient of variation, LSD= least significant difference NS= not significant.

DISCUSSION

In most plant species, seeds vary in their degree of germination between and/or within provenance individuals (Mkonda et al., 2003; Loha et al., 2006). In the present study, variations between provenances were observed. Generally causes of such variability might be attributed to either genetic characters of source population/plant (Shu et al., 2012), or impact of mother plant's environment (Singh et al., 2010). Gutterman (2000) stated that germination of seeds can be influenced by maternal factors, such as position of the seed in the fruit/tree, the age of the mother plant during seed maturation, as well as environmental factors such as day length, temperature, light quality, water availability and altitude. The differences in germination patterns and seedling growth rates may be also related to climatic and geographic influences or to genetic differences (Moles and Westoby, 2004; Raddad, 2007). In the present study, age of mother plant during seed collection and environmental factors such as light quality, water availability and altitude might be the cause for the observed variation in seed germination and seedling vigor. Low germination percent observed in the current study could also be related to seed handling or mixing of ripened and unripen fruit during collection.

Variation among provenances in seedling height has been reported for most tree species. Most variation in seedling height of different species in common-garden studies has been attributed to provenance effect (Shu et al., 2012). Loha et al. (2006) also reported that diameter of *Cordia africana* at the early stage of growth (4 months) had a significant correlation with seed length and weight and stated that these correlations are expected since the emerging seedling depends on the seed reserve for its initial growth until it becomes autotrophic. This implies that seed traits could affect seedling growth at an early stage. In present study, variation was observed in seedling height between provenances, which agrees with the finding of Shu et al. (2012). However no relationship between seedling height and weight was observed in the current study as reported by Loha et al. (2006). Fandohan et al. (2010) noted that larger seeds also showed higher growth speed than smaller ones and that seed traits can be determinants for seedling growth and survival during early life stages of plants. The same pattern was also observed in seedling growth performance of other tree species growing in arid or semiarid areas, such as *Moringa peregrine* (Gomaa et al., 2011), *Acacia senegal* (L.) Willd. in Sudan (Raddad, 2007), *Acacia tortilis* (Forrsk.) Hayne and *Faidherbia albida* (Del.) A. Chev.; in Kenya (Stave et al., 2005). In the present study, large sized seeds showed higher growth speed compared to the smaller ones which might be the result of an adaptation of these provenances to their environments (Ghosh and Singh, 2011).

CONCLUSION AND RECOMMENDATION

Evidence from this study indicated that provenances have an effect on seed germination and seedling performance and best seed sources were identified for selected indigenous tree species. The best seed source for *B. aegyptiaca*, *F. sur* and *T. indica* is Arba Minch area. Similarly, Gununo and Gofa provenances are identified as the best seed source for *A. abyssinica* and *T. brownii* respectively. Since the period of this study was short and at nursery level, progeny tests in the field should be undertaken for a longer period. Further study covering wider geographical range and higher number of provenances is also recommended.

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WOODY SPECIES COMPOSITION, VEGETATION STRUCTURE AND REGENERATION STATUS OF LEPHIS FOREST FIELD GENE BANK, SOUTHEASTERN ETHIOPIA

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ABSTRACT: This study was conducted in Lephis Forest field gene bank in West Arsi Zone, Southeastern Ethiopia. The study aimed to estimate stand structure, floristic composition and regeneration status. Systematic sampling method was used to collect vegetation data. Thirty plots of 20 m x 20 m (400 m^2) for trees, 120 subplots of 5 m x 5 m (25 m^2) for saplings and 30 subplots (2 m x2 m) for seedlings were laid. Specimens of all vascular plants were collected and brought to Ethiopian Biodiversity Institute for identification. A total of 63 woody species belonging 37 genera and 30 families were recorded. Rubiaceae was the most dominant family. The other dominant families were Asteraceae, Rutaceae, Mrysinaceae, Rosaceae and Oleaceae, each represented by two species (5.4%). Four plant communities were identified. The Shannon diversity and evenness indexes for the entire study area were 3.11 and 0.85 respectively. The total basal area of the forest was 174.58 m^2/ha. Density of mature trees, seedling and sapling were 1097, 2061 and 848 individuals per hectare respectively. The population structure and regeneration status of the forest indicated that there are anthropogenic disturbances in the forest. In the regeneration assessment, plants with few numbers of seedlings were found in the forest. Therefore, immediate conservation actions and implementation of forest management are required to facilitate healthy regeneration of the forest.

Key words: Basal area, Diversity, Important value index, Sapling, Seedling, Species richness

INTRODUCTION

The species composition and diversity in a forest can be affected by disturbances in forest which could be the result of both anthropogenic and natural drivers. Assessment of a forest serves as a base for sustainable utilization and conservation of the forest. Forest composition refers to all plant species found in a stand or landscape, including trees, shrubs, forbs, and grasses. It is also used to describe forest communities at the stand or landscape level whose canopies may be dominated by a single tree species or contain a mixture of species (Seidler, 2017). Each individual tree is a structural element of a forest ecosystem, with characteristics such as species, number, size, and spatial distribution (Hui et al., 2019).

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Tree regeneration is the process that allows a forest to sustain itself through the growth and survival of seedlings and saplings that replace large forest trees as they die. Natural regeneration in any plant community requires information on the presence and absence of persistent soil seed banks or seedling banks, quantity and quality of seed, durability of seeds in the soil, losses of seeds to predation and deterioration, triggers for germination of seeds in the soil and sources of re-growth after disturbances (Teketay, 2005).

The flora of Ethiopia reports about 6,027 vascular plant species of which 10% are endemic (Kelbessa and Demissew, 2014). This distribution makes Ethiopia the fifth largest floral composition in tropical Africa (Didita et al., 2010). However, the rich biodiversity of the country is under serious threat due to deforestation, overgrazing, shifting cultivation, forest fire and poaching of forest reserves. One of the forests facing such threat is Lephis forest field gene bank, which is one of the remnant dry Afromontane forests in the country. So far, the floristic composition, regeneration and structural analysis of Lephis forest field gene bank have not yet been investigated. Therefore, the objective of this study was to assess the floristic composition, structure and regeneration status of the species in the forest which could contribute for the effective conservation and management of the forest.

MATERIALS AND METHODS

Description of the study site

This study was conducted in Lephis forest field gene bank located in Gambo natural forest, one of the three forest districts in Arsi (*i.e.* Munessa, Gambo and Shashemene). It is a protected forest owned by Oromia Forest and Wildlife Enterprise (OFWE). It is located at 270 km south of Addis Ababa (Figure 1). Geographically, it is bounded between 7°80´86´´N and 38°49´68´´E. The altitude ranges from 2292 to 2465 m. a.s.l.

The total concession area of the Gambo natural forest is estimated to be 9023 ha, of which 1443 ha is plantation forest and 7580 ha is natural forest (OFWE). The area has a bimodal rainfall with a main rainy season from the end of June to September, and a short rainy season from February to April (Duriax and Baudron, 2016).The mean annual rainfall of the area ranges from 500 mm to 1000 mm and the mean annual temperature is 15 ^{o}C (Duriaux and Baudron, 2016). The vegetation of the area is described as undifferentiated Afromontane forest (Friis and Lawesson, 1993; Muhammad and Elias, 2020).

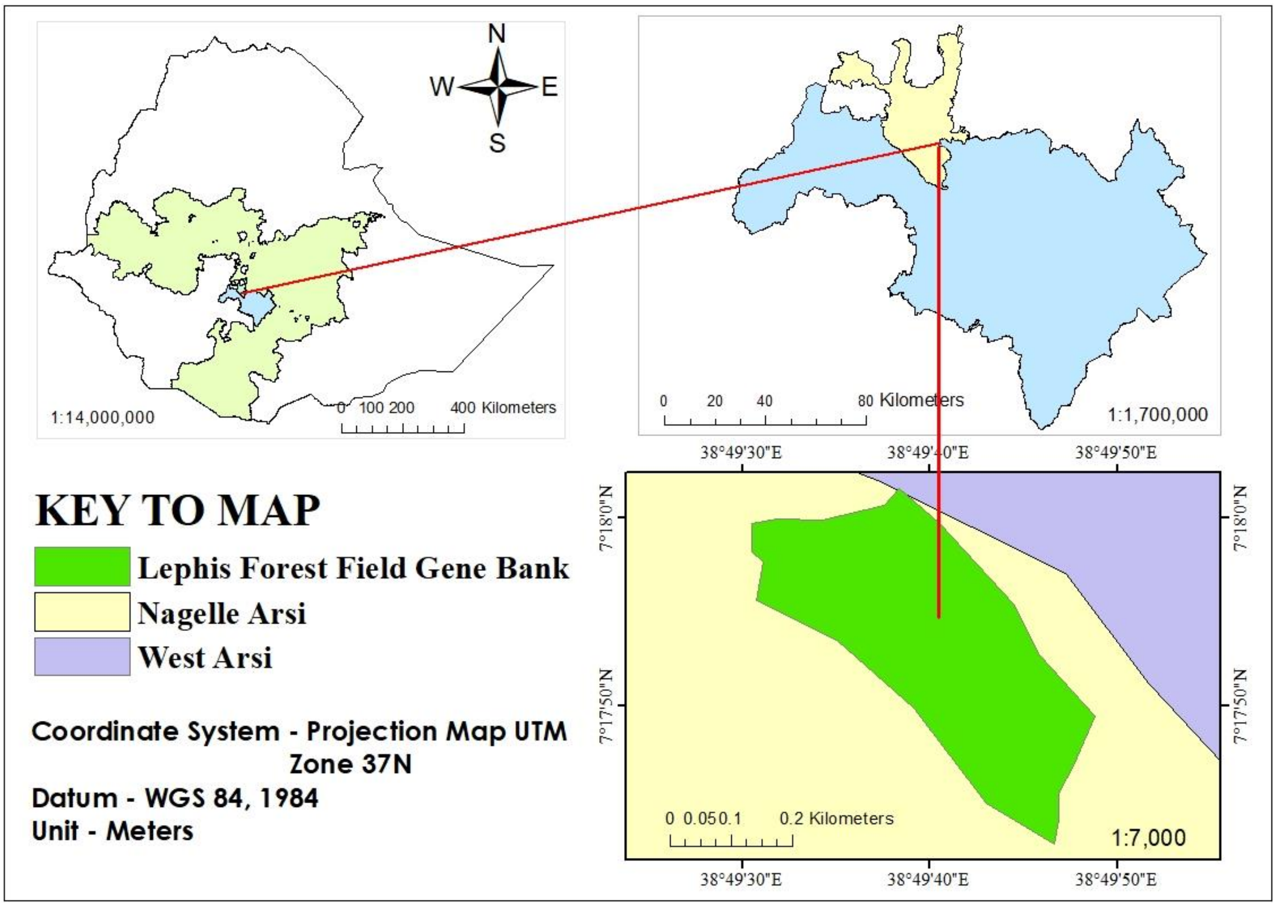

Figure 1. Location of the study area

Sampling procedure and data collection

A reconnaissance survey was carried out from April to June 2021 in order to obtain an impression of the site's conditions, collect information on accessibility and determine sampling sites. Systematic sampling design was used to collect vegetation data. Three transect lines and sampling plots were made based on the total area of the study site for vegetation data collection. The sampling plots were placed at every

100 m distance along the three transect lines laid across the forest. Thirty plots of 20 m x 20 m (400 m^2) were laid along three parallel transects to collect woody species parameters. Within these plots 120 subplots of 5 m x 5 m (25 m^2) for saplings and 30 subplots (2 m x 2 m) for seedlings were laid to count both saplings and seedlings (Owusu, 2019). A total of 30 sample plots (15 at transect number one, 13 at transect number two and 2 at transect number three) with an area of 0.6 ha, 0.52 ha and 0.08 ha respectively were surveyed.

Floristic data collection

All woody species in each plot were identified and scientific and vernacular names were recorded. Diameter at breast height (DBH) with DBH > 2.5 cm was measured using a tree caliper and diameter tape. Height of all individuals of woody species with a DBH > 2.5 cm were measured with a hypsometer. The heights of trees and shrubs 2 m and above were measured and recorded. For the purpose of this study, seedlings, saplings and "mature trees/shrubs" were defined as plants with heights < 1 m, 1–2 m and > 2 m, respectively. Representative plant specimens were collected and pressed to compile a complete list of species. The specimens were dried in deep freezer for 72 hours and identification was confirmed by referring to Flora of Ethiopia and Eritrea and comparing with authentically identified specimen at the Ethiopian Biodiversity Institute following Edwards et al. (1995; 1997), Tadesse (2002) and Hedberg et al. (2003; 2006; 2009). Physiographic variables like altitude, latitudes and longitudes were measured for each quadrant using GPS (Geographical Positioning System).

For vegetation structure data collection, the following activities were performed. Each individual of the woody species in the plots was counted. Basal area, relative dominance, relative density, relative frequency and important value index were determined to describe the vegetation structure of the study area by using Microsoft Excel following Mueller-Dombois and Ellenberg (1974) and Martin (1995). To determine regeneration potential of the site, the total density of seedling, sapling and mature trees were determined.

Data analysis

To quantify biological diversity, species richness, Shannon–Wiener diversity index and evenness were computed following Maguran (1988) and Krebs (1999). To determine floristic similarity between the sample plots, Sorensen's similarity coefficient was computed.

Species richness is a biological appropriate measure of alpha diversity and the total number of species in an ecological community, landscape or region relative to total number of all individuals in that community. Species richness was calculated using Margalef's index of richness (Dmg) as follows:

$$\mathbf{Dmg = S\text{-}1/lnN}$$

where Dmg = Margalef's index of richness, S = total number of species, ln = natural logarithm, **N** = total number of individuals in a sample.

Evenness refers to the variability in the relative abundance of species. It describes the equality of species abundance in a community. Species evenness was calculated by dividing Shannon's diversity index H' by natural logarithm of species richness ln (S).

$$(\mathbf{H'}) = -\sum_{i=1}^{s} Pi \ln Pi$$

where H' = Shannon diversity index, S = the number of species, Pi = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover and ln = log base n (Natural logarithm).

$$Evenness\ (J) = \frac{\mathrm{H}'}{\mathrm{H}'max}$$

Where, H' = Shannon-Wiener diversity index and H'max = lns where S is the number of species.

The higher the value of J, the more even the species are in their distribution within the community or the quadrants. Similarly, the higher the value of H', the more diverse the community or the quadrant are.

Sorensen's similarity coefficient was used to describe the similarity among community types. It is calculated as follows.

$$Sorensen' similarity\ coefficient\ (Ss) = \frac{2a}{2a+b+c}$$

Where, a = number of species in sample a and b, b = number of species in sample 'b' but not in 'a', and c = number of species in sample 'a' but not in 'b'.

Vegetation Structure

Relative density, relative frequency, relative dominance and important value index (IVI) were calculated to determine the vegetation structure and the dominant species of the forest (Muller-Dombois and Ellenberg 1974).

Density is defined as the number of plants of certain species per unit area. Plant density helps to determine percentage germination in the field. It is calculated as:

$$Density = \frac{\text{Number of individuals of tree species per unit area of quadrant(hectare)}\ or\ total\ number\ of\ individuals}{\text{total area of quadrant (hectare)}}$$

Relative density is the study of the numerical strength of a species in relation to number of individuals of all the species and it is calculated as:

$$Relative\ density\ (RD) = \frac{\text{Number of individuals of a tree species}}{\text{Total number of individuals of all species}} x100$$

Frequency is defined as probability of finding plant species or vegetation in a given sample area. The higher the frequency, the more important the plant is in the community. Frequency is computed with the following formula.

$$Frequency = \frac{\text{Number of quadrants inwhich a species is recorded}}{\text{total number of sample quadrants}}$$

Relative Frequency is defined as the degree of dispersion of individual species in an area in relation to the number of all the species these occurred and it is computed as follow:

$$Relative\ frequency\ (RF) = \frac{\text{Frequency of a plant species}}{\text{Sum frequency of all species}} x100$$

Basal area (BA) is cross-sectional area of all of the stems in a stand at breast height (1.3 m above ground level). Basal area per unit area is used to explain the crowdies of the forest stand and expressed in square meter per hectare (m^2/ha). Area of forest stand is also used to calculate the dominance of species.

$$G = \frac{\pi \text{d2}}{4}$$

Where G = basal area, π = 3.14; d = diameter at breast height or stump height.

$$Dominance = \frac{\text{Area covered by a species}}{\text{Sum of al area of quadrants in hectares}}$$

$$Relative\ Dominance = \frac{\text{Basal area of a single species}}{\text{Total basal area of all species}} x100$$

Important value Index (IVI) is the sum of three important parameters (Relative frequency, Relative density and Relative dominancy or abundance). Important value index is used to compare the ecological significance of species (Lamprecht, 1989) and it is calculated as follows:

$$Important\ Value\ Index\ (IVI) = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance}$$

To determine the regeneration status of the site, the total density of seedling, sapling and mature trees were determined and the ratio of seedlings and saplings to adult individuals of woody species, as well as the ratio of seedling to saplings were also computed to make a comparison.

Plant community analysis

Plant communities were analyzed using Statistical Package for Social Science (SPSS Software version 20.0). A hierarchical cluster analysis was made to classify plant communities based on abundance data (McCune et al., 2002**).** A hierarchical agglomerative clustering technique was applied using Euclidean distance and Ward's method to classify plots that produced a dendrogram and cluster IDs. After identification of the major clusters, characteristic species of plant communities were identified by considering abundance of tree species or indicator p-values. The plant communities were named after identifying plant species abundance and indicator p-values.

RESULTS

Floristic composition and species richness

A total of 63 plant species were identified and documented. Of the total plant species, 38 species (60.3%) were trees, 17 (27%) were shrubs, 8 (12.7%) species were liana (Appendix 1). The plant species belong to 37 genera and 30 families. Rubiaceae was the most dominant family in the forest represented by three species (8.1%), followed by Astraceae, Rutaceae, Myrsinaceae, Rocaceae and Olaceae each represented by two species (5.4%). The rest of the families were represented by only one species and each accounted for 2.7% (Figure 2).

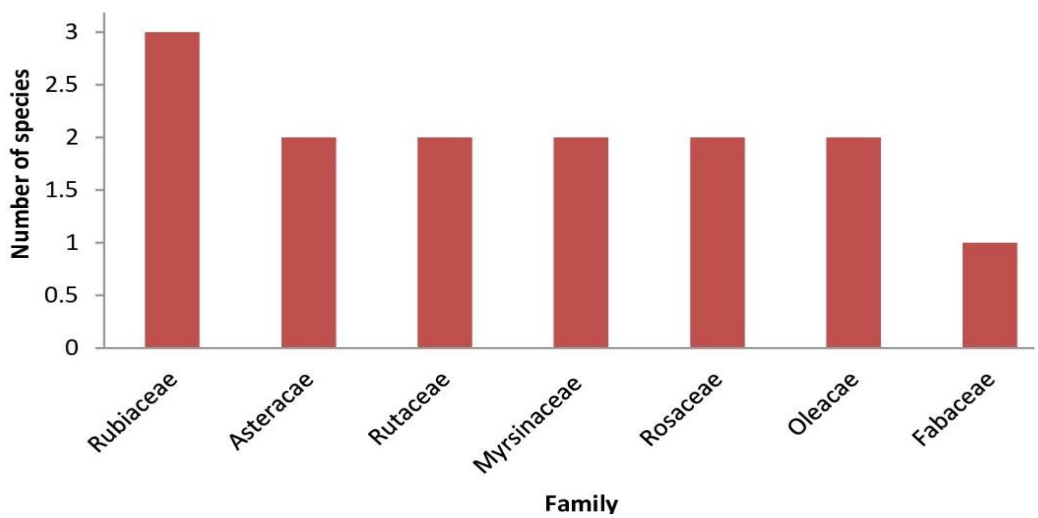

Figure 2. Dominant tree families in Lephis forest field gene bank

Eight (12.9%) endemic plants species namely *Pysnostachyus abyssinica*, *Solanecio gigus*, *Erythrina brucei*, *Lippia adoensis*, *Millettia ferruginea*, *Rhus glutinosa*, *Urtica simensis* and *Vepris dainellii* were identified in the study area.

Shannon diversity index and species evenness for Lephis forest field gene bank were 3.11 and 0.85 respectively.

Plant community classification

Plant community classification from hierarchical cluster analysis resulted in four plant communities (Figure 3).

Species found in the communities with their corresponding *P* values are given in Table 1. The four communities were *Croton macrostachyus–Maytenus gracilipes, Juniperus procera–Measa lanceolata, Croton macrostachyus–Measa lanceolata,* and *Podocarpus falcatus–Croton macrostachyus*.

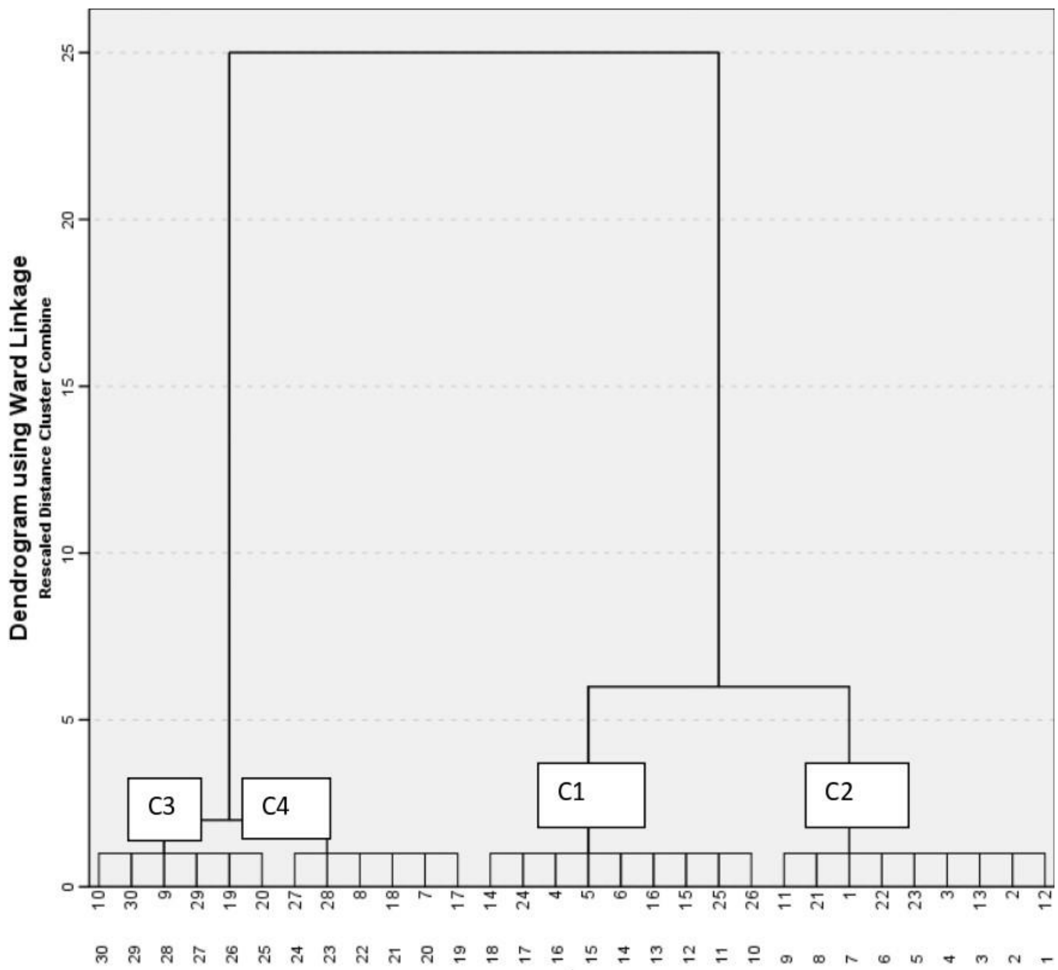

Figure 3. Dendrogram of the vegetation data obtained from hierarchical cluster analysis of Lephis forest field gene bank using Ward's method and Euclidean distance.

Community 1: *Croton macrosthacyus –Mytenus gracilipes* Community type

This community constitutes nine plots (4, 5, 6, 14, 15, 16, 24, 25 and 26). The community occurred in the altitudes between 2292 and 2465 m a.s.l. Tree species found in the community included *Hagenia abyssinica, Measa lanceolata, Podocarpus falcatus, Bersama abyssinica, Teclea nobilis* and *Vepris dainellii.*

Community 2: *Juniperus procera–Measa lanceolata* community type

This community constitutes nine plots (1, 2, 3, 11, 12, 13, 21, 22 and 23). It occurs in the altitudes between 2302 and 2442 m a.s.l. Tree species found in the community included *P. falcatus, Olea europaea, C. macrostachyus, M. gracilipes, T. nobilis, B. abyssinica, Nuxia congesta* and *Pittosporum viridiflorum.*

Community 3: *Croton macrosthacyus– Measa lanceolata* community type

This community comprises six plots (9, 10, 19, 20, 29 and 30). It occurs between altitudes 2326 and 2445 m a.s.l. Tree species found in this community included *M. gracilipes, Juniperus procera, O. europea* and *Myrsine africana.*

Community 4: *Podocarpus falcatus –Croton macrosthacyus* community type

This community comprises 6 plots (7, 8, 17, 18, 27 and 28). It occurs between altitudes 2330 and 2431 m a.s.l. *B. abyssinica, M. lanceolata, M. grascilipes, Canthium oligocarpum, Rhus vulgaris* and *J. procera* were the tree species found in this community type.

Table 1. Species found in the four communities with their corresponding P-values.

Community type	Plant species	Abundance	P-value (P<0.005)
Community 1	*Croton macrostachyus*	347	0.0045*
	Mytenus gracilipes	295	0.0035*
	Hagenia abyssinica	69	0.067
	Measa lanceolata	61	0.150
	Podocarpus falcatus	39	0.275
	Bersama abyssinica	35	0.345
Community 2	*Juniperus procera*	92	0.0023*
	Measa lanceolata	72	0.0032*
	Podocarpus falcatus	60	0.174
	Olea europea	46	0.0034
	Croton macrostachyus	27	0.340
	Mytenus graspalis	19	0.165
Community 3	*Croton macrosthacyus*	97	0.0042*
	Measa lanceolata	75	0.0038*
	Mytenus graspalis	33	0.154
	Juniperus procera	33	0.152
	Olea europea	32	0.126
	Myrsine africana	31	0.137
Community 4	*Podocarpus falcatus*	40	0.0024*
	Croton macrosthacyus	39	0.0022*
	Bersama abyssinica	28	0.134
	Measa lanceolata	26	0.428
	Mytenus graspalis	24	0.362
	Canthium oligocarpum	15	0.257
	Juniperus procera	13	0.482
	Rhus vulgaris	12	0.325

Similarity between plant communities

Sorenson’s similarity coefficient revealed that Community type 1 and 3 had the highest similarity ratio. The least similarity was observed between communities 1 and 4

Vegetation structure

Tree density

The density of individual trees species in the field gene bank was 1097 individuals per ha. *Croton macrostachyus* had the highest density with 159 trees/ha (Table 2). *Measa lanceolata* and *Podocarpus falcatus* had the second and third density with 127 and 120 trees/ha respectively. The least density value was recorded for *Calpurnia aurea* with only one individual per ha (0.09%). The second least densely populated tree species was *Flacourtia indica* with two trees/ha (0.18%).

Table 2. Density of plant species in Lephis forest field gene bank

Plants name	Density of plants
Croton macrostachyus	159
Measa lanceolata	127
Podocarpus falcatus	120
Maytenus gracilipes	87
Hagenia abyssinica	83
Berasama abyssinica	69
Teclea nobilis	64
Vepris dainellii	26

Frequency

The frequency of species with DBH > 2.5 cm ranged from 3.3% to 96.67%. There were five frequency classes which constituted number of plants found in each class (Figure 4). The relative frequency of the species ranged from 2.93 for *Ekebergia capensis* to 8.53% for *Croton macrostachys.*

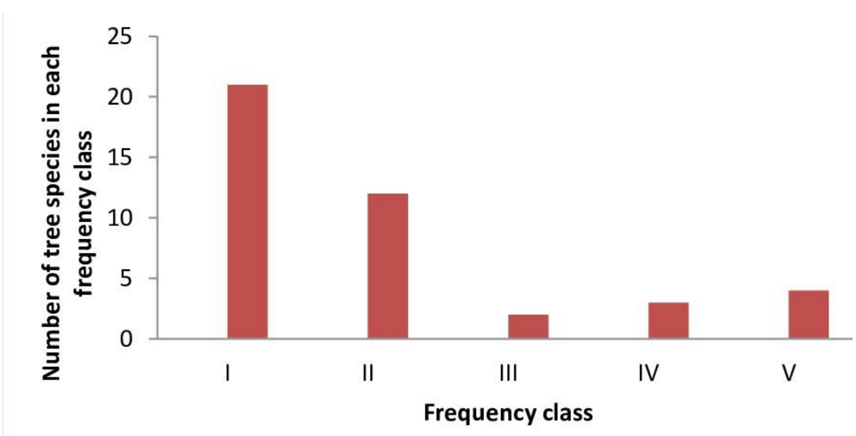

Figure 4. Number of tree species in each frequency classes (I: 1-20%, II: 21-40%, III: 41-60%, IV: 61-80%, V: 81-100%).

Height class distribution

About 1964 tree species attained height > 2 m in Lephis forest field gene bank. Height was classified in to seven classes (Figure 5). Only 2.03% of the plants attained height > 30 m. The general pattern of height class distribution of the forest is reversed J-shaped.

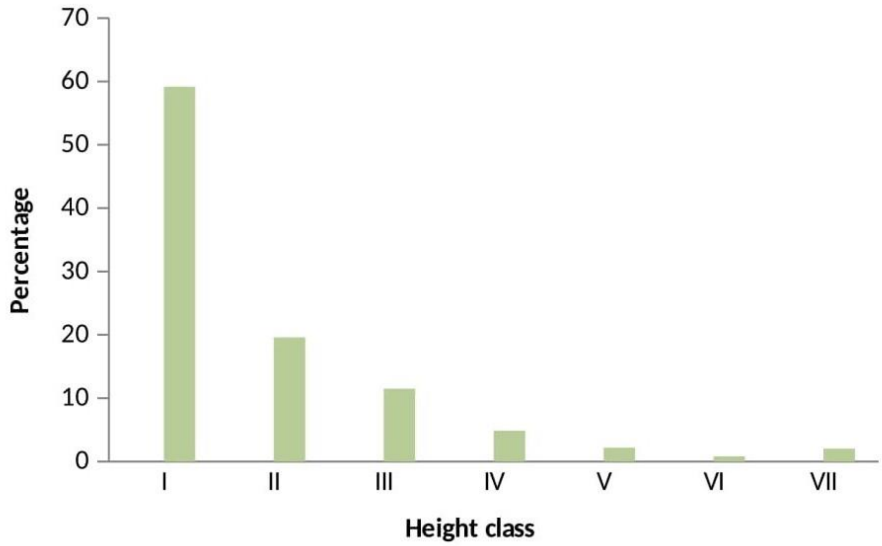

Figure 5. Height class distribution in Lephis forest field gene bank. I: 2.1-6 m; II: 6.1-10 m; III: 10.1-15 m; IV: 15.1-20 m; V: 20.1-25 m; VI: 25.1-30 m and VII: > 30 m.

DBH Class distribution

DBH was classified in to seven classes (Figure 6). Based on the DBH class distribution 79.45% of the individuals were found in the first size class (*i.e*. 2.5 -10 cm). When viewed from the whole set of population structure, the distribution of all individual tree and shrub across size classes showed an inverted “J” shape.

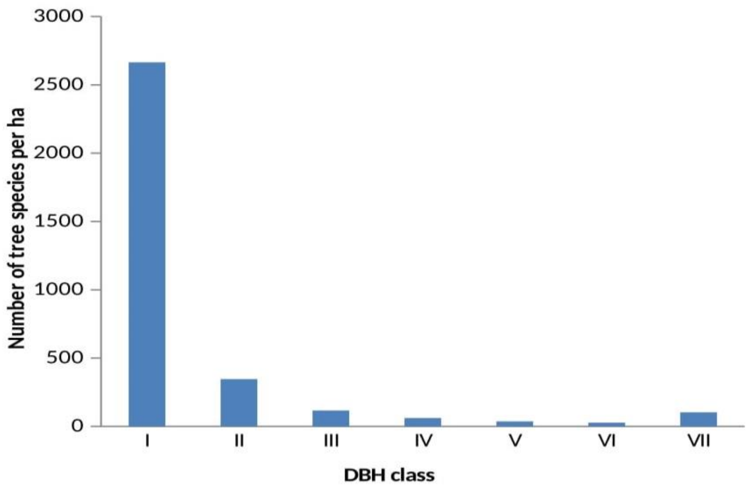

Figure 6. DBH class distribution in Lephis forest field gene bank. Class I: 2.5-10 cm; class II: 10.1-20 cm; class III: 20.1-30 cm; class IV: 30.1-40 cm; class V: 40.1-50 cm; class VI: 50.1-60 cm and class VII: >60.1 cm.

Basal area (BA)

Total BA for Lephis forest field gene bank was 174.58 m^2/ha. From the total basal area 75.13% was contributed by six tree species only (Table 3). *Croton macrostachyus* was the most important tree species because it had the biggest contribution to total basal area. *Pavetta abyssinica* and *Dovyalis abyssinica* exhibited the least BA in the field gene bank with BA values 0.01 m^2 /ha and 0.05 m^2/ha, respectively.

Table 3. Basal area of selected woody species in the study area

Plants name	BA (m^2/ha)
Croton macrosthacyus	62.44
Podocarpus falcatus	26.67
Schefflera abyssinica	20.09
Juniperus procera	19.7
Measa lanceolata	17.9
Prunus africana	10.65
Berasama abyssinica	9.71
Vernonia amygdalina	7.91
Dovyalis abyssinica	0.05
Pavetta abyssinica	0.01

Important Value Index (IVI)

The IVI of the forest ranged from 10.77 to 50.44 (Table 4). The first four tree species (*Croton macrostachyus*, *Podocarpus falcatus*, *Mytenus gracilipes* and *Measa lanceolata*) contributed 45.86% of the IVI and the rest of the species together contributed 54.14% of the IVI. Two species: *Calpurnia aurea* and *Acokanthera schimperi* contributed the least IVI value of 0.39 and 0.40, respectively.

Table 4. IVI of the top 8 tree species with their corresponding Relative Dominance (RDo), Relative Frequency (RF) and Relative Density (RD) in Lephis forest field gene bank

Scientific name of trees	Relative frequency (RF)	Relative dominance (RDO)	Relative density (RD)	IVI
Croton	8.53	27.04	14.87	50.44
Podocarpus falcatus	7.94	11.55	11.23	30.72
Mytenus graspalis	7.65	11.80	8.13	27.58
Maesa lanceolata	7.65	7.75	11.88	27.28
Berasama	7.06	4.20	6.45	17.72
Juniperus Procera	3.53	8.53	3.26	15.33
Haigenia abyssinica	2.64	0.94	7.76	11.35
Teclea nobilis	4.12	0.67	5.98	10.77

Regeneration status of Lephis forest field genebank

Analysis of seedlings and sapling of Lephis forest field gene bank revealed that the total density of mature individuals, seedling and sapling were 1097, 2061 and 848 individuals per hectares respectively (Figure 7). The ratio of seedling to sapling was 2.4, seedling to mature tree was 1.87, and sapling to mature trees was 0.77. Seedling density varied among species that ranges from one individual per hectares for *Dombeya torrida*, *Drasena studeneri*, *Erythrina brucei*, *Flacourtia indica*, *Milletia ferruginia* to 274 for *vernonia auriculifera*.

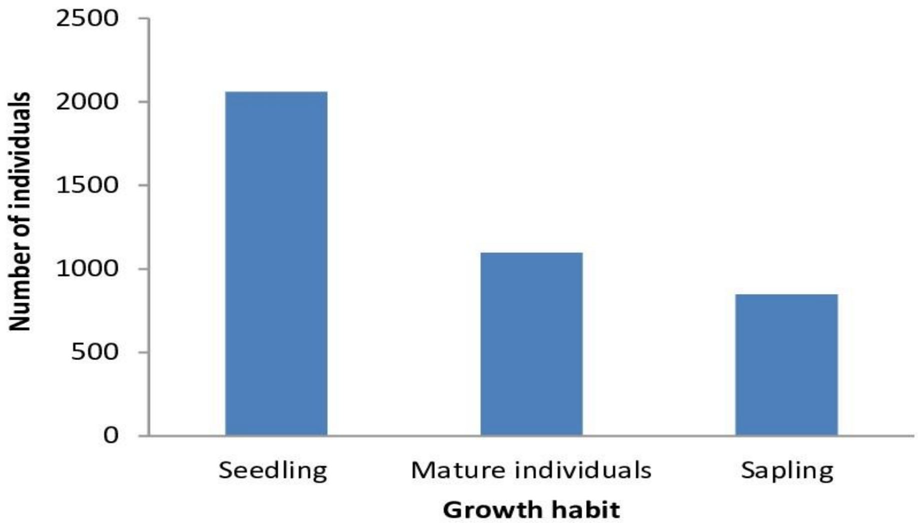

Figure 7. Density of mature trees, sapling and seedling in Lephis forest field gene banks

DISCUSSION

A total of 63 plant species belonging to 37 genera and 30 families were identified and documented. Woody species dominated the forest while Lianas have the least density compared to trees and shrubs. Shannon diversity index and species evenness for Lephis forest field gene bank were 3.11 and 0.85 respectively. Comparison of the Shannon diversity index with similar Afromontane forests in Ethiopia showed that Lephis forest field gene bank is only less than Zege forest which has Shannon diversity index of 3.72 (Alelign et al., 2007). But it is higher than other Afromontane forests such as Kuandisha forest with Shannon diversity index of 2.5 (Birhanu et al., 2016), Menagasha suba forest with Shannon diversity of 2.57 (Beche, 2011), Munesa forest which has Shannon diversity index of 2.6 (Muhammad and Elias, 2020) and Tara Gedam and Abebaye which have Shannon diversity index of 2.88 (Zegeye et al., 2011). The value of Shannon diversity index and evenness of species are affected by both the number of species and the number of stands in the community. The higher the Shannon diversity index the more plant species are in the study area and the lower the diversity index indicates the more disturbance of the forest. The Shannon diversity index obtained in this study (3.11) indicated that Lephis forest field gene bank had diversified plant species. The species evenness value (0.85) indicated that the plant species in the forest were equally distributed.

Plant community classification from hierarchical cluster analysis resulted in four plant communities. Communities 3 and 4 had low plant density. This could be due to susceptibility to human encroachment and free grazing in these communities. Plant community distribution is the manifestation of physical gradients (elevation, soil heterogeneity and microclimate), biotic response to these gradients and historical disturbances (Urban et al., 2000). *Maytenus gracilipes* and *Measa lanceolata* were found to be distributed in all communities while *Hagenia abyssinica*, *Canthium oligocarpum*, *Myrsine africana* and *Pittosporum viridiflorum* were found in only one of the four communities. Except *H. abyssinica* all species were found naturally in the communities while *H. abyssinica* was planted by Ethiopian Biodiversity Institute.

Sorenson's similarity coefficient revealed that Community type 1 and 3 had the highest similarity ratio compared to other communities indicating that these communities had more species in common. This might be associated to slope, altitude, anthropogenic and other environmental factors such as soil type. The least similarity was observed between communities 1 and 4 implying that these communities share less species.

The density of individual trees species in the field gene bank was 1097 individuals per ha. These density is lower compared to some other Afromontane forests in Ethiopia such as Kimphee forest (3059 stems/ha) (Senbeta and Teketay, 2003), Masha Anderacha forest (1709 stems/ha) (Yeshitela and Bekele, 2003), and Dindin forest (1750 stems/ha) (Shibru and Balcha, 2004) but greater than Munesa Natural Forest which is 481 stem/ha (Muhammad and Elias, 2020). This could be due to differences in topographic variations, temperature, rainfall and other climatic factors as well as habitat qualities linked to ecological requirements of component tree species in the respective forests. *Croton macrostachyus* had the highest density with 159 trees/ha. *M. lanceolata* and *Podocarpus falcatus* had the second and third density with 127 and 120 trees/ha respectively. These species together covered 73.25% of the stand density and the rest of the plant species covered only 26.75%.

The frequency of species with DBH > 2.5 cm ranged from 3.3% to 96.67%. There were five frequency classes which constituted number of plants found in each class. *Croton macrostachyus* was the most frequent species with frequency of 96.67%. *P. falcatus* and *M. lanseolata* were the second and third most frequent species with frequency of 90% and 86.67% respectively. A high number of species were found in lower frequency classes and low numbers of species were found in higher frequency classes. This pattern showed the heterogeneity of tree species in the study area.

Based on the DBH class distribution 79.45% of the individuals were found in the first size class (*i.e*. 2.5-10cm). Sum of all classes (class II-class VII) accounted only 20.52% which is much less than half of the first class (Figure 6). As the DBH size increased, the number of individual tree continuously decreased in the size class II up to size class VI but in size class VII a slight increment (3.07%). was observed When viewed from the whole set of population structure, the distribution of all individual tree and shrubs across size classes showed an inverted “J” shape. This indicates a healthy population structure with high densities of seedling (Boz and Maryo, 2020).

The height of woody plant species in the forest has normal distribution pattern except class VII which is slightly exceeding their predecessor. Only 2.03% plants attained height >30 m. This indicated that the small sized individuals dominated the forest, which implies healthy regeneration. In contrast the density of tree species increased a little in class VII. Presence of high number of plant species in the higher height classes in a natural forest indicates presence of adult plant species for reproduction potential of a forest. The general pattern of height class distribution of the forest is reversed J-shaped. Theoretically, such trend depicts healthy population that are naturally replacing themselves through good recruitment (Boz and Maryo, 2020)

Dominance is the measure of tree density (Bettinger et al., 2017). Total BA for Lephis forest field gene bank was 174.58 m^2/ha. Although density of trees of Lephis forest field gene bank is the lowest compared to other Afromontane forest it had high basal area. This may be due to the availability of plant density in height class VII which had large diameter.

Analysis of seedlings and sapling of Lephis forest field gene bank revealed that the density of seedlings was greater than density of mature trees and saplings. The ratio of seedling to sapling (2.4), seedling to mature tree (1.87) and sapling to mature trees (0.77) showed that the density of seedlings was greater than that of saplings. On the other hand, density of mature trees was greater than density of saplings. Density of seedlings indicated normal regeneration in the study area. However, at sapling stage, there is disturbance resulting in decrease in sapling density.

CONCLUSION

A total of 63 plant species were identified and documented in Lephis forest field gene bank which indicated that it is a diversified forest. The variation in species composition and diversity among communities identified in the forest could be associated to different factors, such as altitude, anthropogenic impacts, soil properties, and slope. The density of individual trees species is lower compared to some other Afromontane forests in Ethiopia. Based on the DBH class distribution, small sized plant species dominated the forest. Density of seedling is greater than density of mature individuals which indicated normal regeneration. However, density of sapling has decreased due to disturbance.

RECOMMENDATIONS

Lephis forest field gene bank provides a great economic, ecological and social value for the rural communities living around the forest as a source of cultural medicinal plants and honey bee production. Additionally it is serving as a tourist attraction area since it has other biological resources and a water fall. To continue these services there is a need to enhance conservation efforts. Utilization of the forest genetic resources has to be monitored regularly and forest management plans are required to facilitate healthy regeneration of the forest. Further investigation which can reduce overexploitation of the forest resources in general and remnant tree species particularly species like *J. procera* and *H. abyssinica* is recommended. Species with low Important Value Index and threatened plant species found in the study area need to be prioritized for conservation.

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Appendix 1. List of woody species identified from Lephis forest field gene bank.

No	Species	Family	Local name in Afaan Oromoo	Habit
1	*Acokanthera schimperi* (A.DC) Schweinf.	Apocynaceae	Qararu	Sh
2	*Allophylus abyssinicus* (Hochst.) Radlkofer	Sapindaceae	Hirqamu	T
3	*Apodytes dimidiata* Mey. ex Arn.	Icacinaceae	Oda baddaa	T
4	*Bersama abyssinica* Fresen	Melianthaceae	Koraqqaa	T
5	*Brucea antidysenterica* J. F. Mill.	Simaroubaceae	Cironta	T
6	*Buddleja polystachya* Fresen	Loganiaceae	Bulchana	T
7	*Calpurnia aurea* (Ait.) Benth	Fabaceae	Ceekataa	Sh
8	*Canthium oligocarpum* Hiern	Rubiaceae	Wantefulasa	T
9	*Celtis africana* Burm.f	Cannabaceae	Amallaqqa	T
10	*Clematis hirsuta* Perr. & Guill	Ranunculaceae	Fiitii	L
11	*Cordia africana* Lam	Boraginaceae	Wadessa	T
12	*Croton macrostachyus* Del	Euphorbiaceae	Makkaniisa	T
13	*Discopodium penninervium* Hochst	Solanaceae	Maraaroo	Sh
14	*Dombeya torrida* (J. F. Gmel.) P. Bamps.	Sterculiaceae	Dannisa	T
15	*Dovyalis abyssinica* (A. Rich.) Warb	Flacourtiaceae	Dhangago	T
16	*Dracaena steudneri* Engl.	Dracaenaceae	Worqicha	Sh
17	*Ekebergia capensis* Sparrm	Meliaceae	Ononuu	T
18	*Embelia schimperi* Vatke	Myrsinaceae	Qaanquu	L
19	*Erythrina brucei* Schweinf	Fabaceae	Waleensuu	T
20	*Ficus thonningii* Blume	Moraceae	Danbii	T
21	*Ficus vasta* Forssk.	Moraceae	Odaa	T
22	*Flacourtia indica* (Burm.f.) Merr.	Flacourtiaceae	Hudha	T
23	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	Korolla	T
24	*Hagenia abyssinica* (Bruce) J.F.Gmel	Rosaceae	Heexoo	T
25	*Halleria lucida* L	Scrophulariacea	Minkero	T
26	*Hippocratea africana* (Willd.) Loes.	Celasteraceae	Hombaa	L
27	*Hypericum revolutum* Vahl	Hypericaceae	Garamba	Sh
28	*Ilex mitis* (*L.*) Radlk.	Aquifoliaceae	Xillo	T
29	*Jusminum abyssinicum* Hochst.ex DC.	Oleaceae	Dikii	L
30	*Juniperus procera* Hochst. ex Endl.	Cupressaceae	Hindhessa	T
31	*Justicia schimperiana* (Hochst.ex Nees) T.	Acanthaceae	Dhumuga	T
32	*Lippia adoensis* Hochst. ex Walp	Verbenaceae	Sukayi	Sh
33	*Maesa lanceolata* Forssk	Myrsinaceae	Abbayyii	T
34	*Maytenus arbutifolia* (A. Rich.) Wilczek	*Celastraceae*	*Kombolcha adi*	*Sh*
35	M*yrsine melanophloeos* (L.) R. Br.	Myrsinaceae	Tulla	T

No	Species	Family	Local name in Afaan Oromoo	Habit
36	*Myrsine africana* L	Myrsinaceae	Qacamaa	Sh
37	*Maytenus gracilipes* (Welw. ex Oliv.) Exell	Celastraceae	Kombolcha	T
38	*Nuxia congeta* R.Br. ex Fresen.	Loganiaceae	Bixanna	T
49	*Ocimum urticifolium* Roth.	Lamiaceae	Minantofa	Sh
40	*Olea europaea* L.	Oleaceae	Ejersa	T
41	*Olea capensis*	Oleaceae	Siigida	T
42	*Olinia rochetiana* A. Juss.	Oliniaceae	Gunaa	T
43	*Oncinotis tenuiloba* Stapf	Apocynaceae	Hadha mane	L
44	*Pavetta oliveriana* Hiern	Rubiaceae	Ara	Sh
45	*Pavetta abyssinica* Fresen	Rubiaceae	Gallo dhalaa	Sh
46	*Periploca linearifolia* Quart.-Dill. & A. Rich.	Asclepiadaceae	Aannanno	Sh
47	*Phytolacca dodecandra* L'Her.	Phytolaccacea	Andode	Sh
48	*Pittosporum viridiflorum* Sims.	Pittosporaceae	Amshiqa	T
49	*Podocarpus falcatus* (Thunb.) Mirb.	Podocarpaceae	Birbirsa	T
50	*Polyscias fulva* (*Hiern*) Harms	Araliaceae	Sudubaa	T
51	*Prunus africana* Lam	Rocaceae	Sukkee	T
52	*Psydrax schimperiana* (A. Rich.) Bridson	Rubiaceae	Gallo korma	Sh
53	*Rhus tenuinervis* Engl	Anacardiaceae	Dabobessaa	T
54	*Rhus vulgaris* Meikle	Anacardiaceae	Qamo	Sh
55	*Rubus apetalus* Poir.	Rosaceae	Goraa	Sh
56	*Schefflera abyssinica* (Hochst. ex A. Rich.)	Araliaceae	Gatamee	T
57	*Solanecio gigas* (Vatke) C. Jeffrey	Asteraceae	Workicho	Sh
58	*Stephania abyssinica* (Dillon & A. Rich.)	Menispermacea	Kalaalaa	L
59	*Teclea nobilis* Del.	Rutaceae	Hadhessa	T
60	*Urera hypselodendron* A. Rich.	Urticaceae	Halila	T
61	*Vepris dainellii* (Pichi-Serm)	Rutaceae	Kolaasaa	T
62	*Vernonia amygdalina* Del.	Asteraceae	Ebicha	T
63	*Vernonia urticifolia* A. Rich	Asteraceae	Reejjii	Sh

T = Tree, Sh = Shrub, L = Liana

TEMPORAL AND SPATIAL DISTRIBUTION OF GREVY'S ZEBRA AND HABITAT USE OVERLAP WITH LIVESTOCK IN HALLAYDEGHE ASEBOT PROPOSED NATIONAL PARK, ETHIOPIA

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ABSTRACT: Knowledge on distribution and habitat use overlap with livestock in time and space is crucial for planning the conservation of Grevy's zebra. The objective of this study was to determine the temporal and spatial distributions of Grevy's zebra and of livestock with reference to habitat use overlap in Hallaydeghe Asebot Proposed National Park. Habitat use overlap map was determined by projecting the Grevy's zebra and livestock GPS points in ArcGIS. One-way ANOVA was applied to test seasonal variation in mean abundances of livestock and Grevy's zebra. Habitat use similarity between livestock and Grevy's zebra was computed by S18 Kulczynski, and Pearson correlation coefficient was used to examine the degree of similarity in their habitat use. The habitat use overlap area covered an area of 110 square kilometers in the wet season and 272 square kilometers in the dry season. Results showed that the mean abundance of livestock in dry and wet season was 2.4 ± 0.1 and 3.1 ± 0.1, respectively. The mean abundance of Gravy's zebra in dry and wet season was 0.6 ± 0.1 and 0.2 ± 0.2 respectively. Degree of habitat use similarity between Grevy's zebra and livestock was 50.53% in dry, and 50.32% in wet season. Pearson correlation coefficient result showed that the degree of habitat use similarity between livestock and Grevy's zebra was r = 0.232 in the dry season and r = 0.243 during the wet season. This study concluded that there was habitat use overlap between livestock and Grevy's zebra in Hallaydeghe Asebot Proposed National Park in time and space.

Keywords: *Equus grevyi*, Habitat use overlap, Livestock.

INTRODUCTION

Wild equids play a significant role in maintaining semi-arid and desert ecosystem processes in Africa and Asia. However, their population has declined significantly due to habitat loss and unsustainable hunting (Williams, 2002; Moehlman et al., 2008; IUCN, 2010). The Grevy's zebra (*Equus grevyi* Oustalet) is one of the world's most threatened wild equids and is listed in IUCN's red-list as

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endangered species (Rubenstein et al., 2016). Historically, the Grevy's zebra ranged from east of the Rift Valley in Kenya to western Somalia and northern Ethiopia (Bauer et al., 1994; Kebede et al., 2012). Today it is extinct in Djibouti and Somalia, and its existence in Sudan is uncertain (Rubenstein et al., 2016). In Ethiopia, populations of Grevy's zebra declined from an estimated 1900 in 1980 to 577 in 1992 (Rowen and Ginsberg, 1992) and to 106 in 2003 (Williams et al., 2003; Kebede et al., 2012). The trend from 1980 to 2003 represented a decline of about 94% (Moehlman et al., 2008). The largest population of Grevy's zebra in Ethiopia, in the early 1970s, was in the *Chew Bahir*, which had an estimated 1500 animals but this number has declined to 30 over time (Khalatbari, 2013). Recent data indicated that the number of adult individuals is about 1956 (Rubenstein et al., 2016).

The principal objective for the establishment of the Hallaydeghe Asebot Proposed National Park (here after HAPNP) was to protect the endangered Grevy's zebra and other important grazing wild herbivores and carnivores in the area. The area is home to the Ethiopia's largest population of Grevy's zebra and serves as a buffer zone for the Awash National Park and the Awash West control hunting area. It was established in the 1960s when most of the Ethiopian protected areas were designated (Hillman, 1993; Kebede, 2008).

Competition with livestock for forage and water pose major threats to the survival of Grevy's zebra. The livelihoods of pastoral communities in the HAPNP and surroundings are dependent on livestock production, and livestock numbers are a social indication of the owner's wealth (Kebede, 1999; Mulder et al., 2010). Large numbers of livestock depend on the HAPNP rangelands, resulting in territorial disputes among pastoral communities. Some individuals from local pastoral communities occasionally hunt Grevy's zebra illegally to be used for medicinal purposes and for food (Kebede et al, 2003). The spread of the invasive species *Prosopis juliflora*, especially near villages and cattle trails, has also resulted in loss of forage and habitat degradation (Kebede, 2009). Urban development along the road and recent water borehole and rangeland development project inside the HAPNP are also becoming conservation threats.

Information on the temporal and spatial distribution of the endangered Grevy’s zebra, the types of vegetation they live in and their habitat use overlapping areas with respect to livestock encroachments were lacking in HAPNP. Hence, to conserve the endangered Grevy’s zebra and their habitats in the face of existing and developing conservation challenges, there is a need to develop a management oriented ecological threat monitoring programs based on the temporal and spatial distribution of Grevy’s zebra and livestock. Such study will serve as an important tool for the conservation and management of this endangered species in HAPNP.

The objectives of this study were hence to determine the temporal and spatial distributions of Grevy’s zebra and livestock with reference to habitat used overlap in HAPNP and map the habitat use overlapping areas of Grevy’s zebra and livestock in time and space at HAPNP**.**

MATERIALS AND METHODS

Location of the study area

The HAPNP is one of the protected areas in Ethiopia. It is located in the Great Rift Valley of Ethiopia (approximately 8˚30' to 9˚30'N, 39˚30' to 40˚30'E) (Figure 1) and located within the Inter-Tropical Convergence Zone. The area exhibits both temporal and spatial variability in rainfall, humidity and temperature. It is a semiarid ecosystem with annual rainfall ranging between 400 and 700 mm (Kebede, 2008). The area is known for two distinct rainy seasons, the small rains usually begin in February and last until the end of April and the big rains occur from July to September. The mean seasonal temperature ranges from 25 to 30°C, but the daily maximum temperature may be as high as 38°C in June, while the minimum daily temperature can drop to 15°C in December (Kebede, 2008).

The land cover types of HAPNP are open grassland, forest (Mountain Asebot forest in the eastern part), woodland, wooded grassland and bushland. Most of the plain is dominated by two species of perennial grasses *Chrysopogon plumulosus* and *Sporoblusio cladus***.** The southern, eastern and western edges of the proposed park are dominated by mixed shrub and grasslands shaded by *Acacia senegal* (Kebede et al., 2003). The HAPNP area coverage has been reduced from 1832 to 1099 square kilometer after re-demarcation work in 2014.

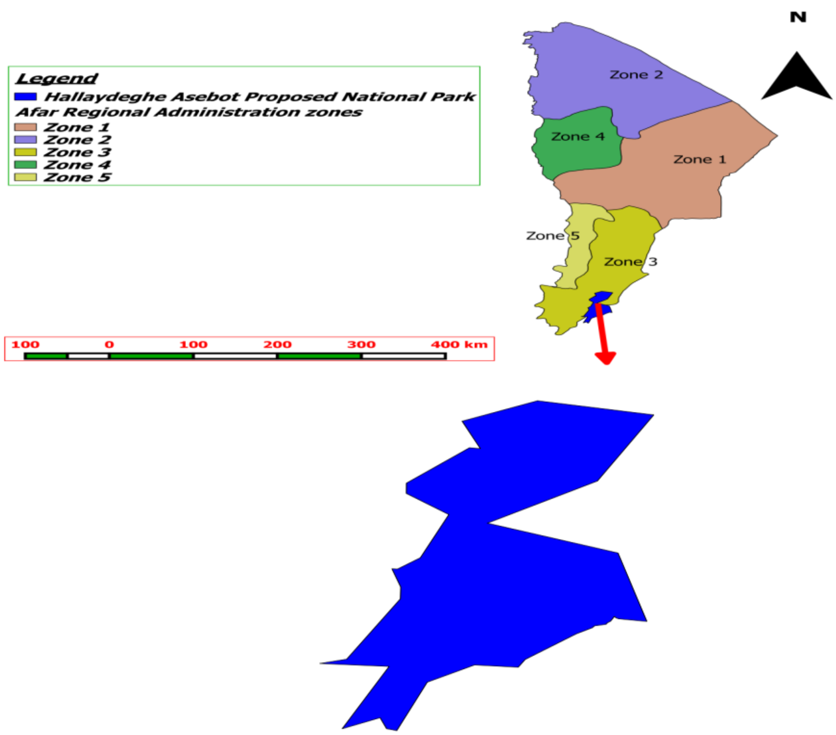

Figure 1. Map of the study area.

Data collection and analysis

Grevy's zebra and livestock distribution data

Grevy's zebra and livestock distribution was studied by collecting data in dry and wet seasons in the HAPNP. These data were collected using 11 ground transect lines in dry season (September 2020 to January 2021) and 10 transect lines in wet season (February to August, 2021). Since the HAPNP is open grassland plain, off-road driving along transect lines which was suggested to be the most efficient method for conducting a survey (Kebede et al., 2012) was used for conducting the census (Figure 2). The driving speed was 10 to 20 km per hour throughout the census period. The dry and wet seasons

Grevy's zebra and livestock transect line census results were obtained from the raw data GPS locations of Grevy's zebra and livestock. Whenever Grevy's zebra and livestock were sighted together, the date, time, GPS location, and total number of individual animals were recorded in open vegetation types. Transects were driven from 06:00 to 10:00 am in the morning and from 3:00 to 5:00 pm in the late afternoon, which are the hours where Grevy's zebra were most active. Site locations of the boreholes and seasonal illegal human settlements were also recorded with a GPS.

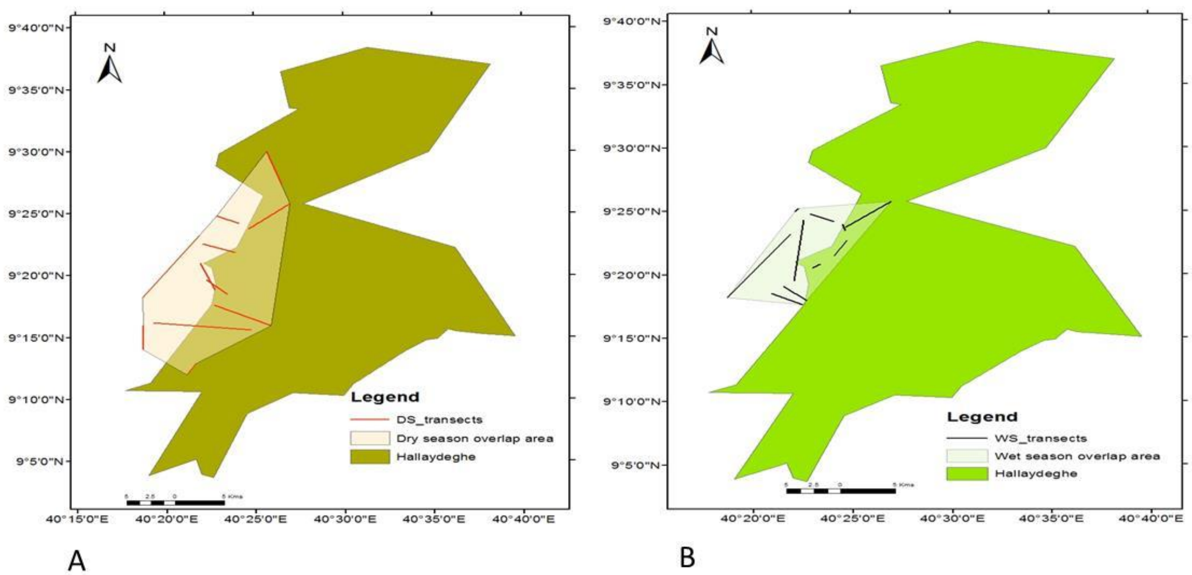

Figure 2. Transects lines used for Grevy's zebra and livestock census in the dry season (A) and wet season (B).

Maps of Grevy's zebra and livestock habitat use overlap

Distribution maps of Grevy's zebra and livestock in their habitat use overlap areas were generated from the GPS locations that were recorded where the zebras and livestock were sighted in HAPNP. This was achieved by initially adding the GIS shape files of HAPNP in ArcMap and overlaying Grevy's zebra and livestock GPS locations onto the shape files of HAPNP. By intersecting the Grevy's zebra and livestock habitat use maps in dry and wet seasons, the final map that identifies the habitat use overlap was developed.

Seasonal variation in mean abundance of livestock and Grevy's zebra

To test whether mean abundance of livestock and of Grevy's zebra differ between dry and wet seasons one-way analysis of variance (ANOVA) was computed using Statistical Package for Social Science SPSS (IBM Corporation, 2011). Data was log transformed before the comparison was made to ensure normality of means. Habitat use similarity between livestock and Grevy's zebra was computed to examine the degree of habitat use similarity between the two. To assess the degree of habitat use similarity for each season, S18 Kulczynski similarity index and Pearson correlation coefficient indexes were computed using Primer software (Clarke and Gorley, 2006).

RESULTS

Grevy's zebra and livestock distribution in dry season and wet seasons

Grevy's zebra and livestock counted in the opened grassland, woodland and wooded grassland were 56 and 4401 in dry season and 101 and 15043 in wet seasons, respectively. Among the 56 Grevy's zebra encountered in the dry season, 39.28% were in open grassland, 35.7% were woodland and 25% were in wooded grassland. Among Grevy's zebra encountered the wet season, 76.24% were in open grassland, 16.8% were in woodland and 6.9% were in wooded grassland. The maximum and minimum group sizes of Grevy's zebra counted in this study were 27 and 1 in the wet season, and 9 and 1 in the dry season respectively. Livestock counted result in the dry season (4401) showed that 26.53%, 58.96% and 14.49% of livestock numbers were found within open grassland, woodland and wooded grassland vegetation types respectively. During the wet season, 62.1% were in open grassland, 20.95% were in woodland and 16.96% were in wooded grassland.

Maps of habitat use overlap of Grevy's zebra and livestock in dry and wet seasons

Gravy's zebra and livestock have a wider area of habitat use overlap during dry season compared to the wet season (Figures 3& 4). The habitat use overlap area covered was 110 Km^2 in wet season of which 32 Km^2 (29%) was inside HAPNP, and 78 Km^2 (71%) was in the buffer zone. The habitat use overlap area covered was 272 Km^2 in dry season of which 155 Km^2 (57%) was inside HAPNP, and 117 Km^2 (43%) was in the buffer zones. The habitat use overlap area coverage in the buffer zones was wider in wet season (71%) compared to dry season (43%).

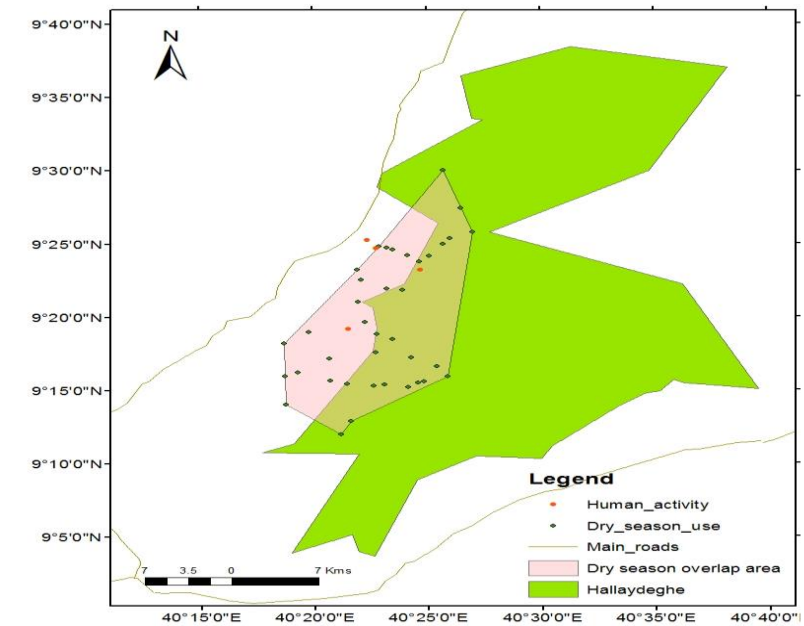

Figure 3. Map of the habitat use overlap between Grevy's zebra and livestock in the dry season.

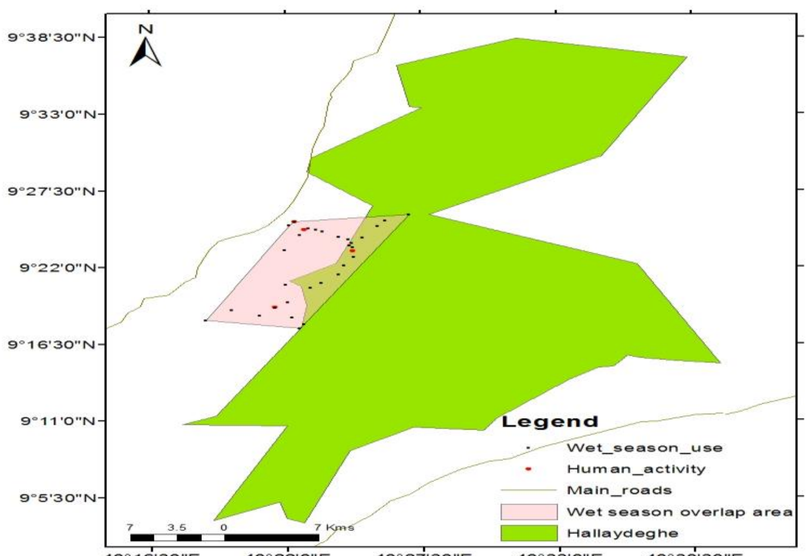

Figure 4. Map of the habitat use overlap between Grevy's zebra and livestock in the wet season.

Seasonal variation in mean abundance of livestock and Grevy's zebra in HAPNP in dry and wet seasons

One-way analysis of variance (ANOVA) results showed that there was a significant ($p<0.01$) seasonal variation in mean abundance of livestock distribution in HAPNP (Table 1). The mean abundance of livestock in the HAPNP in the dry and wet seasons was 2.4 ± 0.1 and 3.1 ± 0.1 (Mean ± SE) respectively. The mean abundance variation value between groups and within groups was 2.12 and 2.77 respectively, where the total mean abundance variation of the livestock was 4.89.

Table 1. Seasonal variation in mean abundance of livestock in HAPNP.

Descriptive		ANOVA					
Season	Mean ± SE	Source of Variation	SS	df	MS	F	P-value
Dry	2.4 ± 0.1	Between Groups	2.12	1	2.12	14.55	0.010
Wet	3.1 ± 0.1	Within Groups	2.77	19	0.15		
		Total	4.89	20			

SS-sum of squares; df-degrees of freedom; MS- mean squares.

The seasonal variation in mean abundance of the Grevy's zebra in dry and wet season results showed that there was seasonal variation in mean abundance of Grevy's zebra distribution in the HAPNP (Table 2). The mean abundance of Grevy's zebra in their preferred vegetation types in dry and wet season was 0.6 ± 0.1 (Mean±SE) and 0.2 ± 0.2 (Mean±SE) respectively. The mean abundance variation value between groups and within groups was 0.41 and 2.63 respectively, where the total mean abundance variation of the Grevy's zebra was 3.04 (SS).

Table 2. Seasonal variation in mean abundance of Grevy's zebra in dry and wet seasons

Descriptive			ANOVA				
Season	Mean ± SE	Source of Variation	SS	df	MS	F	P-value
Dry	0.6 ± 0.1	Between Groups	0.41	1.0	0.41	2.10	0.05
Wet	0.2 ± 0.2	Within Groups	2.63	19.0	0.14		
		Total	3.04	20.0			

SS-sum of squares; df-degrees of freedom; MS- mean squares.

Habitat use similarity between livestock and of Grevy's zebra

The S18 Kulczynski similarity index and Pearson correlation coefficient result showed that there was habitat use similarity between livestock and Grevy's zebra in dry and wet season. The S18 Kulczynski similarity index showed that the degree of habitat use similarity between livestock and Grevy's zebra in dry and wet season was 50.53% and 50.32% respectively. Pearson correlation coefficient results showed that there was similarity in the habitat use between livestock and Grevy's zebra with coefficient value r=0.232 in the dry and r= 0.243 in the wet seasons. Although five different land cover types were found in HAPNP that vary in their importance for wildlife survival, Grevy's zebra and livestock shared the three land cover types which are opened grassland, woodland and wooded grassland.

DISCUSSION

The findings of this study showed that Grevy's zebra and livestock were found in open vegetation in HAPNP, which was in agreement with Sundaresan et al. (2007). This study revealed that currently in HAPNP, the population encompasses 101 Grevy's zebra. The numbers of Grevy's zebra in HAPNP has declined from about 300 in 1978 (Stephenson 1978) to 177 (Thouless, 1995). In 2011, at least 143 Grevy's zebra were reported (Kebede et al, 2012).

During the dry and wet seasons, Grevy's zebra were found both outside and inside the HAPNP boundary. Similar observations were also reported from Kenya. According to the Kenyan Wildlife Service, the majority of Grevy's zebra populations in Kenya live on non-protected community owned lands such as the pastoralist's ranches and private conservancies (KWS, 2012). Williams (2002) also reported that only 0.5% of 57 Grevy's zebra range in Kenya falls within protected areas with the majority of populations occurring in community owned land.

The distribution of most wild animals is often more dispersed during the wet season because of increased availability of resources across landscapes (Jachmann, 1988; Hema et al., 2010). However, in HAPNP, Grevy's zebra were confined to a smaller geographic area in the wet season and had a wider dispersal in the dry season. The reason for this is that large numbers of livestock were brought to the HAPNP through the establishment of illegal settlement in wet seasons (Kebede et al., 2012). As a result, competition for grazing land and water resources between livestock and wildlife increased in the wet season compared to the dry season, which ultimately reduced the amount of available habitat for the Grevy's zebra. During the wet season, available resources were more plentiful, allowing the Grevy's zebra to persist in relatively high number and confined to a smaller area in HAPNP. During the dry season, when the numbers of livestock was reduced, the Grevy's zebra were widely dispersed and generally were found in smaller numbers. This allowed the Grevy's zebra to adjust to the scarcity of available resources.

In terms of spatial coverage, according to Kebede et al. (2012), the distribution of Gravy's zebra covered 437 square kilometers during the wet season and 563 square kilometers during the dry season. In the present study, the distribution of Gravy's zebra covered 272 square kilometers in the dry season and 110 square kilometers in the wet season. The reason for the difference between the two studies could be due to size variation on the park. The earlier study by Kebede et al. (2012) was done before HAPNP's boundary was re-demarcated while the current study was done after the boundary re-demarcation work was completed in 2014 which resulted in a reduction of the total area from 1832 Km^2 to 1099 Km^2.

As revealed by the S18 Kulczynski similarity index and Pearson correlation coefficient, there exist habitat use overlap between Grevy's zebra and livestock in both seasons. They shared the opened grassland, woodland and wooded grassland. Williams (1998) also reported that Grevy's zebra competes for resources with pastoral communities and their livestock in northern Kenya. Loss of access to critical resources due to competition with livestock, and an increasing scarcity of these resources is one of the causes that resulted in the decline of Grevy's zebra population (Williams and Low, 2004).

CONCLUSION AND RECOMMENDATIONS

This study concluded that Grevy's zebra shared common grazing forage resources with pastoral livestock during both wet and dry seasons in Hallaydeghe Asebot Proposed National Park. This habitat use similarity was wider in area coverage in the dry season than the wet season while the seasonal variation in mean abundance of Grevy's zebra and of livestock in dry and wet seasons was seen. Competition with livestock for forage and water pose major threats to the survival of Grevy's zebra. To avoid seasonal livestock pressure formation of alternative rangelands outside the park is recommended. There should be a continuous awareness creation programs for the local pastoral communities about seasonal sharing of grazing land between livestock and Grevy's zebra. Creation of additional income generating activities for the local communities could also be used to alleviate the pressure on the park.

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DO WE NEED IMPORTING EXOTIC BREEDS TO IMPROVE PERFORMANCES OF THE INDIGENOUS ANIMALS? A REVIEW ON BOER GOATS' IMPACT IN ETHIOPIA.

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ABSTRACT: Published literatures were used to review the impact of the Boer goat crossbreeding programs on performances of the indigenous goats in Ethiopia. Growth, reproduction, production and adaptability performances were assessed. The overall growth rate of the Boer goats and their crosses in Ethiopia was generally low as compared to their native areas. Boer kids had better birth weight (3.05–3.50 kg) than their crosses (2.39–3.00 kg) however, this dominancy was not observed at the later ages. The maximum reported litter size at birth for the Boer (1.76) and Central Highland goats (1.75) was comparable while the value of their crosses was lower. Extremely low conception (37.64%), low kidding (21.94%) and high abortion (15.01%) of the Boer were reported while the performance of local goats for conception, kidding and abortion was 54.38%, 47.50%, and 5.62% respectively. Their crosses performed better in conception (73.86%), kidding (60.23%) and abortion (9.09%). Meat production and carcass characteristics of local goats were better than the Boer crosses on poor nutrition, while Boer crosses outstand as the level of supplementation increases. Survival of Boer and the crossbreeds was quite low and below expected, which indicated their sub-optimal adaptability to Ethiopian environment. Therefore, unless it is practiced in a high intensive farming where the health management and supplementation of feeding is appropriate, using Boer goats crossing or replacement cannot help in achieving the required results. At the small holders' level, achieving stable genetic improvement without harming the diversity (options like within breed selection) need to be considered.

Keywords: Adaptation, Boer, Crossbreeding, Ethiopia, Growth, Reproduction

INTRODUCTION

Ethiopian goats

Ethiopia possesses diverse indigenous goat genetic resources (12 populations categorized into 8 breeds) (EBI, 2016) with large population size (52.5 million heads) (CSA, 2020) distributed in all agro-ecological areas of the country. Their small size, early maturity and adaptation to different climates

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together with their requirement of small initial investment allows indigenous goat to easily integrate into different farming systems (Adane and Girma, 2008). Goat production in Ethiopia has a significant contribution to the livelihood of small holder farmers, pastoralists and agro-pastoralists in particular, and to the national export earnings in general. In Ethiopia, indigenous goats are used as a sources of meat, milk, cash, skins, manure etc. (Adane and Girma, 2008; Gizaw, 2009).

Regardless of the aforementioned importance and their quality to adapt to harsh production environments, their productivity is relatively low in comparison to the temperate breeds. For example, Gizaw (2009) reported the moderate prolificacy (dominantly single born kids) of Ethiopian Highland goats. However, Erasmus et al. (1985) reported the improved Boer goat as the most productive and prolific breed with lambs born as 7.6% single, 56.5% twins, 33.2% triplets, 2.4% quadruplets and 0.4% quintuplets. On the other hand, Deribe and Taye (2013) reported birth weight of 2.01 kg, 9.02 kg weaning weight, 20.61 kg yearling weight of Central Highland goats in Sekota. For the improved Boer goats, higher weaning weight of 34.95 kg was reported by Scheltema (1994). Therefore, due to the lower growth and reproductive performance of the Ethiopian indigenous goat genetic resources, due consideration need to be given towards the improvement of their genetic makeup which in turn maximizes productivity and production at individual and national level.

Genetic improvement

Productivity can be maximized by improving both genotype and/or the production environment (Falconer, 1989). The production environment can be improved through improvements of feeds and nutrition, health follow-ups, and different management practices (von Kaufmann and Peters, 1990). On the other hand, the genetic makeup can be improved either through within breed selection or crossbreeding with high performing exotic breeds, while total substitution of local genotypes with exotics can also be attempted (Solomon and Kasahun, 2008).

Genetic improvement through within breed selection is a time-consuming process, with up to <5% genetic progress per generation (McDowell, 1972, 1988), while it can provide stable genetic gain, adaptation, and maintain diversity (conservation). The other route, crossbreeding, can lead to rapid improvement by enhancing the genetic performance. Both ways have their own merits and demerits depending on the available information including the awareness, within and among breed variations, and set up of the breeding objectives. When there is low within breed variation or heritability of a desired trait, crossbreeding or replacement of the local animals could be considered (Falconer, 1989). However, it is important to evaluate available genotypes before a decision is made to introduce exotic breeds (genotypes). Breeds adapted to environments similar to where they were to be introduced may have better chance of survival and productivity (Solomon and Kasahun, 2008). On the other hand, in case of higher within breed genetic variation it is important to consider selection based genetic improvement programs.

Crossbreeding attempts in Ethiopia

Over the past few decades, several goat breeds including Anglo-Nubian, Saanen, and Toggenburg goats have been introduced to Ethiopia under different projects (Abebe, 2022; Solomon et al., 2014). Most of these goat breeds were introduced under donor driven projects. All projects were initiated for improving the milk and carcass yield keeping in mind the effects of heterosis (FARM Africa, 1996; Kasahun and Solomon, 2008).

Melka Werer and Holleta research centers attempted to study the production performance (growth and milk production) of Saanen goats and their crosses with Afar and Highland goats respectively. Accordingly, 50% and 25% crossbreds were disseminated to farmers in their respective areas. However, the activities were discontinued before any evaluation had been done at on-farm level on the disseminated genotypes (Solomon et al., 2014).

Similarly, a study aimed to the production of crossbred goats of Somali and Hararghe highland goats with Anglo-Nubian to benefit women in the highlands of Hararghe and areas surrounding Hawassa had resulted in the distribution of 900 F1 crossbreeds. However, it was ended due to lack of efficient exit strategy: during the termination of the project, the work was not transferred to a responsible organization which can handle and monitor the activities (Solomon et al., 2014).

The introduction of Toggenburg goats to cross with Arsi-Bale and Somali goats at Hawassa and Haramaya University for the purpose of teaching had achieved its educational goals and finally the project ended its activities by distributing indigenous goats to some of the established women's group around the area (Solomon et al., 2014).

The above mentioned and others crossbreeding plans in Ethiopia were unsuccessful towards maintaining stable genetic improvement and change in the livelihood of the smallholder farmers (Abebe, 2022). This failure was mainly due to little or no consideration of smallholder farmers' needs, opinions, active participation, decisions, and local practices (Abebe, 2022). Similarly, lack of baseline production data, poorly managed institutional synergies, in addition to the insufficient and poor-quality feeds and forages, disease and parasite incidence, poor veterinary services, and a lack of infrastructure as well as the termination and weakness of goat genetic improvement projects were among the major reasons for crossbreeding failure (Abebe, 2022).

Boer goats were also imported to Ethiopia by the Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) aiming a sustainable increase in small ruminant productivity. The ESGPIP was a USAID-funded project operating with a goal to sustainably increase sheep and goat productivity in Ethiopia to consequently enhance economic and food securities by addressing a large number of factors, including human and institutional capacity building, applied research and technology transfer and introduction of improved genotypes (Yami and Merkel, 2008). The project imported Boer goats and Dorper sheep from South Africa into Ethiopia in 2007 which was the first ever importation of these animals into the country. These animals were aimed to form the backbone of a crossbreeding program designed to utilize the fast growth rate and larger carcass of these animals with the native adaptability and toughness of local breeds. The resulting crossbreds were aimed to be able to supply the export market with the desired frame size and carcass characteristics (American Institute for Goat Research). The Boer goat, developed in South Africa through crossing with different breeds, is a meat breed but milk and skin are also important products. Boer goats are also known for their fertility and fast growth (Casey and Van Niekerk, 1988). It has been reported that Boer goats can improve growth, reproduction and survival performances of many indigenous breeds (Erasmus, 2000).

The overall objective of the current review was to summarize the major achievements and miscarriage of the genetic improvement of the Ethiopian indigenous goat genetic resources through crossbreeding with Boer goats. The specific objectives were to review the effect of crossing indigenous goat genetic resources with Boer goats on the adaptability, growth, production and reproduction performances, and to give a country wide picture which can be useful in decision making for the future genetic improvement efforts that also need to consider maintaining the diversity of indigenous genetic resources.

MATERIALS AND METHODS

This review mainly considers the published reports following the implementation of the Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP), which was funded by the United States Agency for International Development (USAID). Hawassa, Mekelle and Haramaya universities and the national and regional research institutions were the collaborators of the project by allowing a breeding, evaluation and dissemination centers. Most of the selected centers /sites fall within the lowland and midland agro-ecologies with comparatively higher temperature. Majority of the studied goats receive intensive management with sizeable concentrate supplementation based on their body weights.

RESULTS

Evaluating the performances of the pure and cross-bred goats include the assessment of their growth, reproductive and survival /adaptability performances in different locations. Better performance of a breed with better adaptation can meet the expected goals of the crossbreeding program.

Growth performances

Least square means with their respective standard errors (LSM ± SE) of the growth traits of Boer goats and their crosses with different Ethiopian indigenous goat breeds at different locations of the country are presented in Table 1 and 2.

Table 1. On-station live body weights of Boer goats and their crosses with different indigenous goat breeds of Ethiopia at different age stages.

Location	Genotype	Birth Weight (kg)	Weaning Weight (kg)	6 Months Weight (kg)	Yearling Weight (kg)	Source
Adamitulu	Boer	3.50±0.08	12.53±0.41	15.44±0.64	30.53±1.59	Debele et al. 2016
Ataye	Boer	3.05±0.06	10.87±0.36	12.47±0.51	18.30±0.88	Mustefa et al. 2019a
Ataye	B x CHG 50%	2.62±0.04	8.80±0.22	11.15±0.31	16.73±0.48	Mustefa et al. 2019a
Sirinka	B x CHG 50%	2.78±0.03	10.50±0.21	14.06±0.26	19.93±0.37	Deribe et al. 2015
Sirinka	B x CHG 75%	2.67±0.05	9.48±0.35	12.86±0.48	19.35±1.01	Deribe et al. 2015
Sirinka	B x CHG 50%	2.58±0.02	9.60±0.16			Tesema et al. 2017
Sirinka	B x CHG 75%	2.70±0.05	9.74±0.34			Tesema et al. 2017
Abergelle	B x ABR 50%	2.90±0.09	15.30±0.39	19.60±0.47	27.85±0.53	Belay et al. 2014
Haramaya	B x HIG 50%	2.50±0.10	10.00±0.30	14.50		Teklebrhan 2018
Haramaya	B x SOM 50%	3.00±0.10	11.00±0.10	15.50		Teklebrhan 2018
Konso	B x WOG 50%	2.82	11.61	16.18	29.18	Dea et al. 2019
Dilla	B x ARB 50%	2.84±0.08	21.10±0.72			Debele et al. 2015
Sirinka	B x CHG 50% F1	2.54±0.02	9.77±0.16	13.6±0.19		Tesema et al. 2021
Sirinka	B x CHG 50% F2	2.55±0.03	9.99±0.24	14.1±0.28		Tesema et al. 2021
Sirinka	B x CHG 50% F3	2.39±0.05	9.39±0.48	14.5±0.51		Tesema et al. 2021

B= Boer, CHG= Central Highland Goats, ABR= Abergelle, HIG= Highland Goats, SOM= Somali Goats, WOG= Woyto-Guji Goats, ARB= Arsi-Bale Goats, kg= Kilo grams.

The body weight of the pure Boer kid from birth to yearling age was reported to be higher in Adamitulu than Ataye site. Comparable birth weights of the crosses were reported in the different sites studied, while high variabilities were seen for their weaning weights. Extremely high weaning weight (21.1 kg) was reported from the crosses of Boer goats with Arsi-Bale goats in Dilla site while the lowest (8.8 kg) was seen in the crosses of Boer with Central Highland goats in Ataye site. Similarly, the Ataye site also produced crosses with the lowest body weight at six months' (11.15 kg) and yearling age (16.73 kg). On the other hand, the Boer by Abergelle crosses dominate the body weight at six months' age. Similarly, the Boer by Woyto-Guji crosses had the highest yearling weight. In line with the above results, highest pre-weaning average daily body weight gains (175.83 grams) was observed in Dilla from the crosses of Boer with Arsi-Bale goats. The crosses of Boer with Abergelle and Woyto-Guji goats also produced relatively higher pre-weaning weight gain (103 and 97.73 grams respectively). The reports from Ataye site regarding the pre-and post-weaning daily weight gain were the lowest among the others.

Table 2. On-station average daily body weight gains of Boer goats and their crosses with different indigenous goat breeds of Ethiopia.

Location	Genotype	Average Daily Body Weight Gains			Source
		Birth –Weaning (g)	Weaning – 6 Months (g)	6 Months – Yearling (g)	
Ataye	Boer	83.94±3.76	25.57±3.29	27.62±2.69	Mustefa et al. 2019a
Ataye	B x CHG 50%	67.05±2.26	31.46±2.00	28.40±1.46	Mustefa et al. 2019a
Sirinka	B x CHG 50%	85.17±2.26	34.94±1.76	31.85±1.79	Deribe et al. 2015
Sirinka	B x CHG 75%	75.36±3.79	32.84±3.24	36.11±4.86	Deribe et al. 2015
Sirinka	B x CHG 50%	77.20±1.80			Tesema et al. 2017
Sirinka	B x CHG 75%	78.00±3.60			Tesema et al. 2017
Abergelle	B x ABR 50%	103.00±2.98	93.70±2.50	69.20±1.40	Belay et al. 2014
Konso	B x WOG 50%	97.73			Dea et al. 2019
Dilla	B x ARB 50%	175.83 ± 6.00			Debele et al. 2015
Sirinka	B x CHG 50% F1	79.63±1.75	40.21±1.44		Tesema et al. 2021
Sirinka	B x CHG 50% F2	82.11±2.52	30.84±1.77		Tesema et al. 2021
Sirinka	B x CHG 50% F3	77.87±5.10	41.87±4.49		Tesema et al. 2021

B= Boer, CHG= Central Highland Goats, ABR= Abergelle, WOG= Woyto-Guji Goats, ARB= Arsi-Bale Goats, g=grams.

Reproduction performances

Percent reproductive performances of the pure Boer, indigenous and their crosses at different locations of the country are presented in Table 3. Among the pure Boer, those from Adamitulu site were more fertile (with average litter size at birth (LSB) of 1.76) than those from Ataye site with LSB of 1.5. Among the others, Central Highland goats (CHG) in Sirinka site produced higher kids per birth (1.75). Values of litter at birth were lower for the crosses. Breed wise comparisons in the same study area (Ataye site) showed extremely low conception and kidding rate of the pure Boer does. Similarly, abortion rate was lower for the indigenous CHG breed, while highest barren and abortion rates were seen in the pure Boer does. Age at first mating and kidding of the 50% crosses of Boer with Woyto-Guji was 8.10±1.27 and 12.91±1.22 months respectively (Dea et al., 2019).

Table 3. On-station reproductive performances of Boer goats and their crosses with different indigenous goat breeds of Ethiopia.

Location	Genotype	LSB	Conception %	Kidding %	Abortion %	Source
Adamitulu	Boer	1.76				Debele et al. 2016
Ataye	Boer	1.50±0.01	37.64	21.94	15.01	Mustefa et al. 2019b
Ataye	CHG	1.50±0.00	54.38	47.50	5.62	Mustefa et al. 2019b
Ataye	B x CHG 50%	1.50±0.01	73.86	60.23	9.09	Mustefa et al. 2019b
Sirinka	B x CHG 50%	1.62±0.03				Tesema et al. 2017
Sirinka	CHG	1.75±0.02				Tesema et al. 2017
Konso	B x WOG 50%	1.26				Dea et al. 2019
Sirinka	B x CHG 50% F1	1.48±0.03				Tesema et al. 2020
Sirinka	B x CHG 50% F2	1.62±0.06				Tesema et al. 2020
Sirinka	CHG	1.58±0.03				Tesema et al. 2020

B= Boer, CHG= Central Highland Goats, WOG= Woyto-Guji Goats, LSB= Litter size at birth.

Meat, milk and carcass characteristics

Alongside the growth and reproductive performances, some production traits including meat and carcass characteristics were also among the important traits in evaluating a breed. Accordingly, the dressing percentage was evaluated for both the local Arsi-Bale and its F1 crosses with Boer. Similar value of 41.1% dressing percentage was obtained (Mohammed et al., 2012) under low-quality basal grass hay diet. The rib eye measurements were not significantly different for both the locals and 50% crosses with 11.6 and 15.1 cm^2 respectively (Tesema et al., 2018). Similar proportional yield as percentage of empty body weight was also obtained from the two genotypes (Tesema et al., 2018).

With uniform management condition (600 grams of concentrate supplementation for 90 days after the age of nine months) 34.2 kg vs 25.5 kg slaughter body weight, 17.6 kg vs 11.8 kg hot carcass weight, and 51.7% vs 46.2% dressing percentages were obtained from the 50% crosses of Boer vs the local CHG respectively (Tesema et al., 2018). The study by Tilahun et al. (2013) in Sirinka agricultural research center also showed 27.6 kg vs 20.4 kg slaughter body weight, 12.8 kg vs 9.0 kg hot carcass weight, 44.4% vs 42.8% dressing percentage obtained from the 50% crosses of Boer vs the local CHG respectively.

The Boer crossbreds' average daily milk yield was also evaluated and compared with the indigenous Central Highland goats in Sirinka. Accordingly, the Boer by Central Highland crossbreds had higher average daily milk yield (0.41±0.03 kg) than the local Central Highland goats (0.28±0.02 kg) (Tesema et al., 2020).

Adaptability

Kid survival and mortality rates of a breed can show the adaptability performance of the breed to the given environment. Accordingly, pure Boer and 50% F1 crosses with CHG perform 56% and 54% pre-weaning kid survival respectively, while the values were 33% and 44% for the yearling age survival in Ataye site (Mustefa et al., 2019b). Higher mortality rates of 48% and 41% were also reported in South

Omo and Konso areas respectively for the crossbreeds of Boer with Woyto-Guji goats (Molla, 2016; Dea et al., 2019).

DISCUSSIONS

Growth performances

Considerable pre and post-weaning growth rates are among the main requirements in improving productivity of a given population. The Boer goats are known for their significant growth rates; Kids weigh 3–5 kg at birth and can reach 40–50 kg at six months of age. Mature male and female Boer goats weigh up to 130 and 80 kg, respectively, with most animals weighing 75 – 90 kg and 50 – 60 kg for males and females, respectively (Casey and Van Niekerk, 1988). However, summary of the results on the on-station growth performances in the Ethiopian condition were unable to proof such achievements (Table 1). The growth rate of the Boer goats and their crosses is generally low in comparison to the expectation.

Comparing locations, Boer goats from Adamitulu had higher body weights at different stages than their counterparts from Ataye site which might be due to the differences in management condition. Among the different indigenous breeds which are crossed with the exotic Boer goats, Abergelle and Woyo-Guji goats produces heavier crossbreeds in most of the reported body weights. The availability of green feed, better management might be some of the environmental factors favoring these breeds, while breed complementarity or nicking effect had its own role in the genetic makeup of the crossbreeds. The overall lowest results were reported in Ataye site of Debre Berhan Agricultural Research Center, which might be due to the less attention given to the management practices or adaptation problems.

Daily body weight gain of Boer goats was reported to be one of the outstanding performances they show (Van Niekerk and Casey, 1988). The reports of Van Niekerk and Casey (1988) show body weight gains of 200 and 176 grams per day under favorable nutritional condition and the extensive subtropical condition respectively. However, none of the current results from Ethiopia come close to this figure.

Comparatively highest weight gains were reported at the pre-weaning stage than the post weaning stages which can be linked directly to dams' milk production performance. The lower weight gains at the post weaning stages show their failure to perform at the given environments.

Relative to the different locations and genotypes, the 50% crosses of Boer with Abergelle and Woyto-Guji goats gained more weight than the others while, outstanding performance was reported in Dilla (Table 2) from 24 kids only. On the other hand, reports of Tesema et al. (2018) show better weight gain and feed conversion ratio results by increasing concentrate supplementation in the indigenous CHG and 50% crosses of Boer. According to the report of Tesema et al. (2018), significant difference between the crosses and locals was not observed in daily weight gain as the concentrate supplementation increase up to 600 grams per day, while, some numerical differences exist (117 and 93.3 grams for the crosses and locals respectively). Therefore, improving management and supplementing the indigenous goats is economical comparing to the crossbreeds as the indigenous Central Highland goats adapts the environment better than the Boer goats (Tesema et al., 2018). Realizing the expected higher growth performances of Boer goats in their native environment, the overall reported weights and weight gains of the crosses at different age stages in Ethiopia were worse due to the sub-optimal adaptability of the breed to the local environment.

Reproduction performances

Reproductive qualification may be considered as one of the most important benchmark related to adaptation (Erasmus, 2000). Reproductive performances can be measured and expressed in terms of kidding and weaning rate, kidding interval, and litter size at birth and at weaning (Greyling, 1988). From such perspective, the Boer goat was recognized as a most productive and prolific breeder (Erasmus, 2000). However, current reports did not find a way to confirm this.

The overall Boer conception and kidding rates were lower while the abortion rates were higher enough comparing them with the local CHG and its F1 crosses (Table 3). This might be due to change in the production environment which is in line with the reports of Devendra and Burns (1983) who shows the excellent accommodation and adaptation ability of the indigenous goat breeds in a fluctuating environment. This was further supported by other studies. Reproduction performances can be altered by the genotype of a given breed and the production environment where the animals are reared, however, it is vulnerable to the later (Greyling, 2000). Numerous factors can considerably affect the production environment including the seasonal availability of feed /nutrient, temperature fluctuations and changes in management systems (Riera, 1982). Additionally, due to the low heritability of reproductive traits, massive genetic transmission may not be expected from an exotic breed towards the indigenous breeds.

Higher litter size at birth (1.76) was reported for the pure Boer goat in Adamitulu area than Ataye site which might be directly linked to the management differences and suitability of the area for Boer goat. On the other hand, the value was lower for their crosses. Therefore, the crossbreeds cannot be a good choice for a breeding program which aims at increasing twinning rate. Despite their lower litter size at birth, the crossbreeds had comparatively higher conception and kidding percentages. The reports of Mustefa et al. (2019b) show highest barren and abortion rate of the pure Boer goats in Ataye which can restrict the genetic improvement program. The short age at first mating and kidding of the Boer by Woyto-Guji crosses reported by Dea et al. (2019) in Konso hints the better performance of the breed in feed available and good management area.

Meat, milk and carcass characteristics

The observed comparable dressing percentages (Mohammed et al., 2012) and rib eye measurements (Tesema et al., 2018) between the locals and Boer crosses can have generalized us that the use of local goats for meat production and carcass characteristics can be more economical on poor nutrition (grazing only). However, superiority of the Boer crosses was observed as the level of supplementation increases (Tesema et al., 2018). Therefore, better meat, milk and carcass characteristics of Boer or Boer crossbred goats was not and cannot be achieved by lower quality diets which might be due to the high nutrient use of the exotic breed or its crosses for maintenance (Tilahun et al., 2013). This indicates Boer goats or their crosses cannot perform to their full extent at smallholder level where quality feed is not available.

Adaptability

Survivability performance results showed us that the overall kid survival of the pure Boer as well as their crossbreeds with indigenous goats at different age stages was quite low as compared to their native area, which indicates their sub-optimal adaptability to Ethiopian environment (Mustefa et al., 2019b; Dea et al., 2019). These reports were in contrary with the report of Cameron et al. (2001) which states the high demand of the Boer goats for crossbreeding purpose due to their desirable genetic traits for meat production and hardiness to several diseases in the United States of America.

Heart water was the major disease which affects the pure and crosses of the Boer with indigenous goat breeds while pyogenic infection/caseous lymphadenitis, and wart/orf diseases were also among the other common diseases reported in the country (Molla, 2016; Debele et al., 2016). Similarly, Hunduma et al. (2010) also reported respiratory problems, gastrointestinal parasites, local abscess, diarrhea, and orf as the major health problems for the Boer goats in Adami-tulu with high prevalence of 42.2 %. The reports of Alemnew et al. (2020) picks Agalactia as the primary health problem which causes about 49% of the mortality of Boer goats in Ataye site. The possible reason for Agalactia might be poor mothering ability, pendulous udders and/ or adaptability problems (Alemnew et al., 2020).

In the reports of Terefe et al. (2012), most of the imported Boer goats in Adamitulu area were infected with two or more types of parasite (Eimeria, Strongyle-type and Strongyloides species). The results indicate that internal parasites are likely to be one of the major problems that influence the efficient utilization of production potential of the goats. In addition to addressing the common diseases reported above, efficient and effective control and prevention mechanisms for heart water should be focused for better use of the imported Boer goats in some selected parts of Ethiopia (mostly for commercial and education purpose).

CONCLUSION AND RECOMMENDATION

The reviewed documents showed high mortality and low survival of the imported Boer goats, and questioned the adaptability of the breed and its crosses in Ethiopia. The poor survival, growth and reproductive performances of the breed, in addition to being a threat in maintaining diversity of indigenous breeds, can lead us to choosing a more sustainable genetic improvement mechanism. In such situation, addressing the need for sustainable genetic improvement of goats can only be achieved through within breed selection. As per the reports of EBI (2016) the biggest threat to the conservation of the Ethiopian indigenous breeds is uncontrolled crossbreeding. Therefore, in addition to the failure of achieving their objectives (improvement), this exotic goat breed has also a negative impact in maintaining the diversity of the indigenous genetic resources. Unless it is practiced in a high intensive farming where the health management and supplementation of feeding is appropriate, using Boer goats crossing or replacement cannot help in achieving the required results in meat production. Therefore, achieving the improvement without harming the diversity need to be considered in on farm situation of Ethiopia. This can be attained through the within breed selection-based genetic improvement program which nowadays is broadly exercised and known as Community Based Breeding Program (CBBP).

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Lemessa, D., Hylander, K. and Hambäck, P. 2013. Composition of crops and landuse types in relation to crop raiding pattern at different distances from forests. *Agriculture Ecosystems and Environment*, **167:71-78**.

Mewded, B., Negash, M. and Awas, T. 2020. Woody species composition, structure and environmental determinants in a moist evergreen Afromontane forest, southern Ethiopia. *Journal of Forestry Research*, **31(4): 1173-1186**.

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- **Acknowledgements:** appear in a separate paragraph before the reference, and should be as brief as possible. All sources of funding should also be declared.

2.4 References style

EthJBD follows referencing style described below. Unpublished results and personal communications are not recommended on the reference list, but maybe mentioned in the text and indicated in footnotes. Citation of a reference as 'in press' implies that the item has been accepted for publication. Moreover, citation in the text should follow the same referencing style. The citation styles described below is also applicable for Ethiopian Authors' work.

2.5 Citation in the reference list

For books with one author includes the following:

Example: One author AND first edition:

Acquaah, G. 2012. Principles of plant genetics and breeding. Oxford: Wiley-Blackwell.

Example: One author AND NOT the first edition

Dahl, R. 2004. Charlie and the chocolate factory. 6th ed. New York: Knopf.

Books with Two or More Authors:

Example:

Desikan, S. and Ramesh, G. 2006. Software testing. Bangalore, India: Dorling Kindersley.

For Chapters in Edited Books:

Harlan, J. R. 1971. On the origin of barley: a second look. In: R. A. Nilan, ed., Barley Genetics vol. II Proc. 2nd Barley Genetics Symposium. Washington State Univ. Press, Pullman, pp. 45 - 50.

Multiple Works by the Same Author:

Start from the oldest publication

Example:

Brown, D. 1998. Digital fortress. New York: St. Martin's Press.

Brown, D. 2003. Deception point. New York: Atria Books.

For Print Journal Articles:

The standard structure of a print journal citation includes the following components:

Last name, First initial. Year published. Article title. *Journal*, **Volume (Issue number): Page(s).**

Examples:

Engels, J. M. J. 1994. Genetic diversity in Ethiopia in relation to altitude. *Genetic Resources and Crop Evolution*, **41: 61-73**.

Lemessa, D., Hylander, K. and Hambäck, P. 2013. Composition of crops and landuse types in relation to crop raiding pattern at different distances from forests. *Agriculture Ecosystems and Environment*, **167:71-78**.

Mewded, B., Negash, M. and Awas, T. 2020. Woody species composition, structure and environmental determinants in a moist evergreen Afromontane forest, southern Ethiopia. *Journal of Forestry Research*, **31(4): 1173-1186**.

For Journal Articles Found on a Database or a Website:

When citing journal articles found on a database or through a website, including all of the components found in a citation of a print journal, but also include the medium ([online]), the website URL, and the date that the article was accessed.

Structure:

Last name, First initial. Year published. Article Title. *Journal*, [online] **Volume(Issue number): page(s).** Available at: URL [Accessed Day Mo. Year].

Example:

Raina, S. 2015. Establishing Correlation Between Genetics and Nonresponse. *Journal of Postgraduate Medicine*, [online] **61(2):148**. Available at: http://www.proquest.com/products-services/ProQuest-Research-Library.html [Accessed 8 Apr. 2015].

For Websites:

When citing a website, use the following structure:

Last name, First initial. Year published. Page title. [online] Website name. Available at: URL [Accessed Day Mo. Year].

Bejiga, G. and van der Maesen, L.J.G. 2006. *Cicer arietinum* L. [online] PROTA. Available at: https://uses.plantnet-project.org/en/Cicer_arietinum_(PROTA) [Accessed 1 Mar. 2020].

When no author is listed, use the following structure:

The website name, Year published. *Page title*. [online] Available at: URL [Accessed Day Mo. Year].

Example:

Avogel.com, 2015. *A. Vogel plant encyclopaedia.* [online] Available at: https://www.avogel.com/plant-encyclopaedia/ [Accessed 20 Apr. 2015].

6.2.6 Citation in text

One author: The last name of the author followed by year of publication will be cited in the text.

Example: ……..(Brown, 2005).

Two authors: The last name of the authors are joined by "and" followed by year of publication.

Example: ……….. (Tesfaye and Girma, 2019).

More than two authors: The last name of the first author followed by "et al., " and year of publication

Example :…………(Adugna et al., 2019).

2.7 Tables

Tables should be as editable text and be placed on a separate pages at the end of the manuscript. Number tables consecutively (i.e. Table 1, Table 2, etc.) in accordance with their appearance in the text and avoid vertical lines and shading in the table cells. Table captions should be descriptive and appear above the table. Footnotes and sources to tables should be placed under the table. Larger datasets can be uploaded separately as Supplementary Files

2.8 Figures

Figure should be prepared in formats like JPEG, TIFF and JPG, with the resolution of 300 dpi or higher. Captions should be numbered consecutively (Figure 1, Figure 2, etc.) and placed below the figure. Figures from other sources should be used with the permission of the publishers of the articles. Figure citations in the text should always be with capital "F" as follows:

One figure (e.g. Figure 1), and more than one figure (e.g. Figures 1–3, Figures 2A–E.)

2.9 Abbreviations and symbols – All abbreviations used in the text should be defined in their first use. Abbreviations used only in tables and figures can be defined in the table foot note or figure legend

2.10 Units – All measurements should be in the metric system. Geographic coordinates should be written as degree, minute and second. Example: 36°31'21"N; 114°09'50"W

2.11 National Administration units– At initially, all administration units such as Woreda, Kebele, Zone etc. should be described in a bracket at the first mention of the word.

3. Manuscript submission and checklist

Manuscripts should be submitted to the EthJBD via e-mail or online submission system in word format (.doc, .docx). The submission should be accompanied by a cover letter stating the novelty of the finding and the manuscript was neither submitted nor published elsewhere

The author(s) should ensure that the entire checklist stated in the guide for authors are present; and these include:

- Title and corresponding author with contact details (email and postal addresses)
- Abstract and Keywords
- Main text
- All figures with captions
- All tables with captions
- All figures and tables are cited in the main text
- A reference section containing all sources cited in the text
- Declaration and conflict of interest statement
- Referee suggestions and their contact details (optional)

8. Proofreading

PDF proofs are to be sent by email to the corresponding author for correction. Authors are responsible for the final proofreading of their manuscripts and no corrections are accepted after re-submission. The corrected version should be returned to the editor-in-chief/associate editor within a week.

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