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Urban Homegarden for Woody Species Conservation and Carbon Sequestration: The Case of Jimma City, Southwest Ethiopia

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Abstract
Homegardens in urban are found to be an important refuge for native biodiversity and provide huge contribution for climate change mitigation. The study was undertaken to investigate potential of homegarden in conservation of woody species and carbon sequestration in Jimma City. A complete listing of woody species within 138 homegardens and 39 sample plot size 10m×10m (100m^2) were surveyed. Diameter at breast) height and the height of the tree were measured. Shannon diversity and Jaccard coefficient of similarity index were used to determine the species composition. Allometric equation was used to estimate aboveground carbon stocks of woody species. A total of 40 woody species (36 in homegarden and 22 in government institution) belonging to 24 families were recorded. Very significantly higher ($P<0.001$) species richness and diversity were observed in homegardens. But no significant difference was observed ($p>0.5$) among homegardens in three kebeles. Jaccard coefficient of similarity index (47.5%) showed low similarity in woody composition between two systems. About 2,877.13Mgha^{-1}(884.2 Mgha^{-1} in homegarden &1,992.95Mgha $^{-1}$ in government institution) carbon of about 319.57Mg of CO_2 equivalents were measured. Very highly significant ($p<0.001$) and non-significant difference ($p>0.05$) in carbon storage were observed between systems and among homegardens respectively. The result reveled homegardens in Jimma city have good potential for biodiversity conservation and climate change mitigation. Hence, responsible bodies need to consider the role of homegarden in maintaining native biodiversity and climate change mitigation in urban development planning.
Keywords: Biodiversity conservation, government institution compound, carbon stock, climate change mitigation.
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1. Introduction

Vegetation in urban landscape including agroforestry have played important role in maintaining the well-being of inhabitants through provision of numerous ecosystem services necessary for the human development. They are important for role playing in intrinsic value, natural and cultural heritage, sense of place, climate amelioration, noise amelioration, pollution filtration, water-sensitive urban design and human health and wellbeing (McDonnell and Hahs, 2012). Urban vegetation area can provide high impact ecosystem services (Dearborn and Kark, 2009) such as climate-change mitigation through increasing carbon storage and uptake, providing more shade and cooling thereby reducing overall energy consumption, and significantly reducing the urban heat island effect (Secretariat of the Convention on Biological Diversity, 2012). They can also play important part in maintaining biodiversity that are under risk of disappearance in the natural habitat by offering a unique opportunity for preservation (Mengistu and Alemayehu, 2017).

However, urbanization transforms the local biophysical environment especially forestland (Sejati et al., 2018) and accelerates biodiversity loss (Akinnifesi et al., 2010). The removal of trees and breakdown of traditional agroforestry systems (Thaman et al., 2006) associated with urbanization attributed to greatest local extinction rates and frequently eliminates the large majority of native species (Mckinney, 2002).

The rapid urbanization in Ethiopia, which has increased from 3.7% in 1984 to 19% in 2014 and predicted to climb up to 38% in 2050, have expanded their territory into the immediate hinterlands (Mengistu and Alemayehu, 2017) such as forest, wetlands and other ecosystem. Besides, urban forests in Ethiopia have encountered various problems such as encroachment, illegal cuttings, low legal enforcement and improper tree selection (Shikur, 2012). Enormous observable environmental changes including forest cover change, which could have potential impact on ecological functioning and environmental sustainability, were reported in and around Jimma City due to urban expansion (Chalachew et al*.,* 2015). Such loss of forest resources contributed substantial increase in concentration of CO_2 in the earth's atmosphere (IPCC, 2007; Nair et al., 2010; Axel et al., 2011). Nevertheless agroforestry such a homegardens in urban area can play important role in biodiversity conservation and mitigation of CO_2. Homegardens, as the most elaborate manmade, tree-crop-animal associations, resembling a natural ecosystem and offer valuable ecosystem functions (Kumar and Tripathi, 2017). They maintain the biological diversity of native and exotic as well as managed or wild species (Kunhamu, 2013) and hold a large potential for climate change mitigation through storing carbon (Verchot, 2007; Nair et al., 2009; Mattsson et al., 2015).

Studies reported the potential of agroforestry in conservation biodiversity and storage of carbon. For instance, Mengistu and Alemayehu (2017) reported that various species of higher plant species of various use in Bahir Dar

City, Ethiopia. On other hand, Kumar (2011) and Bajigo et al. (2015) reported about 24.32 Mg C ha^{-1} and 86.4 Mg C ha^{-1} in rural homegardens of central Kerala, India and Ethiopia. However, the research report on role of urban homegarden for carbon sequestration is scarce in general. Because of this and other reason, the potential of agroforestry especially understanding for C sequestration and biomass production is limited (Jose and Bardhan, 2012) or marginalized in urban area (Tellström, 2014). Other scholar (e.g. Thaman et al., 2006; Kunhamu, 2013) also stated the limited understanding of agroforestry from ecosystem service perspective. The same is true in Ethiopia, where climate change mitigation roles of agroforestry remain largely unknown (Seta and Demissew, 2017). Such lack of awareness due to lack of scientific information has triggered the loss of biodiversity and increase in CO_2 in general and urban area in specific.

But native and exotic woody species in homegardens and compounds of different government and non-governmental institution, and rode sides of Jimma City need to be studied and their essential role in mitigation of CO_2 and thereof mitigating climate change should be documented. Thus, studies that evaluate the environmental role of urban homegarden of Ethiopia in general and Jimma City in particular are crucial for improving the understanding of the role of urban forests and agroforestry in ecosystem services especially biodiversity conservation and climate change mitigation. This is apparent to have decision makers and city planners prioritize their existence for climate change mitigation and adaptation options. Thus, this study was aimed to evaluate the potential of homegarden for conservation of woody species and carbon sequestration in selected kebeles of Jimma City, southwest Ethiopia.

2. Materials and Methods

2.1 Description of the study area

Jimma City is located in Jimma Zone of Oromia Regional State (Figure 1). It is located at 335 km southwest of Addis Ababa, federal capital of Ethiopia. Geographically, it is located in latitude 7°40′ N to 7.667°N and longitude of 36°50′E to 36.833°E. The elevation ranges from 1700 to over 2000 m.a.s.l. The City is characterized by flat to gently sloping topography and undulating landscape. The main economic activities in the City are commerce and small scale manufacturing enterprises (World Bank, 2011). The mean emperature of the City is ranges from 12°C to 29°C with the mean daily temperature of 19.5°C. The rainfall is unimodal distribution with mean annual rainfall of around 1500mm and annual potential evaporation is about1465mm. Geologically, the area consists of various Tertiary Volcanic and younger Quaternary Sediments with reddish brown residual soils and alluvial soils of brownish gray and grayish white clay soils. Homegardens, riparian forests, green areas, trees in compounds of institutions, remnants of natural forest are major vegetation characterize Jimma City. Though, the original vegetation of the Jimma area has been totally modified by human activities and currently it is covered by some remnant trees, bushes and shrubs (World Bank, 2011).

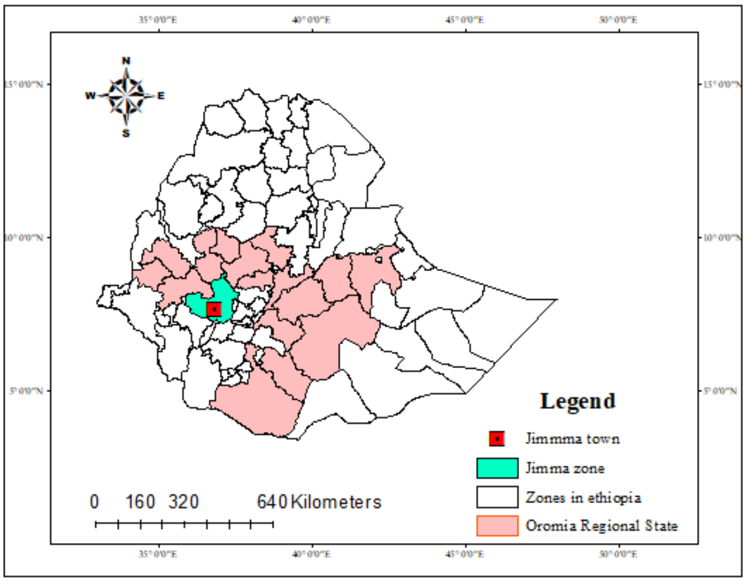

Figure 1 Map of the study area

2.2 Research methods

2.2.1 Sampling techniques and data collection methods

Reconnaissance survey was conducted to collect basic information and understand biophysical setting of the study area for determination of the sampling design. Three representative *kebeles* (the smallest administrative unit) were selected purposively based on presence of homegarden agroforestry system. In each selected *kebele*, three villages were selected randomly and investigated. After households who have woody species in their homegardens were identified, homegarden of household heads were randomly selected as sampling plots for biomass assessment. A total of 138 (46 from each kebele) households' homegardens were investigated. The total numbers of households were determined using the following formula as the total numbers of the population were unknown (Cochran, 1977):

$$n = \frac{Z^2 pq}{e^2}$$

Where: *n* = size of sample, *p*=0.1 (proportion of population to be included in the sample i.e. 10%); *q*=1-*P* i.e. (0.9); e = 0.05 (5% standard error considered.), and *z* = 1.96 (as per table of area under normal curve for the given confidence level of 95%).

Eight governmental institutions were also selected purposively based on based on the presence of woody species in their compounds with exception of security related institution were investigated. In government institution, a total of 39 sample plots placed at most five sample plots of 10 × 10m (100m^2) at each corner and one at the center were used. Furthermore, no sample plots were used for homegarden rather complete measure of woody species was carried out (Motuma et al., 2008).

Therefore, all tree species in each sample plot/homegarden were recorded and diameters at breast height (DBH, 1.3m) were measured for all woody species ≥5cm except for coffee (MacDicken, 1997). The diameter of coffee shrubs was measured at 15cm aboveground (Segura et al, 2006). Only woody species with DBH ≥5cm were taken for determining above ground biomass (Sales, 2005; Motuma et al., 2008). The diameter of tree was measured following standard procedure provided by FAO (2012) using calipers and diameter tapes. In addition, at every sampling point, number of individuals per plot and the height was measured and recorded. Tree/woody species with height more than 2.5m was measured by using measuring suunto clinometer while woody species with height ≤2.5m was measured by graduated stick. Furthermore, the area of homegarden and GPS readings of each sampling plots/households homegardens were measured and recoded respectively.

2.2.2 Data analysis

2.2.2.1 Analysis of woody species composition

Woody species composition and structure were determined through quantitative analysis such as diversity indexes and important value index (IVI) respectively. Diversity index such as Shannon diversity index, evenness and Jaccard coefficient of similarity index were used to determine the species composition. Shannon diversity index (H') was used to determine species diversity using the following formula:

$$H' = \sum_{i=1}^{s} P_i \, lnP_i$$

Where H' is Shannon diversity index, p_i is proportion of individuals found in the i^{th} species and S = number of species in community.

Evenness (Shannon equitability) index (E) was calculated as:

$$E = \frac{H'}{lnS}$$

Jaccard coefficient of similarity index (JCS) was used to assess the similarity of plant species composition between homegarden and government institutions using the formula (Kent and Coker, 1992):

$$\text{JCS} = \frac{C}{A + B + C} \times 100$$

Where: C= the number of species in common (homegarden and government institutions compound), A= the number of unique species in homegarden, B= the number of unique species in government institution compound. The Jaccard coefficient of similarity index value was converted to percentage to show the percentage similarity between two systems.

The important value indexes (IVI), which is the sum of relative frequency (RF), relative density (RD), and relative dominance (RDO), were analyzed using the formula (Mueller-Dombois and Ellenberg, 1974; Martin, 1995) as:

IVI = RDO + RF + RD

Where RDO, RF and RD were computed as follows:

$$\text{Relative Dominance (RDO)} = \frac{\text{Dominance of a specie}}{\text{Total dominance of all species}} \times 100$$

$$\text{Dominance (D)of species} = \frac{\text{Total basal area}}{\text{Area sampled}} \text{ x } 100\%$$

$$BA = \frac{\pi (DBH)^2}{40000}$$

Where, BA = basal area (m^2); DBH is the diameter of trees at breast height (cm)

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \text{ x } 100\%$$

$$\text{Frequency of a species (F)} = \frac{\text{Number of plots with that species}}{\text{Total number of plots}} \times 100$$

$$R\text{elative density (RD)} = \frac{\text{Density of a species}}{\text{Total density of all species}} \text{ x}100\%$$

$$\text{Density (D)} = \frac{\text{Number of indivduals of that species}}{\text{Sample area (ha)}} \times 100$$

2.2.2.2 Estimation of carbon stock

The total carbon focused only on the live wood biomass carbon (above and below ground biomass of live woody species) because of continuous removal dead wood and leaf litter in homegarden agroforestry system. Therefore, sum of the above ground biomass (AGB) and belowground biomass (BGB) was taken as total tree biomass. The AGB carbon stocks were calculated for each tree and aggregated to calculate total AGB carbon stock in each homegarden and tree in governmental institutions. Assessments of AGB were done non-destructively using allometric biomass regression equations. Due to the lack of a standard approach and available allometric equations to estimate AGB for homegarden agroforestry systems in Ethiopia, allometric equations developed by Steffan-Dewenter et al (2007) for Tropical Agroforestry was used as:

$$lnY = -3.375 + 0.948 \times \ln(D^2 \times H)$$

Where; Y=aboveground total biomass per tree (kg), D=DBH (cm) and H=Height (m).

BGB was determined by multiplying AGB by root to shoot ratio of 0.26 (Hangarge et al., 2012; Suryawanshi et al., 2014, Patil, et al., 2016). This is because determining below ground biomass is difficult, expensive and laborious (Brown, 1997) and uncommon in the literature. Therefore, BGB was estimate as:

$$BGB = 0.26 \times AGB$$

Total biomass of a tree was the sum of the above and below ground biomass (Sheikh et al., 2011) as:

$$Total\ biomass = AGB + BGB$$

For comparisons on unit area basis, total biomasses were extrapolated to hectare size. Finally, as carbon stock of woody species was calculated based on the association that carbon stock any plant species is 50% of its biomass (Brown 1997; Pearson et al., 2005). Therefore, biomass carbon stock of a woody species (DBH≥5cm) was calculated for each woody species and aggregated to calculate total biomass carbon stock for each homegarden and government institutions compound:

$$\text{Total biomass carbon}_{tree} = \text{Total biomass x } 50\%$$

The total amount of CO_2 sequestered (CO_2 equivalent (CO_{2e})) by the tree was calculated by multiplying the amount of carbon in the biomass by 3.67 (which is the ratio of the atomic mass of CO_2 (44.01) to the atomic mass of carbon (12) (Kauffman and Donato, 2012).

$$CO_{2e} = TCS \times 3.67$$

Statistical analysis

SPSS (Statistical package for social science, version 20.0) and PAST (PAleontological STatistics Version 3.23) software were used to summarizes and analyze data. Descriptive statistics such as total, mean and standard deviation were used to summarize total biomass and carbon stock. Two (independent) sample *t*-tests was use to show the differences in biodiversity and total carbon stock between the homegardens and in government institutions while one-way ANOVA was used to test the difference in biodiversity and total carbon stock between homegardens in three *kebeles*. A significant difference in mean values for carbon stock was tested by least significance difference at $p < 0.05$.

3. Result and Discussion

3.1 Floristic composition and structure

3.1.1 Floristic composition

A total of 40 woody species belonging to 24 families were recorded from homegarden and government institution compound. From the total species recorded, 36 species belongs 23 families and 22 species belongs to 13 families were recorded from homegarden and governmental institution respectively (Table 1).

Table 1. Woody species in homegarden and government institutions and their origin

Scientific name	Family Name	Presence/absence		Origin
		Gov. inst.	HG	
Acacia bussei	Fabaceae	+	+	N
Albizia gummifera	Fabaceae	+	+	N
Annona senegalensis	Annonaceae	+	+	N
Annona squamosa	Annonaceae	+	+	E
Casuarina equisetifolia	Casuarinaceae	+	+	E
Coffee arabica	Rubiaceae	+	+	N
Cordia Africana	Boraginaceae	+	+	N
Croton macrostachyus	Euphorbiaceae	+	+	N
Dracaena steudneri	Dracaenaceae	+	+	N
Erythrina abyssinica	Fabaceae	+	+	N
Eucalyptus camaldulensis	Myrtaceae	+	+	E
Euphorbia abyssinica	Euphorbiaceae	+	+	N
Grevillea robusta	Proteaceae	+	+	E
Juniperus procera	Cupressaceae	+	+	E
Mangifera indica	Anacardiaceae	+	+	E
Melia azedarach	Meliaceae	+	+	E
Persea americana	Lauraceae	+	+	E
Psidium guajava	Myrtaceae	+	+	N
Sesbania sesban	Fabaceae	+	+	N
Albizia schimperiana	Ebenaceae	−	+	N
Bridelia micrantha	Euphorbiaceae	−	+	N
Callistemon citrinus(Curt) Skeels	Myrtaceae	−	+	N
Casimiroa edulis	Rutaceae	−	+	E
Catha edulis	Celastraceae	−	+	N
Citrus sinensis	Rutaceae	−	+	E
Combretum aculeatum	Combretaceae	−	+	N
Dovyalis abyssinica	Flacourtiaceae	−	+	N
Ekebergia capensis	Meliaceae	−	+	N
Millettia ferruginea	Fabaceae	−	+	E
Moringa oleifera	Moringaceae	−	+	E
Olea europaea subsp.	Oleaceae	−	+	N
Prunus africana	Rosaceae	−	+	N
Sapium ellipticum	Euphorbiaceae	−	+	N
Schinus molle	Anacardiaceae	−	+	?
Spathodea campanulata	Bignoniaceae	−	+	N
Vernonia amygdalina	Asteraceae	−	+	N
Vernonia mycrocephala	Asteraceae	−	−	N
Acacia tortilis	Fabaceae	+	−	N
Pithecellobium duice	Fabaceae	+	−	E
Ficus vasta Forssk	*Moraceae*	+	−	N

Note: HG= homegarden, Gov inst. = governmental institution+ =presence,−= absence, N= native, E=exotic

About 62.5 % (25) species native including endemic (e.g. *Millettia ferruginea*) was recorded in homegarden indicating homegardens including urban area are important refuges for biodiversity reserves. Eight families (Figure 2) such as *Fabaceae, Euphorbiaceae, Myrtaceae, Rutaceae, Anacardiaceae, Annonaceae, Asteraceae and Meliaceae* consist of two and above species. The family *Fabaceae* (14.3 % or 5 species) and *Euphorbiaceae* (11.43% or 4 species) are the families with highest species in homegarden and while *Fabaceae* was the highest (28.6 % or 6 species) in governmental institution. The result revealed that the numbers of species recorded in homegardens were higher than reported by Mengistu and Asfaw (2015), which was 15 in Dallo Mena District, South-East Ethiopia.

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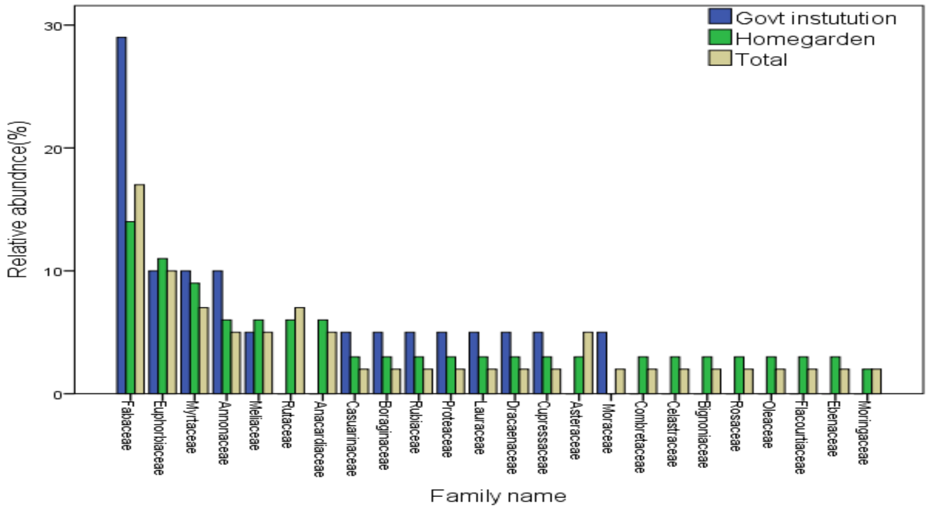

Figure 2. Relative abundances of families in homegarden and governmental institution

3.1.2 Species diversity, richness and equitability

The overall diversity index (species richness, H' and E) of the entire homegarden and governmental institution (Table 2) revealed homegardens were higher (H'=2.34) in species diversity than governmental institutions compound (H'=2.17). At individual homegarden and/or plot level, homegardens were highly significantly richer (p<0.001) and diverse than government institution compound. However, density of woody species (individual/ha) was very highly significantly higher (p<0.001) in governmental institution than in homegarden. Based on Cavalcanti and Larrazábal (2004), the diversity index (H') showed medium diversity and low diversity at site and plot level as it was between 2.0 and 3.0(medium) and between 1.0 and 2.0(low) respectively. The evenness index (E) also revealed that the distribution of species within homegardens were low which indicated there is the dominance of one or few species in the community. Jaccard coefficient of similarity index (JCS) 47.5%, which indicate there was low (below average) similarity in composition of woody species between homegarden and government institution compound.

Table 2. Diversity indices for species from homegarden and government institution

Diversity indices		Homegarden	Govt. inst.	Test statistics	
		Mean±Std. Dev.	Mean±Std. Dev.	t-test	p-value
Species richness	system level	36	22		
	Plot level	7.43±2.10	4.71±1.27	7.05	0.0001***
Shannon	Site level	2.34	2.17		
diversity(H')	Plot level	1.54±0.32	1.14±0.29	5.24	0.0001***
Evenness(E)	Site level	0.38	0.57		
	Plot level	0.45±0.12	0.41±0.098	1.94	0.0573^{ns}
Density	Plot level	353.41±223.69	1287±617.35	-12.014	0.0001***
JCS index		47.5%			

Note: *** very highly significant at p<0.001, ^{ns}=non-significant.

However, all diversity indices and density (individual per ha) were not significant different (p>0.05) among homegarden in all *kebeles* (Figure 3). This might be due to more or less similar landholding size, similar farming system and socioeconomic dependence on plant species.

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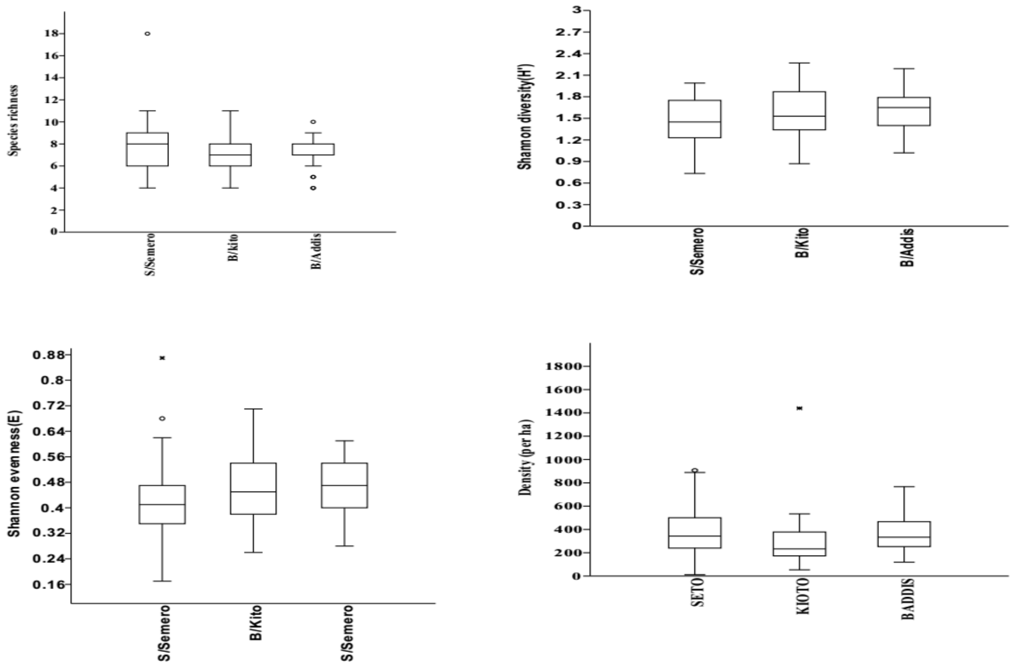

Figure 3. Boxplot comparison of diversity indices and density species in homegarden of three kebeles

3.1.3 Vegetation structure analysis

Relative frequency, relative density, relative dominance and importance value index (IVI) are important parameters commonly used to investigate the structure of vegetation. In homegarden (Table 2), *Ekebergia capensis (*12.53%), *Persea Americana* (8.14%), Mangifera *indica* (7.69%), *Croton macrostach'yus* (6.47%) and *Grevillea robusta* (5.88%) made the largest contribution to the basal area and represent the most ecologically important woody species in homegarden. The result also revealed that *Coffee arebica*(11.71%), *Mangifera indica* (11.55%), *Persea Americana* (9.27%), *Juniperus procera*(7%), *Grevillea robusta* (6.83%), *Psidium guajava*(6.67%) and *Cordia Africana(*6.5%) scored the highest relative frequency, that reflects their pattern of distribution and an approximate indication of the heterogeneity of a stand (Zegeye et al. 2005; Melese and Ayele, 2016). Similarly, *Coffee arebica* (42.17%), *Mangifera indica (*22.34%), *Persea Americana* (17.71%), *Citrus sinensis* (15.55%), *Grevillea robusta (*15.12%), *Ekebergia capensis (*14.77%), *Juniperus procera* (13.88%), *Croton macrostachyus (*12.76%), *Cordia Africana* (12.75%), *Psidium guajava* (10.17%) and *Dracaena steudner*(10.1%) contributed a total of 62.18% of the total IVIs, indicating that they are the most ecologically important woody species in homegarden system. Furthermore, these trees might have a multipurpose role both in terms of ecological and economic values for the local communities. Similar trends were observed by Mengistu1 and Alemayehu(2017) in Bahir Dar City, Ethiopia where fruit woody species such as *Mangifera indica*(20.3%), *Psidium guajava*(134.%) *and Persea Americana*(11.6%) were the most abundant perennial plant species. On other hand, non-fruit woody species such as *Juniperus procera, Eucalyptus camaldulensis, Erythrina abyssinica*

Croton macrostachyus and *Grevillea robusta* all together accounted for about 63.03% of IVI value in governmental institutions. The difference in species based IVI between homegarden and government institution could be the difference in socioeconomic and ecological significance of the species for household and the government institution.

Table 3. Species with highest IVI in homegarden and government institution compound

Species in homegarden	IVI	Species in government institution compound	IVI
Coffee arebica	42.17	*Juniperus procera*	35.69
Mangifera indica L	22.34	*Eucalyptus camaldulensis*	27.489
Persea americana	17.71	*Erythrina abyssinica*	23.704
Citrus sinensis	15.55	*Croton macrostachyus*	22.934
Grevillea robusta	15.12	*Grevillea robusta*	20.934
Ekebergia capensis	14.77	*Ficus vasta Forssk*	20.09
Juniperus procera	13.88	*Melia azedarach*	19.312
Croton macrostachyus	12.76	*Cordia Africana*	18.89
Cordia Africana	12.75	*Persea americana*	17.973
Psidium guajava	10.17	*Psidium guajava*	13.754
Dracaena steudner	10.05	*Sesbania sesban*	12.373
Percent	62.18%	*Percent*	77.73%

3.2 Estimated carbon storage

Biomass density indicates the potential amount of CO_2 that can be released to the atmosphere when vegetation is burned or cleared. The total amount carbon stored due to the presence of wood biomass was estimated to 87.08Mg (2,877.13Mgha^{-1}) of which homegarden agroforestry contributed about 64.35Mg (884.18Mgha^{-1}) and 22.73Mg (1,992.95Mg/ha) of biomass carbon from government institution. Thus, a total of about 319.57Mg of CO_2 equivalents were estimated to sequestered from both homegarden and government institution. From this homegarden agroforestry sequestered about 236.145Mg (73.89%) of CO_2 equivalent from atmosphere.

On area basis, the result revealed that total biomass carbon ranges from 0.34 Mgha^{-1} to 22.39 Mgha^{-1} with mean value of 22.48Mgha^{-1} was stored in woody biomass of both institutions. The result revealed that that carbon stored in governmental institution (62.28 Mgha^{-1}) was significantly higher (p <0.001) than that of homegarden (9.21 Mgha^{-1}) (Figure 4).

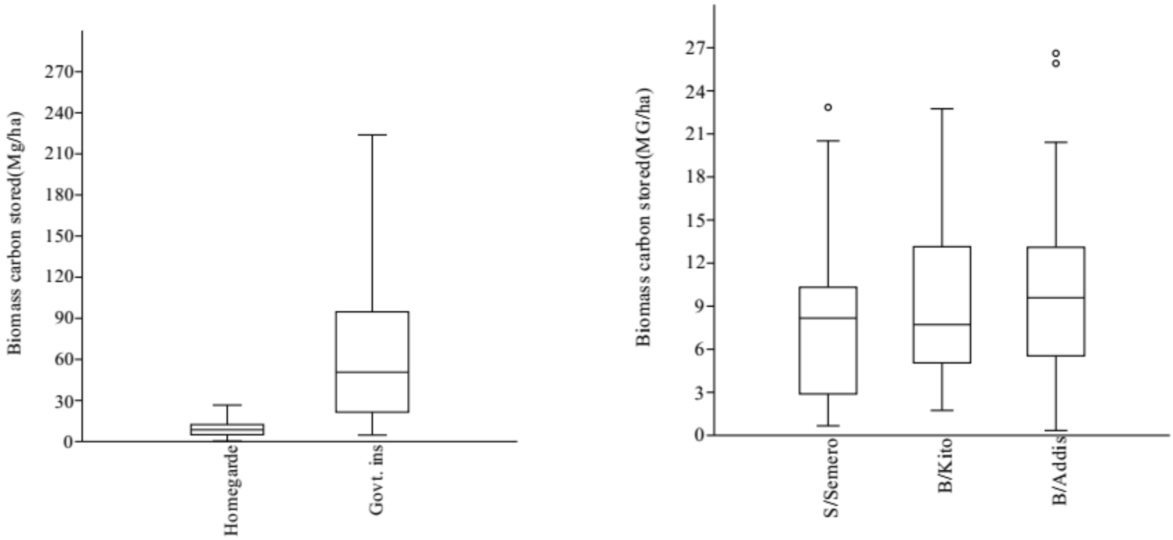

Figure 4. Boxplot comparison of carbon stored in homegarden and government institution compound (left) and across homegarden in three kebeles (right).

The reason for higher amount of carbon storage in governmental institutions could be due to the differences in composition of tree, density and type of management practices. As it was reported depicted in Table 2 and Table 4, there was highly significant difference in density between two system and strong correlation between density and amount of carbon stored(r=0.59**). As the result revealed species with lower basal area (DBH) such as *Coffee arebica* and other woody species were dominant in homegarden (Table 2) whereas large tree like *Juniperus procera, Eucalyptus camaldulensis, Erythrina abyssinica, etc.* large basal area are found in government institutions contribute much carbon storage. Different scholars also revealed that species composition (Montagnini and Nair, 2004; Henry et al., 2009) and woody species volume (Perez and Kanninen, 2003; Henry et al., 2009; Guiabao, 2016: Seta and Demissew, 2017) have direct impact on above ground biomass produced and in turn on total carbon stored in woody species. Besides, woody species in governmental institutional compounds are woodlot type distribution with higher density than homegarden. Henry et al (2009) and Bajigo et al. (2015) confirmed this that woodlots stored higher amount of carbon than homegarden agroforestry because of high basal and stand density.

Besides, the total biomass carbon of the study homegarden was higher than that reported by Waktole(2019) in homegarden (5.54Mg/ha) and pastureland (3.47 Mg/ha) of Sokoru District, Jimma Zone. Moreover, it was also higher than that reported in Gununo Watershed, Wolayitta Zone, Ethiopia (8.29 MgCha^{-1}) (Bajigo et al., 2015**).** The overall above ground carbon (AGC) stored in study homegarden (17.84Mgha^{-1}) was higher than that stored in homegardens in a dry zone area of Moneragala district, Sri Lanka, which was 12.7 Mg C ha^{-1} (Mattsson et al., 2015) and reported by Roshetko et al. (2002) in Indonesia which ranges from 55.8 to 162.7 Mg C ha^{-1}. But the amount of biomass carbon stock from government institutions (124.56Mg/ha) were less than but comparable to that reported by Tsegaye(2015) from Urban Public Parks in in Addis Ababa which was reported as 142.498Mg/ha and by Yilma (2016) from church forests in Addis Ababa, which was 147.5Mg/ha.

Table 4. Correlation between biodiversity index and biomass carbon stock

	Density	Carbon (Mgha^{-1})	Spp. richness	H'	E
Density	1	**0.588****	**-0.294****	**-0.281****	0.04
Carbon (Mgha^{-1})		1	-0.143	-0.151	0.028
Spp. richness			1	**0.481****	**0.306****
H'				1	**0.487****
E					1

**. Correlation is significant at the 0.01 level.

The major reason difference in amount of carbon in study area and other area could be attributed to variation in composition and structure tree and woody species, type of tree management practices. Households in all *kebeles* mostly pruned and cut trees at some height above ground to reduce the risks associated with falling of tree on their house due to wind, commands from Ethiopian electric power corporation to reduce electric contact and to control the effect of ape disturbance around the home. Such management practices have direct effect on total biomass produced (Mattsson et al., 2015) and carbon stored as it reduce the amount of biomass above cut directly. In addition, high variability in carbon estimate report could be difference in climatic conditions of research area (Mattsson et al., 2015)and variation in ages of agroforestry (Yilma, 2016) and variation in methodologies used to estimate carbon in woody biomass(Atangana et al., 2014).

The result showed no significant difference in carbon stored (Bossa-Addis =10.73±12.21, Bossa-kittoo = 12.59±18.83 and Seto-Smero =10.69± 7.12) between three study *kebeles* both at kebele level (F= 2.2, p= 0.12) and homegarden level (F=0.23, p= 0.82). This could be due to similar or non-significant in species composition or diversity, density and tree management practices in all *kebeles*. According to Mattsson et al. (2015), carbon estimates are reflection of the differences in tree density, tree diversity and management practices between individual homegardens.

Among woody species (37) inventoried for carbon estimation (DBH≥5cm) 13 species (Figure 5) together accounted for about 96.23% of total carbon produced. Among these, *Juniperus procera* (22%), *Eucalyptus spp.* (14%), *Cordia africana (*12.3%) *and Persea americana* (11.2%) are the major contributors. This is contrast to the results reported by Seta and Demissew (2017) where *Albizia* trees contributed 33% of above ground carbon (AGC) stock while *Cordia africana* contributed about 37% of the standing AGC stock in rural agroforestry in Wenago District, Ethiopia where such species are retained as shed tree for coffee. But in this study *Albiza* specie (both *Albizia gummifera* and *Albizia schimperiana*) accounted for only 0.55% of carbon stored in homegarden system.

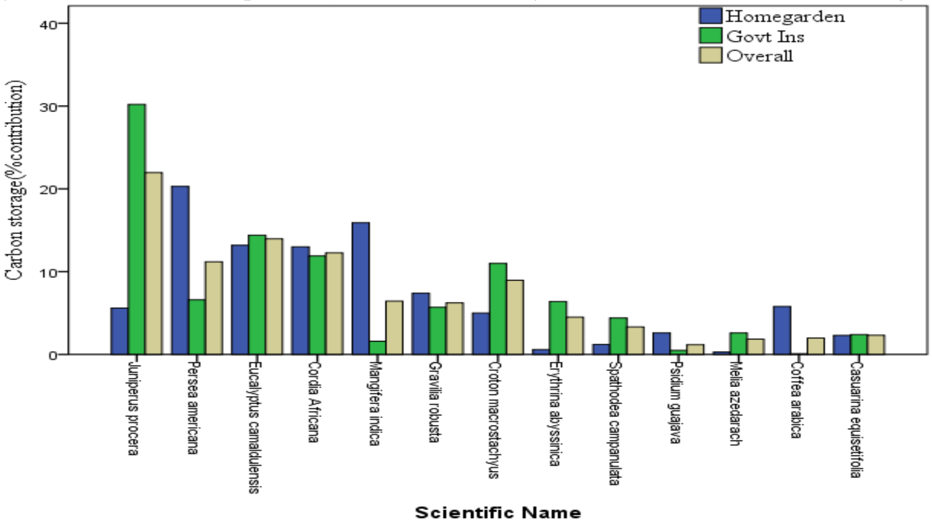

Figure 5. Species contribution in total biomass produced in homegarden and government institution compound

The difference may due to variance in preference to tree related livelihood strategies such as dependence on coffee based income and tree management system in rural area could be different from urban. Denu et al.(2016) reported that farmers preferred to some species such as *Albizia gummifera* related to their flat canopy cover and the perceived quality of coffee yield beneath, were in line with the abundance of tree species in the coffee plots. But in homegarden agroforestry, the highest (62.4%) total biomass was produced by fruits tree such as *Persea Americana* (20.26%), *Mangifera indica* (15.94%), *Eucalyptus spp.* (13.16%), *Cordia Africana* (13%), and *Gravilia robusta* (7.38%). Of these fruits such as *Persea Americana* and *Mangifera indica* accounted for about 36% of total biomass produced in homegarden. This indicated that fruit trees sequester huge amount carbon because of their dominance in homegarden agroforestry in urban area.

The total AGB carbon in three kebeles were higher than those reported in other area, for instance Kumar

(2011) reported that aboveground standing stocks of C ranged from 16 to 36 Mg ha^{-1} in tropical home-gardens of Central Kerala, India whereas Mattsson et al. (2015) reported above-ground biomass carbon stock of 13 Mg ha^{-1} in Sri Lanka. The study also indicated that the amount of stored(ranges from 0.34$Mgha^{-1}$ to 26.61$Mgha^{-1}$) is higher than that reported by Nair et al. (2010),which indicated the available estimates of carbon stored in agroforestry range from 0.3 to 15 Mg C ha^{-1} in above ground. But the result showed lesser amount of carbon than reported in homegardens in Indonesia, which stored much higher to 55.8 to 162.7 Mg C ha^{-1} (Roshetko et al., 2002). However, majority of studies in homegarden estimated carbon stored in the soil which are important storage of carbon. Despite of these, the result indicated that homegarden of Jimma City contributed important contribution to CO_2 mitigation through storage of carbon in their ABG and BGB.

4. Conclusion and Recommendation

Homegarden and government institutions in Jimma City are found to be an important refuge for native and endemic species of woody biodiversity and provide huge contribution for climate change mitigation through sequestration of CO_2. Homegarden maintaining a quite a very good number of native plants spices that are deteriorating or facing a risk of disappearance in the natural habitat. However, few exotic (both fruit and tree) species are the dominant and substitute native species in homegardens and government institution compound have adversely affects plant diversity in Jimma City. Despite of these, all woody species in both systems are important in sequestering huge carbon dioxides.

In conclusion, urban homegardens in Jimma city have unleashed potential and a good future prospect for biodiversity conservation and climate change mitigation. To successfully realize the potential of urban vegetation in general and homegarden in specific requires awareness to decision makers and public and support to homegarden owners in terms of technical knowhow and access to and choice of appropriate planting species is desired. Besides, enriching with species socio-economically and environmentally multipurpose functions is important. Furthermore, urban land use/ development plan need to give much consider to native species as possible to maintain so as to create biodiversity-friendly gardens

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