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Research Article

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Assessing Woody Species Diversity And Management Activities Used In Parkland Agroforestry Practices At Kalu District, South Wollo, Ethiopia

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Abstract

Parkland agroforestry is the types of multipurpose trees agroforestry system characterized by well-grown scattered trees on cultivated and recently fallowed fields. It is the most dominant agroforestry practice in the semi-arid and sub-humid zones of Ethiopia. This study was conducted at Kalu district, South Wollo, Ethiopia to assess the ecological significance of parkland agroforestry practices and how do farmers manage the parkland trees and the factors that influence farmers' management techniques. Multistage sampling method was adopted by selecting sample kebeles from lowland and midland parkland agroforestry. Woody species inventory was conducted on 60 plots having each 50 m x100 m on cultivated land along 6 transects. All woody species found in the plots following transect line having stem diameter ≥ 5 cm and height of >2 m above ground were taken. Semi-structured questionnaire and group discussion were employed for gathering qualitative data. The data collected through the questionnaire interviews, species richness and structures were analyzed using Statistical package for Social Science (SPSS 20) software and Microsoft excel version 2010 at 5% level of significance. Woody species frequency, abundance, basal area, height and diameter class distribution were computed to characterize woody species structure. A total of 21 indigenous woody species were collected from the two agro-ecologies of parkland agroforestry. The collected species belonging to eight families, and Fabaceae were the dominant families. Shannon and Simpson indices of woody species diversity, evenness of lowland was higher than midland agro-ecologies. Zizipus spina-christi and Acasia seyal were dominant tree species in both agro-ecologies. Woody species retained within farmer's cultivated land for different purposes. Looping, pollarding, pruning, protection and coppicing were common management practices. Among socioeconomic variables only sex, land holding size and access to extension service were influence woody species management. Woody species diversity was relatively low at Kalu district. Land shortage, drought, free grazing, absence of planting activity and high charcoal demands were the most challenging problems for the sustainability of parklands at the district. Governmental decision-makers and other stakeholders typically face with regard to Parkland trees conservation and agricultural intensification and development objectives.

Keywords: Parkland Agroforestry, Woody Species, Tree Management, Diversity, South Wollo

1. Introduction

Agroforestry is a collective name for land-use systems and technologies, where woody perennials are deliberately retained on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence [1]. Specifically agroforestry can defined as a dynamic ecologically based natural resources management system that through integration of trees on farms and in the agricultural landscape, increase and sustains production for enhance social, economic and environmental benefits for farmers at all levels [2].

Agroforestry systems range from subsistence livestock silvo-pastoral systems to home gardens, on-farm timber production, and tree integrated with crops (multipurpose trees) within a wide diversity of biophysical conditions and socio-ecological characteristics [3]. Agroforestry system consists of more than one agroforestry practices that practiced extensively in a given locality or area by considering biological, ecological and economic interactions among the components. Whereas, an agroforestry practice indicates specific land management actions on a farm units in spatial and temporal arrangement [4]. Agroforestry practices address issues of soil fertility, soil erosion and diversification of products and create favorable microclimates as resilience to climate variability [5].

Parkland agroforestry is the types of multipurpose tree agroforestry practices characterized by well-grown scattered trees on cultivated and recently fallowed land and develop when crop cultivation on a piece of land becomes more permanent. Numerous valuable native plant species reserved within the crop fields and form remarkable parts of the farm land and found all over the world [6]. The trees scattered far apart so that they do not compete with crops [2].

A range of ecosystem services and benefits delivered from parkland agroforestry practices. Parkland agroforestry contributes to biodiversity conservation through providing additional habitats for native tree with minimal disturbances. Parkland trees used to satisfy household needs such as cooking, household utensils, farming tools and traditional medicine [7]. Parklands minimize work load of women and children by creating labor division to harvest fuel wood as socioeconomic development, and they are important to save woodlands from degradation [8]. Trees found in parklands serve for food security in Africa; moreover integration of trees and agriculture is a global issue on climate change adaptation and mitigation to increase resilience and sustainability [9]. Parkland agroforestry are common practices in Ethiopia and cover a large part of the agricultural landscapes [10]. Trees in parklands have great role for stabilizing the pressure on the local forest areas by providing multiple products and fodder demands to livestock [11].

While agroforestry parklands relevant for traditional land use system, however, know a day's their sustainability is under a serious threat of degradation because of rapid change to crop lands and fallow lands become short for when increasing continuous tillage and lead to inadequate or lack of tree regeneration. Demand for arable land and unsustainable cropping practices induced degradation of the soil and tree components of agroforestry parklands in the semi-arid areas of Africa [12]. In Ethiopia trees and shrubs are disappearing fast in agricultural landscapes particularly in northeastern Ethiopia [13]. Protection of trees and replanting are not encouraged due to population pressure, the farmer's own perceptions, attitudes, management problem, and small farm size. South Wollo also is facing land degradation problems particularly soil erosion, runoff and decline soil structure due to clearance of vegetation from forest and parklands, uncontrolled and heavy grazing [14]. Parklands in Kalu district degraded due to charcoal selling, small farm size, free grazing and related factors.

Appropriate intervention needed to reduce degradation of parklands and to improve different products with species selection. Farmers' involvement in tree/shrub management practices primarily to satisfy these different needs and benefits. The sustainable management of parklands is increasing importance, and should begin with a thorough knowledge of parkland growth rates and production levels, including wood, fruit and foliage, as well as factors affecting them [12].

Proper management practices can be effective by assessing the various diversity indices of the existing woody plants, i.e., their abundance, density, frequency and species richness. Characterizing diversity of trees and shrubs, understanding of existing indigenous knowledge available for tree management including show factors that influence these management activities are very relevant for sustainability and development of parkland agroforestry to offer various ecosystem services. As a result this work would be relevant for Climate Smart Agriculture by providing information on the richness and structural status of woody species in addition to local knowledge used for appropriate conservation and management measures in parkland agroforestry of Kalu district, South Wollo, Ethiopia.

1.1. Statement of the Problem

Agroforestry parklands has shown that they are a rational land uses system developed by farmers to diversify production for subsistence and for income generation, as well as to minimize environmental risks related to the high climatic variability in the region [15]. It is the most dominant agroforestry practice in the semi-arid and sub-humid zones of Ethiopia [16]. Selective preservation of these valuable trees thought to have decreased the overall number of trees in parklands in recent years [17]. Agroforestry parklands are also degraded in fast rate due to increase population density , farmers shifting for woody production provides fuelwood and other tree products [18]. At Kalu, parkland tree species were subject to degradation due to high demand of fuelwood production and free grazing in most parts of the district. The common parkland trees are available for fuelwood demands and local farmers use these trees for charcoal production since other areas like forest and communal lands forbidden to local use. In addition, plantations activities in cultivated lands were very low.

Parkland agroforestry degradation leads reduces both richness and abundance of useful trees and shrubs leaving in farmlands of the rural poor [19]. On the other hand, farmers need alternative agricultural practice like monocrops, priority low cost and higher subsistence than parkland trees. In general different qualitative and quantitative data indicated that there is rapid degradation and decline of agroforestry parklands in terms of density, composition and regeneration status [8,12,15].

There for, conservation of woody plant diversity within agricultural landscapes is critical for farmer's livelihoods and ecosystem services in areas that loss the woody plants especially in high forest degraded areas. For this reason, accurate information on diversity analysis, existed indigenous knowledge on management activities found in the locality and different socioeconomic challenges affect sustainable management and development of agroforestry parklands are highly required at large-scale. Assessing woody species diversity and management practices applied by local farmers which are relevant for conservation and in further improving their management strategy to increase the benefits they provide to species in relation to rural communities is very important. The purpose of the study was to asses woody species diversity, structure, benefits and management practices applied in parkland agroforestry of Kalu district, South Wollo Ethiopia.

1.2. Research Objective

1.2.1. General objective

The overall objective of this study was to assess and document the ecological significance of parkland agroforestry practices and how do farmers manage the parkland trees spatially and temporally using their own indigenous knowledge existed in the locality and the factors that influence farmers' management techniques at Kalu district, South Wollo, Ethiopia.

1.2.2. Specific objectives

➢ To determine the woody species composition and diversity in parkland agroforestry practice at Kalu district.
➢ To evaluate management activities applied by farmers to trees found in parkland agroforestry practices at Kalu district
➢ To assess socioeconomic factors affecting parkland agroforestry practice and parkland tree management types in the study area.

1.3. Research Questions

1. What is parkland agroforestry species composition and structure in Kalu district?
2. How much diverse and evenly distributed are woody species in parkland agroforestry practices of Kalu district?
3. How local farmers do manage the woody species in the parkland agroforestry practice of this locality?
4. What are the socioeconomic factors that influence management of woody species in parkland agroforestry practices in Kalu district?

1.4. Significance of the Study

Natural forest could disappear in few years due to degradation in alarming rate if appropriate or alternative measure and solutions are not taken [20]. In this case agroforestry parklands are vital to reduce the pressure on natural forest by supplying possible products on farmer's farmland particularly in subsistence farming systems. As a result knowing diversity, composition and structure of trees including management strategies of trees with right integration of crop components is one part of as agroforestry practice for biodiversity conservation and delivering ecosystem services as farmers' livelihoods.

There for, the present study would be relevance as benchmark or supplementary information on woody species diversity and management activities used by local farmers in parkland agroforestry practices and it would be used as a reference material for similar and related studies concerning on parkland agroforestry at Kalu district. It would relate to Climate Resilient Green Economy policy of the country which may used to strengthen ecological role of parkland agroforestry practices for building green economy in different parts of Ethiopia.

Specifically, the result of the study would be expected to have the following contributions:
♥ It would be provided an insight towards structure and composition of trees and shrubs in parkland agroforestry at Kalu district and can give the right picture for the concerned bodies and local dwellers to have justifiable action on the system.
♥ It would be significant to assess and find the role of parkland agroforestry at Kalu district.
♥ It would be generated first hand information to understand parkland agroforestry management techniques applied by local farmers.
♥ It would be enabled as to know factors influence woody species management activities in parkland agroforestry of Kalu district.
♥ Recommendations are provided for to sustainability of parkland agroforestry practices in the district.

1.5. Scope and Limitation of the Research

The study was conduct purposely at Kalu district specifically by considering woody species in parkland agroforestry which are available in cultivated lands, but not fallow lands, depend on agro-ecology due to time and finance constraints. Woody species diversity relation to biophysical factors was not including in this study. For instance, effects of each individual tree species on soil fertility and crop production on underneath parkland trees were not examined.

1.6. Ethical Consideration

In this study, ethical issues were taken into consideration from the level of planning to report. Before the actual research conduction starts the legal permission was secured from the concerned body of Kebele administration. A researcher showed the purpose of the study has that described to the participants.

During data collection, the consent of respondents was respected and not enforced to participate. It showed a research problems were benefited participants and respected norms and charters of indigenous societies. The study sites were disrupted as little as possible especially at data collection. The respondents were informed that the information they offers confidential and serves only for the purpose of the research. The data were collected based on the willingness of the respondents and honest with respected to acknowledging the contribution of participants, colleagues and collaborators [21]. At a presentation of research, all cited works were listed in the reference part of the thesis avoided disclosing information of identities of participants [22].

2. Literature Review

2.1. Agroforestry System and Practices

The concept of agroforestry puts woody perennials, including trees and shrubs as pillars for the practice and indicates specific land management actions on a farm and other management units in the spatial and temporal arrangement [4]. Agroforestry is the incorporation of trees in the farmland and rangeland, diversified and production for the social, economical and environmental benefits in sustainable conditions [10]. Integrating trees in the farming system are the ancient practices in the world for different goals. This is commonly known as the agroforestry system resulting the sustainable land-use system and resilient agriculture in producing food and the nutritional security for livelihoods of farmers in rural [23].

An agroforestry system is a specific local example of a practice, characterized by environment, tree species and their arrangement, the management, and a socioeconomic functioning [24]. In agroforestry systems there are three basic components that are managed by the land user, namely, the woody perennial, agricultural crops including pasture species, and the animal. In order for a land-use system designated as an agroforestry system, it must always have a woody perennial. Woody tree species are important component interactions as tree-crop interaction and tree-animal interaction in all agroforestry systems [20].

According to ICRAF agroforestry classification, agroforestry system can classify into four based on the nature of composition; agrisilviculture, silvopasture, agrosilvopasture and multipurpose trees system. Agrisilviculture refers to integrating of agricultural crops with perennial tree/shrub species, silvopasture is growing of animal forage with woody species, agrosilvopasture refers to the combination of the three components (animal, agricultural crop and trees) and multipurpose trees system refers to the management of trees to yield different products and services important for farmers' livelihoods and welfare.

Multipurpose tree agroforestry system consisted numerous practices like parkland agroforestry depend on spatial and temporal arrangements of components for household objectives. Agroforestry practices provide ecosystem services like provisioning , regulating, supportive and cultural services when it practices in large scale. Growing agricultural crops under scattered trees on farmlands under smallholder farming conditions which is including in multipurpose tree is common agroforestry practices. Trees found on farmland does not have any specific pattern [25]. This gives the fields a characteristic dotted look, in a unique mosaic way, with trees and vegetation in various locations.

2.2. Parkland Agroforestry practices

"Parkland agroforestry" defined as deliberate association of well-grown multipurpose trees scattered across cultivated or recently fallowed fields as a result of farmer choice and protection. Trees in parkland agroforestry characterized by well known scattered and deliberately retained in a piece of cultivated lands to reduce competition to crops; this system is also known as scattered tree.

Parkland agroforestry should relate to domestication, seek to improve the quality and growth rate of tree products, pest resistance, potential adaptability and companionship with crops. There are three categories of parkland agroforestry to explain the current condition of woody species diversity in parkland: Species selected and protected by farmers (species able to grow and become mature tress);species not selected nor particularly protected but retained in farmer's field (species regenerate from remaining root stock left after the field clearing);species planted by farmers because of their valuable products (commonly exotic and fruit tree species) [6].

2.3. Woody Species biodiversity and Composition in Parkland Agroforestry

Woody plants have aerial stem, which persists for more than one season and in most cases a cambium layer for periodic growth in diameter. Trees and shrubs are including in this category. Trees considered to woody plants that grows from single main trunk and don't branched at or near the base of the plant [26]. Shrubs are self-supporting woody plants that have several stems at or near the base of the plant. Biodiversity refers to variety of organisms within a particular area and include species, ecosystem and genetic diversity. The focus area in this study was species diversity in parkland agroforestry. Species diversity is the number of different species and the number of individual species within any one community. Whereas species richness is the number of different species present in an area.

Diversity in woody species provides information about community composition than species richness and takes consideration of relative abundances of different woody species into account. Agroforestry rich in diversity in structure and composition influenced by climate, elevation, soil moisture, farm size and crop pattern in addition to management prescription [27]. The more species present in a sample the richer the area. The rich diversity makes species ecologically resilient and thus gives them the ability to provide more and better ecological functions [28].

2.3.1. Woody species density in parklands

Goods and services are offered from agroforestry parklands beyond improve resilience to food security and climate mitigation, particularly depend on density and types of woody species present in smallholder farm. Maximum tree densities are determined by on the whole nutrient pool of the system but trees redistribute or increase nutrients availability by understanding way of integrating in crop system. As increasing tree density in parklands, especially sites of the lowest productivity, it can be expected low herb productivity because the tree density has negative effect on herbaceous plant biomass production. On the other hand herbaceous productivity is high with low tree densities, in this case farmers reduce the number of trees to favor other species (crop), and decrease with increasing density.

2.4. Role of Woody Species in Parkland Agroforestry

In recently, farmers are integrating trees either deliberately retained or planted within annual crops become modern way of increasing production capacity in a single land in order to have multiple benefits from different tree species on their farmlands. Like natural forests, agroforestry parklands provide a variety of subsistence uses and market activities, as well as significant environmental services and sociocultural and spiritual values. The system improves diversified income by introducing trees in all dimensions while intensifying agricultural practice. It shows social stability and ecosystem sustainability if it is correctly designed and implemented.

2.4.1. Production roles of woody species in parkland agroforestry

Productive roles of parkland agroforestry systems are mainly refers to provisioning services like food, fodder, manure, fuel wood and farm tools which are mainly required to meet basic needs of the communities. In developing countries 80 percent of wood production used for fuel wood production as sources of energy. Smallholder farmers have maintained for a variety of tree species in the agricultural landscape to provide food, cash income, medicine, fodder, bee forage, fuel wood, timber and others. Parkland are source of foods for seasonal nutritional balance in smallholder farmers and used as forage for animals. Beyond traditional medicine and food security, parklands have national significance in international market as export earnings particularly *Acacia Senegal* (gum arebica) and *Vetellaria paradoxa* (kernels) in Sahelian countries. *Acacia Senegal* and *Acacia seyal* are important sources of gum in Sahel, West Africa.

2.4.2. Protective and regulating roles of woody species in parkland agroforestry

Parkland agroforestry practices contribute to the conservation of plant genetic resources and remnant species and preventing habitats on surrounding natural forest. Trees as part of the farming system play the role of maintaining and restoring the physical environment needed to sustain agricultural production through restoration of soil nutrients. Trees in farm land relevant for protection and conservation functions such as for bird watching towers, live fences, control of runoff, protection of soil through reducing wind speed, improvement of soil fertility, and maintenance a healthy ecological state as well as providing proximate and ultimate ecosystem services.

As one of the climate smart agriculture approaches, integrating trees into the agricultural systems (cropping, pastures, and fences) parkland agroforestry has already proven to an effective strategy to protect arid areas against land degradation and reduction of biomass. In terms of greenhouse gas emissions, Parkland agroforestry is generally recognized as the climate smart agriculture practice with the greatest potential for contributing to climate change via high carbon sequestration in tree species and in the soil. Scattered *Acacia tortilis* in parkland agroforestry reduces soil alkalinity due to its high organic matter content with litter fall and fast decomposition rate. The same is true for *Faiderbia albida* and *Croton macrostachyus* trees. Moreover, Scattered *Cordia africana* trees on farmers' maize fields considerably improve soil properties under their canopies in comparison to the adjacent open areas [29].

2.4.3. Socioeconomic and cultural benefits of parkland agroforestry

Collection, processing and commercialization activities surrounding parkland products are the source of a strong interdependence between participants which promotes social integration, transfer of technical knowledge and economic exchanges. In most cases the activities have responsible to women than men since poor women are vulnerable to impoverishment. In this case trees grown in farm land are relevant to supply fuelwood by decrease work load and great opportunities of specially women and children to collect fire wood far from their home in turn have positive impact on socioeconomic development.

Besides subsistence and commercial roles, trees in parklands attached to cultural aspects including language, history, art, religions. A lot of tree products are used to in traditional religious like funeral ceremonies, healing treatment and marriage ceremonies. Trees and shrubs used as traditional medicine such as, *Croton macrostachyus* for malaria, diarrhea, epilepsy, ringworm and skin rush, Cordia africana to cure evil eyes, *Euphorbia candelabrum* for ringworm, *Millettia ferruginea* for fungal infection, *Vernonia amygdalina* for diarrhea and stomach ache.

2.4.4. Woody species preference in local farmers

Smallholder farmers have maintained a variety of tree species in the agricultural landscapes as trees offer a range of socioeconomic and ecological benefits. The main reason farmers keep and conserve trees are for the aim of forage to livestock, fencing services, fuel wood production and their harmonize nature of the trees with growing annual crops. Moreover, farmers retained and protect trees in parkland agroforestry system for the purpose of soil improvement agriculture landscape systems since most tree species increase soil nitrogen availability due to N-fixation.

Multiple-use species and species with major uses such as Cordia africana and Croton macrostachyus are part of GTP II and green legacy of Ethiopia, preferred by households and tolerated, encouraged, or deliberately grown together with other crop components use as agricultural commodities, including products derived from forests and trees. Scattered Cordia africana trees in farmlands serve different assets for poor farmers, hence integration of this important parkland tree species in the farming system should encourage. Balanitus aegyptiaca tree species deliberately retained on sorghum farm lands to provide diverse benefits like medicine, fodder, food, wood products and improved sorghum yields in North Ethiopia [26].

Trees in parklands diminished sunlight reaching to crops and vary depend on tree phenology, leaf density and arrangement, and crown dimensions. However, tree shade increases understory herbaceous productivity by reducing temperature and evapotranspiration. Indigenous tree species like Acacia tortilis deliberately retained in parklands have ability improve soil fertility lead to improve crop production and forage production. It also used for medicine, food, fodder, fuel wood and construction materials.

Faidherbia albida trees selected in parklands due to reverse phenology (shades during the early rainy season and re-grow its leaves when the dry season begins);this makes compatible with food crops. It supply nitrogen, potassium and organic carbon for under their canopies for enhance crop production.

2.5. Tree management in Parkland Agroforestry practices

Farmers' involvement in tree/shrub management requires a clear understanding of the households' needs that trees can satisfy and the priority species to satisfy these needs. The sustainable management of parklands is increasing importance, and should begin with a thorough knowledge of parkland growth rates and production levels, including wood, fruit and foliage, as well as factors affecting them. The usual tree management practices include fertilizer application, pruning, coppicing, prescribed burning, pollarding, thinning, protection from animals and humans, mulching and watering.

2.5.1. Assisted tree regeneration

Assisted regeneration in parkland agroforestry can important for continuous production of wood and fodder where areas in high population density and pressure in high forest. The objective of assisted regeneration is to encourage farmers to find, protect and stimulate the growth of naturally regenerating shrubs and trees in their fields. Young woody plants are protected from grazing, tillage and fire in farmer's field and it requires five to ten years for harvesting.

2.5.2. Planting of parkland species

Farmers are planting different tree species to get numerous benefits including subsistence and conservation activities in their agricultural landscapes. Planting trees on-farm assists in reducing the pressure on already heavily overburdened resources. However, in many cases planting takes place deliberately in their surrounding area and compounds where management and protection activities are easier and not in far-away fields (parklands). Indeed, in planted parkland agroforestry they prefer planting of exotic tree species rather indigenous wood species require long time to reach maturity and provide yields. Therefore, right planting of parkland trees should be encouraged to meet their local needs from fruits and wood products.

2.5.3. Silvicultural techniques

Silvicultural tasks can driven from sustain socioeconomic needs by creation or maintenance and transforming into goal oriented activities. Development of parkland agroforestry assisted by silvicultural techniques which selected by farmers for desire shape to enhance productivity. According to parkland tree management practices such as coppicing, pollarding, lopping, pruning, and thinning are familiar in Tembaro district of Southern Ethiopia to increase growth, minimize competition in addition to supply provisioning services like wood, fodder and other materials [30]. Major management practices suggested for agroforestry technologies are weeding mulching, pollarding, thinning and pest controls [31].

*** Pruning (Debranching)**

Pruning takes place depend on the aims of farmer, because the activity may have both positive and negative effects, as improve crop yields and give branches for fence or fuelwood but also reduce fruit, leaf and wood production. Farmers prune trees more intensively for old age trees if they want rejuvenating them and reducing shade takes place during the second half of the dry season. Regular pruning increase the ratio of leaf biomass and canopy re-growth capacity when it is practice quarterly, however pruning have radical negative effect on pod production. It can also easy and cheapest to protect trees from pest and disease infestation by removing affected side branches, but too much pruning lead to cause of parkland degradation.

*** Coppicing, Pollarding and Lopping**

The need for more protection for parklands is because crops associated in parklands are highly susceptible for grazing animals than home gardens and woodlots. Lopping is management practices by which only tip of branches from the crown of trees may be liberated. Coppice (cut at the base to encourage bushy shoot re-growth) and pollarded (cut above grazing height to encourage shoot re-growth) to limit crop yield depression or for gathering wood and other tree products. It is done when one intends to get more sprouts to come and to get fuel wood, mulch, fodder or construction materials to optimize productivity. In low tree and shrub density of farmers apply no thinning and less coppicing in composition of parkland agroforestry.

*** Tree Fertilization**

Currently, priority use of available fertilizer resources is usually directed to crop rather than tree yield improvement. Fertilizer application is the most common management in Gununo watershed of Woliata zone because of low nutrient availability, presence of agricultural crops and species diversity.

2.5.4. Genetic Improvement of Parkland Species

Nowadays, perception of farmers changed to domestication of parkland agroforestry trees. The term domestication can defined as human-induced change in the genetics of plants to breed it into wider cultivation by local farmers, relation to commercialize of products. The improved tree germplasm, the largest genetic variation should be selected, contribute to the productivity and sustainable conservation as adoption of parkland agroforestry and leads to chance of farmers increase interest developing parkland trees. As a result, quick delivery of germplasm needed for efficient propagation methods depends on farmer needs, where domestication strategy different species to species, their uses and environmental condition. Indigenous knowledge practiced by farmer available for potential impact of tree genetic improvement. Genetic improvement takes consideration of erosion by parasite attack trees in agroforestry parklands.

2.6. Institutional and Socioeconomic Factors Influencing Woody Species Management in Parkland Agroforestry

Knowledge regard to management systems greatly help to researchers and policy-makers to aid rural communities in further developing and modernize sustainable parkland agroforestry system. Trees found on farmer private fields are more secure than lands in group rights like fallow and bush areas and then farmers easily decide intensive management and resource accesses or conflict resolution. On the other hand land owners have exclusive rights for tree cutting, pruning, planting and fruit gathering according to tree species and type of uses.

Forest resource legislation to extensive conserve and management is relevant only local populations engaged in formulation processes and rely on forest resources for their basic needs. Local involvement of farmers on natural resource regulation for further development is very important issue to effective implementation in district or national level. Therefore, the state should be adjusting institution for technical assistance and resource allocation to manage forest resource within communities effectively. Forest agents should be provided continuous formal and informal training in participatory research and about improved tree management techniques by considering social forestry services and policies. Socioeconomic related issues are influencing factors that affecting the diversity of on-farm woody species in the parkland agroforestry system. For instance, household age is the determinant factor that influences species diversity and management in parkland agroforestry and age has a positive correlation with a mean number of stem per farm in Tembaro district of South Ethiopia.

2.7. Factors Influence for Sustainability of Parkland Agroforestry practices

2.7.1. Status of Land Tenure and Tree Resources

The issues of tenure right, especially migrants in developing countries, are not secure and stable to plant and manage trees in agroforestry parklands . Tenure insecurity in Ethiopia was among the major deterrents to tree planting in the past. Farmers tended to reluctant to plant trees if there were uncertainties whether they would continue to have rights of access to their holdings, since tenure insecurity and periodic division of plots make them less concerned about the health of their farms. For this reason, clear legal frame-work for tenure security and forestry extension service need to develop information in farmers with regard to land and tenure rights in agroforestry parklands.

Tenure right need to addressed include improvement of product quality, establishment of grading system, information exchange system to market signals, development and transfer of technologies, promotion of local use, processing and packing of parkland products and strength the capacity of local producer. Farmers' right on land and tree resources should be clear for natural interest their sustainable use because tee management in parkland agroforestry mostly responsible to landholders. In addition, legal activities appropriate regulation of harvesting efficient penalties in natural forests can outstanding inspiration to incorporate trees in cultivated lands.

2.7.2. Low Attention of Agricultural Policy In Parkland Agroforestry Users

Agricultural practices contribute to depletion of parkland woody species and causes decrease species diversity and structure in cultivated land. Clear agricultural policies required to enhancing local use of parkland products by improving genetic resources and domestication. Forestry extension service need to develop information in farmers with regard to land and tenure rights in agroforestry. Government of Kenya initiating farmers to increase planting and sustainable management of trees in farmlands and there is regulation allocating of funds up to 10 percent. In addition, the government apply different options to increase agroforestry trees by supplying seeds and seedlings to meet farmers, demand.

However, trees in parklands considered as obstacle for intensive production system, as a result avoid woody plants in crop fields. For instance in Senegal, government was subsidies and encouraged if farmers clear all trees and stumps from their field because a thought of that trees were not compatible with animal traction. Additionally, modern mechanized technologies like tractor on parklands may remove park land trees due to relate to the way they have applied than their incompatibility. Supply of chemical fertilizer with low prices in agricultural policy of also lead to degradation of parkland agroforestry or negative effect on conservation and improvement of woody plants in agricultural fields. The land proclamations of Ethiopia do not specify clear instruction for farmers on how to manage and conserve indigenous trees on farm lands.

2.4.3. Farmer's Assumption

Farmers think that they will not benefit from parkland trees due to slow growth rate, long juvenile period before fructification and production of fruit or pods vary from year to year and one individual to another. Trees were removed to give animal space to maneuver and ringing problems where tree roots are superficial. As a result farmers may be reluctant to carry out management activities (thinning, cleaning, pest and disease control, coppicing or pruning) which are very necessary to optimizing their land use system, and they choose drop from their fields in West Africa. Similarly, the case is true in Ethiopia the assumption is that parkland trees affect crops due to shading effects and farming activities.

2.4.4. Population density

There is real association population density with a particular parkland agroforestry types results to degradation and unsustainable use by slow down regeneration status. On the other hand, increasing population density simultaneously shortage of arable land and reduce or eliminate fallow lands will exist and this lead to intimidating sustainability of parklands. Population density may a driver of parkland trees sustainability by farmers shifting for woody production provides fuel wood and other tree products. Free grazing, charcoal selling, shortage of farmland and lack of awareness are main limiting factors to improve parkland agroforestry in Northern Ethiopia.

3. Materials and Methods

3.1. Description of Study Area

The study was conduct in Kalu district which is one of the 23 districts of South Wollo of Amhara Regional state, Ethiopia. The administrative center of Kalu district is Kombolcha town, which is located about 23 kilometers south east, the main road Dessie to Addis Ababa far from the zonal capital city, Dessie and 376 km northeast far from Addis Ababa, capital city of Ethiopia. Kalu district approximately lies between 11° 00' 0.00" N and 39° 49' 59.99" E latitude and longitude respectively. It covers 85154.25 ha and bordered on the west by Dessie Zuria, on the north by Wore Babo and Tehuledere, on the south and east by the Oromia Zone, on the southeast by Albuko, southeast by Argobba special woreda. The altitude of the woreda ranges between 800 meters above sea level in the lowlands bordering the Oromia Zone and 1,750 mean above sea level at the foot of the mountains north of Kombolcha [32].

Out of the total area of the district, 24734 ha (29%) used for agriculture, 937 ha (1.1%) covered with grazing land, 3732.25 ha (4.4%) covered by forest and shrubs, 31 ha (0.04%) covered by water body like river, 3786 ha (4.4%) not used to for any activities (district office of agriculture). Some 37% of the district is mountainous, 55.5% is rugged, 23.5% terrain, 5% is plain lands and 6% rift valley.

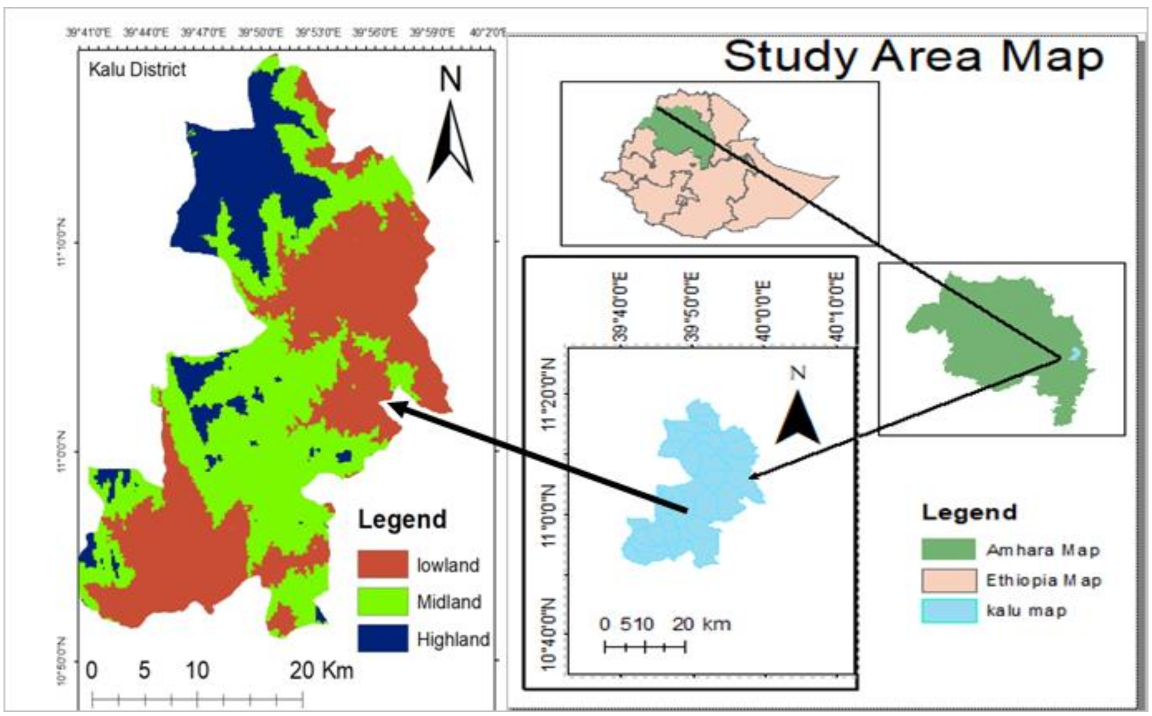

Figure 1: Geographical Location of the Study Area

3.1.1. Agro-Ecologies and Climatic Condition

Three agro-ecological zones found in Kalu district with 26% dega, 51% weinadega and 23% land area kolla classified as highland, midland and lowland respectively (district office of agriculture). There is bimodal rain in the district. For belg production season, the rain starts in January and ends in March. The summer months (June-August) are the second and major raining months for meher production. Annual average rain fall ranges from 750 mm to 981 mm. The minimum and maximum air temperature is 13°C and 31°C respectively.

3.1.2. Demographic Characteristics

According to report (2007) the district has a total population of 186,181 of whom 94,187 are men and 91,994 women; 19,810 or10.64% are urban inhabitants. With an area of 851.54 square kilometers, Kalu has a population density of 218.64, which is greater than the Zone average of 147.58 persons per square kilometer. A total of 41,648 households counted in this woreda, resulting in an average of 4.47 persons to a household, and 40,115 housing units. In terms of religion 98.73% of the population is Muslim, while 1.17% followers of Ethiopian Orthodox Christianity [30].

3.1.3. Soil Type and Crop Production

The soils are generally fertile and range from sandy loam, loam to silty loam. The major soil types in terms of area covered are phaezoms, cambisols, lithosols, and vertisols. The farming system dominated by subsistence small- scale farming system. Rain-fed agriculture is dominant to crop production. The climate condition varies over periods which deteriorate crop productivity in the district. The commonly practiced cropping system is mixed cropping. The common produced crops include sorghum, teff, maize, wheat, chick pea and millets at large and other crops like fruit, oil seeds and pulses like mung bean (Vigna radiate) and bolekie (Phaseolus vugries), vegetable, chat and spices are also produced.

3.1.4. Livestock Production

The livestock population, according to district agricultural office, was about 87199 cattle, 22288 sheep, 40117 goats, 6758 donkeys, 893 horses, 862 mule and 2190 camels. About 3436 hives were which include traditional ones.

3.2. Study Sites and Sampling Techniques

3.2.1. Selection of the Study Sites

Kalu district comprises a total of 35 rural and 5 urban kebeles. The district has 8 kebeles in dega (high land), 18 kebeles in Weinadega (midland) and 9 kebeles in Kola (lowland) agro-ecological zones (District office of agriculture). Highland agro-ecology was not including in this study since availability of woody species in parkland agroforestry is rare according to researcher's reconnaissance survey undertaken at this agro-ecology. To select representative study sites within midland and lowland agro-ecological zone, administrative units were used. The smallest administrative unit in the district is kebele, which means Peasant Associations or villages. In this case three kebeles (villages) were select randomly from the district, one kebele from lowland, two kebeles from midland based on the woody vegetation coverage in the cultivated lands.

3.2.2. Sampling Techniques

In this study it was applied multi-stage sampling technique, where combinations of sampling techniques were used to analyze and present data. Purposive sampling, Stratified sampling, simple random sampling and systematic random sampling were employed. In the first stage, the study area, Kalu district, was purposely selected based on availability of woody species incorporating in farmers cultivated lands (parkland agroforestry). The Key Informants and Focus Group members who are assumes to be resourceful persons are also selected purposely to gather appropriate and useful information to complement the survey data. In the second stage, the study area was stratified in to two agro-ecological zones (midland and lowland) based on altitudinal ranges. In the third stage, sample households were select with simple random sampling techniques for household survey. Finally, systematic sampling method was applied to find the sample plots to collect woody species structure and composition.

3.3. Data Collection Method

Both quantitative and qualitative data were collected from primary as well as secondary sources and the data were collected from key informants (KIs), focus group discussion (FGDs), field observation and HH (house hold) survey. Primary data collected in three kebeles; from KIs, FGDs, and HHs survey and tree inventories. Secondary data obtained from relevant published and unpublished data sources.

3.3.1. Household Selection for Questionnaire Survey

Names of all household heads living in the kebele were obtained from the kebele office and cross-checked with key informants for its inclusiveness. A total of 148 farmers; 55, 40, 53 were randomly selected from Mekanity, Weraba and Birkodebele respectively (Table 1: Number of total and sampled households included in the formal survey) according to farmers having parkland agroforestry in the kebeles. The sample size includes 7% of the total households.

Semi-structured questionnaire were employed for selected households. In this regard, carefully designed open for quantitative data and close-ended questionnaires consisting of interrelated issues were administered by trained expert enumerators under the supervision of the researcher and the development agents of the selected kebele. To convey the questions effectively to the rural interviewees, the questionnaires were translated into the local Amharic language.

Then households stratified in to three categories according to wealth status; namely rich, medium and poor. The identifying households in to each wealth category were set by key informants and cross check by personal observation. The criteria used for identifying wealth-ranking was based on land holding size, number of livestock, and number of horticultural crops especially fruits.

No	Name of the kebele	Agro-ecology	Total	sample HHs
1	Mekanity	Lowland	798	55
2	Birkodebele	midland	735	53
3	Weraba	midland	565	40
	total		2098	148

Table 1: Number of Total and Sampled Households Included in The Formal Survey

3.3.2. Key informants (KIs)

Key informants (KIs) are those people who are knowledgeable about the area (farming activity and livelihood activities of the communities) and are elderly persons who lived in the area for more than 35 years. For this study, KIs are peoples who are knowledgeable and understanding about the existing condition of woody species found scattered on their farm, their traditional management techniques and the purposes of incorporating trees in cultivated lands. The key informants were selected by snowball method (Bernard, 2011). To select each farmer who can identify key informants, kebele tour was employed with kebele council members and development agents. During the kebele tour, five farmers randomly asked to give the names of five key informants from each kebele. At all kebele, a total of 15 key informants were suggested. The key informants were individually interviewed on the overall information that has risen as criteria. Like most qualitative data collection, key informants asked repeatedly to explore issues in-depth based on open-ended questions.

3.3.3. Focus Group Discussion

Focus Group Discussion was applied with model farmers, elder farmers, development agents and gender and youth representatives. Focus group discussions were used to gather socio-economic information and about woody species in parkland agroforestry status from the representatives of the users. In a focus group discussion, a group of people having similar concerns and experience regarding a subject encouraged to participating. FGD considered 6-12 individuals per kebele (Elder, 2009). In this case 6 individuals were selected from each kebele. Therefore, one FGD in each sample kebeles that make up a total of three FGDs which have 18 participants. The discussion was facilitated by the researcher together with the enumerators based on the designed checklist.

3.3.4. Tree inventories

Before starting, field reconnaissance survey was carried out for one week in the selected kebeles to select sampling sites and to get first-hand information about the study area. A total of 6 transect lines (2 transect lines in each kebele) were established for the inventory of trees in the parkland agroforestry. A distance of 10 meters separated the road from the first quadrate to avoid roadside effect. Quadrate sizes were 50 m x 100 m (5000 m2) because of the low density of trees for all selected samples and transect length was set at 5 km with some adjustment (Nikiema, 2005) (Figure 2: Sampling design in the field for inventory of woody species. The total number of plots along transect lines used was 60 (20 quadrants for each kebele). Along each transect line 10 quadrates were used.

Cultivated lands (crop fields) were considered to lay down the plot in the parkland agroforestry in each kebele. The first transect line and quadrate was laid out randomly, and the rest were systematically by using compass. The geographical positions of quadrates were recorded with a GPS GARMIN 72H allowing their accuracy location to allocate the x-y axis of plot. The distance between each transect and plots were 2 km and 250 m respectively with exclude none targeted habitats (e.g. rivers, rocky hills and farmer's compounds).

All woody species found in the plots following transect line having stem diameter ≥ 5 cm (Giday & Gebremeskel, 2019) and height of 2 m above ground were recorded with data collection sheet. The diameters at breast height (DBH at 1.30 m above the ground) were measured using tree caliper, and heights were measured using Blume-leiss hypsometer. For trees /shrubs forking at or just above 1.3 m is measured both stems above the fork and the average was taken or treats as one tree. For woody species forked below 1.3 m, individual stems were separately measured and then average DBH was taken.

All trees and shrubs in each sample were recorded to decide the diversity and relative dominance with common and scientific names with the help of members of local communities participating in the survey. For specimen identification, Flora books of Ethiopia (1989), Honeybee flora of Ethiopia (1994), Flora of Ethiopia and Eritrea (1995), (Azene bekele, 2007) were used, supported by expertise's.

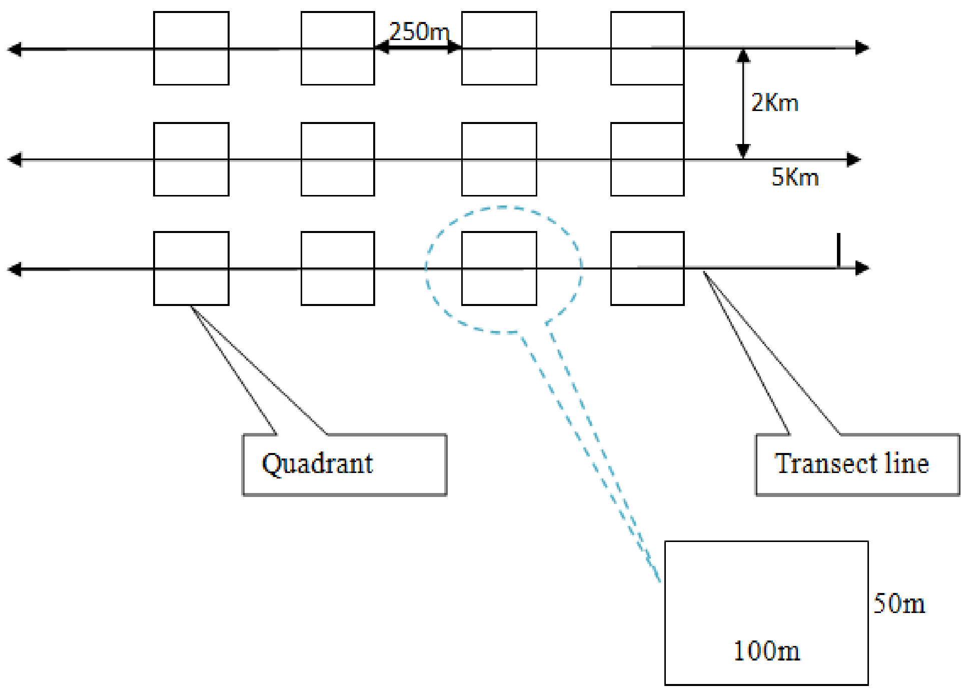

Figure 2: Sampling design in the field for inventory of woody species

3.4. Data Analysis and Presentation

3.4.1. Vegetation structural analysis The vegetation structure was described using frequency distribution, density, DBH, height and Importance Value Index (IVI). The density of woody species and basal area of the vegetation was computed on hectare basis. Important value index (IVI) was computed for all woody species based on relative density (RD), relative dominance (RDo) and relative frequency (RF) to determine their dominance position.

Basal area

Basal area is the cross-sectional area of woody stems at breast height. It measures the relative dominance (the degree of coverage of a species as an expression of the space it occupies) of a species in an area. Basal area was calculated for each woody species as follows.

$$BA = \frac{(\pi DBH)2}{4}$$ Where, π=3.14

BA=Basal area (cm)^2

DBH= diameter at breast height (cm)

Density

The density of woody species is one of the most important structural parameters to be considered during data analysis. Density of a given species expressed as a number of stems per hectare. Density was calculated by summing up all stems across all area and converting into hectare basis.

Frequency

Frequency is defined as the probability of chance of finding a species in a given sample area or quadrate (Kent and Coker,1992). Thus, it shows the presence or absence of a given species within each sample plot. On the other hand, relative frequency shows the frequency of a species in relation to all other woody species constituting the forest under investigation (Tefera et al., 2015).

The density (D), relative abundance or relative density (RD), relative dominance (RDo), frequency (F) and relative frequency (RF) were calculated as:

$$\text{Density (D)} = \frac{\text{Total number of individual of species}}{\text{Sample area(ha)}}$$

$$\text{Relative Density (RD)} = \frac{\text{Number of individual of species}}{\text{Total number of individual}} * 100$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Dominance of species}}{\text{Total dominance of all species}} * 100 \quad \text{OR}$$

$$\text{Relative Dominance/basal area (RDo)} = \frac{\text{basal area of one species}}{\text{Total basal area}} * 100$$

$$\text{Frequency (F)} = \frac{\text{Area of the plot in which species occurs}}{\text{Total number of sample plot}}$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequencyof species}}{\text{Sum of frequencies of all species}} * 100$$

3.4.2. Important Value Index

Species important value, which is measured on the basis of species density, frequency and dominance values permit a comparison of species in the vegetation being studied and reflects the occurrence, dominance and abundance of a given species in relation to other associated species in an area [33]. It is an important tool to compare the ecological significance of a species. Therefore, measuring the species importance value is a good index for summarizing vegetation characteristics and ranking the species for management and conservation practices.

The importance value index (IVI) indicates the importance of species in the system, and it was calculated with three components. Importance value for each woody species is the sum of relative density, relative dominance and relative frequency. IVI=Relative Density + Relative Dominance + Relative Frequency

(IVI=RD + RDo + RF)

3.4.3. Diversity analysis

Diversity includes both species richness and evenness. The Species richness is the total number of species in the community [34]. Evenness refers to the variability in the relative abundance of species. The diversity is measured by using diversity index, from the records of the number of species and their relative abundances within the community. According to, a diversity index is a mathematical measure of species diversity in a community, and it helps to measure a quantity for example, species that presents in a dataset. Diversity indices provide more information about community composition than simply species richness; they take the relative abundances of different species into account. It also takes into account measuring how evenly the basic entities (such as individual species) are distributed among the groups under discussion. Diversity indices provide important information about rarity and commonness of species in a community. The value of a diversity index increases both when the number of types increases and when evenness increases [35].

There are different indices that may be used to measure biodiversity. The Shannon index and Simpson indices are the most common diversity indices. The species diversity in biodiversity can be estimated using species richness, Simpson diversity index and Shannon evenness.

* Shannon Diversity Index

The Shannon diversity index is the most widely used type of diversity index. It measures the uncertainty and disorder that, how difficult it would be to predict correctly the species of the next individual collected in the sample. The quantity of uncertainty is related to the diversity of a community. The Shannon index considers all species are found in a sample and that they are randomly sampled. It is easy to calculate, however, it does not indicate the dominance of a population. It is also moderately sensitive to sample sizes and more emphasis to species richness component of the diversity [36].

Shannon diversity index is calculated as:

$H' = -\sum p_i \ln p_i$ Where;

H′ = Shannon diversity index,

Pi = proportion of individuals found in the ith species or the number of individuals of one species divided by total number of individuals in the samples. Values of the index (H′) ranges 1.5 - 3.5, but sometimes the value can exceed 4.5.

The Shannon's equitability or evenness (J) of the species in each agro-ecology was computed by the following formulae to estimate the homogeneous distribution of tree species on farms.

$$J = \frac{H'}{Hmax} = J = \frac{H'}{\ln S} \qquad \text{with } H_{max} = \ln s$$

Where, J = Evenness (equitability)

H′ = Calculated Shannon-Wiener diversity

H_{max} = ln(s) [species diversity under maximum equitability conditions]

S = the number of species (Kent and Coker,1992).

The measure of evenness (E) is the ratio of observed diversity to maximum possible diversity. Evenness has values between 0 and 1, where 1 represents a situation in which all species are equally abundant. From these calculations, species richness and heterogeneity as well as density of trees/shrubs were characterized for each farm.

Simpson's Diversity Index

Simpson's diversity Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species. Simpson's diversity index gives relatively little weight to the rare species. Simpson's diversity index is the most sensitive to changes in more abundant species and hence places more weight on the most abundant species in the community. It can be seen that the more species in the community and the higher the index, indicating a good diversity of the community. The greater the Simpson index, the higher the diversity. It measures the probability of dissimilarity of the population, thus, a highly similar population would indicate lower diversity.

Simpson′s diversity index (D) is calculated as:

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

Where D = Simpson's index

n = the total number of organisms of a particular species

N = the total number of organisms of all species

The value ranges from 0 (low diversity) to a maximum of (1-1/S), where S is the number of species. It is less affected by sample size and no sensitive to species richness [37].

Finally, diversity index was converted to true diversity (effective number of species) by using the formula:

TD = eH

Where TD = True diversity

e = Base of natural logarithm

H= Shannon diversity index
When we convert to true diversities (effective number of species) we create a powerful and intuitive tool for comparing diversities of different communities. As a heterogeneity measure Shannon and Simpson diversity indices take into account the evenness of abundance of species. Shannon diversity index place more weight on the rare species in the sample. The assumption is that species-rich communities in ecosystem are healthier than species-poor communities. However, it does not indicate the dominance of a population. In contrast, Simpson index is a dominance index because it gives more weight to common or dominant species, and it gives relatively little weight to the rare species. Simpson diversity index is recommended for ranking of dominance species.

According to for purposes conservation planning when selecting sites to be protected and when the objective is to detect effects of external factors on diversity, such as when assessing anthropogenic impacts on species diversity, compound indices are often preferred over species richness [38]. There for, in order to get better picture on extent of woody species richness in parkland agroforestry and to identify the most dominant woody species in terms of the greatest important value in ranking order, Shannon, Simpson and evenness indices were employed in this study.

*** Similarity Analysis**

Similarity indices measure the degree to which the species composition of different systems is alike. Many measures exist for the assessment of similarity or dissimilarity between vegetation samples or plots. Some are qualitative and based on presence/absence data, while others are quantitative and will work on abundance data. Of the large choice available, the Sorensen similarity coefficient was applied to qualitative data and is widely used because it gives more weight to the species that are common to the samples rather than to those that only occur in either sample. The Sorensen coefficient of similarity (Ss) is given by the formula:

$$Ss = \frac{2a}{2a+b+c} x\ 100$$

Where Ss= Sorensen similarity coefficient
a = number of species common to both samples
b = number of species in sample 1
c = number of species in sample 2

3.4.3. Statistical Data Analysis

The data collected through the questionnaire interviews, species richness, structures and composition were analyzed using Statistical package for Social Science (SPSS 20) software and Microsoft excel version 2010. Binary logistic regression model (Logit) was carried out to analyze the factors affected woody species management activities in parkland agroforestry practices at the study area based on the prepared questionnaire. The model was used in this study to determine the relationship between socioeconomic variables with households who managed or not managed woody species in parkland agroforestry at the study area at ≤ 5% significance level of interval and 95% of confidence level.

Descriptive statistics such as frequency distribution, mean, maximum, minimum, standard deviation, standard error and percentage were used to analyze the quantitative data. These descriptive analyses were used to identify types of management practices, abundance, dominance or distribution of woody species in parklands in local farmers. The results were presented by using tables, percentages and figures.

Inferential statistics such as Chi-square (X2) and independent t-test were used to identify the association between categorical and continuous variables and woody species management. These inferential statistics were used to verify the presence of significant deference between respondents' age, gender, family size, level of education, landholding size, sex, livestock holding, etc., and these independent factors weather affect or not in management activities of parklands in the study area. Data that were obtained from KIs and FGDs and other qualitative data were analyzed in qualitative way.

4. Result

4.1. Woody Species Composition

Totally, 21 woody species were collected from two agro-ecoloies zone of Kalu district parkland agroforestry. Out of this, 9 woody species were collected from lowland whereas 12 species were collected from midland agro-ecology (Table 2: Species composition in midland and lowland parkland agroforestry of Kalu district. Five species were common in both agro-ecologies of parkland agroforestry. Chi-Square revealed that there was no significance difference in terms of species composition between two agro-ecology parkland agroforestry (p>0.05) of Kalu district.

Agro-ecology	**Midland**	**Botanical Name**
		Acacia seyal
		Ziziphus spina-christi
		Cordia africana
		Acacia lahai
		Sterculia africana
		Schinu molle
		Faiderbia albida
		Ehretia cymosa
		Olea africana
		Croton macrostachyus
		Acacia polyacantha
		Albizia gummifera
	Lowland	*Ziziphus spina-christi*
		Acacia seyal
		Acacia etbaica
		Olea africana
		Croton macrostachyus
		Acacia aska
		Ekebergia capensis
		Acacia lahai
		Adansonia digitata

Table 2: Species Composition in Midland and Lowland Parkland Agroforestry of Kalu District

The collected species belonging to eight families, and Fabaceae were the dominant families. These families were diverse in terms of species composition being 7 out of 16 collected species followed by Boraginaceae represented by 3 species (Table 3: Woody species with their respective families). The total number of individual species were 209 and 77 in midland and lowland parkland agroforestry of Kalu district, respectively (Table 2: Species composition in midland and lowland parkland agroforestry of Kalu district; indicated that significant difference with t=3.05 and p=0.016 between the two agro-ecologies in terms of parkland agroforestry species abundance.

No	*Scientific name*	Local name	Family name	Habit	Origin
1	*Schinu molle*	Qundo berbere	Anacardiaceae	Tree	Indigenous
2	*Cordia Africana*	Wanza	Boraginaceae	Tree	Indigenous
3	*Ehretia cymosa*	Hulaga	Boraginaceae	Tree	Indigenous
4	*Adansonia digitata*	Abwar	Boraginaceae	Tree	Indigenous
5	*Croton macrostachyus*	Bisana	Euphorbiaceae	Tree	Indigenous
6	*Acacia seyal*	Wacho	Fabaceae	Tree	Indigenous
7	*Acacia lahai*	Lafto girar	Fabaceae	Tree	Indigenous
8	*Acacia polyacantha*	Polycanta	Fabaceae	Tree	Indigenous
9	*Albizia gummifera*	Sesa	Fabaceae	Tree	Indigenous
10	*Faiderbia albida*	Doret girar	Fabaceae	Tree	Indigenous
11	*Acacia etbaica*	Tikur girar	Fabaceae	Tree	Indigenous
12	*Acacia aska*	Girar	Fabaceae	Tree	Indigenous
13	*Ekebergia capensis*	Sombo	Meliaceae	Tree	Indigenous

14	*Olea africana*	Weyra	Oleaceae	Tree	Indigenous
15	*Ziziphus spina-christi*	Qurqura	Rhamnaceae	Tree	Indigenous
16	*Sterculia africana*	Adebule	Sterculiaceae	Tree	Indigenous

Table 3: Woody Species With Their Respective Families In Parkland Agroforestry at Kalu District

4.2. Structure of Woody Species

Analysis of population structure for each tree species made on the basis of DBH and height class distribution to determine their regeneration and recruitment status. For the purpose of studying the population structures in parkland agroforestry, the diameter and height of all individual woody plants were categorized into an arbitrary diameter classes.

4.2.1. Basal Area

Total basal area of woody species of each agro-ecology was calculated from measured diameter at breast height (DBH) of individual tree. Based on this, *Acacia seyal* had highest basal area followed by *Ziziphus spina-christi and Cordia africana ,* respectively in midland agro-ecology of parkland agroforestry while *Acacia polyacantha* and *Albizia gummifera* had accounted lowest basal area, they had attained less than one percent ((Table 2: Species composition in midland and lowland parkland agroforestry of Kalu district.

In lowland agro-ecology zone of parkland agroforestry, Ziziphus spina-christi had highest basal area with followed by Acacia seyal and Olea africana. On the other hand Acacia aska and Adansonia digitata were attaining the lowest basal area (Table 2: Species composition in midland and lowland parkland agroforestry of Kalu district. The total basal area in midland and lowland agro-ecology of parkland agroforestry was 0.291 m2/ha and 0.86 m2/ha respectively (Table 2: Species composition in midland and lowland parkland agroforestry of Kalu district.

Botanical Name	F	RF (%)	D	RD (%)	Dom	RDo (%)	IVI
Ziziphus spina-christi	24	31.2	1.2	31.2	0.031	36.1	98.5
Acacia seyal	21	27.3	1.05	27.3	0.019	21.7	76.3
Acacia etbaica	10	13.0	0.55	14.3	0.006	7.4	34.7
Olea africana	6	7.8	0.3	7.79	0.012	14.0	29.59
Croton macrostachyus	5	6.5	0.25	6.5	0.007	8.3	21.3
Acacia aska	3	3.9	0.1	2.6	0.004	1.5	8
Ekebergia capensis	3	3.9	0.15	3.89	0.003	3.01	10.8
Acacia lahai	3	3.9	0.15	3.89	0.004	4.8	12.59
Adansonia digitata	2	2.6	0.1	2.6	0.002	2.9	8.1
Total	**77**	**100**	**3.85**	**100**	**0.86**	**100**	**300**

Table 4: Summary of Important Value Index of Woody Species in Lowland Plaf of Kalu District

Botanical Name	F	RF (%)	D	RD (%)	Dom	RDo(%)	IVI
Acacia seyal	77	36.8	2.08	39.7	0.119	40.9	117.4
Ziziphus spina-christi	73	34.9	1.7	33.01	0.081	27.8	95.71
Cordia africana	17	8.1	0.40	7.66	0.029	10.0	25.76
Acacia lahai	16	7.7	0.38	7.18	0.023	8.0	22.88
Sterculia africana	11	5.3	0.28	5.26	0.002	5.2	15.76

Schinu molle	4	1.9	0.10	1.9	0.001	2.7	6.5
Faiderbia albida	3	1.3	0.08	1.44	0.015	1.3	4.04
Ehretia cymosa	2	1.0	0.05	0.96	0.008	0.56	2.52
Olea africana	2	1.0	0.05	0.96	0.003	1.1	3.06
Croton macrostachyus	2	1.0	0.05	0.96	0.003	1.1	3.06
Acacia polyacantha	1	0.5	0.03	0.48	0.002	0.4	1.38
Albizia gummifera	1	0.5	0.03	0.48	0.004	0.86	1.84
Total	**209**	**100**	**5.23**	**100**	**0.291**	**100**	**300**

Table 5: Summary of Important Value Index of Woody Species In Midland Plaf of Kalu

The mean basal area of midland parkland agroforestry was 0.0014±0.0007 per plot while the mean basal area of lowland parkland agroforestry was 0.0012± 0.0006 per plot. There was significance different between the two agro-ecology in terms of mean basal area (p<0.005) (Table 6: Mean basal area per plot of midland and lowland parkland agroforestry of Kalu district).

	N	Mean	SD	SE	*P-value*
Basal area of woody species in midland agro-ecology	209	0.0014	0.0007	0.00049	
Basal area of woody species in lowland agro-ecology	77	0.0012	0.0006	0.0007	0.001

Table 6: Mean Basal Area Per Plot of Midland And Lowland Parkland Agroforestry of Kalu District

4.2.2. Frequency of Woody Species

In lowland parkland agroforestry, Ziziphus spina-christi, Acacia seyal and Acacia etbaica were the most frequent species and infrequent species in lowland parkland agroforestry was Adansonia digitata (Table 6: Mean basal area per plot of midland and lowland parkland agroforestry of Kalu district). Acacia seyal and Ziziphus spina-christi were the most frequent species in midland parkland agroforestry, respectively. Whereas Ehretia cymosa, Olea africana, Croton macrostachyus, Acacia poyacantha and Albizia gummifera were existed infrequently in midland parkland agroforestry (Table 6: Mean basal area per plot of midland and lowland parkland agroforestry of Kalu district).

4.2.3. Density of woody species

Totally, 286 woody species were collected from 30 hectare from the two agro-ecologies. The mean number of trees in lowland and midland agro-ecologies of parkland agroforestry was 5.23±0.341 and 3.85±0.342 per plot, and 10.65±0.84 and 7.7±0.68 per ha respectively (Table 6: Mean basal area per plot of midland and lowland parkland agroforestry of Kalu district). Lowland PLAF accounted higher abundance than midland PLAF.

Agro-ecology	Number of stems/plot			Number of stems/ha		
	Mean		SE	Mean		SE
Lowland	5.23	±	0.341	10.65	±	0.836
Midland	3.85	±	0.342	7.70	±	0.685
Overall mean	4.54	±	0.34	9.17	±	0.75

Table 7: Mean Number of Stems of Woody Species Per Plot And Per Hectare In Midland And Lowland Agro-Ecology

4.2.4. Diameter Class Distribution

The diameters of all individual woody plants were categorized into eight arbitrary diameter classes in both agro-ecologies of parkland agroforestry to understand the distribution classes (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). In midland parkland agroforestry, Acacia seyal and Zizipus spina-christi had contributed highest diameter class (> 40 cm) and again they had accounted the lowest DBH distribution class (5-10 cm) at the same time. Number of individual woody species decreases with increasing diameter and the structure of woody species resembles inverted J-shape which shows high proportion of woody species were represented by small individuals i.e. belonging to the DBH classes 5-10 (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). A majority of these larger and small trees represented by Acacia seyal and Ziziphus spina-christi species.

In lowland parkland agroforestry, Zizipus spina-christi resemble highest DBH (>40 cm), and Zizipus spina-christi, Acacia etbaica and Acacia seyal resemble relatively the lowest diameter distribution with 5-10 cm. About 68.8% of woody species found in the first lowest diameter classes. Then the number of individual woody species decreases with increasing diameter and the structure of woody species resembles inverted J-shape which shows highest number of individual woody species belonging to the DBH classes 5-10 cm (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

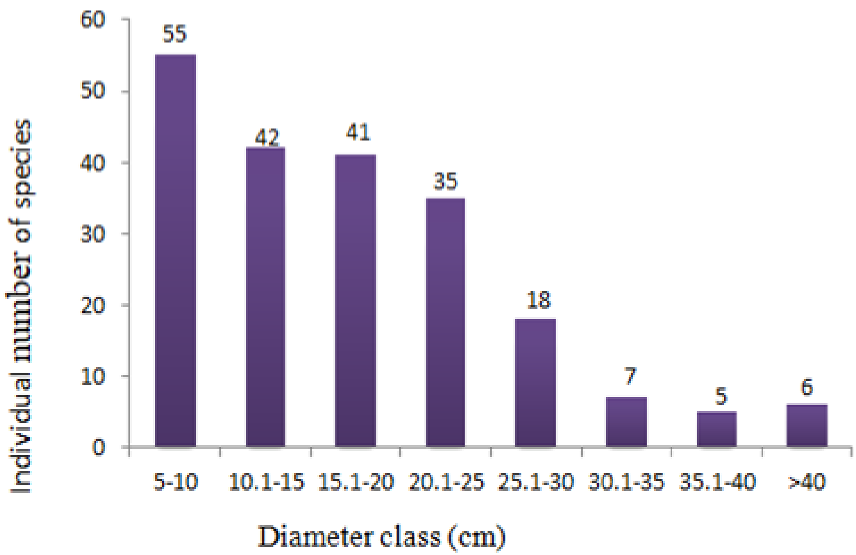

Figure 3: Diameter Class Frequency Distribution of Woody Species In Midland Parkland Agroforestry of Kalu District

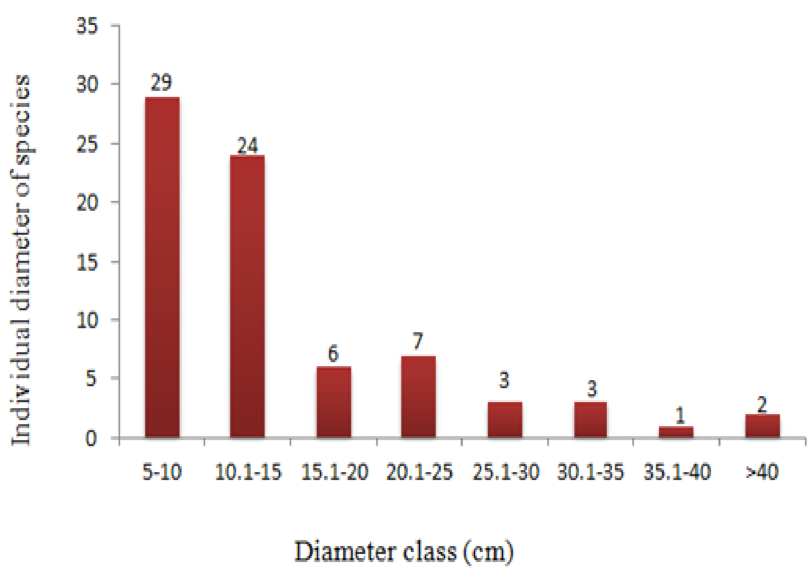

Figure 4: Diameter Class Frequency Distribution of Woody Species In Lowland Parkland Agroforestry of Kalu District

4.2.5. Height Class Distribution

The heights of woody species were categorized into five arbitrary height classes in the two agro-ecological zones of parkland agroforestry (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). Ziziphus spina-christi and Acacia seyal represented the highest diameter class (>14 m), and Acacia seyal and Cordia africana had relatively contributed lowest height class distribution (2-5 m) in midland parkland agroforestry. About 42.5% of the total height class lied at Intermediate height classes(5.1-8 m) and the dominant species in this height classes were relatively Ziziphus spina-christi, Acacia seyal, Cordia africana and Acacia lahai. The height distribution of midland parkland agroforestry seems like bell shape, which shows the highest number of trees in intermediate classes but low number in small and large height classes (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

In lowland parkland agroforestry, in the higher height classes (>14 m) Ziziphus spina-christi and Olea africana were the dominant species whereas Ekebergia capensis, Acacia seyal, Acacia etbaica and Ziziphus spina-christi were relatively the dominant species in the lowest height classes (2-5 m). About 40.2% of the species were included at intermediate height classes (5.1-8 m). The shape of height class distribution of lowland parkland agroforestry resembles near to bell shape i.e. more species found in intermediate height class distribution but low number of species found in lower and higher class distribution (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

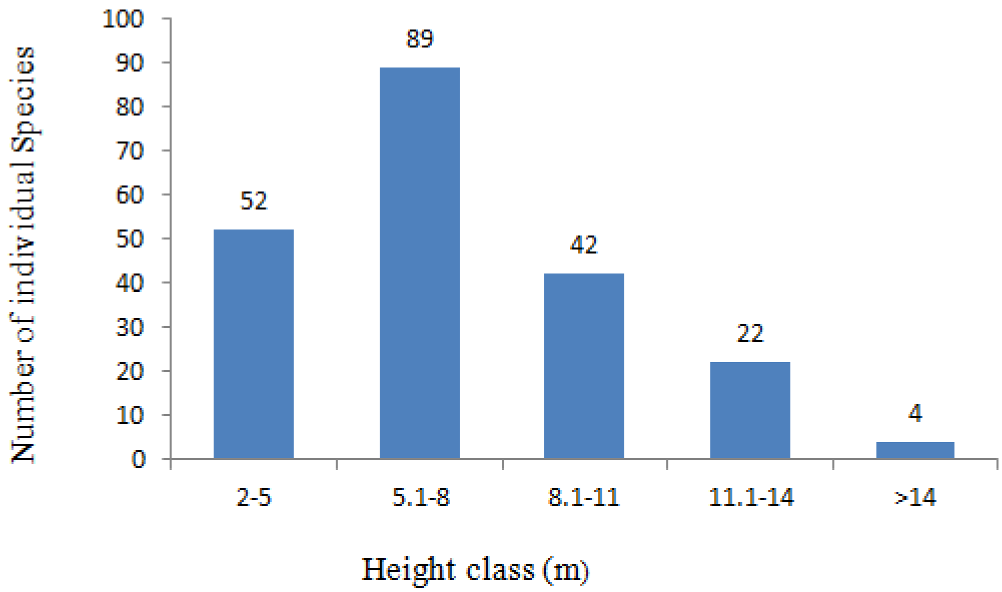

Figure 5: Height Class Frequency Distribution of Woody Species In Midland Parkland Agroforestry of Kalu District

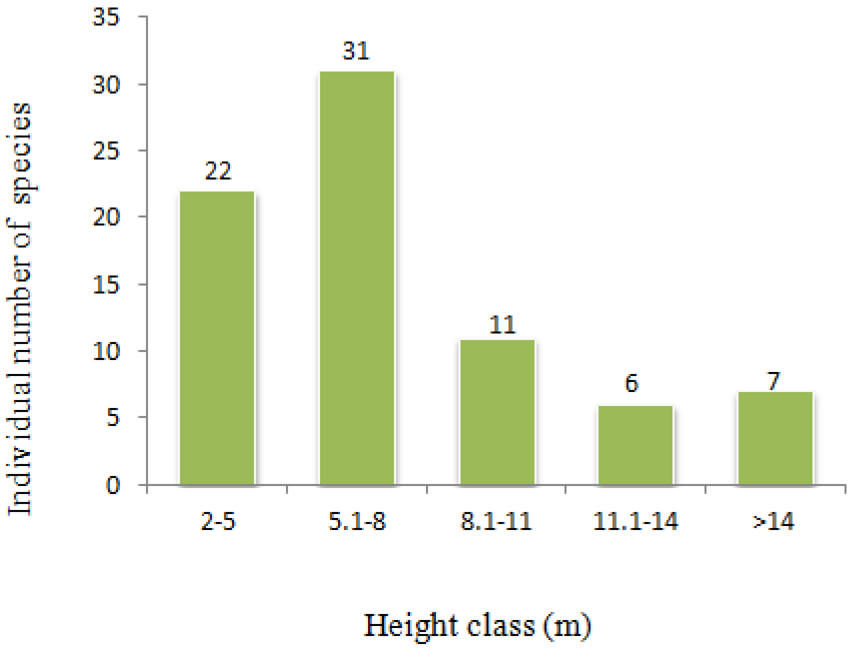

Figure 6: Height Class Frequency Distribution of Woody Species In Lowland Parkland Agroforestry of Kalu District

4.3. Important Value Index (IVI)

Important value index of each agro-ecology of parkland agrogorestry was assessed. Accordingly, in the midland parkland agroforestry, Acacia seyal and Ziziphus spina-christi were the first and second top ranked woody species in terms of important value indices. About 71% mean IVI of woody species consisted by these species. On the other hand Acacia polyacantha and Albizia gummifera were the lowest mean important value indices (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

In lowland parkland agroforestry, Ziziphus spina-christi and Acacia seyal were the first and second top ranked woody species in terms of important value index. But Adansonia digitata and Acacia aska were the lowest species in terms of IVI with the mean value 8.1 and 8 respectively (Table 4). Ziziphus spina-christi were ranked first in lowland PAF and ranked second in midland PAF (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district)

4.4. Diversity of Woody Species

The value of Shannon and Simpson diversity indices at low and midland parkland agroforestry were 1.82 and 0.80 and 1.60 & 0.72, respectively. Similarly, the value of woody species richness in midland and lowland parkland agroforestry were 209 and 77, respectively. (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

Agro-ecology	Shannon diversity index (H′)	Simpson՝s index(D)	Shannon՝s evenness (J)	True diversity	Species richness	Sorensen Similarity percentage
Midland	1.60	0.72	0.30	4.95	209	47.6
Lowland	1.82	0.80	0.42	6.17	77	
Mean	1.71	0.76	0.36	5.56	9.5	

Table 8: Mean Diversity Indices And Species Richness of Woody Species In Midland And Lowland Parkland Agroforestry of Kalu District

Similarity Analysis

Similarity on woody species composition between lowland and midland parkland agroforestry were 47.6%. Five woody species (Ziziphus spina-christi, Acacia seyal, Acacia lahai, Croton macrostachyus and Olea africana) were found in both agro-ecologies (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

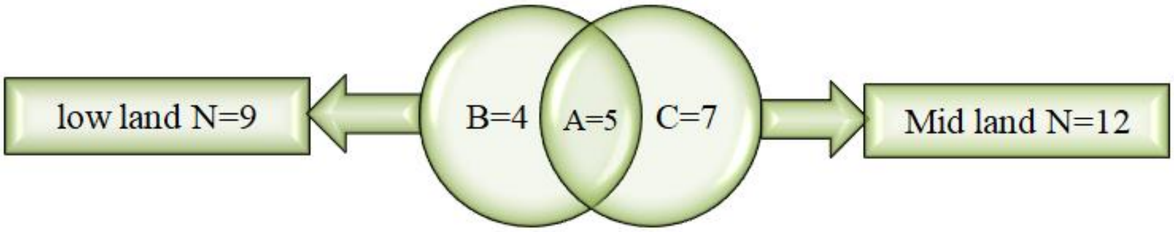

Figure 7: Venn Diagram of The Species Richness Pattern In Midland And Lowland In Plaf of Kalu District, South Wollo, Ethiopia

4.5. Species Preference, Benefits And Management of Woody Species In Parkland Agroforestry

4.5.1. Woody Species Preference and Ranking

Main occupations of households was crop production and some of them was mixed farming (crop and livestock production).In Kalu district trees were integrated in different densities with crops such as wheat (Triticum species), maize (Zea mays), Sorghum bicolor, Mung bean (Vigna radiate), Eragrostis tef, linseed (linum usitalissiun) ,bolekie (Phaseolus vugries, etc. However, Sorghum bicolor and Eragrostis tef were the most abundant crops. Woody species preference was based on contribution to ecological service, economical benefits and multipurpose uses. Farmers retained tree species which is compatible with their crops, ability of improve soil fertility and having other multipurpose functions. About 83.1% from (N=148) respondents retained different types of woody species on their farm. To assess farmer's preferences, respondents were asked to rank the most important woody species among species they retain. Accordingly, Ziziphus spina-christi and Acasia seyal were the most preferred woody species retained in the parkland agroforestry at Kalu district. Farmers prefer the first three trees in the order of, Zizipus spina-christi>Acacia seyal>Cordia africana (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).These species in most cases retained after naturally regenerated, in some cases retained during the conversion of forest and shrub lands in cultivated lands.

Woody species	Rank			Relative score			Total relative score
	1	2	3	1	2	3	
Zizipus spina-christi	24	16	10	5.70	3.66	2.22	11.58
Acacia seyal	20	15	9	3.96	3.21	1.80	8.97
Cordia Africana	8	8	4	0.63	0.91	0.36	1.90
Acacia lahai	7	5	4	0.49	0.36	0.36	1.20
Olea Africana	7	4	3	0.49	0.23	0.20	0.91
Schinu molle	7	4	3	0.49	0.23	0.20	0.91
Acacia etbaica	5	3	3	0.25	0.13	0.20	0.58
Croton macrostachyus	5	4	3	0.25	0.23	0.20	0.68
Faiderbia albida	4	3	2	0.16	0.13	0.09	0.38
Ehretia cymosa	4	2	1	0.16	0.06	0.02	0.24
Sterculia Africana	4	3	1	0.16	0.13	0.20	0.49
Acacia aska	3	2	1	0.09	0.06	0.20	0.35
Ekebergia capensis	2	1		0.04	0.01		0.05
Albizia gummifera	1	-	-	0.01			0.01
Acacia polyacantha	-	-	1			0.20	0.20

Adansonia digitata	-		-				
Total	101	70	45				

Table 9: Ranking of Preference of Woody Species Retained In Plaf of Kalu District

4.5.2. Benefits of Woody Species in Parkland Agroforestry

Farmers used parkland trees like as living bank for their immediate and long term objectives and needs. The purpose of management practices was to increase the growth of active shoots and branches, minimize competition to crops by reducing shading effect, use intermediate products for fuel wood, fence, fodder and construction of houses and others. Totally 15 use types of PLAF were identified at Kalu district (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

Botanical Name of Species	Benefits gained from parkland species														
	FW	SI	TM	FD	SD	CN	FO	MD	FN	FT	FH	BM	CH	BW	CY
Acacia polyacantha	√	√	√	√	√	√		√	√	√	√	√	√		√
Acacia aska	√	√	√	√	√	√		√	√	√	√	√	√		√
Acacia etbaica	√	√	√	√	√	√		√	√	√	√	√	√		√
Acacia lahai	√	√	√	√	√	√		√	√	√	√	√	√		√
Acacia seyal	√	√	√	√	√	√		√	√	√	√	√	√		√
Adansonia digitata	√	√	√	√	√	√		√	√	√	√	√		√	√
Albizia gummifera	√	√	√		√	√		√	√	√	√	√	√	√	√
Croton macrostachyus	√	√	√	√	√	√		√	√	√	√	√	√	√	√
Cordia africana	√	√	√		√	√	√	√	√	√	√	√	√	√	√
Ehretia cymosa	√	√	√	√	√	√		√	√	√	√	√			√
Ekebergia capensis	√	√		√	√	√			√	√	√	√		√	√
Faiderbia albida	√	√	√	√	√	√		√	√	√	√	√	√		√
Olea africana	√	√	√	√	√	√		√	√	√	√	√	√	√	√
Schinu molle	√	√	√		√	√		√	√	√	√	√	√		√
Sterculia africana	√	√	√		√	√			√	√	√	√	√	√	√
Zizipus spina-christi	√	√	√	√	√	√	√	√	√	√	√	√	√		√

Table 10: List of Parkland Species and Their Respective Benefits Provided For Households At Kalu District

Where; "√"represents the species renders that particular benefit key FW=fuel wood, SI=soil improvement and protection, TM=timber, FD= animal fodder, SD= shade, CN= construction of house, FO= food, MD= medicine, FN= fence, BM= beehive making and hanging, FH=forage for honey bees, CH=charcoal, FT= farm tools, BW=bird watching tower, CY=crop yield improvement.

With respect to respondents, above 90 % of households were used parkland species for firewood consumption and more than 80% of them used these tree species for charcoal production (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). Households were sold parkland trees to the nearest town whether in the form of charcoal (especially) or by collecting and transporting as firewood. In addition, households use PLAF as fodder their animals. For instance the nutritional content of Z.spina Christi leaves shows that suitable for small ruminant feeds during dry season. It is very good feeding of goats or camel.

No	Use type	No of respondents	Respondents (%)
1	Firewood	143	96.6
6	Shade	137	92.6
2	Charcoal	128	86.5
11	Fence (dry and/or live)	125	84.5
5	Soil fertility	112	75.7
7	Construction	97	65.5
10	Food	96	64.9
9	Farm tools	95	64.2
4	Fodder	88	59.5
3	Timber	80	54.1
8	Crop yield improvement	67	45.3
13	Medicine	37	25
12	Others	35	23.6

Table 11: Uses Of Parkland Woody Species Respect To Sample Households

Households perceived parkland trees were relevant for soil improvement and prevention from erosion and most of them were used to shade for livestock and human beings (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). One of the roles of parkland trees are the provision of pollen and nectar for honey bees. Farmers had also used these tree species for traditional medicine in the district. For instance, Croton macrostachys had dissolved in water and drink for human stomach disorder. The leaves had also crushed and rubbed on cattle for protection of diseases locally called mech. The branches of Olea species used to brush teeth clean and strong. Decoction leaves of Ehretia cymossa used to treat cattle and human cough. The leaf, bark and roots of Zizipus spina-christi concoctions used to traditional medicines like dandruff and stomach disorders.

4.5.3. Woody Species Management Practices

The most important management practices were looping, pollarding, pruning, protection and coppicing. Each type of management practices including protection of woody species illustrated in Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district. Looping and pollarding were the top most important types of management practiced in the study area. On the other hand, coppicing were practiced only in some households. Pollarding was predisposing of old branches done to reduce excessive shading of underneath crops or to reduce bird infestation at harvesting season. Lopping was done to allow the mother trees to grow taller without casting too much shade over the crops below. Looped or pollarded branches were used fuel wood consumption, dry fence or fodder in the household.

Species	Management practices				
	Lopping	pollarding	Pruning	protection	Coppicing
Acacia polyacantha	-	1	-	1	1
Acacia aska	-	-	2	2	-
Acacia etbaica	6	5	5	6	3
Acacia lahai	10	4	-	7	-
Acacia seyal	43	40	-	37	-
Adansonia digitata	4	-	3	-	2
Albizia gummifera	2	-	4	4	3
Croton macrostachyus	21	22	-	10	10
Cordia africana	30	30	27	21	-
Ehretia cymosa	8	8	7	6	6
Ekebergia capensis	-	-	6	4	4
Faiderbia albida	5	5	-	4	-
Olea africana	-	-	26	20	-
Schinu molle	9	-	4	7	-
Sterculia africana	10	4	10	8	-
Zizipus spina-christi	51	51	62	30	33
Total	199	170	156	167	62

Table 12: Management Practices Employed By Respondents For Parkland Woody Species At Kalu District

4.5.4. Selected Months for Management

The application of any management practices was based on the traditional knowledge of households. Farmers were perceived resultant effects of different types of management prescriptions. For instance application of pollarding and looping were for the need of enough light to associated crops and for fencing activities. Households were perceived mainly two tree management seasons. About 56% of the respondents were applying management practices on the months of April to June. About 14.2% of the respondents were employed management practices on October-December. But 29.7% were practiced on both seasons (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

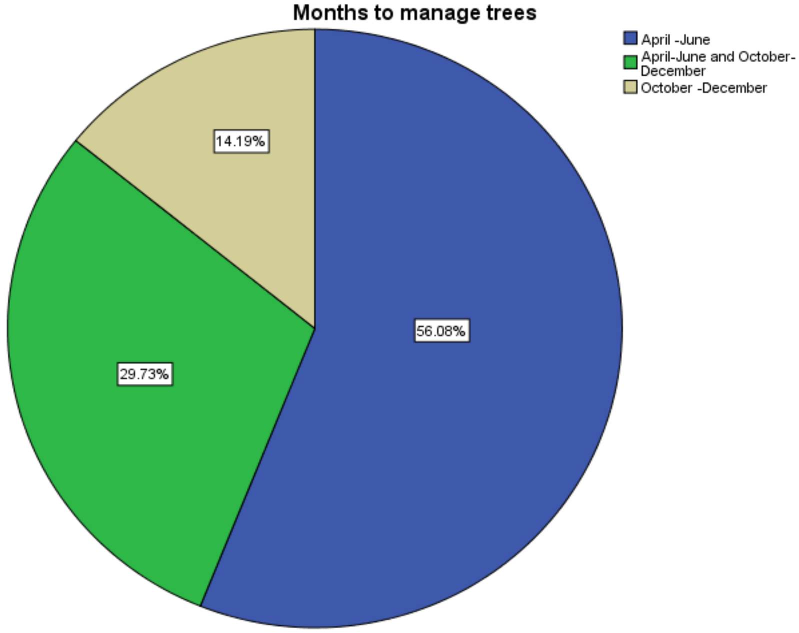

Figure 8: Selected Months For Farmers To Woody Species Management Practices In Their Farmlands At Kalu District

4.6. Socioeconomic Factors Associated to Woody Species Management in Parkland Agroforestry

Woody species management in PLAF can be influenced by many households' related socioeconomic characteristics. About five categorical and six continuous socioeconomic variables were used to assess the relation with PLAF management practices. Chi-square for categorical and independent t-test for continuous variables was employed to test relation of socioeconomic variables with parkland agroforestry woody species management. About five socioeconomic variables like sex, family size, farm size and wealth status was significantly (P<0.005) related to woody species management in PLAF but the other variables were not significant (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

Socioeconomic variables	*Chi-square* value	*t*-value	*p*-value
Sex of the HHH	0.001		0.001*
Age of the HHH		-0.44	0.657
Education status of HH	0.334		0.285
Family size		2.489	0.034*
Farm size		3.427	0.001*
Wealth status	0.019		0.030*
Number of livestock		0.294	0.769
Access to extension service	0.001		0.001*
Access to credit	-0.022		0.792
Distance to market		1.577	0.122
Distance to road		1.58	0.12

Note: * association is significant at p<0.005

Table 13: Socioeconomic Variables Associated to Woody Species Management in PLAF at Kalu District

*** Sex of the Household**

Out of 148 respondents, 86.5% and 13.5% are males and females respectively. About 119 (80.4%) of the households practiced woody species management and 20% were not managed woody species of parkland agroforestry. Among those who manage woody species, 109 (73.6%) were male and 10 (6.7%) were females. Among those who did not practice management of woody species, 6.7% were males and 12.8% were females (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). Sex had positive relation and highly statistically significant effect on woody species management (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

		Management of woody species	
Sex of household head		Yes	No
	Female	10	10
	Male	109	19
Total		119	29

Table 14: Sex of Sample Households

*** Family Size**

Family size in this study was considered number of individual person who resides in the households in permanently. The average family size of sample household was 5.31 people per household with standard error 0.167. The maximum family size was 11 and the minimum family size of sample household was 1. Family size was significant and positively related to woody species management of parkland agroforestry (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

	N	Mean	S.D	S.E	Min	Max
Family size	148	5.31	2.033	0.167	1	11
Farm size (ha)	148	0.56			0	2

Table 15: Family and Farm Sizes of Sample Households at Kalu District

*** Farm Size**

The average land holding size of the household was 0.56 ha. The maximum and minimum land size was 2 hectare and 0 hectare, respectively (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). Out of 148 respondents, three households have no farmland. More than 60% of the respondents had a farm size of 0.25-0.5 hectares Land holding size was positively related to management of woody species and there was highly statistically significant (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

Wealth Status

Wealth status will hypothesize influenced for woody species management in the area especially in farmland. About 80.4% of respondents were practice woody species in parkland agroforestry. Out of these, 25%, 29% and 26.4% were classified as poor, medium and rich, respectively. About 19.6% of respondents were not practice woody species management. Out of these respondents, 11.5%, 3.4% and 4.7% were poor, medium and rich, respectively (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).The percentage of poor households was comparatively higher compared to medium and rich households. Wealth status was significant and has positive relation with woody species management of parkland agroforestry (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

		Management of parkland agroforestry		
		Yes	No	Total
	Yes	83	10	93
Access to credit services	No	36	19	55
Total		119	29	148

Table 17: Household's Access To Extension Service Across Woody Species Management In Parkland Agroforestry Of Kalu District

4.7. Socioeconomic Determinants Influencing Woody Species Management In Parkland Agroforestry: Logistic Regression Results

Binary logistic regression model was used to assess the influence of explanatory variables on woody species management by symbolized 1 if households manage woody species and 0 if they were not applying management practices. The model includes 11 independent variables, 6 variables (family size, farm size, number of livestock, distance to market and road), were continuous and 5 of them (sex, age, wealth status, level of education, access to extension service and credit), were dummy variables. Of the 11 explanatory variables, only 3 variables (sex, farm size and access to extension serves) were found to be significant explained decision of farmers manage woody species in their parkland agroforestry (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

* Sex

This is a dummy variable with 1 for male and 2 otherwise. Female-headed households were less likely to manage woody species than male-headed households and the difference were statistically significance. The negative coefficient and Odds ratio showed that female-headed households 0.112 times less likely manage woody species than male-headed households. In other words, if other factors being held constant, the probability of household in favoring woody species management was decrease by a factor of 0.112 for female-headed households than male-headed households (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

* Farm Size

It was the strongest predictor implementation of woody species management next to access to extension service in this model having Odd ratio of 0.597. Farm size was significant explanatory variable and positively influencing the probability of households willing to manage woody species in parklands. The positive coefficient and odd ratio showed that, if other factors being held constant, the probability of households willing to woody species management practice increase with a factor of 0.597 for households holding large farm size than households holding small farm size (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

Access to extension service

Extension service was strongly significant with Beta coefficient 1.75 in this model with p-0.001 at 5% level of significance and positively association to woody species management. Households had access of extension service were more likely practice woody species management than those who had no accesses. If other variables being held to constant, the probability of households managing woody species increase with the factor of 0.175 for households access of extension service than who had no access extension services (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).

Independent Variables	B(Coefficient)	Significance	Exp(β) Odds ratio
Sex	-2.192	.001*	.112
Age	-.015	.434	1.015
Family size	.282	.051	.754
Wealth status	.095	.814	1.099
Farm size	.516	.038*	.597
Access to extension service	1.745	.001*	.175
Livestock	.040	.690	1.041
Access to credit	-.525	.435	1.691
Distant to market	.622	.067	.537
Distance to roads	.512	.018	.672
Level of education	.459	.406	1.583
Constant	3.518	.078	33.722

Note: Chi-Square= 43.837, R-model =0.523, * significant level at 5%

Table 18: Result of Binary Regression For Factors Affecting Parkland Agroforestry Management

4.8. Sustainability of Parkland Agroforestry

About 87.1% of the respondents were responded that woody species in parkland agroforestry were decrease through time, 4.7% were said to increase and the 8.1% were responded that there was no change (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). According to respondents the major reason for decline of woody species in parklands were increased fuel-wood demands, increase wood demand for timber and construction and land scarcity. Furthermore impact of dry season, charcoal selling, uncontrolled grazing and browsing were bottlenecks for increasing sustainability of PLAF.

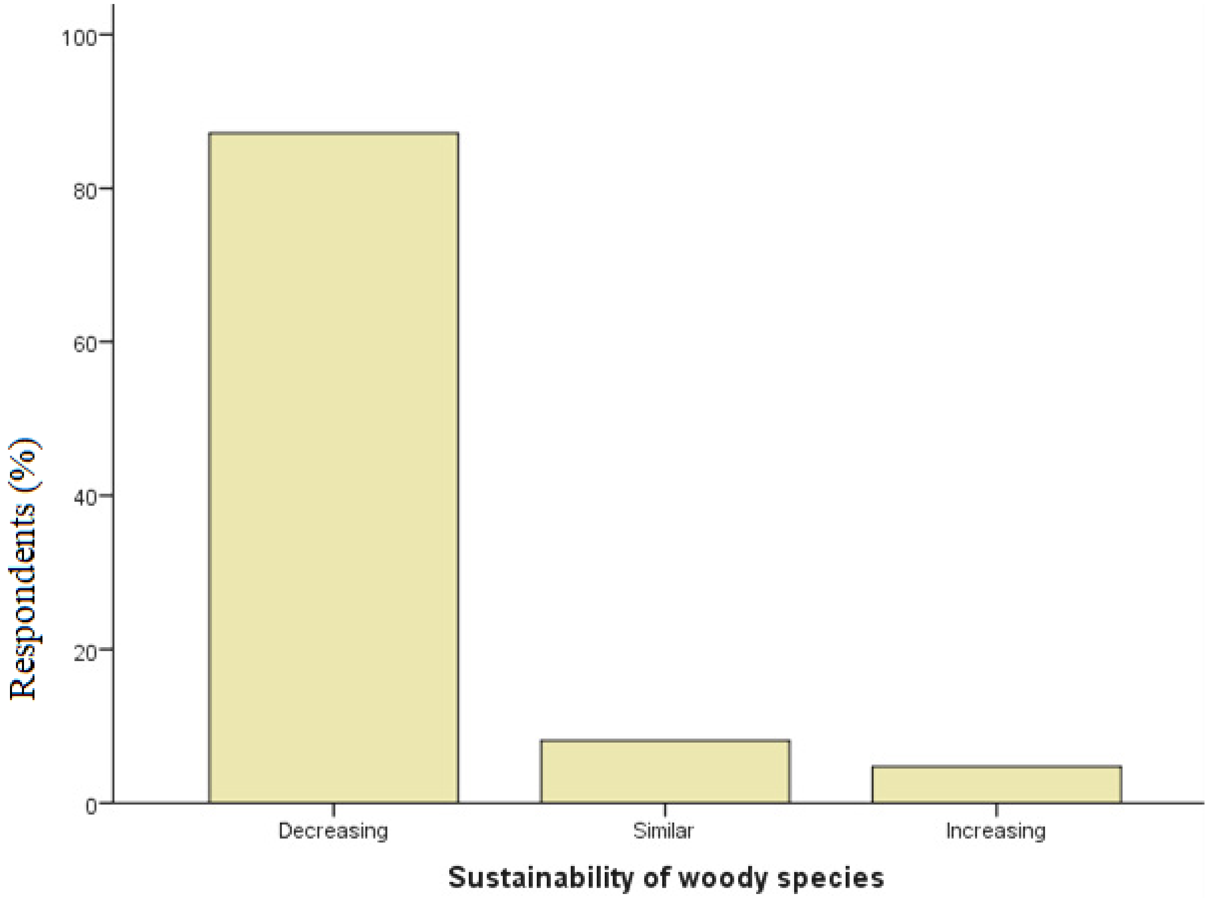

Figure 9: Sustainability of Woody Species In Parkland Agroforestry of Kalu District Respect To Respondents

5. Discussion

5.1. Woody Species Composition, Structure, Diversity and Similarity

Composition of woody species allows comparison of individual pants across each agro-ecology by describing ecological sites to evaluate the current condition. Based on this, about 21woody species were collected in both agro-ecologies of parkland agroforestry. Different species richness was studied in different areas of parkland agroforestry system. But, woody species richness of this study was relatively low compared to others. Twenty two woody species were collected from traditional parkland agroforestry of sub-humid lowland of Ethiopia, 27 woody species were recorded from parklands ofTembaro district, South Ethiopia and 55 woody species identified in Dellomenna district PLAF, Southeastern, Ethiopia [39].

All collected species were trees and indigenous in terms of habit and origin respectively (Table 3: Woody species with their respective families). It was in agreement with [40] parkland agroforestry mainly indigenous woody species retained and dispersed in crop lands. Selected tree species in farmers of northern Ethiopia are mostly indigenous species scattered in farmed areas, including leguminous trees and woody crops. However, 30% exotic species and 70% indigenous tree species were reported in farmland tree species of East shewa [41].

The total basal area of woody species in lowland was higher than midland PLAF. The reason would be unlike density of woody species, basal area is a function of size of a woody species stems than simple stem counting. Hence, a majority of woody species in lowland PLAF may have large girths or stem sizes than midland PLAF i.e. retained for many years without cutting. The basal area of woody species was seemed to lower compared to previous studies was found 1.10 m2/ha in South Burkina Faso parklands; was reported 2.2 m2/ha in East Shewa farmlands.

The overall mean number of trees in Kalu district of parkland agroforestry was 4.54 ± 0.34 and 9.17 ± 0.75 per plot and per hectare respectively (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). It indicated that there were a high number of trees per hectare recorded in lowland PLAF than midland PLAF. In other PLAF studies such as reported 19 trees per hectare in Semi-arid of East Shewa on crop land and about 0.3 to 8 trees per hectare in farmlands of Dera wereda. Also reported that mean number of species per quadrate is 4.05 in West Africa PLAFs. Densities of woody species were relatively low in the study area. In agreement with density decrease with increasing distance from the resident area. Trees would be grown in a scattered form over a crop field, usually between 1-20 trees per hectare to minimize impact on the companion crop [27,42].

Inverted J-shape of diameter classes explored in parkland agroforestry of both agro-ecologies. The reason would be due to sprouts coppiced from old tress and regenerating of species in cultivated land especially at summer season. A majority of these larger and small trees represented by Acacia seyal and Ziziphus spina-christi species. The shape of height class distribution of both agro-ecologies of parkland agroforestry resembles near to bell shape. Low height distribution in large height classes can be due to frequent looping, pollarding and pruning of species, and it is common practice in parkland agroforestry. But low height distribution in lower height classes may be for the reason of small tree species naturally regenerating in farmlands.

The value of Shannon, Simpson evenness and true diversity indices of lowland parkland agroforestry were higher compared to midland parkland agroforestry. In other ways, lowland agro-ecology had higher number of woody species abundance than midland parkland agroforestry. More number of trees and high basal area of woody species in lowland PLAF leads to more diverse than midland PLAF. It was confirmed studied woody species diversity and structure in Gindebert, Oromia regional state [43]. In addition, the true diversity (effective number of species) in lowland and midland parkland agroforestry was 6.17 and 4.95, respectively (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). From this, we can possible be concluded lowland parkland agroforestry was more diverse than midland parkland agroforestry. In other words, there was high species richness in lowland parkland agroforestry compared to midland parkland agroforestry. The variation could be site characteristics, altitudinal variation, management practices and other socioeconomic factors [44]. Tree species differ depending on their agro-ecological suitability such as rainfall, altitude, and soil and natural distribution patterns.

The values of mean Shannon and Simpson's indices, and evenness in PLAF of Kalu district were 1.71, 0.76 and 0.36, respectively Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). The results were relatively low compared to other several related studies. Reported that the values 0.82, 0.46 and 0.81 are Shannon index, Simpson index and evenness, respectively in species diversity of parkland agroforestry in Northern Ethiopia. Also reported the Shannon diversity index and evenness as 1.05 and 0.78, respectively in parkland agroforestry at South Burkina Faso. Species diversity in farmland agroforestry is relatively low compared to home garden agroforestry due to species frequently prune and lopped or damage with livestock.

Similarity of species composition in this study was 47.6 percent (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district). High similarity could be the likeness of species in two agro-ecologies. In other ways tree species which are dominant in midland PLAF also dominant in lowland PLAF. Acaicia polyacantha and Albizia gummifera in midland PLAF, Adansonia digitata and Acacia aska in lowland PLAF were needing special attention and appropriate conservation or management at the district. Since species with lower IVI need high conservation efforts whereas those with higher IVI require wise management [45].

5.2. Purpose of Woody Species Retaining and Management Practices in Parkland Agroforestry

Farmers at Kalu district grow and retained woody species depend on different function simultaneously, N-fixing, low crown density, quick return, used for farm tools and utensils. Households prefer tree species which have diverse functions and compatible for their crops. Consistently parkland trees have the characteristics of deep rooting, preferably reaching ground water table, capacity to fix nitrogen produce litter that decomposes well and add as much as possible to soil organic.

A range of ecological benefits and services can be supplied by parkland agroforestry at the district, species such as microclimate amelioration, soil conservation. Provision of fuel woods, food and fodder. Most woody species were used more than one purpose for the household. For instance, more than 11 months in the year of fuel wood demand cover by PLAF in dry lands of Tigray [46]. Other use types at Kalu include Beehive making, beehive suspending and bee forage, for crop harvesting activates specially branches were used to pilling the crop harvest, brushing and cleaning crop threshing sites. It is in agreement to the report. Scattered native trees are great role prevention of soil erosion in cultivated lands. Parklands create additional income diversification and food the time when crop harvesting is low in extreme conditions. Parkland agroforestry system also attains biodiversity conservation by providing supplementary habitat with low disturbance.

Local farmers perceived provisioning, regulating and supporting services of trees in their cultivated fields. Zizipus spina-christi and Acasia seyal were dominant tree species in both agro-ecologies of PLAF. However, Cordia africana and Ficus sycomorus are the most common species in farm land agroforestry of Dera wereda, and Faidherbia albidia is the dominant parkland trees in Tigray region (Hagos, 2020). Households were incorporated Zizipus spina-christi and Acasia seyal tree species to crops in their farm for different purposes. The leaves of Ziziphus spina-christi were potential nutrition supplement to indigenous goats, lactating caws and beef cattle due to high digestibility and nutritional composition of Ca, P, Mg, K and Na [47].The matured Ziziphus spina-christi species maintained higher soil seed bank composition inside their canopies and the seeds can germinate easily [48]. Coppicing ability was also better and fast by producing more sprouts after cutting. Zizipus spina-christi trees improve physical (bulk density and moisture status) and chemical properties of soil [49]. The fruits were source of income for farmers. Moreover, the species were relevant for farm and construction tools, fuel wood or charcoal production and traditional medicine. Acacia seyal were also one of the dominant PLAF species and farmers grow on their farm for its fuelwood or cash income. It shows positive significant to available nitrogen and increase the grain yield of integrated tef crops for the reason of improves soil moisture content and bulk density of the soil [50,51].

On the other hand, according to key informants, households who had not retained tree species on their crop land were fulfill their wood demand from their own grazing lands, woodlots and shrubs/trees found in other alternative lands. In other ways they are reluctant to incorporate perennial trees to their annual crops in different forms. Farmers have indigenous knowledge for management of trees. More than 80 % of sample households were manage woody species retained on their farm land in different ways to reduce competition on crops and other purposes like woody products, dry fence and forages for their livestock. Trees are vital on farming systems, especially in tropics purposely retained by local farmers if they are not obstruct with crops. The dominant incorporated trees were naturally having dispersed or light crown cover in Kalu district allows light and aeration for underneath crops. However, households were selected management practice is mainly to minimize component interaction and enhance whole function of the system per land management unit. In the district, looping, pollarding, pruning, protection and coppicing were common practices in PLAF. Lopping is management practices by which only tip of branches from the crown of trees may be liberated and is used to reduce the shading effect of branches on annual crops and to get fodder. Households lop the trees atleast once every two years to minimize shading to agricultural crops grown underneath and initiate the growth of sprouts from meristematic tissues. Pollarding attributed to the need of light by the associated crops in parklands where mostly shade tolerant species integrated. In the present study the practices undertake mainly for Acacia seyal followed by Ziziphus spina-christi species mainly in onset of rainy season. They Pollarded at intervals of 3-4 years which were cutting of the whole canopies leaving the trees completely bare. Pruning of woody species also performed in summer but especially at crop harvesting season mainly for fodder, and for dry fences of harvested crops and crop residues. Farmers apply no thinning and less coppicing in composition of parkland agroforestry. But field observation and focus group discussion revealed some woody plants found in farm fields observed died due to poor management techniques, for instance inappropriate lopping and pollarding, and farming activities. Management of trees in parkland agroforestry is not sufficient and well doing in PLAFs.

According to the respondents, the purposes of managing woody species in their parkland were to increase growth, minimize shading effect on crops, and use for various purposes including fuel wood, fencing, fodder, construction materials, soil improvement and the like. In agreement tree management practices were carried out to increase the function of trees now and the future, and interdependent of the target or objective of households. Important tree branches or leaves of species incorporated in cultivated lands should be reduced before onset of rain for enhance crop production and soil fertility. Similarly, at Kalu district households who were practiced management activities on April-June were for the purpose of reduce light competition on their crops, dry fence and relatively for fuel wood consumption. In addition, tree components have gotten better favorable condition to release new branches and leaves in the rainy season. It is consistent to the report of in Gedeo,s agroforestry. Households who were practiced management activities on October-December were mainly for protection of crops from bird attacking and dry fence for crops, crop residues or fruits eg.Catha edulis. Households were protected woody species on their cultivated lands from damaged with livestock (goats, cattle, camel) and pests. The study was confirmed to protection and assisted regeneration was known management practice applied in parkland agroforestry of sub-humid lowlands of Ethiopia.

5.3. Socioeconomic Factors Affecting Woody Species Management in Parkland Agroforestry

To quantify the factors influencing farmers' management of woody species or not, a binary logistic regression model was adopted. Logistic regression analysis is a well-established approach in empirical studies focused on finding the determinants and decision in agroforestry, technology adoption and tree planting. Only three explanatory variables were affected woody species management in this model.

5.3.1. Sex of the Household

The direction of influence of sex variable for woody species management was predicted to be indeterminate. That means it may affect woody species management positively or negatively. However, it was found to be negatively affected in the present study. The negative sign in coefficient of binary logistic regression model showed that female-headed households were low participation in woody management than male-headed households (Figure 3: Diameter class frequency distribution of woody species in midland parkland agroforestry of Kalu district).This is because in most rural area of Ethiopia women are less likely to participate in farm activities and decision making than men [52]. In addition, women were marginalized from contract of their farm lands due to widowed or divorced, less participate in management activities of woody species; since agroforestry practice by its nature are labor intensive activities.

5.3.2. Farm Size

Landholding (farm size) is a continuous variable measured in hectares. Large land sizes allow farmers to diversify their income and help incorporate trees for numerous purposes with different management techniques. Woody species abundance and richness increase as farm size increase, because the number of woody species requires sufficient land and farmers with more land size are favored for diversifying woody species. According to binary logistic regression model, farm size were strong factor influencing woody species management activity in PLAF practices. Farmers who owned large farm sizes practice woody species management than who owned less farm sizes. On the other hand, farm size has significant positive relationship with number of trees and basal area of farmlands (small farms has fewer trees than large farms).

5.2.3. Access to Extension Service

Forestry extension programs including training are accountable for promoting the management of agroforestry by providing technical advice and inputs such as improved seedlings. People had participated in different agroforestry training are planting more trees than who do not participate i.e., training increase the level of knowledge for local people for component interaction, management and importance of woody species. About 53 % of the households were attained training programme related to crop and livestock production but less emphasis about parkland tree species management. Formal and informal extension service is relevant for farmers to understand the merits of trees incorporating in their fields and diverse benefits in different dimensions. Moreover extension service is an important factor that influenced woody species richness. According to group discussion households attended extension service atleast once a year associated to agricultural practices. However, Poor extension service and low level of awareness of farmers are main constraints affecting households to improve parkland agroforestry practices.

5.4. Constraints for Woody Species Management and Sustainability in Parkland Agroforestry

According to group discussion and respondents the coverage of woody species in parkland agroforestry were reduced in the last two decades especially in midland parklands. The reason could be tenure insecurity, population density or low extension services regarding to parkland agroforestry. Low woody species diversity in midland might be due to road and market accessibility than lowlands. In recent years households planted exotic tree species and fruits around their home rather retained indigenous species on farm areas. This is in line with findings. Other reason would be poor regeneration management of parklands [53]. Group discussion revealed that woody species in the study area were facing different problems. Among the constraints, land shortage, drought, free grazing, absence of planting activity and high charcoal demands were the most challenging problems. Land scarcity leads households to give more attention for crop production (mono-crops) rather incorporated trees on their farm. Farmers were also felling parkland trees for charcoal production without replacing them. The result in agreement. Free grazing, shortage of farm land, wood and charcoal selling, lack of awareness and government focus are major constraints to improve parkland agroforestry. According to the respondents, more than 97% of parkland trees were either naturally regenerated or retain during conversion of trees to cultivated lands. In other words deliberate regenerating and planting of woody species were not encouraged in the study area.

There was a belief in some farmers that crops cannot grow well in the shade of nearby trees and could affect farming activities, so trees would often be cleared from cropland. They assumed that trees affect annual crops by creating shading and are created good environment for bird attacking on crops. In agreement with farmers perceived that parkland trees are incompatible with agronomic activity also stated that retaining and planting of parkland species is discouraged due to population growth, farmer's own perception, land degradation and small farm size in n poor regeneration management. But crops may be influenced with competition and shading effect of trees if appropriate intervention and management practices were not adopted.

6. Conclusion

Agroforestry parklands are a rational land used system developed by farmers to diversify production for income generation. Assessing ecological significance of parkland agroforestry practices and management practices is relevant for sustainable improvements. The result of the present study was identified 21 woody species belonging to 8 families in two agro-ecologies parkland agroforestry of Kalu district. Woody species found on farmland scattered without any specific pattern at each agro-ecology. Woody species inventory at parklands of Kalu district was provided information on existing situation of species richness, diversity, evenness, population structure, density and important value index. Ecological study of woody species vegetation structure, richness and diversity is very necessary for information to design a conservation strategy in the future. The difference was existed in species densities and basal area between two agro-ecologies. Hence, lowland parkland agroforestry supports high species diversity than midland parkland agroforestry. Zizipus spina christi and Acacia seyal were the leading tree species in both agro-ecologies. However, Acaicia polyacantha, Albizia gummifera, Adansonia digitata and Acacia aska were need proper conservation and management at the district.

Farmers in the study area were retained and manage woody species for their socioeconomic and ecological benefits like woody products soil conservation, house construction and the like. In addition, they provide favorable microclimate condition through shading and buffer in extreme environmental conditions. Biodiversity especially native tree species are conserved in agricultural landscapes by adopting biodiversity-friendly practices. Households perceived different PLAF management practices depend on their needs and objectives. Looping, pollarding, pruning, protection and coppicing were common management practices. The most common management seasons they were adopted were April-June and October-December. The purposes of managing woody species in their parkland were to increase growth, minimize shading effect on crops, and use for various purposes. Socioeconomic factors like sex, farm size and access to extension services were influence management of woody species. Woody species diversities were seemed to decrease at the district. Small land size, drought, free grazing, absence of tree planting and charcoal production were common constraints to improve PLAF in the study area.

7. Recommendation

Household, especially give more attention for cash crops rather than scattered tree species which were incorporated to their cultivated lands. Observation indicated that woody species are frequently damaged and of poor quality due to frequent lopping, browsing or pollarding and pruning. For instance they lop and pollard trees with local axe without giving much attention to where and how to cut the branches. Extension services related to PLAFs were less compared to deliver to crop and livestock production. In addition, the current legal frame work does not provide sufficient incentives and appreciation for farmers to retain and sustainable management of indigenous trees on their farms. Here of in order to sustainable parkland trees, regular allowable management practices (appropriate silvicultural techniques, regeneration and genetic improvement), the effective enforcement of extension agents and harvesting of tree products ensures replacing the cut one and ownership exclusion rights would be necessary.

Moreover, the economic benefits of parkland trees are relatively low compared to other products for instance horticultural crops. In order to maintain farmland agroforestry in sustainable manner it should be important to increase the benefits of smallholder farmers derive from this practice by producing the environmental services and products. In general, it needs to be scale up parkland agroforestry because it is option for reduce deforestation and degradation of natural forest and promotes Green Legacy of the country. This would be successful when governmental institutions, decision-makers and other stakeholders typically face with regard to Parkland trees conservation and agricultural intensification and development objectives [54-59].

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