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Influences of Tree Species and Canopy Cover on Aboveground Biomass Yield and Ground Cover of Herbaceous Plants in Eastern Oromia, Ethiopia

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Abstract: The study was conducted at Keramile protected open forest of Goro-gutu district, Eastern Ethiopia, with the objective to examine the effects of tree species on the above ground aboveground biomass yield and ground cover of the herbaceous plants. Three tree species, Podocarpus falcatus and Juniperus procera from indigenous and Cupressus lusitanica from exotic tree species were used. Twenty large trees from each tree species, a total of 60 trees were selected purposively and 480 samples (four quadrats under and outside canopy in four directions for each tree) of herbaceous plants were collected. The results of the current study showed that tree species, canopy cover and their interactions had significant ($P<0.05$) influence on herbaceous plant above ground aboveground biomass yield and ground cover. The herbaceous plants differed in terms of above ground aboveground biomass yield and ground cover between the three tree species and canopy types. The herbaceous plant above ground aboveground biomass yield and ground cover were significantly ($P<0.05$) higher under P. falcatus than to J. procera and C. lusitanica trees, while no significant differences were ($P>0.05$) found between J. procera and C. lusitanica trees. The above ground aboveground biomass yield and ground cover obtained outside canopy was significantly higher than under canopy cover of the three tree species examined. The overall result showed that tree canopy cover strongly decreased aboveground biomass yield ($P<0.0001$) and ground cover ($P<0.0001$) of the herbaceous plants. The increased above ground aboveground biomass yield and ground cover of herbaceous plants in the outside canopies in the current study indicates that the presence of these tree species in the study area could increase the vulnerability of the herbaceous plant community to future disturbances, such as climate events. Generally, tree species, canopy cover and their interaction had negative impact on ground cover and aboveground biomass yield of herbaceous plant, in Keramile protected open forest, Goro-gutu district, eastern Ethiopia. Therefore, integrated forest and herbaceous plant management and conservation is crucial in Keramile protected open forest, Goro-gutu district, eastern Ethiopia and areas receiving similar practice.

Keywords: Tree Species, Outside Canopy, Inside Canopy, Aboveground Aboveground Biomass Yield, Ground Cover

1. Introduction

The demands and perceptions on open grassland ecosystem services vary among stakeholders [20], and geographical regions [2]. The herbaceous plants in grasslands have been traditionally sources of medicinal plants and other medicinal resources [15] and they performs an important function in decreasing the amount of gas causing the greenhouse effect in the atmosphere and in the solution of ecological problems in the global context. Thus contribute to the reduction of the amount of the main gas causing the greenhouse effect and can sequester relatively large amounts of carbon [26]. The grasslands herbaceous plant also reduces runoff extremes by maintaining sufficient recharge of groundwater and by increasing landscape water holding capacity. It is noteworthy that a natural mechanism of flood regulation is one of important ecological functions which are performed by herbaceous plant. They regulate the timing and magnitude of water runoff, flooding, and aquifer recharge, particularly in terms of the water storage potential of the ecosystem [15].

Herbaceous plants in open areas provide an important habitat for several wild pollinator species. Decline of natural pollination diversity and intensity can be reflected by decreasing yields of agricultural crops, as was documented [17]. The open area covered with the herbaceous plant as a component of agricultural landscape play a role in aesthetic enjoyment of landscape and social cohesion of rural areas [15] and in areas attractive to tourists may be used for recreational purposes as areas of high natural absorbance [23, 32].

Tree canopies alter the abiotic environment for understory plant directly by affecting light availability, temperature, humidity, etc. and indirectly by influencing soil processes [36]. Canopy alters micro environmental conditions in terms of reduced air and soil temperature, wind speed and irradiation, resulting in decreased soil evaporation and increased relative humidity [29]. The interception of solar radiation is a major factor affecting the understory [13]. Canopy is the key regulator of solar radiation absorption and can prevent over 95% of light radiation from reaching the Earth's surface [16]. Plants under the tree canopy are benefitted by increased organic matter and moisture in the soil, wind protection, reduced air, and soil temperature, reduced daily oscillations of temperature, increased humidity, lower water vapor deficit and reduced transpiration [19, 36]. However, the negative effects of tree canopy also exist, such as reduced light availability for photosynthesis, tree root competition for water and soil nutrients, allelopathic effects of trees, increased phytophagous fungi and pests and rainfall interception [36]. The effects of trees on the associated understory herbaceous productivity vary with the environment or the climatic conditions [18]. Different herbaceous plant species will respond differently to different types of tree canopies; therefore, results of study from one area with specific tree species cannot be extrapolated to other areas with different trees and herbaceous plant species composition.

People and ecosystems are two independent entities, the human interventions always affect the functions of the ecosystems and consequently the services and benefits derived. The human interventions especially when trade-offs in the improved human development are at the expense of severe damages to ecosystems. In particular, cases mentioned are ecosystem level losses of biodiversity [8], depletion of water resources, increased carbon dioxide emissions and reduced ecosystem resilience [25]. The decline in plant cover with grassland afforestation has been attributed to several factors, including the exclusion of shade-intolerant native species by increasing plantation canopy over, allelopathy, and the physical barrier of litter (particularly pine litter) or slash to germination [6].

Changes in land use have caused drastic fragmentation of the landscape, affecting ecosystem functions [12]. Tree plantation establishment for rehabilitation of deforested or degraded areas in some parts of the country has up to now have been moderately unsuccessful. The major reason for the failure might be due to lack of incentives, compensation for protection and maintenance of the planted areas, lack of attention to the local conditions, conflict and lower soil fertility. These factors enforce the expansion of tree plantation in protected areas of open forests, where herbaceous plant productivity and survival rate for tree plantation has been estimated to be high. This shows that conservation strategies almost exclusively focus on forests conservation. These processes might be driven by unbalanced overall agricultural and policy support; which highlights the problem when decision making in one sector does not consider the implications for other sectors. In this case, the absence of combined effect and inadequate management has been degraded the capacity of herbaceous plants to supply ecosystem service.

Human population is projected to increase from the current 7 billion people, to 10 billion people by 2050 [35]. This population growth, translated into an increasing global food demand, strongly threats natural areas worldwide; particularly grasslands with those strong potential for agricultural expansion [21]. However, conservation policies have focused on the threats exerted to forests, at the extreme of neglecting natural grasslands as a specific and fundamental conservation target [11]. In addition, these policies may even result in increased pressure over non forested landscapes, such as natural grasslands [24]. Therefore, the productivity of herbaceous plants may thus be further threatened by forest centered policies. This suggests that lack of integrated forest and herbaceous plant/ grassland management would pose a serious challenge for grassland conservation and management in Eastern Ethiopia. Therefore, future threats to grasslands appear high; a serious challenge to both wild and domestic herbivores, thus threatening a need to feed a rapidly growing human population. Thus, proper management and conservation of herbaceous plant is very crucial under the rapidly growing human population, changing climate and global warming.

Studies from eastern Oromia, Ethiopia in semi-arid areas, where water scarcity is the major problem, have shown the beneficial effects of trees on under story herbaceous plants [34]. However, no information or data is available on the influence of tree species on herbaceous plants aboveground biomass yield and ground cover at high altitudes areas of eastern Oromia, Ethiopia. Therefore, the study evaluated the influences of the dominant tree species of the study area; *Podocarpus falcatus, Juniperus procera* and *Cupressus lusitanica;* on aboveground biomass yield and ground cover of the herbaceous plants in high altitude Keramile open forest ecosystem of Goro-gutu districts, eastern Oromia.

2. Material and Methods

2.1. Description of the Study Area

The study was conducted at Keramile protected open forest in Goro-Gutu district. Goro-gutu district is found in eastern highlands of Ethiopia, Eastern Hararghe Zone of the Oromia National Regional State. It is 408 km from Addis Ababa at 9°35'N, 38°18'E; on the main road to Harar and it is located 107 km from the Zonal capital Harar. The agro-ecological classification of the Goro-Gutu district indicated that 28% of the total area is classified as mid-land "woina-dega", 49% as lowland "kola" and 23% as highland "dega". The land use pattern within the district shows that 43% of the total area is arable land; 2.3% pasture and 19.95% is forest and bush land, 34.8% degraded and settlement areas. The district is characterized by mountain, plateau, dissected gullies and degraded hills. It has bimodal rainfall patterns. The annual average rain fall is 900mm with the corresponding temperature range of 16-20°C and 20-24°C during the coldest and warmest months respectively.

The district is characterized by open forest which is made up of trees or shrubs and dominated with grass species. The plant description presented by East Hararghe Planning and Economic development shows that the Keramile protected open forest is characterized by Dry Evergreen Montane Forest and Grassland Complex on the basis that the plant type occurring in an altitudinal range of 2000 - 2300 m, with average annual temperature and rainfall of 16-24°C and 800-1200 mm, respectively.

The ridge harbors a wide variety of trees, shrubs, and herb species. Amongst the most common trees are *Juniperus procera, Cupressus lusitanica, Podocarpus falcatus, croton macrostachyus, cordia Africana, ficus sycomorus, hagenia abyssinica, olea europaea, acacia abyssinica, acacia decurrens, acacia saligna, eulcalyptus globules, psidium guajava, schinus molle, gravillea robusta* and *casuarinas cunninghamiana*. The whole area is dominated by *Juniperus procera, Cupressus lusitanica* and *Podocarpus falcatus*. The area is well known by its native plant and plantations of exotic tree species.

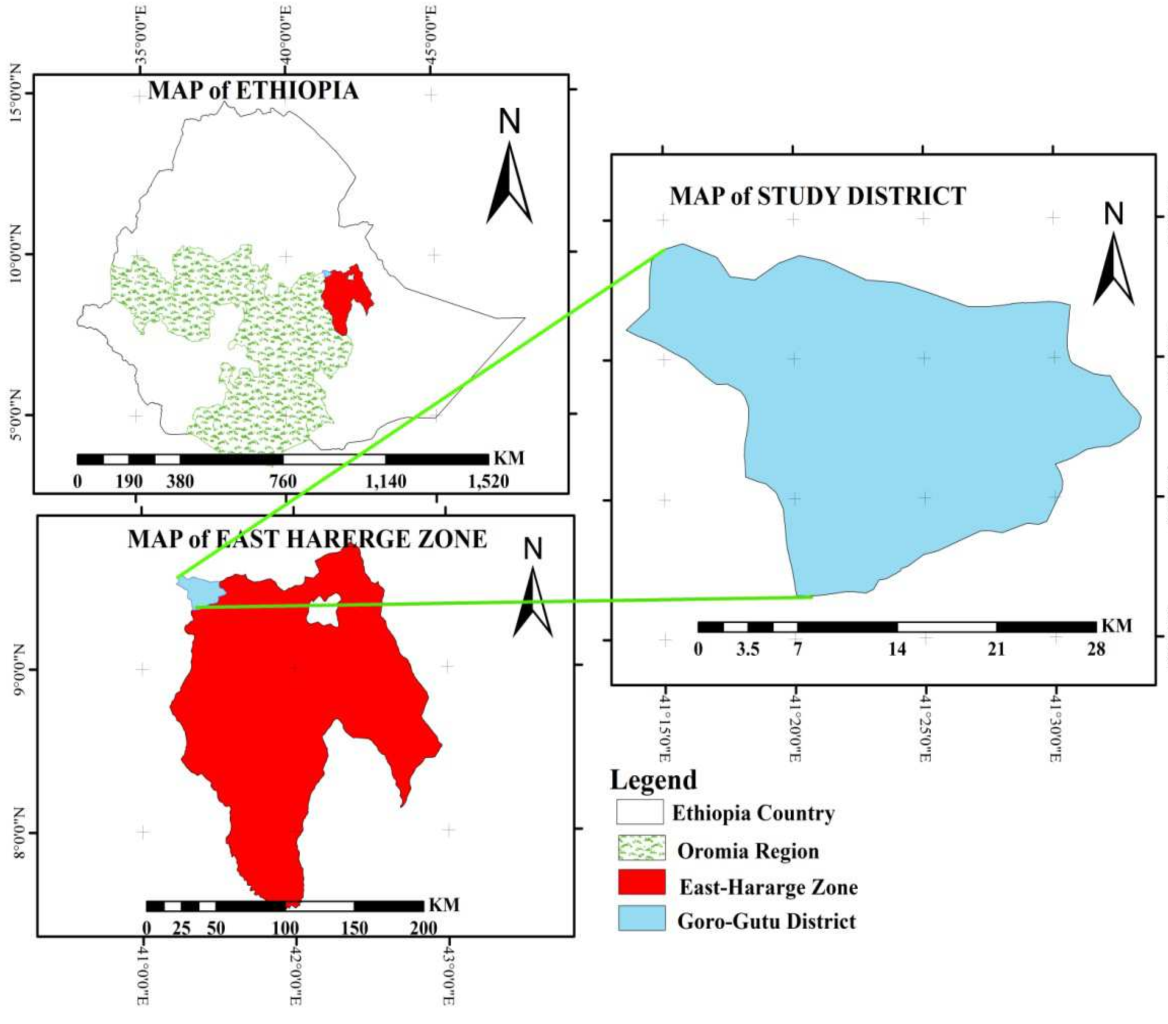

Figure 1. *Location of the study area, Goro-Gutu district, eastern Ethiopia.*

2.2. Selection of Sampling Sites

Based on visual field observation three dominant tree species, representing one exotic (*Cupressus lusitanica*) and two indigenous (*Podocarpus falcatus* and *Juniperus procera*), found in isolation, were selected for this study. The species used in this study are representative of the dominant trees in the study area. Based on their canopy sizes and tree heights, compared to other woody species, they represent suitable species for a purposive study of the effects of tree species on herbaceous plants. Accordingly, 20 matured trees, from each species, were purposively selected based on their similar canopy size and tree height. In total, 60 trees (3 tree species x 20 trees for each species) were selected for this study.

Tree height was measured using clinometers. The canopy cover of the trees was measured by using the measuring tape on ground level through the canopy length and then canopy area was calculated by using perpendicular diameters in two dimensions at right angle according to Savadogo and Elfving [31],

$$CA=CD_1XCD_2 \text{ X } \frac{\pi}{4}$$

Where:

CA= Canopy/crown area

CD_1 and CD_2 = Canopy diameters in two dimensions at right angle

Table 1. *Heights and crown diameters of the three tree species used in the study (mean±SE).*

Tree species	Height (m)	Crown diameter (m)
P. falcatus	33.00±0.96	5.03±0.08
J. procera	26.00±0.96	5.20±0.08
C. lusitanica	29.67±0.96	5.40±0.08

2.3. Sampling of Herbaceous Plant Aboveground Aboveground Biomass Yield and Ground Cover

Under each selected individual tree, the herbaceous plant aboveground biomass and ground cover were measured using $1m^2$ quadrat (under inside and outside canopies of individual trees) (Figure 2) in September-October 2018, during the flowering stage of most herbaceous species. Four quadrats in four directions (north, south, east and west) [34] were used under the inside and outside canopy of each individual tree, yielding 480 samples (3 tree species x 20 trees/species x 2 canopy cover x 4 directions as sample quadrats).

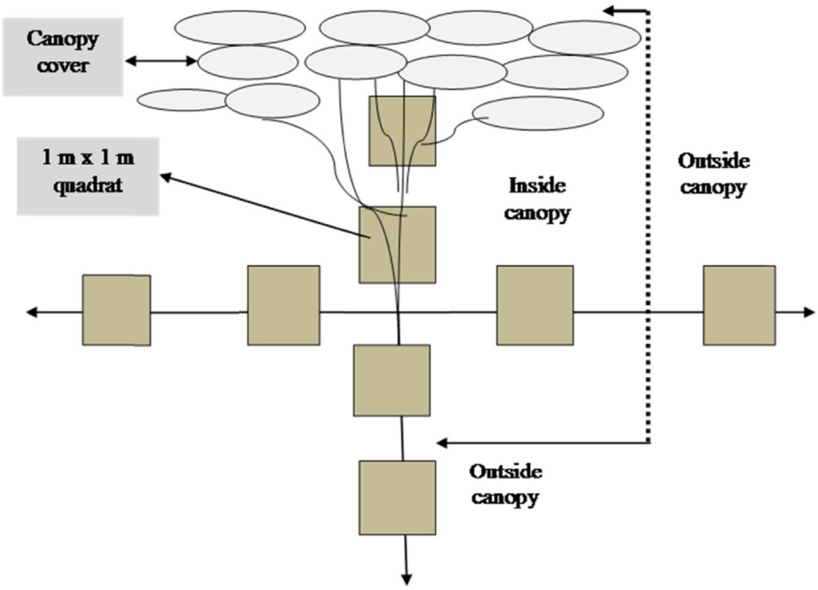

Figure 2. *Sampling design for herbaceous plant data collection under and outside tree canopies at Keramile open forest, Goro-gutu district [34].*

All herbaceous samples, grasses and non-grasses, were clipped at ground level and then placed in a plastic bag separately for dry matter (DM) analysis. The destructive method was used to estimate herbaceous aboveground biomass yield. In each of the quadrat, the herbaceous plant was harvested at the ground level using hand shears to assess the dry matter aboveground biomass. Then, the fresh cut samples were weighed using a simple balance immediately. Samples were oven dried at 65°C for 24 h and then weighed until the sample achieved constant weight. The percentage of ground cover of herbaceous plant in each 1 m^2 quadrat was estimated visually before clipping. Accordingly, a 1 m^2 quadrat was divided into eight equal parts and all ground covers of herbaceous plant in the selected 1 m^2 were transferred to one of the eighths in order to facilitate visual estimation [3]. Cover data was obtained by individual plant species and these data was summed to obtain total ground plant cover in each quadrat. The estimation of ground cover recorded for each quadrat to compare the ground cover of herbaceous plant under each tree and open areas.

Data Analysis

The herbaceous plant data from all quadrats were combined by tree species separately to it's under canopy and outside canopy. The data obtained from the herbaceous plant were subjected to two ways ANOVA (Analysis of Variance) in the factorial experiment, with tree species as one factor and canopy type as the other factor. All statistical analyses were performed using SAS software [30] by the General Linear Models (GLM) procedure. Before performing ANOVA, the data were log-transformed to increase normality. The model included the effects of tree species, canopy cover and their interaction as independent factor.

Mean separations were tested using the least significance difference (LSD) and significant levels considered at P<0.05. The statistical model used for this study was:

$$Y_{ij} = \mu + T_i + C_j + CT_{ij} + e_{ij}$$

Where: - Y_{ij} = over all observation
μ = over all mean
T_i = tree species effect
C_j = canopy effect
CT_{ij} = interaction effect
e_{ij} = error effect

3. Results and Discussions

3.1. The Effect of Tree Species and Canopy Cover on Herbaceous Plant Above Ground Aboveground Biomass Yield

Tree species had a significant (P <0.01) effected on aboveground biomass yield of herbaceous plant, as the as the highest aboveground biomass yield of herbaceous plant was obtained under *P. falcatus* than under *J. procera* and C. *lusitanica* canopies. Under the canopy of *P. falcatus,* it was 1.68 t/ha, under the canopy of *J. procera* 0.66 t/ha, while under the canopy of C. *lusitanica* it was 0.50 t/ha. The highest aboveground biomass yield under canopy was recorded by *P. falcatus.* This might be associated with the difference in soil nutrient availability, litter quality and light intensity under the tree species. Canopies can vary greatly within forests. Different trees intercept different amounts of light and canopies are almost invariably broken by gaps that yield microsites in the understory with much elevated resource levels. The closed/dense canopy cover of *J. procera* and *C. lusitanica* allowed less light to reach the lower ground when compared with *P. falcatus*. As a result, the presence of many shade-intolerant species decreased, by which herbaceous aboveground biomass yield was reduced. The tree species might be also vary greatly in the chemical and physical characteristics of the litter they produce, which influences soil properties and results in complex patterns of variations in soil under the tree species. The improved soil fertility status under this tree may lead to the higher aboveground biomass production of herbaceous plant than the other tree species. Lara Van Meter, [22] reported that *C. lusitanica* have low nutrient contents and this may contribute to the lack of understory plant. However, dry aboveground biomass of herbs was not significantly different between *J. procera* and *C. lusitanica* tress.

The aboveground biomass yield of herbaceous plant was also strongly (P <0.0001) influenced by the canopy cover in the current study, indicating that a higher amount of herbaceous aboveground biomass was recorded outside canopy than under canopy (table 1). The average total aboveground biomass yield of herbaceous plants outside canopy was 2.43 t/ha, while in the inside canopy area it was 0.95 t/ha. In the under canopy area, the total aboveground biomass was significantly lower. The lower aboveground biomass yield of herbaceous plant under canopy area can be associated with a reduction in light availability and rainfall under the tree canopies. It means that the shading effect of canopy cover suppressed the growth of herbaceous plants not tolerant to shade and eventually they it might be die. Seedling might be difficult for herbaceous plant adapted to the open areas because of light levels, thick layers and burial by debris falling from the canopy. The very low level of light provides little energy for plant growth. Tree canopies alter the abiotic environment for understory plant directly by affecting light availability, temperature, humidity and indirectly influencing soil processes [36]. Different studies have reported that the growth of understory herbaceous plants increases when root competitions from trees are removed. The negative effects of tree canopy, such as reduced light availability for photosynthesis, tree root competition for water and soil nutrients, allelopathic effects of trees, increased fungi and pests diseases and rainfall interception also reported by Valladares *et al.,* [36]. Ishii et al [16] also reported that canopy is the key of solar radiation absorption and can prevent over 95% of light radiation from reaching the Earth’s surface.

Water and nutrients might be the limiting factors for understory herbaceous plants. Canopy trees use large amounts of water and nutrients. And also they have access to the energy to support high root growth and build large root systems, allowing them to obtain below ground resources effectively when compared with herbaceous plants. Similarly, Hewitt *et al.,* [14] reported that grassland afforestation decrease in aboveground aboveground biomass. Where, trees in our study sites have confirmed to decrease the aboveground biomass production On the other hand, the higher soil pH might be the factor brought lower aboveground biomass yield under the canopy cover. Most of the plants that naturally grow in the open area are intolerant to the low pH. Thus, it indicates that aboveground biomass yield of herbaceous plant was highly influenced of herbaceous plant under canopies. The decreased aboveground biomass yield under canopies might be also associated with the higher herb species richness in the outside canopy than under canopy cover. Species-rich grasslands achieve higher aboveground biomass and hence hay yield [5].

3.2. The Effect of Tree Species and Canopy Cover on Herbaceous Plant Ground Cover

Tree species had shown significant (P <0.04) influence on ground cover of herbaceous plant. The mean ground cover of herbaceous plant was higher under *P. falcatus* than under canopies of *J. procera* and *C. lusitanica* (Table 2). Under the canopy of *P. falcatus,* it was 55.60%, under the canopy of *J. procera,* it was 28.06%, while under the canopy of C. *lusitanica* it was 23.27%. It might be contributed to the trees dense canopy under which few herb plants can survive and grow well. Dense tree canopy cover inhibits growth of some herbaceous plants under the tree canopies. Through P. *falcatus* rough/open canopy, sufficient light penetrated to permit herbaceous plants growth. Because of this higher herb species developed under *P. falcatus* tree species than *J. procera* and *C. lusitanica* trees. Similar to this finding, Bol and Vroomen [4] reported that, the *C. lusitanica* tree species dense foliage blocks out light and prevent understory growth. Lara Van Meter [22] also reported *C. lusitanica* does have an effect on the soil chemistry and this may contribute to the lack of understory underneath.

Ground cover of herbaceous plant was strongly (P<0.0001) affected by the canopy cover of the tree species, showing higher amount outside canopy than under canopy cover (Table 2). This might be associated with mass of litter, light and moisture availability for normal plant growth. Campbell *et al.* [6] reported that decline in plant cover with grassland afforestation has been attributed to the exclusion of shade-intolerant native species by increasing plantation canopy over and the physical barrier of litter slash to germination herbaceous plants. The competition among understory plant species and the tree for soil moisture, soil nutrients make it difficult to the herbaceous plant under canopy healthy and productive causing plant cover loss. In line to the present study result, Nisar *et al.* [27] also reported that the canopy of tree species had a great influence on herb cover underside it. Alrababah *et al.* [1] also observed that afforestation of grasslands significantly decreased the coverage of undergrowth and that the vegetative cover was high under no tree cover but was very low to completely absent under dense tree cover.

Table 2. *Effect of canopy cover on aboveground biomass/dry matter yield (t ha^{-1}) and ground cover (%) of herbaceous plant, with statistical results of the GLM (F, P-value)*.*

Tree Species	Canopy cover	DM	Cover
P. falcatus	Under canopy	1.68±0.198^{b}	55.60±5.47^{b}
	Outside canopy	2.51±0.198^{a}	67.34±5.47^{a}
J. procera	Under canopy	0.66±0.198^{c}	28.06±5.47^{c}
	Outside canopy	2.43±0.198^{a}	65.40±5.47^{a}
C. lusitanica	Under canopy	0.50±0.198^{c}	23.27±5.47^{c}
	Outside canopy	2.36±0.198^{a}	63.23±5.47^{a}
Tree species (TS)	SL	*	*
Canopy cover (CC)	SL	***	***
TS*CC	SL	*	*

Where: ^{a,b,c}Means within a column with different superscripts differ significantly (P < 0.05),* =(P < 0.05); ** = (P < 0.01); *** = (P < 0.001); SL: significance level; DM = dry matter

4. Conclusions and Recommendations

The results of the current study showed that *P. falcatus* had higher herbaceous plants ground cover and aboveground biomass than *J. procera* and *C. lusitanica* tree species; but lower than the outside canopy areas. No appreciable differences in terms of herbaceous plants ground cover and aboveground biomass production were observed between *J. procera* and *C. lusitanica* tree species. In general, the current study revealed that, the open areas/outside canopy had higher herbaceous plants ground cover and aboveground biomass yield than under canopy cover of the tree species. All these results emphasized that tree species affected herbaceous plants ground cover and aboveground biomass yields of the study area in a different way, with *J. procera* and *C. lusitanica* tree species having the greater negative impacts than *P. falcatus.*

Generally, the increased ground cover and aboveground biomass production of herbaceous plant in the outside canopies in the current study indicates that the presence of these large trees, *P. falcatus, J. procera* and *C. lusitanica,* in Keramile protected open forest could increase the vulnerability of the herbaceous plant community to future disturbances, such as climatic events. The Keramile protected open forest is a home to grassland herbaceous plant disappeared on farmland, roadside and degraded grasslands. However, the study shows that many of the benefits or an ecosystem service of this high altitude grassland is under threat from human actions taken, tree plantations, which are incompatible with grassland biodiversity and ecosystem functions. This shows that the gains derived from tree plantations to increase the supply of only forest ecosystem service have been achieved at the losses in many ecosystem services of the grasslands. Thus, proper management and conservation of grassland herbaceous plant in open areas are very crucial under the rapidly growing human population, changing climate and global warming. Therefore, to maintain and enhance the ecosystem services of forests and grasslands/open areas for the benefit of present and future generations; efforts to conserve and restore forests and herbaceous plant should be integrated. Additionally, regional and national assessments are needed to determine where and what kind of conservation and restoration should occur to strictly protect the remaining natural herbaceous plant, particularly high altitude areas. A further study of changes in herbaceous plant ground and aboveground biomass production in the long term of different tree species is needed to understand ecological consequences of tree plantation and to promote sustainable management.

Abbreviations and Acronyms

ANOVA	Analysis of Variance
FAO	Food and Agriculture Organization
GLM	General Linear Models
SAS	Statistical Analytical System

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Appendix

Table 3. *ANOVA for the influences of tree species and canopy cover on aboveground biomass yield and ground cover of herbaceous plants.*

Source	DF	Type III Sum of Squares	Mean Square	F-value	P_r>F	CV	R^2
Tree Species							
Aboveground biomass	2	1.505544	0.75277222	6.42	0.0127	20.25577	89
Cover	2	1093.846211	546.923106	6.10	0.0149	18.7137	84
Canopy Cover							
Aboveground biomass	1	9.91608889	9.91608889	84.51	0.0001	20.25577	89
Cover	1	4022.746006	4022.74600	44.87	<.0001	18.7137	84
TS*CC							
Aboveground biomass	2	0.97067778	0.48533889	4.14	0.0430	20.25577	89
Cover	2	750.589744	375.294872	4.19	0.0418	18.7137	84
Error							
Aboveground biomass	12	1.40806667	0.11733889				
Cover	12	1075.813067	89.651089				
Corrected Total							
Aboveground biomass	17	13.80037778					
Cover	17	6942.995028					

Where: DF = degree of freedom, CV= coefficient of variation, Pr > F = probability, CC= canopy cover and TS=tree species

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