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Effects of selective tree species on phytosociology and production of understorey vegetation in mid-Himalayan region of Himachal Pradesh

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Abstract
Characteristic of ground vegetation in *Pinus roxburghii*, *Acacia mollissima*, *Quercus leucotricophora*, *Eucalyptus tereticornis*, *Ulmus villosa* and mixed forest plantations were compared with grassland in mid-Himalayan region. Herbage density, basal area and biomass (aboveground and belowground) increased gradually from June till August in all systems. Maximum herbage density (1597 tillers/m^2), basal area (63.10 cm^2/m^2), aboveground (3.61 t/ha) and belowground (4.03 t/ha) biomass was recorded in grassland in the month of August. There was 33.24% (*Pinus roxburghii*) to 71.19% (*U. villosa*) decrease in peak aboveground biomass of herbage under trees as compared to grassland. Further, aboveground biomass of herbage under trees accounted for only 0.75% (*U. villosa*) to 2.47% (*Pinus roxburghii*) of total aboveground biomass of vegetation in plantations. Total (herb + shrub + tree) biomass (191.30 t/ha), carbon density of vegetation (86.21 t/ha) and soil (49.13 t/ha) was highest in *U. villosa* plantation. Carbon density (vegetation + soil) in systems decreased in the order: *U. villosa* (135.34 t/ha) > Mixed forest (97.63 t/ha) > *E. tereticornis* (96.51 t/ha) > *A. mollissima* (88.37 t/ha) > *Q. leucotricophora* (86.72 t/ha) > *P. roxburghii* (85.94 t/ha) > grassland (45.61 t/ha).

Keywords: Basal area, Biomass, Carbon density, Vegetation density

Introduction

Study of floral composition and functions of constituent species is important to determine plant assemblages related to existing conditions in an area. Communities change due to seasons, biotic factors, interactions and management practices. Conversely, species also adapt themselves to prevailing climatic conditions and biotic factors. In Himachal Pradesh, mid-hill agro-ecological zone (650 to 1800 m above mean sea level), has tropical through sub-tropical to sub-temperate climate and exhibits diverse forest and grasslands vegetation which are important fodder resources for livestock. The retention of trees in grasslands is an age old practice here to sustain fodder production. However, in last two decades, scientific know how in managing grazing resources has given impetus to plant multipurpose trees in them to enhance productivity. In the process many plantations have emerged in the area which serves as grazing resource.

Beneficial effect of trees in silvopastoral systems by promoting resource islands and increasing the sustainability have been reported around the world. Trees improve microclimatic conditions, which improves soil fauna and microorganisms (Gupta *et al.,* 2007; Fang *et al.,* 2014). They regulate herbage growth by altering their biological cycle, increase competition for light, moisture and nutrients (Sharma and Gupta, 2005). Tree also influence productivity through adding high amount of leaf litter, acts as a protective layer to maintain physical properties, temperature and compaction change of soil, increase soil moisture retention and promote efficient nutrient cycling (Sarvade *et al.,* 2014). Nonetheless ground vegetation under tree canopy conserve moisture and improves soil properties besides providing forage to animals. The present work was undertaken to highlight the influence of trees on composition, distribution and production of herbage under trees.

Materials and Methods

Sites description: The study was conducted at Y. S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh (India) bounded by 30° 51' N latitude and 76° 11' E longitude, located at 1300 m amsl falling under mid-hill zone. The area received 1085 mm annual rainfall of which 81.87% (971 mm) was received during the study period (June to October, 2007). Minimum air temperature was recorded as 8ÚC in October and maximum 33ÚC in June. Pure plantations of *Eucalyptus tereticornis*, *Quercus leucotricophora*, *Acacia mollissima*, *Ulmus villosa* and *Pinus roxburghii* along with mixed forest which had trees of *P. roxburghii, A. mollissima* and *E. tereticornis* in the ratio of 17:5:5 and pure grassland adjacent to these plantations were selected for the study.

Floristic composition and phytosociology

In each system three sample plots of 0.1 ha were marked and numbers of trees were recorded. Shrub species were studied from quadrat of 5 x 5m in each sample plot. While, herbage composition was determined by harvesting vegetation from five random quadrats (50 x 50cm, standardised through species area curve method) at monthly interval from June to October. Density, basal area, frequency and Importance value index (IVI) of each herb species was determined by following Misra (1969).

Biomass and carbon density

In every sampling month, herbage biomass was determined by harvesting vegetation from the five quadrats laid in each system. Belowground biomass of herbage was determined by excavating a monolith of size 25 x 25 x 30 cm from each quadrat. Soil was removed by careful tapping, plant samples were washed and segregated into species. Roots of each species were stored in separate paper bags. Biomass of shrubs was determined by uprooting few sample of each species from sample plots. Samples of stem, branches, leaves and roots of every sample plant were stored in separate paper bags. Plant samples (herb and shrub) were dried in oven at 70°C for 72 hours and weighed to determine their dry weight.

Stem volume of *P. roxburghii, E. tereticornis* and *Q. leucotricophora* trees was determined by following FRI (1996); *U. villosa* by Kishor (1991) and *A. mollissima* by Gupta (1998). Specific gravity of wood samples of each tree was determined by maximum moisture method. The aboveground and belowground biomass of trees was determined by following IPCC (2006) guidelines. The aboveground carbon in trees was determined by the method of Koach (1989), whereas the carbon content in belowground parts of tree and carbon density in understory vegetation (herb and shrub) was determined by following Woomer (1999).

***Soil organic carbon, bulk density and carbon density*:** Composite soil samples from each sample plot were collected from top 0-30cm depth and prepared for estimating organic carbon following Walkley and Black (1934). Bulk density (BD) of soil was estimated by weighing bottle method (Singh, 1980). Soil organic carbon (%) was converted to soil organic carbon density (t/ha) following Joa Carlos *et al.* (2001).

***Statistical analysis*:** The ANOVA was performed to detect significant differences in herbage density, basal area and biomass under plantations and grassland using SPSS statistical software package. Community analysis package (CAP, 4.1.3) was used for Agglomerative Ward's Euclidean cluster analysis.

Results and Discussion

Trees and soil characteristics of the study site

Tree density in the plantations differed significantly and it varied from 622 (*P. roxburghii*) to 1378 (*Q. leucotrichophora*) trees/ha. However relative light intensity curtailment under trees did not differ significantly among plantations. Soil in grassland exhibited high bulk density and low organic carbon compared to plantations, however least organic carbon was recorded under *P. roxburghii* plantation. Soils organic carbon in the study site ranged from 0.81 to 1.31% and the bulk density from 1.10 to 1.48 g/cc (Table 1).

Floristic composition

In the present study, a total of 12 grasses *viz*., *Apluda mutica*, *Arundinella nepalensis, Chloris barbata, Chrysopogon fulvus, Cymbopogon martinii, Dichanthium annulatum, Heteropogon contortus, Ischaemum aristatum, Panicum coloratum, Panicum maximum, Themeda anathera* and *Urochloa panicoides*; 2 sedges *viz*., *Cyperus rotundus* and *Eriophorum comosum*; 1 forb *viz*., *Micromeria biflora* and 1 legume *viz*., *Lespedza gerardiana* were recorded. Fifteen herb species were recorded in grassland, *Q. leucotrichophora* and mixed forest, 14 in *A. mollissima*, 13 in *E. tereticornis*, 12 in *P. roxburghii* and 10 in *U. villosa* plantations. Highest number of herb species were recorded in August in all systems revealing that their high rate of germination after the onset of rainfall in June. Beside herbs, 9 shrub species *viz*., *Myrsine africana*, *Pyrus pashia*, *Leptodermis lanceolata, Rubus ellipticus, Berberis lycium, Rhamnus virgatus, Eleagnus unmbella, Lonicera quinqilocularis* and *Rosa moschata* were also recorded only in *Q. leucotrichophora* and *U. villosa* plantations.

The species composition of herbage in systems formed three groups with Ward's clustering (Ward, 1963). Group 1 represented grassland and mixed forest showing least dissimilarity in species composition. Group 2 had *P. roxburghii* and *E. tereticornis* plantations, while rest of the plantations formed Group 3 (Fig. 1).

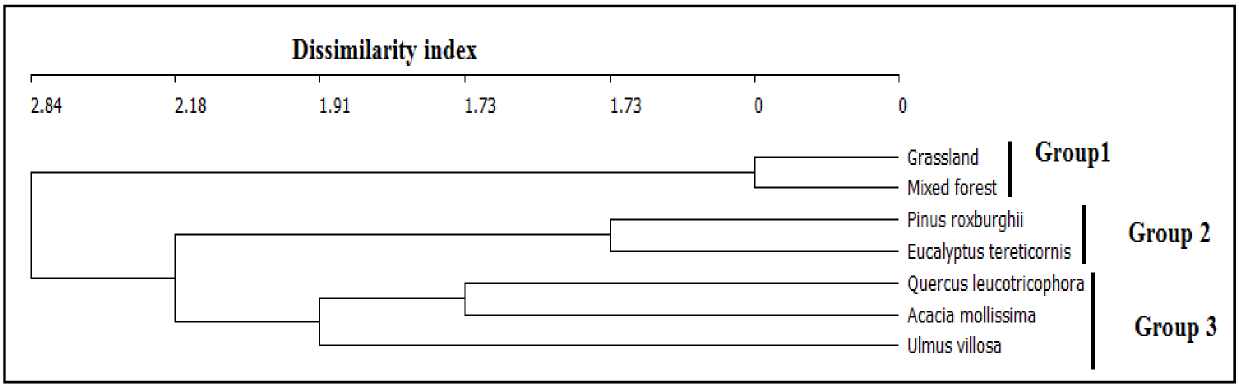

Fig 1. Systems clustering based on herbage species composition

Table 1. Tree characteristics and soil properties in systems selected for study

System	No. of trees/ha	DBH (cm)	Height (m)	Relative light intensity under trees (%)	Soil organic carbon (%)	Soil bulk density (g/cc)
Grassland	-	-	-	-	0.95	1.48
Q. leucotricophora	1378	4.77-17.6	6-10	76.07	1.27	1.13
Mixed forest	1200	4.14-25.6	8-13	67.48	1.25	1.10
U. villosa	1289	6.05-19.9	10-20	68.73	1.31	1.12
A. mollissima	1200	4.45-23.07	8-15	66.68	1.23	1.21
E. tereticornis	1022	4.93-19.7	6-12	73.81	1.10	1.26
P. roxburghii	622	19.9-40.60	14-20	64.76	0.81	1.39

Phytosociology

Monthly herbage density and basal area in all systems increased gradually from June to August and decreased thereafter. Such seasonal growth of vegetation following rainfall pattern is characteristics of monsoonal grasslands (Gupta *et al.*, 2000; Sharma and Gupta, 2005). It was also recorded that these phytosociological parameters maintained higher values in grassland during different months as compared to plantations. The density and basal area in grassland ranged from 657.20 (Oct.) to 1597.00 (Aug.) tillers/m^2, and 29.55 (Oct.) to 63.10 (Aug.) cm^2/m^2, respectively (Table 2).

Peak density and basal area of herbage, which is a manifestation of its maximum growth potential, was less in plantations as compared to grassland (Table 2). Peak density of herbage in systems decreased in the order; Grassland > Mixed Forest > *Q. leucotrichophora* and *E. tereticornis* > *U. villosa* > *A. mollissima* > *P. roxburghii.* The peak basal area of herbage among systems decreased in the order: Grassland > *P. roxburghii* > Mixed forest > *A. mollissima* > *E. tereticornis* > *Q. leucotrichophora* > *U. villosa* in August month. It was evident that peak density of herbage decreased by 28.8 7% to 47.09% and peak basal area by 33.76% to 55.15% under trees as compared to grassland. Decrease in herbage density and basal area under trees can be related to light curtailment under trees to the extent of 23.93 to 33.32% in the present study that might have impaired the understory growth as reported by Ludwig *et al.* (2004). It may also be due to decrease in LAI of herbage under trees as contended by Sharma and Gupta (2005). An allelochemicals released by *E. tereticornis* and *P. roxburghii* are also well known to have negative effect on herbage growth (Rizvi *et al.*, 1999).

Individual contributions of constituent species to the herbage density and basal area revealed that *C. fulvus*, and *P. maximum* were the major contributors among different species in all the systems. While, *H. controtus*, *A. nepalensis* and *T. anathera* were the other prominent contributors (Table 3). Importance value index of herbage species in different systems revealed that *C. fulvus* was the dominant species in all systems except for *E. tereticornis* plantation where *P. maximum* was the dominant species (Table 3).

Table 2. Variation in herbage density, basal area and biomass in systems during sampling months

Treatments	**Herbage vegetation parameter**			
	Density (tillers/m²)	**Basal area (cm²/m²)**	**Aboveground biomass (t/ha)**	**Belowground biomass (t/ha)**
Grassland				
June	1213.80	44.92	2.57	2.47
July	1289.60	55.34	3.20	2.85
August	1597.00	63.10	3.61	4.03
September	1239.00	43.80	2.62	3.12
October	657.20	29.55	1.78	2.41
Q. leucotricophora plantation				
June	758.40	27.00	0.81	1.27
July	887.20	29.10	1.06	1.85
August	997.60	31.40	1.25	2.27
September	740.32	26.00	1.15	2.04
October	623.20	20.00	0.98	1.76
Mixed forest plantation				
June	930.40	33.40	0.94	2.04
July	1025.80	36.10	1.15	2.22
August	1136.00	39.50	1.49	2.67
September	821.00	31.20	1.36	2.38
October	700.00	23.00	1.13	2.06
U. villosa plantation				
June	612.00	21.00	0.75	1.13
July	776.80	25.40	0.93	1.51
August	912.40	28.30	1.04	1.99
September	723.60	24.00	0.96	1.69
October	596.80	21.20	0.87	1.46
A. Mollissima plantation				
June	697.60	24.40	0.77	1.39
July	732.00	29.40	1.01	1.67
August	859.20	32.50	1.16	2.13
September	797.60	28.30	1.07	1.82
October	543.60	18.50	0.91	1.60
E. tereticornis plantation				
June	884.80	30.60	0.89	1.60
July	924.80	31.60	1.12	1.98
August	997.60	32.30	1.42	2.43
September	800.80	30.10	1.35	2.21
October	556.00	21.80	1.05	1.94
P. roxburghii plantation				
June	543.80	17.70	0.80	0.92
July	673.20	27.70	1.68	1.43
August	845.20	41.80	2.41	2.31
September	789.00	34.80	1.84	1.73
October	524.20	25.10	1.19	1.24
$CD_{0.05}$ (S×M)	30.51	8.07	0.187	0.22

Where, S = Systems and M = Months

Table 3. Range of contributions by important herb species to the herbage in systems during sampling months

Important species in systems	Density (tillers/m²)	Basal area (cm²/m²)	Importance Value Index (IVI)	Above ground biomass (t/ha)	Below ground biomass (t/ha)
Grassland					
C. fulvus	182.20-360.80	10.80-19.10	74.50-94.00	0.35-0.51	0.53-0.91
H. controtus	98.20-157.80	2.40-7.00	27.90-48.90	0.17-0.20	0.20-0.42
P. maximum	239.60-310.40	6.90-11.40	54.30-76.90	0.27-0.37	0.67-1.18
Q. leucotricophora plantation					
A. *nepalensis*	70.00-230.40	2.10-5.50	23.10-71.00	0.03-0.30	0.05-0.66
C. fulvus	152.80-404.80	7.90-14.70	71.00-108.50	0.37-0.62	0.56-1.28
H. contortus	26.40-122.40	0.20-2.80	14.30-34.50	0.04-0.25	0.05-0.31
P. maximum	11.20-150.00	1.20-4.50	15.80-43.00	0.01-0.10	0.07-0.24
T. anathera	89.00-120.00	2.10-4.30	29.70-46.90	0.12-0.28	0.21-0.41
Mixed forest plantation					
A. *nepalensis*	3.40-82.40	0.70-1.40	8.30-21.60	0.08-0.18	0.07-0.12
C. fulvus	86.40-336.00	9.50-16.30	61.70-87.50	0.35-0.47	0.68-0.89
H. contortus	116.80-183.60	4.10-6.30	35.20-65.80	0.08-0.21	0.31-0.55
P. maximum	159.20-272.00	2.20-7.60	40.50-56.50	0.18-0.24	0.29-0.62
T. anathera	20.00-100.00	0.70-1.80	6.60-29.80	0.01-0.20	0.08-0.24
U. villosa plantation					
A. *nepalensis*	19.20-82.20	1.30-3.60	15.90-32.40	0.10-0.16	0.18-0.32
C. fulvus	340.00-491.80	10.00-16.00	110.00-134.30	0.10-0.22	0.52-0.91
H. contortus	4.30-50.00	0.70-2.60	6.70-26.80	0.02-0.10	0.04-0.25
P. maximum	3.20-54.00	0.50-1.70	5.70-40.10	0.02-0.18	0.02-0.12
T. anathera	41.60-143.60	2.30-5.40	29.80-47.70	0.08-0.25	0.23-0.39
A. mollissima plantation					
A. *nepalensis*	81.40-213.60	5.40-6.00	22.60-57.20	0.06-0.25	0.36-0.51
C. fulvus	168.00-279.20	10.20-15.30	55.60-105.00	0.28-0.43	0.45-0.86
H. contortus	11.60-119.20	0.40-2.20	3.30-30.70	0.03-0.11	0.03-0.11
P. maximum	32.00-166.40	0.10-1.00	9.90-39.20	0.04-0.13	0.04-0.08
T. anathera	5.60-112.80	1.20-4.00	10.20-29.80	0.01-0.04	0.01-0.04
E. tereticornis plantation					
A. *nepalensis*	26.80-102.40	0.30-3.10	16.80-30.90	0.11-0.22	0.04-0.60
C. fulvus	86.40-202.80	7.20-13.70	56.40-69.90	0.19-0.35	0.39-0.81
H. contortus	131.20-252.80	4.60-10.30	51.20-65.50	0.23-0.39	0.09-0.60
P. maximum	109.20-268.00	3.40-9.10	37.80-73.80	0.10-0.22	0.23-0.59
P. roxburghii plantation					
A. *nepalensis*	52.00-255.20	2.55-13.75	37.70-86.60	0.16-0.62	0.11-0.54
C. fulvus	93.60-302.80	5.00-11.40	44.00-80.00	0.24-0.78	0.26-0.80
P. maximum	22.60-100.80	0.45-5.80	11.90-26.70	0.04-0.21	0.01-0.20
T. anathera	73.60-269.60	4.40-18.20	46.40-100.20	0.30-0.87	0.40-0.85

Biomass

The changes in aboveground and belowground biomass of herbage along different months, in all systems, closely followed the trend in herbage density and basal area (Table 2). Monthly aboveground herbage biomass in grassland in different sampling months varied from 1.78 to 3.61 t/ha and it varied from 0.75 to 2.41 t/ha in plantations. Likewise, monthly belowground biomass of herbage in grassland varied from 2.41 to 4.03 t/ha and from 0.92 to 2.67 t/ha in plantations (Table 2). Adverse effect of trees on biomass was evident from the results that peak herbage aboveground and belowground biomass in plantations was less than grassland. It was noted that there was 33.24% (*Pinus roxburghii*) to 71.19% (*U. villosa*) decrease in peak aboveground biomass and 42.68% to 50.62% decrease in belowground biomass of herbage under trees as compared to grassland. Decrease in biomass of herbage under trees has been reported by other workers (Bahar, 2003; Sharma and Gupta, 2005).

It was also noted that only few herb species contributed significantly to the aboveground and belowground biomass of herbage in all systems (Table 3). In grassland, *C. fulvus*, *H. contortus* and *P. maximum* were the major contributors whereas, in plantations, *A. nepalensis, C. fulvus*, *H. contortus, T. anathera* and *P. maximum* contributed significantly to the herbage biomass in different sampling months.

Shrubs produced 1.41 and 1.46 t/ha aboveground and 2.13 and 2.25 t/ha belowground biomass in *Q. leucotricophora* and *U. villosa* plantations, respectively (Table 4). The herbage production recorded in the present systems, its variation along the growing season with dependence on climatic variables and prominent contributions from only few species in a community corroborates with the results reported by researchers for the Solan region (Sharma and Gupta, 2005; Gupta and Chib, 2011).

Carbon density

Aboveground and belowground herbage carbon density in grassland was 1.62 and 1.81 t/ha, respectively and it was higher than herbage carbon density in plantations where it varied from 0.46-1.08 and 0.89-1.20 t/ha, respectively (Table 4). Amongst plantations herbage aboveground and belowground carbon density was highest in *P. roxburghii* and mixed forest plantations while, their lowest values were recorded in *U. villosa* plantation.

Table 4. Biomass production and carbon density of vegetation in systems

System/Plantation	Biomass production(t/ha)							Carbon density (t/ha)							
	Herbs		Shrubs		Trees			Herbs		Shrubs		Trees			
	AG	BG	AG	BG	AG	BG	Total (V)	AG	BG	AG	BG	AG	BG	Soil (S)	Total (V+S)
Grassland	3.61	4.03	-	-	-	-	7.64	1.62	1.81	-	-	-	-	42.18	45.61
Q. leucotricophora	1.25	2.27	1.41	1.46	68.24	17.06	93.03	0.56	1.02	0.71	0.73	34.12	7.67	41.91	86.72
Mixed forest	1.49	2.67	-	-	85.94	21.48	111.58	0.67	1.20	-	-	42.97	9.66	43.13	97.63
U. villosa	1.03	1.99	2.13	2.25	134.97	33.74	191.30	0.46	0.89	1.07	1.13	67.48	15.18	49.13	135.34
A. mollissima	1.16	2.13	-	-	74.40	18.60	96.29	0.52	0.95	-	-	37.20	8.37	41.33	88.37
E. tereticornis	1.42	2.43	-	-	92.76	23.19	119.80	0.64	1.10	-	-	46.38	10.44	37.95	96.51
P. roxburghii	2.41	2.31	-	-	93.32	18.66	116.70	1.08	1.04	-	-	46.66	8.40	28.76	85.94

AG = peak aboveground; BG = peak belowground biomass; V = vegetation (herbs + shrubs + trees) and S = Soil

The aboveground carbon density of trees ranged from 34.12-67.48 t/ha and belowground carbon density from 7.67-15.18 t/ha with their highest values in *U. villosa* and lowest in *Q. leucotricophora* plantations (Table 4). Carbon density of vegetation (herb + shrub + tree) in systems decreased as: *U. villosa* > *P. roxburghii* > *E. tereticornis* > mixed forest > *A. mollissima* > *Q. leucotricophora* > grassland. Soil carbon density was highest under *U. villosa* (49.13 t/ha) plantation followed by mixed forest (43.13 t/ha). Total carbon density (vegetation + soil) was highest in *U. villosa* (135.34 t/ha) plantation followed by mixed forest (97.63 t/ha).

The carbon density of vegetation in present systems is low as compared to the native forests of Himalayan region which can be related to differences in their species composition and biomass production beside tree density (Gairola *et al*., 2011). It can also be related to short rotation age of trees in present plantations compared to the long rotation age of trees in native forests (Bangroo *et al.,* 2013; Devi *et al.,* 2013). Differences in carbon density among plantations in the present study was due to difference in inherent growth potential of constituent tree species, varying tree density and difference in soil characteristics.

Conclusion

The vegetation communities did not vary significantly in herbage composition. Herbage density, basal area, biomass and carbon density decreased under trees. The tree composition, tree density and soil characteristics were responsible to the differences in biomass and carbon stock amongst plantations. *Ulmus villosa* plantation produced highest biomass and thus, is better for re-vegetating degraded areas in mid-Himalaya. Mixed forest and *E. tereticornis* plantations can also be considered for restoring ecology of degraded lands.

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