REHABILITATION OF SHIFTING CULTIVATION AREAS THROUGH AGROFORESTRY: A CASE STUDY IN EASTERN HIMALAYA, INDIA

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BHATT BP, SINGHA LB, SATAPATHY KK, SHARMA YP & BUJARBARUAH KM. 2010. Rehabilitation of shifting cultivation areas through agroforestry: a case study in eastern Himalaya, India. A study was carried out for 10 years (1992–2002) in Meghalaya, India, involving seven multipurpose tree species, *viz. Acacia auriculiformis, Alnus nepalensis*, *Bauhinia purpurea*, *Exbucklandia populnea*, *Ficus hookeri*, *Michelia champaca* and *M. oblonga* planted on shifting cultivation degraded land. The tree species were intercropped with broom grass (*Thysanolaena maxima*). The study revealed that *M. champaca* had the highest survival (80%) and *F. hookeri,* the lowest (40%). Current annual increment (CAI) was highest in *A auriculiformis* (2.3 m and 2.6 cm respectively for height and diameter growth), while mean annual increment (MAI) for height and diameter growth was highest in *E. populnea* (1.4 m) and *A nepalensis* (1.9 cm) respectively. *Exbucklandia populnea* exhibited the greatest height (14.8 m). Diameter growth was, however, highest (63.2 cm) in *A. nepalensis* after 10 years. Maximum basal cover, leaf area and standing biomass were recorded in *A. auriculiformis* including its timber (0.3 m^3/tree) and standing volume (220.3 m^3 ha^{-1}). Lowest standing volume was, however, recorded in *B. purpurea* (15.4 m^3 ha^{-1}). Variations were observed for growth performance and biomass yield of the tree species. *Thysanolaena maxima* exhibited total productivity of 89.3 q ha^{-1} in control plots (without trees) with fodder, spike and firewood yield of 36.3, 16.5 and 36.6 q ha^{-1} respectively. However, its productivity reduced 40% when intercropped with *A. nepalensis*. Reduction in the yield of broom (5.2%) was lowest when intercropped with *B. purpurea*. The results revealed that *A. auriculiformis, A. nepalensis, E. populnea* and *Michelia* spp. (tree crops) and *T. maxima* (understorey crop) could be recommended for restoration of shifting cultivation areas in eastern Himalaya, India.

Keywords: Land degradation, broom grass, multipurpose trees

BHATT BP, SINGHA LB, SATAPATHY KK, SHARMA YP & BUJARBARUAH KM. 2010. Pemulihan kawasan pertanian pindah melalui perhutanan tani: kajian kes di timur Himalaya, India. Kajian dijalankan di Meghalaya, India selama 10 tahun (1992–2002). Tujuh spesies pokok serba guna iaitu *Acacia auriculiformis, Alnus nepalensis*, *Bauhinia purpurea*, *Exbucklandia populnea*, *Ficus hookeri*, *Michelia champaca* dan *M. oblonga* ditanam di atas tanah usang pertanian pindah. Spesies tersebut ditanam secara selingan dengan rumput *Thysanolaena maxima*. *Michelia champaca* menunjukkan kemandirian tertinggi (80%) manakala *F. hookeri* terendah (40%). Nilai pertambahan tahunan semasa (CAI) paling tinggi dalam *A auriculiformis* (2.3 m untuk ketinggian dan 2.6 cm untuk pertumbuhan diameter). Min pertambahan tahunan (MAI) bagi ketinggian dan pertumbuhan diameter masing-masing paling tinggi dalam *E. populnea* (1.4 m) dan *A. nepalensis* (1.9 cm). *Exbucklandia populnea* menunjukkan ketinggian maksimum (14.8 m). Sebaliknya selepas 10 tahun, pertumbuhan diameter paling tinggi (63.2 cm) dalam *A. nepalensis. Acacia auriculiformis* merekodkan nilai litupan pangkal, luas daun, biojisim pokok dirian, isi padu kayu (0.3 m^3/pokok) dan isi padu pokok dirian (220.3 m^3 ha^{-1}) yang maksimum. Namun, *B. purpurea* merekodkan nilai isi padu pokok dirian yang terendah (15.4 m^3 ha^{-1}). Terdapat variasi antara spesies untuk pertumbuhan pokok dan hasil biojisim. *Thysanolaena maxima* menunjukkan produktiviti sebanyak 89.3 kuintal ha^{-1} dalam plot kawalan (tanpa pokok) dengan hasil foder, bulir dan kayu api masing-masing bernilai 36.3 kuintal ha^{-1}, 16.5 kuintal ha^{-1} dan 36.6 kuintal ha^{-1}. Produktiviti *T. maxima* menurun sebanyak 40% apabila ditanam secara selingan dengan *A. nepalensis*. Penurunan hasil *T. maxima* paling sedikit (5.2%) apabila ditanam secara selingan dengan *B. purpurea*. Keputusan menunjukkan bahawa penanaman *A. auriculiformis, A. nepalensis*, *E. populnea* dan *Michelia* spp. (pokok tanaman) dengan *T. maxima* (tanaman tingkat bawah kanopi) boleh disyorkan untuk pemuliharaan kawasan pertanian pindah di timur Himalaya, India.

INTRODUCTION

The impact of low productivity and less efficient shifting cultivation on the environment has been a global concern (Nair 1984, Ramakrishnan 1992). Shifting cultivation is also the mainstay of the economy of the tribal folk in the north-eastern hill (NEH) region of India. There are varying estimates of areas affected by shifting cultivation in the NEH region. However, the cumulative area affected by shifting cultivation from 1987 till 1997 was reported as 1.7 million ha (Anonymous 1999). Adverse effects of shifting cultivation and allied deforestation have been reported as depletion of plant and animal genetic resources, desertification, soil erosion inducing nutrient loss, and siltation in the lotic and lentic water bodies (Ramakrishnan 1993, Zhang & Cao 1995, Cao & Zhang 1996).

Soil loss on steep slopes (44–53%) due to shifting cultivation in NEH region was reported as 40.9 tonnes ha^{-1} and the corresponding losses per ha were 702.9 kg of organic carbon, 145.5 kg of P_2O_5 and 7.1 kg of K_2O. Soil erosion under the first and second years as well as on abandoned shifting cultivation area was estimated at 147, 170 and 30 tonnes ha^{-1} $year^{-1}$ respectively (Singh & Singh 1981).

Research efforts are being taken to determine alternative systems to shifting cultivation, which could enhance productivity and enable sustainable cropping systems, thereby minimising the overexploitation of land, water and forest resources. In this context, agroforestry has been considered as one of the best options to replace/supplement shifting cultivation (Bhatt *et al.* 2001). Other workers have also given special emphasis on agroforestry, an alternative means of shifting cultivation (Kang *et al.* 1981, Sanchez & Salina 1981, Duguma *et al.* 1994).

Agroforestry models could be implemented for long-term sustainability, profitability and minimisation of resource and environmental risks particularly in the region where shifting cultivation has already caused serious environmental degradation. The NEH region of India possesses almost double the rate of land degradation due mainly to shifting cultivation (Anonymous 2000), very high rate of biomass consumption for fuel, fodder and timber (Bhatt & Sachan 2003), and coal mining and urbanisation (Shankar *et al.* 1993), compared with the national average of 20.2% (Anonymous 2000). In the study area alone, 44.2% of the total geographical area has been reported as degraded (Anonymous 2000). Keeping these facts in view, various agroforestry systems (AFSs) are being evolved for restoration of degraded lands. This paper reports the growth and biomass performance of silvipastoral AFS developed over shifting cultivation degraded area.

MATERIALS AND METHODS

The experiment was conducted in the Farming System Research Project (FSRP) experimental block of the Indian Council of Agricultural Research (ICAR) Research Complex for NEH region, Meghalaya, India (25° 39'–25° 41' N latitude, 91° 54'–91° 63' E longitude and 950–1082 m asl altitude). The area selected was a shifting cultivation degraded land. The climate is subtropical humid with an annual precipitation of 2138 mm. The mean minimum and maximum temperatures approach 4 °C in January and 28 °C in July. The soil is sandy loam, characterised by P-deficient acidic Alfisol (Singh *et al.* 1995). Soil pH ranges from 4.2 to 4.5.

Silvipastoral AFS was selected to develop over an area of 2.9 ha of land. The average slope percentage of the area ranged from 32.2 to 41.8% (Anonymous 1990). The whole area was divided into 21 blocks (each having 1200 m^2 area) to accommodate seven multipurpose tree species with three replications. Pits of 0.6 × 0.6 × 0.6 m were prepared at a spacing of 5 × 5 m (400 plants ha^{-1}) before the onset of monsoon and 15 g of lime and 10 kg of farmyard manure (FYM) were applied in each pit before planting the seedlings. Lime and FYM were mixed thoroughly with soil and each pit was filled three months before planting.

One-year-old healthy seedlings of *Acacia auriculiformis*, *Alnus nepalensis*, *Bauhinia purpurea*, *Exbucklandia populnea*, *Ficus hookeri*, *Michelia champaca* and *M. oblonga* (all indigenous except *A. auriculiformis*) were planted. Block planting was carried out for each species, accommodating 35 seedlings in each block. Planting was carried out along the slope so as to create homogenous environment for growth of each species. The tree species were intercropped with broom grass (*Thysanolaena maxima*). Broom suckers were planted at a spacing of 0.6 × 0.6 m in each block of tree crops. Three plots (each of 1200 m^2 area) were planted with broom only to serve as control. Studies on growth performance of all the silvipastoral components were recorded from the first year of planting. Fresh biomass and plant dry matter production were estimated after

10 years by random sampling and harvest method following Misra (1968), and Mueller-Dombois and Ellenberg (1974). To observe the difference between tree species, the critical difference (CD) was recorded at 5% level of significance.

RESULTS

Significant difference ($p < 0.05$) was observed for survival percentage between species (Table 1). *Michelia champaca* exhibited the highest survival (80%), followed by *M. oblonga* (72%), *E. populnea* (71%) and *A. auriculiformis* (70%). *Ficus hookeri* had the lowest (40%) survival.

Maximum current year annual increment (CAI) was observed in *A. auriculiformis* for both height and diameter at breast height (dbh) with values of 2.3 m and 2.6 cm respectively. Minimum CAI was observed in *F. hookeri* with 0.45 m and 0.50 cm for height and dbh respectively. Mean annual increment (MAI) for tree height was greatest in *E. populnea* (1.4 m), followed by *A. auriculiformis* and *M. oblonga* (1.3 m for both species) but lowest in *M. champaca* (0.4 m). However, MAI for diameter growth was highest in *A. nepalensis* (1.88 cm), followed closely by *A. auriculiformis* (1.87 cm). MAI for diameter growth was lowest in *B. purpurea* (0.8 cm). Both CAI and MAI exhibited significant variations between species (Table 1).

Maximum height growth (Table 2) was recorded in *E. populnea* (14.8 m), followed by *A. auriculiformis* (14.6 m) and *M. oblonga* (12.8 m). Lowest height growth was recorded in *F. hookeri* (4.2 m). The greatest dbh was recorded in *A. nepalensis* (20.1 cm), followed by *A. auriculiformis* (19.8 cm) and *E. populnea* (18.9 cm). *Bauhinia purpurea* exhibited the lowest diameter growth (8.7 cm). Maximum timber, branch and total volumes were observed in *A. auriculiformis,* thereby exhibiting the highest standing volume. *Exbucklandia populnea* and *A. nepalensis* ranked second and third respectively in volume production. *Ficus hookeri* had the lowest timber volume. Significant differences were observed for tree height, dbh and timber volume between species (Table 2).

Table 1 Survival percentage, current year annual increment (CAI) and mean annual increment (MAI) of trees after 10 years (mean ± SD, n = 10)

Tree species	Survival (%)	CAI		MAI	
		Tree height (m)	Dbh (cm)	Tree height (m)	Dbh (cm)
Acacia auriculiformis	70.0 ± 6.5	2.30 ± 0.15	2.60 ± 0.45	1.25 ± 0.04	1.87 ± 0.15
Alnus nepalensis	45.5 ± 8.0	1.10 ± 0.07	2.00 ± 0.25	1.00 ± 0.08	1.88 ± 0.10
Bauhinia purpurea	50.0 ± 5.0	0.75 ± 0.03	0.65 ± 0.11	0.67 ± 0.03	0.79 ± 0.07
Exbucklandia populnea	71.0 ± 5.0	1.45 ± 0.05	2.00 ± 0.21	1.44 ± 0.03	1.66 ± 0.14
Ficus hookeri	40.0 ± 4.0	0.45 ± 0.03	0.50 ± 0.09	0.41 ± 0.04	0.84 ± 0.08
Michelia champaca	80.0 ± 5.5	1.61 ± 0.07	1.80 ± 0.16	0.40 ± 0.05	1.19 ± 0.11
M. oblonga	72.0 ± 7.0	1.40 ± 0.05	0.51 ± 0.08	1.25 ± 0.07	1.26 ± 0.09
CD (5%)	8.64	0.47	0.38	0.27	0.36

Table 2 Tree height, dbh and timber volume of trees after 10 years (mean ± SD, n = 10)

Tree species	Tree height (m)	Dbh (cm)	Timber volume (m^3 $tree^{-1}$)	Branch volume (m^3 $tree^{-1}$)	Total volume (m^3 $tree^{-1}$)	Standing volume (m^3 ha^{-1})
A. auriculiformis	14.58 ± 0.89	19.81 ± 1.27	0.317 ± 0.016	0.234 ± 0.013	0.551	220.28
A. nepalensis	10.38 ± 0.77	20.10 ± 1.67	0.202 ± 0.003	0.083 ± 0.016	0.285	114.13
B. purpurea	6.80 ± 0.67	8.67 ± 1.12	0.020 ± 0.001	0.018 ± 0.008	0.038	15.39
E. populnea	14.75 ± 0.76	18.94 ± 1.84	0.247 ± 0.01	0.053 ± 0.005	0.300	120.08
F. hookeri	4.24 ± 0.23	8.78 ± 0.95	0.014 ± 0.001	0.025 ± 0.008	0.039	15.46
M. champaca	7.18 ± 0.86	12.63 ± 0.96	0.045 ± 0.002	0.040 ± 0.005	0.085	33.96
M. oblonga	12.80 ± 1.14	13.42 ± 0.69	0.132 ± 0.001	0.006 ± 0.002	0.138	55.09
CD (5%)	0.85	1.52	0.18	-	-	-

Basal cover (Table 3) was highest in *A. auriculiformis* (758.7 cm^2 $tree^{-1}$), followed by *E. populnea* (556.8 cm^2) and *A. nepalensis* (507.0 cm^2). *Bauhinia purpurea* exhibited the lowest cover (173.9 cm^2). For canopy cover, *A. nepalensis* and *B. purpurea* respectively exhibited the largest (50.2 m^2 $tree^{-1}$) and lowest values (10.2 m^2 $tree^{-1}$). Leaf area (Table 3) was highest in *A. auriculiformis* (182.3 m^2) and lowest in *M. oblonga* (15.6 m^2).

Total standing biomass (Table 4) was maximum in *A. auriculiformis* [6.2 quintal (q)/tree], followed by *E. populnea* (3.6 q/tree), where 1 quintal = 100 kg. The lowest yield was observed in *B. purpurea*, i.e. 0.5 q/tree. The contribution of various tree components to total biomass (Table 4) depicted that dry bole biomass was highest in *A. nepalensis* (78.5%), followed by *M. oblonga* (73.4%) and *E. populnea* (71.8%). *Ficus hookeri* contributed the least bole biomass (35.6%) but had the maximum branch biomass (32.9%) compared with the other species. Foliage/fodder yield was also highest (31.5 %) in *F. hookeri*, followed by *E. populnea* (16.8%) and *B. purpurea* (16.7 %). Dry matter yield of firewood was highest in *A. auriculiformis* (0.9 q/tree), followed by *A. nepalensis* (0.2 q/tree). Significant ($p < 0.05$) variations were observed for biomass partitioning between species (Table 4).

Table 3 Basal cover, canopy cover and leaf area of trees (per tree basis) after 10 years (mean ± SD, n = 10)

Tree species	Basal cover (cm^2)	Canopy cover (m^2)	Leaf area (m^2)
A. auriculiformis	758.74 ± 65.00	13.84 ± 0.07	182.32 ± 0.06
A. nepalensis	506.98 ± 85.64	50.24 ± 0.13	70.20 ± 0.03
B. purpurea	173.87 ± 25.16	10.17 ± 0.02	63.14 ± 0.03
E. populnea	556.80 ± 50.50	14.85 ± 0.05	165.02 ± 0.02
F. hookeri	179.49 ± 22.75	11.33 ± 0.03	55.90 ± 0.03
M. champaca	196.90 ± 18.45	17.71 ± 0.03	71.82 ± 0.04
M. oblonga	267.62 ± 36.85	16.25 ± 0.01	15.62 ± 0.02
CD (5%)	30.31	3.31	6.45

Table 4 Biomass production after 10 years (mean ± SD)

Tree species	Standing biomass (quintal/tree)				Dry matter yield (quintal/tree)			
	Trunk	Branch	Foliage	Total	Trunk	Branch	Foliage	Total
A. auriculiformis	3.700 ± 0.055	2.150 ± 0.120	0.380 ± 0.070	6.230 ± 0.245	1.776 ± 0.026	0.885 ± 0.049	0.136 ± 0.025	2.797 ± 0.100
A. nepalensis	2.132 ± 0.075	0.650 ± 0.125	0.091 ± 0.007	2.873 ± 0.207	0.967 ± 0.034	0.217 ± 0.042	0.048 ± 0.004	1.232 ± 0.078
B. purpurea	0.245 ± 0.065	0.183 ± 0.080	0.049 ± 0.015	0.477 ± 0.160	0.102 ± 0.027	0.063 ± 0.027	0.033 ± 0.010	0.198 ± 0.064
E. populnea	2.834 ± 0.045	0.500 ± 0.045	0.300 ± 0.050	3.634 ± 0.140	0.902 ± 0.014	0.143 ± 0.013	0.211 ± 0.035	1.256 ± 0.062
F. hookeri	0.150 ± 0.010	0.180 ± 0.060	0.151 ± 0.055	0.481 ± 0.125	0.053 ± 0.004	0.049 ± 0.016	0.047 ± 0.017	0.149 ± 0.037
M. champaca	0.597 ± 0.070	0.375 ± 0.050	0.091 ± 0.010	1.063 ± 0.130	0.150 ± 0.011	0.090 ± 0.020	0.042 ± 0.005	0.282 ± 0.036
M. oblonga	0.607 ± 0.035	0.056 ± 0.015	0.042 ± 0.008	0.705 ± 0.058	0.182 ± 0.012	0.034 ± 0.006	0.032 ± 0.001	0.248 ± 0.019
CD (5%)	0.22	0.13	0.09	0.18	0.09	0.07	0.07	0.11

1 quintal = 100 kg

Standing biomass (Table 5) for all components was highest in *A. auriculiformis* (2492.0 q ha^{-1}), followed by *E. populnea* (1453.6 q ha^{-1}) and *A. nepalensis* (1149.2 q ha^{-1}). Dry matter yield was also highest in *A. auriculiformis* (1118.8 q ha^{-1}), followed by *E. populnea* (502.4 q ha^{-1}). On average, standing biomass per ha was more than two-fold higher in *A. auriculiformis* compared with *E. populnea* and *A. nepalensis*. Lowest biomass per ha was observed in *B. purpurea* (Table 5).

Annual fodder production of understorey crop, *T. maxima,* was recorded as 36.3 q ha^{-1} with a total standing biomass of 89.3 q ha^{-1} in the control (without tree) plots (Table 6). Yield of broom in the understorey plots was reduced by 5.2–40% with the lowest reduction in the understorey of *B. purpurea* and highest, in *A. nepalensis*. However, there was an increasing trend of foliage/fodder production in *T. maxima* when intercropped with trees having lesser canopy cover. Therefore, fodder production was maximum in the understorey of *B. purpurea* (35.5 q ha^{-1}). Maximum dry spike production (8.3 q ha^{-1}) and firewood yield (13.7 q ha^{-1}) were also recorded when intercropped with *B. purpurea*. Component-wise, fodder, spike and firewood contributed 41.0–45.4, 17.0–21.6 and 35.9–40% (dry weight basis) respectively to the total standing biomass in understorey plots, irrespective of tree species, indicating significantly ($p < 0.05$) low yield of broom in the understorey of trees compared with the control (Table 6).

DISCUSSION

Among the selective seven trees introduced in the FSRP experimental block, *A. auriculiformis* gave the best production of timber and fuelwood. Positive correlation was noticed between tree height and dbh. Further, height and diameter growth showed significant positive correlation with timber volume. Leaf size of *A. auriculiformis* was the smallest, although this species bore the highest number of leaves and hence largest leaf area, which ultimately increased the surface area for photosynthesis. This may be the reason for the fastest growth rate and productivity of standing biomass and dry matter accumulation in this species (Datta *et al.* 2004). The larger branches and branching pattern of *A. auriculiformis* drastically increased its standing biomass and dry matter yield. *Ficus hookeri* is one of the most popular fodder trees of eastern Himalaya (Yadav *et al.* 2001). *Exbucklandia populnea* is another potential species, which also has comparatively larger leaf area, resulting in fast growth and relatively high productivity of timber, fuelwood and fodder. *Alnus nepalensis* is also a fast-growing species. Owing to its large canopy cover and nitrogen-fixing ability, *A. nepalensis* is preferred as shade tree in traditional agroforestry systems of eastern Himalaya (Chauhan & Dhyani 1990, 1991, Dhyani *et al.* 1994).

Table 5 Biomass productivity of trees after 10 years (mean ± SD)

Tree species	Standing biomass (quintal ha^{-1})				Dry matter yield (quintal ha^{-1})			
	Trunk	Branch	Foliage	Total	Trunk	Branch	Foliage	Total
A. auriculiformis	1480.00 ± 22.00	860.00 ± 48.00	152.00 ± 28.00	2492.00 ± 98.00	710.40 ± 10.40	354.00 ± 19.60	54.40 ± 10.00	1118.80 ± 40.00
A. nepalensis	852.80 ± 30.00	260.00 ± 50.00	36.40 ± 2.80	1149.20 ± 82.80	386.80 ± 13.60	86.80 ± 16.80	19.20 ± 1.60	492.80 ± 31.20
B. purpurea	98.00 ± 26.00	73.20 ± 32.00	19.60 ± 6.00	190.80 ± 64.00	40.80 ± 10.80	25.20 ± 10.80	13.20 ± 4.00	79.20 ± 25.60
E. populnea	1133.60 ± 18.00	200.00 ± 18.00	120.00 ± 20.00	1453.60 ± 56.00	360.80 ± 5.60	57.20 ± 5.20	84.40 ± 14.00	502.40 ± 24.80
F. hookeri	60.00 ± 4.00	72.00 ± 24.00	60.40 ± 22.00	192.40 ± 50.00	21.20 ± 1.60	19.60 ± 6.40	18.80 ± 6.80	59.60 ± 14.80
M. champaca	238.80 ± 28.00	150.00 ± 20.00	36.40 ± 4.00	425.20 ± 52.00	60.00 ± 4.40	36.00 ± 8.00	16.80 ± 2.00	112.80 ± 14.40
M. oblonga	242.80 ± 14.00	22.40 ± 6.00	16.80 ± 3.20	282.00 ± 23.20	72.80 ± 4.80	13.60 ± 2.40	12.80 ± 0.40	99.20 ± 7.60

1 quintal = 100 kg

Table 6 Annual average of biomass production of broom grass (*Thysanolaena maxima*) in the understorey of trees (mean ± SD)

Tree species	Standing biomass (quintal ha^{-1})				Dry biomass (quintal ha^{-1})			
	Fodder	Spike	Firewood	Total	Fodder	Spike	Firewood	Total
A. auriculiformis	33.50 ± 2.25	13.21 ± 2.25	31.15 ± 1.14	77.86 ± 4.64	15.31 ± 1.18	6.63 ± 0.67	12.52 ± 1.16	34.46 ± 3.37
A. nepalensis	21.15 ± 1.21	8.90 ± 1.15	23.55 ± 1.87	53.60 ± 5.23	9.67 ± 1.12	4.47 ± 0.58	9.47 ± 1.35	23.61 ± 4.45
B. purpurea	35.45 ± 2.26	15.12 ± 2.63	34.11 ± 1.66	84.68 ± 4.55	16.20 ± 1.40	8.26 ± 0.76	13.71 ± 1.06	38.17 ± 4.80
E. populnea	32.67 ± 1.17	11.15 ± 1.22	30.66 ± 1.19	74.48 ± 7.58	14.93 ± 1.20	5.60 ± 0.65	12.33 ± 1.18	32.86 ± 5.69
F. hookeri	35.14 ± 2.35	14.50 ± 1.15	33.67 ± 2.19	83.31 ± 5.69	16.06 ± 1.07	7.28 ± 0.58	13.54 ± 0.88	36.88 ± 2.53
M. champaca	29.71 ± 3.26	11.67 ± 1.51	28.17 ± 2.36	69.55 ± 7.13	13.58 ± 1.19	5.86 ± 0.46	11.32 ± 1.14	30.76 ± 3.89
M. oblonga	30.15 ± 1.25	12.50 ± 1.21	28.55 ± 1.65	71.20 ± 8.11	13.78 ± 2.40	6.28 ± 0.45	11.48 ± 1.26	31.54 ± 3.47
Control (without tree)	36.25 ± 1.15	16.46 ± 1.75	36.60 ± 1.75	89.31 ± 6.25	16.57 ± 3.99	8.27 ± 0.67	14.70 ± 1.50	39.54 ± 3.37
CD (5%)	3.77	3.82	5.39	7.09	1.12	0.76	0.07	2.37

1 quintal = 100 kg

Growth and biomass performance of the tree species in the present investigation were well within the range as reported by Dhyani *et al.* (1994) for *E. populnea* and *A. auriculiformis*, Dhyani and Tripathi (1999) for *A. nepalensis*, Bhatt and Verma (2002) for *B. purpurea* and *Michelia* spp. and Yadav *et al.* (2001) for *F. hookeri*. *Alnus nepalensis,* although having low survival, possesses multiple uses, and is the most sustainable and profitable species in the region (Sharma *et al.* 1997). In an earlier study, Maikhuri *et al.* (1995) also recorded comparatively low survival for *A. nepalensis* on degraded lands. However, height and diameter growth were highest in this species after three years compared with other broad-leaved trees (Maikhuri *et al.* 1997). Growth and biomass performance of *B. purpurea* were also found to be well within the range as reported by Vishwanathan *et al.* (1999) in silvipastoral system on marginal lands of north-west India. Thus, the present findings are in agreement with the observations of earlier workers. A multistoried agroforestry system (tree planted together with black pepper and pineapple) is very popular in the region with *A. auriculiformis* forming the topmost storey (Datta *et al.* 2004). Its cultivation is particularly suitable in humid tropics (Duguma *et al.* 1994). *Michelia champaca* and *M. oblonga* are promising timber species (Bhatt *et al.* 2001). Various other multipurpose trees are cultivated in the region for timber, fuelwood and fodder requirements (Chauhan & Dhyani 1990, 1991, Borthakur 1992, Sharma *et al.* 1997).

As far as management practices are concerned, *A. auriculiformis* and *Michelia* spp. are clear felled, whereas pollarding is practised in the rest of the species. Among the various tree species, *A. nepalensis* has profuse coppicing ability. Hence, this species is conserved for biomass augmentation even in shifting cultivation areas. *Acacia auriculiformis* and *A. nepalensis* have nitrogen-fixing ability and, therefore, enrich the soil in degraded areas. *Acacia auriculiformis* and *E. populnea* seem to be the most suitable species to rehabilitate dry and exposed shifting cultivation degraded areas. Other species, however, need comparatively good soil depth for better growth and biomass augmentation. *Alnus nepalensis, B. purpurea* and *F. hookeri,* particularly, thrive well on north facing slopes. Many food crops are cultivated in the understorey of these tree species, e.g. turmeric, pineapple, black pepper and tea in association with *A. auriculiformis*; cereals, turmeric, ginger, beans, large cardamom and millet with *A. nepalensis*; and colocasia, tapioca, ginger, turmeric, maize, paddy, buckwheat with the rest of the tree species in agrisilviculture agroforestry system in eastern Himalaya (Chauhan & Dhyani 1990, Sharma *et al.* 1997, Bhatt *et al.* 2001, Datta *et al.* 2004).

In hilly regions, fodder plant species are of great importance and play a key role in meeting the nutritional requirements of livestock (Negi & Todaria 1994). *Exbucklandia populnea, F. hookeri* and *B. purpurea* have been found as promising fodder species in eastern Himalaya (Yadav *et al.* 2001). Broom (*T. maxima*), a tall grass up to 4 m high with dense bushy foxtail like terminal panicles, also thrives well in the degraded experimental plots. Its spike is used as a sweeping broom, the leaves as palatable fodder during the lean period, and the matured stem as fuel. However, its spike is the most remunerative part in terms of monetary gains. It is harvested twice a year, and two-year-old plant can provide a net return of 44 113 Rs ha^{-1} (USD 929) (Bhatt *et al.* 2001). In the present study, the productivity of broomsticks was 8.27 q, which could fetch a price of Rs 37 215 (USD 827). Hence, broom can be an ideal understorey vegetation to rehabilitate the degraded areas in the region. It can also act as soil binding species on vulnerable slopes where soil erosion are predominant (Singh *et al.* 1996).

Since degraded lands of the NEH region are typically characterised by impoverished or eroded soils, hydrological instability, reduced primary productivity and diminished biological productivity, priority should be given to rehabilitate such areas through agroforestry models. Shifting cultivation has been found to be the main cause of resource degradation in this part of Himalaya. Hence, agroforestry could replace/supplement shifting cultivation for long-term sustainable production. *Acacia auriculiformis, A. nepalensis, E. populnea* and *Michelia* spp. (tree species) and *T. maxima* (understorey crop) have been found suitable to be used in agroforestry due to their fast growth and multiple uses.

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