

Status, vegetation composition and biomass of forests of Arun valley, East Nepal

Ripu M. Kunwar¹ and Ram P. Chaudhary²

Arun valley is rich in pristine forest vegetation and exhibits lush forests of *Shorea robusta* (Sal) at tropical, *Castanopsis hystrix* and *C. tribuloides* at subtropical and *Quercus lamellosa*, *Q. glauca* (Oak) and *Acer spectabilis* (Maple) at temperate regions. A total of 20 forests types and 12 forest communities were observed. Of the 12 forest communities, the matured ones were found in Faksinda (850m), Tashigaun (2110m) and Mudhe-Num (2350m). Maximum tree species richness (12) and density (725 pl/ha) were also recorded at Seduwa (1570m). The highest total aboveground biomass (442.57 ton ha⁻¹) of *Daphniphyllum-Eurya* forest community was at Tashigaun, followed by (277.85ton ha⁻¹) of *Castanopsis-Viburnum* at Mudhe-Num. Correlation study revealed the negative value ($r = -0.58$) between stand density and gbh (girth at breast height) of tree individuals. A significant positive correlation existed between gbh and basal area ($r = 0.90$), gbh and biomass ($r = 0.79$), gbh and height ($r = 0.70$). It had not such relationship with canopy cover, species richness and elevation due to presence of anthropogenic disturbances. Occurrence of various types of forests and their communities and diverse vegetation was attributed due to the influence of soil, climate, altitude, landscape and east Himalayan floristic effect. Conservation measures are therefore urgently needed to protect it from human onslaughts.

Keywords: Arun valley, *vegetation.*, species richness, species diversity, biomass

Arun valley ranges from 435m to snow covered Mt. Makalu (8,463m) within an aerial distance of 40km. It is one of the wettest areas of the country possessing 27 types of forest (TMI/IUCN 1995). It shares 1.5% of the country's land but covers 60% of the country's flowering plants comprising 56 rare and threatened plants that includes archaic and primitive species such as *Tetracentron sinense*, *Talauma hodgesonii*, *Magnolia campbelli*, *Michelia* species etc. (Chaudhary and Gupta, 1998) and lush Sal, *Castanopsis*, Oak, maple forest communities (Chaudhary and Kunwar, 2002). Knowledge of forest structure is a necessary tool for understanding forest dynamics (Nadkarni *et al.*, 1995) and thus possible protection functions. Hence, this study aims at analyzing the ecological characteristics (canopy cover, girth at breast height, height of tree individuals, basal area, above ground biomass and diversity index-species richness) of forests and forest communities of Arun valley.

Materials and methods

Present study was conducted in Sankhuwasabha, Bhojpur, Dhankuta and Tehrathum districts of Arun

valley. The study area was divided into Mangtewa site (Bung, Bumlingtar, Cheskam, Tamku and Mangtewa), Makalu-Pathivara site (Makalu, Yaphu, Hatiya, Chepuwa, Seduwa, Num, Kuwapani, Faksinda and Pawakhola), Lower Arun site (Chichila, Diding, Hookse, Sabhakhola, Khandbari, Tumlingtar, Aankhibhuin and Baireni) and Tinjure-Milke-Jaljale site (Deurali, Sanischare, Mudhe and Tinjure). Reconnaissance survey was undertaken in Dec.1998, Sep.-Oct. 1999 and Feb.-March 2001. Quantitative study was carried out as described by Zobel *et al.* (1987). Total area sample (using systematic random sampling) for study was 3.84 ha (each quadrat measuring 20 × 20 m) within altitude 450 to 2620m. Girth of trees (C) exceeding 10cm at 1.37m above the ground was measured using measuring tape. It was converted to basal area (BA) by the formula $BA = 7C^2/88$. Height of the standing trees was measured by crown cover (canopy cover) of each forest community was estimated through visual observation. Above ground biomass of tree species was estimated using non-harvest method following Brown and Iverson (1992).

¹ Society of Economic and Environmental Development, Kathmandu (ripu@wlink.com.np)

² Central Department of Botany, TU Nepal (ram@cdbtu.wlink.com.np)

$$Y = 1.276 + 0.034 (D^2H)$$

where,

Y = Biomass (kg/tree), D = Diameter at breast height in cm, and H = height in meter

Results and discussion

Forests types

Of 20 forest types observed (Table 1), 15 were recorded from Mangtewa site and 14 from Makalu-Pathivara site followed by eight in lower Arun valley, and two in Tinjure-Milke-Jaljale site. Such variations could be due to the influence of soil, climate, altitude, etc. Contrarily, Duwadee (2000) and Kunwar (2000) did not find the significant relationship between species diversity and soil nitrogen and pH at lower Arun river basin Sal forests.

Shorea robusta (Sal), the commonest species was found is associated with *Schima wallichii*, *Alstonia scholaris*, *Lagerstroemia parviflora*, *Syzygium cumini*, *Semecarpus anacardium*, and the common herbs, shrubs and lianas were *Pogonatherum crinitum*, *Flemingia strobilifera*, *Mimosa rubicaulis*, *M. pudica*, *Desmodium sp.*, *Bauhinia vahlii*, etc. (Kunwar et al., 2000).

Schima wallichii and *Castanopsis indica* is predominant at between 600-1800m and *S. wallichii* and *Castanopsis tribuloides* at 1300-1800m. *Quercus lamellosa* is associated

with *C. tribuloides*, *C. hystrix*, at 1800-2300m. The wide distribution of *Castanopsis* in between 600-2300m supports the fact that the Arun valley is a capital of *Castanopsis*. Forests of *Quercus lamellosa* was particularly abundant at lower temperate zone (2000-2600m) in association with *C. tribuloides* in lower part and *Litsea* species and *Ilex* species in upper part of this zone. Secondary forest consisting almost entirely of *Symplocos* sp., *Sarcococca* sp., and occasionally *Daphniphyllum himalense* were observed at places where the oak has been cut. Secondary *D. himalense* forests were abundantly observed at Makalu-Pathivara (2110m) site. Upper temperate zone was covered with *Q. semecarpifolia*, *Acer*, *Litsea*, *Rhododendron* species more prominently in east facing slopes, which was also rich in orchids and epiphytes.

Forest communities and vegetation

A total 12 different forest communities were recorded (Table 2), of which five were recorded from Makalu-Pathivara site, three from Mangtewa site, and two each from lower Arun valley and Tinjure-Milke-Jaljale sites. Five communities were *Castanopsis* dominant, three *Shorea robusta* dominant, and one each was *Daphniphyllum-Eurya*, *Rhododendron-Eurya*, *Bombax-Erythrina*, and *Alnus-Cardamom* dominant. There were two cardamom cultivated forest communities (*Alnus-Cardamom* forest community at Kuwapani and *Castanopsis-Eurya-Cardamom* forest community

Table 1. Forest types of Arun valley

Zone	Forest types	Altitude cover (m)
A- Tropical and Subtropical (<2000 m)	Sal forest	300-1000
	Tropical deciduous riverine forest	300-1100
	Tropical evergreen forest	500-1200
	<i>Terminalia</i> forest	500-1500
	<i>Dalbergia sissoo</i> - <i>Acacia catechu</i> forest	300-1200
	Sub tropical deciduous forest	500-1400
	<i>Schima-Castanopsis</i> forest	1300-1800
	Sub tropical semi evergreen hill forest	600-1600
	<i>Shorea-Pinus</i> mixed forest	900-1900
B- Temperate (2000-3000m)	<i>Castanopsis tribuloides</i> and <i>C. hystrix</i> forest	1800-2100
	<i>Quercus lamellosa</i> forest	2000-2600
	Lower temperate mixed broad leaved forest	1500-2300
	Upper temperate mixed broad leaved forest	2400-3300
	<i>Rhododendron</i> forest	2100-2800
C- Subalpine (3000-4000m)	<i>Betula utilis</i> forest	2800-3700
	<i>Abies spectabilis</i> forest	3100-3700
	Open pasture	3200-3500
	<i>Rhododendron</i> scrub	3500-4000
	<i>Berberis</i> scrub	3600-3800
	<i>Juniperus recurva</i> scrub	3600- <

Sources: Stainton (1972), Shrestha (1989), TMI & IUCN/Nepal (1995), Bajracharya (1999), Shakya (1999), Carpenter (2000), Chaudhary et al. (2001) and field observation.

at Chichila-Diding). Deliberate replacement of native *Castanopsis* by *A. nepalensis* was found to be a common practice that is gradually threatening the species richness of Arun valley.

Quantitative analysis

We have listed 61 trees and shrubs from Arun Valley. Of these species *Acacia catechu*, *Acer oblongum*, *Alstonia scholaris*, *Bombax ceiba*, *Cyrtia chinensis*, *Daphniphyllum himalense*, *Lithocarpus fenestrata*, *Magnolia doltsopa*, *Michelia champaca*, *Pandanus furcatus*, *Shorea robusta* and *Tetracentron sinense* have been enlisted as threatened.

Makalu-Pathivara site was found rich in terms endangered and threatened species and number of species occurred. Among the 61 tree species, 36 were from Makalu-Pathivara, 24 from Mangtewa, 20 from lower Arun valley and 14 from Tinjure-Milke-Jaljale site. Makalu-Pathivara and Mangtewa sites were dense, diverse and rich among all study sites. A similar result was obtained by TMI & IUCN/Nepal (1995) from Sankhuwa and Sisuwa VDCs of Arun valley.

The height of tree species ranged from 2 - 24m on hill slopes between 15% and 55% (Table 3). Highest forest canopy cover (80%) was found in *Castanopsis-Viburnum* forest community at Mudhe-Num while

the least (55%) in cardamom cultivated forest community at Kuwapani and Chichila-Diding. Low forest canopy cover was due to selective felling, lopping and clearing of the forest for cardamom cultivation. Such destruction of forests gives way to invasive species viz. *Ageratum conyzoides*, *Aconopogon molle*, *Eupatorium adenophorum*, *E. odoratum*, etc. which affect sustainability of livelihood, food security and essential ecosystem services and dynamics (Kunwar, 2003).

Trees having smaller gbh (girth at breast height) were found in regenerated *Shorea-Aegle* forest at Baireni-Aankhibhuin. Forests having smaller gbh of individuals indicate the continuous disturbances (Karki *et al.*, 2001). The largest tree gbh were recorded in *Daphniphyllum-Eurya* forest community at Tashigaun and *Bombax-Erythrina* forest community at Faksinda. Forest communities at Tashigaun and Mudhe-Num were also recorded to have tallest and matured tree individuals of *Quercus lamellosa*. Species diversity in tree layer declined with increasing elevation. Presence of tallest trees, highest canopy cover and presence of tree species having larger gbh indicates low stand density per hectare and that the forest was natural and undisturbed.

Table 2. Forest communities and their dominant vegetation of Arun valley

Sites	Altitude (m)	Forest community	Dominant vegetation
Lower Arun valley Hookse	450	<i>Shorea - Semecarpus</i>	<i>Shorea robusta</i> , <i>Semecarpus auacardium</i> , <i>Schinus mollichii</i> , <i>Lagerstroemia parviflora</i> , <i>Adina cordifolia</i> .
Lower Arun valley Aankhibhuin	600	<i>Shorea - Aegle</i>	<i>S. robusta</i> , <i>Aegle marmelos</i> , <i>L. parviflora</i> , <i>Hollarena antidysentrica</i> , <i>Rhus</i> sp.
Mangtewa Bumlingtar	700	<i>Shorea - Syzygium</i>	<i>S. robusta</i> , <i>Syzygium cumini</i> , <i>L. parviflora</i> , <i>S. wallichii</i> , <i>Lencoseptrum canum</i>
Makalu-Pathivara Faksinda	850	<i>Bombax - Erythrina</i>	<i>Bombax ceiba</i> , <i>Erythrina stricta</i> , <i>Myrsine</i> sp., <i>Castanopsis hystrix</i> , <i>S. wallichii</i>
Makalu-Pathivara Sedluwa	1570	<i>Schinus - Castanopsis</i>	<i>C. hystrix</i> , <i>S. wallichii</i> , <i>Rhododendron arboreum</i> , <i>Rhus parviflora</i> , <i>Macaranga denticulata</i>
Mangtewa Chichila- Diding	1900	<i>Castanopsis - Eurya- Cardamom</i>	<i>C. hystrix</i> , <i>Anomium subulatum</i> , <i>Viburnum mullaba</i> , <i>Alnus nepalensis</i> , <i>Eurya cerasifolia</i>
Makalu-Pathivara Kuwapani	2000	<i>Alnus - Cardamom</i>	<i>A. nepalensis</i> , <i>A. subulatum</i> , <i>Dichroa febrifuga</i> , <i>Eupatorium adenophorum</i> , <i>Ageratum conyzoides</i>
Mangtewa Chichila-Diding	2000	<i>Castanopsis - Eurya</i>	<i>C. hystrix</i> , <i>C. indica</i> , <i>E. cerasifolia</i> , <i>A. nepalensis</i> , <i>Lyonia ovalifolia</i>
Makalu-Pathivara Tashigaun	2110	<i>Daphniphyllum - Eurya</i>	<i>Quercus lamellosa</i> , <i>Q. glauca</i> , <i>Daphniphyllum himalense</i> , <i>E. cerasifolia</i> , <i>V. mullaba</i> ,
Makalu-Pathivara Mudhe-Num	2350	<i>Castanopsis - Viburnum</i>	<i>C. hystrix</i> , <i>V. mullaba</i> , Kharanc, <i>Q. lamellosa</i> , <i>Holoptelia integrifolia</i>
Tinjure-Milke-Jaljale Sanischare	2350	<i>Castanopsis - Eurya</i>	<i>C. hystrix</i> , <i>E. cerasifolia</i> , <i>V. mullaba</i> , <i>A. cordifolia</i> , <i>Q. lamellosa</i>
Tinjure-Milke-Jaljale Deurali-Tinjure	2620	<i>Rhododendron - Eurya</i>	<i>R. arboreum</i> , <i>E. cerasifolia</i> , <i>Q. glauca</i> , <i>Edgeworthia gardnerii</i> , <i>L. ovalifolia</i>

Table 3. Ecological characteristics of different forest communities of Arun valley

Location	Altitude (m)	SR. SR.	SD. (Pl/ha)	gbh (cm/pl.)	BA (m ² /ha)	B. (t/ha)	H. (m/pl.)	C. (%)
Lower Arun valley								
Hookse	450	9	33 – 999	14 – 131	21.27	65.17	3 – 11	70
Lower Arun valley								
Aankhibhuin	600	11	33 – 533	14 – 110	8.65	70.41	4 – 7	60
Mangtewa Bumlingtar	700	11	33 – 633	14 – 125	12.61	52.34	3 – 16	60
Makalu-Pathivara								
Faksinda	850	9	100 – 400	21 – 326	59.51	103.301	5 – 23	55
Makalu-Pathivara Seduwa	1570	12	25 – 1425	12 – 129	28.25	62.15	3 – 7	70
Mangtewa Chichila-Diding	1900	5	25 – 1025	13 – 131	21.64	89.74	5 – 14	55
Makalu-Pathivara								
Kuwapani	2000	1	0 – 850	39 – 76	10.98	40.99	3 – 14	55
Mangtewa Chichila-Diding	2000	6	33 – 1366	13 – 180	51.24	222.98	6 – 14	70
Makalu-Pathivara								
Tashigaun	2110	10	25 – 425	17 – 420	85.05	442.57	2 – 22	60
Makalu-Pathivara								
Mudhe-Num	2350	9	25 – 650	16 – 250	47.41	277.85	3 – 24	80
Tinjure-Milke-Jaljale								
Sanischare	2350	9	33 – 700	13 – 260	53.84	187.19	2 – 14	70
Tinjure-Milke-Jaljale								
Deurali-Tinjure	2620	9	33 – 300	14 – 300	32.54	148.36	4 – 17	70

SR. = Species richness, SD. = Stand Density, gbh. = girth at breast height, H. = Height, C. = Canopy, B. = Biomass, BA. = Basal Area,

Species richness was found higher in *Schima-Castanopsis* forest community at Seduwa. The species diversity and richness was found increasing with light availability, a fact also supported by Carpenter (2000). As agricultural practices, irrational harvesting and disturbances pose 18% threat to the plant diversity (Freemark *et al.*, 2001), and species diversity could be controlled by habitat condition (Oshawa *et al.*, 1973) a controlled management and preservation of biodiversity rich zones, is therefore immediately needed.

The highest total basal area 85.05m² ha⁻¹ in *Daphniphyllum-Eurya* forest community at Tashigaun and the least 8.65m² ha⁻¹ in *Shorea-Aegle* forest community at Baireni-Aankhibhuin was found (Table 4). Basal area value 32-36m² ha⁻¹ of *Shorea robusta* forest from lower Arun valley (Duwadee *et al.*, 2002)

ranges within the present study result. The highest aboveground biomass of 442.57ton ha⁻¹ was found in *Daphniphyllum-Eurya* forest community at Tashigaun followed by 277.85ton ha⁻¹ in *Castanopsis-Viburnum* forest community at Mudhe-Num. It was supported due to higher gbh and height of plant species. Giri *et al.* (1999) found 348.02ton ha⁻¹ biomass in *Shorea-Terminalia* forest of Royal Bardia National Park, Nepal. In Arun valley, all three *Shorea* dominant forest communities (*Shorea-Aegle*, *Shorea-Semecarpus*, *Shorea-Syzygium*) possessed the less amount of biomass content.

Gradient Analysis

The successional stage of the forest with its various ecological components like canopy cover, tree height, gbh, basal area, biomass, density and elevation were

Table 4. Correlation between different parameters of forests, tree and physiography

	A SD ha ⁻¹	A. gbh	A. Ht	A. BA	Biomass	Canopy	SR	Altitude
A. SD ha ⁻¹	-		-0.48	-0.21	-0.28	0.20	-0.18	-0.06
A. gbh	-	-	0.70	0.90	0.79	0.10	0.21	0.41
A Ht	-	-	-	0.62	0.54	-0.01	0.03	0.31
A. BA	-	-	-	-	0.85	0.18	0.13	0.42
Biomass	-	-	-	-	-	0.30	0.10	0.54
Canopy	-	-	-	-	-	-	0.29	0.35
SR	-	-	-	-	-	-	-	-0.35
Altitude	-	-	-	-	-	-	-	-

A. SD = Average Stand Density, gbh = girth at breast height, Ht. = Height, BA = Basal Area, SR = Species richness

correlated (Table 4). The gbh, height of tree individuals and basal area per site were used as a parameter for estimating the successional stages. Based on these parameters, the forest communities *Daphniphyllum-Eurya*, *Bombax-Erythrina* and *Castanopsis-Viburnum* were recorded under the category of mid level succession. Former two were well grown and possessed highest gbh and basal area and better height. A positive correlation between forest age and the increase of basal area in young secondary forest was assumed. (Kappelle *et al.* 1995). The correlation value lesser than 0.5 was considered as less significant and did not interpret well in the present study.

Correlation between stand density and gbh of tree species was negative ($r = -0.58$). Forests having high stand density were composed of smaller trees. A significant correlation existed between gbh and basal area ($r = 0.90$), gbh and biomass ($r = 0.79$) and gbh and height ($r = 0.70$). However, it did not have such relationship with canopy cover, species richness and elevation. The relationship was insignificant between gbh and canopy cover, particularly due to presence of anthropogenic disturbances. There was no significant relationship with number of plant species and other parameters. Height, gbh, basal area, biomass and canopy increased with altitude, but species richness and density showed the opposite phenomenon.

Diversity has been mostly assumed to decrease with elevation (Gentry, 1988). While it was partially supported from present study where stand density per hectare was negatively correlated ($r = -0.35$) with increasing elevation. There was a mid-level elevational peak of tree species richness along the elevational gradient, which is similar to that of Grytness and Vetaas, 2002, and Bhattarai and Vetaas, 2003. However, the mid-level elevation peak was not true hump-shaped because of the presence of least number of species at Kuwapani (2000m) and Chichila-Diding (1900-2000m). This was particularly due to human interferences for cardamom cultivation.

Decrease in species number and stand density was due to increasing elevation because the latter tends to produce more acidic soils. Table 4 shows a prominent correlation between basal area and gbh. Similarly, height showed similar trend in relation to basal area and biomass. There was positive correlation of gbh with all ecological parameters except density. The negative correlation was set up between stand density

and diversity was due to the presence of homogenous monoculture forest stands. Among the twelve forest communities, five were dominated by *Castanopsis bhystrix* and three were dominated by *Shorea robusta*.

Conclusion

Occurrence of total 20 forest types and 12 forest communities within small area of Arun valley was due to the influence of local environmental factors (soil, climate, altitude, moisture, precipitation and landscape) and east Himalayan floristic effect. There were five *Castanopsis* dominant forest communities, three *Shorea robusta* dominant forest communities, one *Daphniphyllum-Eurya* forest community, *Rhododendron-Eurya* forest community, *Bombax-Erythrina* forest community, and *Alnus-Cardamom* forest community each. There was common practice of relegation of native forest tree species (*Castanopsis* species) and afforestation of *Alnus* species for cardamom cultivation. Such practice has posed serious threat to the Arun valley biodiversity. Replacement of native forest communities affects local livelihood and forest diversity. Human interferences alter the natural forest vegetation and give way to alien species and ultimately replacing the native ones. Local-level control and conservation of biodiversity rich zones is therefore, immediately needed to maintain the cordial atmosphere between forest and people.

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