An Ecological Analysis of Himalayan Forest Ecosystems

V. P. Upadhyay

ABSTRACT The paper deals with certain phytosociological parameters and litter decomposition in five forest ecosystems, *viz.* sal forest, pine-mixed broadleaf forest, pine forest, mixed oak-pine forest and mixed oak forest located between 300 m and 2150 m altitude. The dominant tree species in the above zones are *Shorea robusta, Pinus roxburghii, Quercus leucotrichophora, Quercus floribunda and Quercus lanuginosa.* The rate of decomposition of leaf litter was found higher at sal forest site followed by pine mixed broadleaf, oak, oak-pine and pine forest sites. The release of N, P, K, Ca and Na was found higher at sal forest site compared to the other sites during decomposition.

INTRODUCTION

Investigation on phytosociology and decomposition is an important aspect of ecosystem structure and function. A major part of annual gain of energy and matter by plants is returned to the forest floor as litter which enters into the decomposition subsystems as dead organic matter or detritus. Decomposition of litter is regulated by a host of variables including the litter's physical and chemical properties, habitat, and macro and micro faunal responses. In spite of the complexity of the decay process, the two most important control of litter decomposition rates are probably the prevailing climatic conditions and the susceptibility of the substrate to attack by specialized decomposers, *i.e.* substrate quality (Meentemeyer, 1978). Decomposition in terrestrial ecosystem is commonly studied using the litter bag method, which consists of enclosing the plant material of known mass and chemical composition in a screened container. Initially, a large number of bags are placed in the field and at each sampling date randomly chosen set of bags is retrieved and analysed for loss of mass and changes in chemical composition. The litter bag method may underestimate the actual decomposition (Wieder and Lang, 1982), it is still assumed, however, that the results of litter bag studies will reflect trends characteristic of unconfined litter and as such allow for comparisons among species, sites and experimental manipulations.

STUDY SITE

Five forest ecosystems were selected for vegetation analysis and decomposition study. The sites ranged in altitude from 329-2150 m and were located between 29° 7' to 29° 26' N lat and 79° 15' to 79° 38' E long.

The forest sites were Chorgalia (sal forest), Kalona (pine-mixed broadleaf forest), Baldiyakhan (pine forest), Ranikhet (mixed oak-pine forest) and Kilbury (mixed oak forest). The sal forest site occupied the lowest position in the altitudinal gradient and the mixed oak forest site the highest. The climate of sal forest site was monsoon subtropical and of others monsoon temperate.

The leaf litter species and the sites were as follows:

Litter species	Forest site/Altitude
S. robusta	
M. philippensis	Sal forest, 329 m
L. ovalifolia	
Q. glauca	Pine-mixed broadleaf forest, 1250 m
R. arboreum	
P. roxburghii	Pine forest, 1500 m
M. esculenta	Mixed oak-pine forest, 1750 m
Q. lanuginosa	
Q. floribunda	Mixed oak forest, 2150 m

In addition to the above, leaf litter of *Q. leucotrichophora* was selected for placement on the forest floors of each site as standard material.

RESULTS AND DISCUSSION

VEGETATIONAL ANALYSIS

Tree layer analysis was carried out by taking 10×10 m quadrat. A total of 10 quadrats were studied for phytosociological observation. At the sal forest site *S. robusta* had greatest density (194 trees/ha) and at the pine mixed broadleaf forest sites *P. roxburghii* had the greatest density (163 trees/ha) among the tree layer species. At the pine, the the mixed oak pine and the mixed oak forest sites, *P. roxburghui, Q. leucotrichophora* and *Q. lanuginosa* had, respectively, greatest den-

Table 1: Composition of tree and sapling layer of experimental forest sites

Species	Tree layer Density (ha⁻¹)	Total basal cover (m²ha⁻¹)	Importance value Index (IVI)	Sapling Density (ha⁻¹)	Total basal cover (m²ha⁻¹)	Importance value (IVI)
Sal Forest						
Shorea robusta Gartn.	194	51.21	174	0	-	-
Mallotus philippensis Mudl. Arg.	106	3.36	61	44	0.12	216
Cassia fistula Linn.	56	0.79	36	13	0.07	84
Lagerstroemia parviflora Roxb.	31	1.10	24	-	-	-
Litsea polyantha Juss.	6	0.37	5	-	-	-
Pine-mixed broad-leaf forest						
Pinus roxburghii Sarg.	63	12.74	85	2	0.01	8
Qoercus leucotrichopora A.Camus.	30	3.52	36	0	-	-
Syzigium cumini Lamk.	31	0.98	25	3	0.02	19
Machilus duthiei King.	27	1.23	22	5	0.03	23
Myrica esculenta Thunb.	19	0.79	17	3	0.01	15
Lyonia ovalifolia (Wall) Drude.	27	0.53	17	8	0.04	41
Quercus glauca Thunb.	17	1.35	15	-	-	-
Symplocos ramosissima Wall.	19	0.35	14	16	0.06	74
Rhododendron arboreum Smith.	17	0.63	12	-	-	-
Pyrus pashia Buch-Ham ex D. Don	8	0.49	9	-	-	-
Carpinus viminea Lindl.	11	0.32	9	-	-	-
Symplocos crataegoides Buch-Ham.	10	0.19	8	5	0.03	29
Engelhard tia - colebrookiana Lindl.	6	0.15	5	-	-	-
Myrsine semiserrata Wall.	6	0.11	4	8	0.05	39
Ilex dipyrena Wall.	5	0.12	4	-	-	-
Unidentified	3	0.12	4	-	-	-
Eugenia frondosa Wall.	3	0.28	3	-	-	-
Symplocos crataegoides	5	0.14	3	2	0.01	10
Euonymus tingens Wall.	5	0.09	3	2	0.01	9
Acer oblongum Wall. ex DC.	2	0.07	2	-	-	-
Eurya acuminata DC.	2	0.03		3	0.01	10
Acer laevigatum Wall.	2	0.02	2	2	0.01	10
Randia tetrasperma Benth & Hook	-	-	-	2	0.003	7
Pine forest						
P. roxburghii	575	33.32	247	50	0.30	169
M. esculenta	58	2.12	31	17	0.11	75
L. ovalifolia	8	0.11	7	-	-	-
R. arboreum	8	0.08	7	-	-	-
S. ramosissima	8	0.29	8	-	-	-
P. pashia	-	-	-	17	0.10	56
Mixed oak-pine forest						
Q. leucotrichopora	433	19.06	135	75	0.21	97
P. roxburghii	67	12.14	55	42	0.05	49
M. esculenta	175	4.27	54	50	0.17	80
Cedrus deodara Loud.	33	2.96	22	-	-	-
R. arboreum	25	0.46	10	-	-	-
Symplocos crataegoides	8	0.08	4	-	-	-
M. duthiei	17	0.19	8	-	-	-
Cupressus torulosa Don.	17	1.01	7	8	-	-
Acacia nilotica (Linn) Del.	8	0.31	5	42	0.09	51
Ilex dipyrena Wall.	-	-	-	8	0.01	11
Mixed oak forest						
Quercus lanuginosa Don.	629	42.21	179	221	0.77	234
Quercus floribunda Lindl.	257	13.37	80	50	0.10	49
R. arboreum	86	3.48	31	-	-	-
Q. leucotrichopora	21	0.62	10	-	-	-
P. pashia	-	-	-	7	0.04	17

sity, *i.e.*, 575, 433 and 629 trees/ha compared to other tree layer components (Table 1).

The values of frequency, density and abundance of individual species of herb layer were recorded for all forest sites. The herb layer was studied by taking 1×1 m quadrat. The herbs were sampled in the rainy season where they are normally most abundant.

WEIGHT LOSS

The litter bag technique was followed for decomposition experiments. A total of 120 litter bags each having five grams air dried leaf litter for each species were placed on the forest floor of respective forest sites. A random collection of 5 litter bags in each month for each species was made to find out the weight loss and nutrient release.

In the present study the species placed at the sal forest site decomposed at a faster rate and the

Table 2: Analysis of herbaceous vegetation on different forest sites

Species	Frequency (%)	Density (ind. m^{-2})	Abundance (ind. m^{-2})
Sal forest			
Desmostachya bipinnata	25	2.90	11.50
Clerodendron infortunatum Linn. (shrub) seedlings	100	5.93	5.93
Pine-mixed broad-leaf forest			
Chrysopogon serrulatus Trin	20	22.30	111.50
Carex condensata Nees ex Wieght	10	11.00	110.00
Muhlenbergia himalensis Hack ex HK.F.	10	10.50	105.00
Cappilidium assimile	10	7.20	72.00
Apluda mutica Linn.	20	4.90	24.50
Cyperus iria Linn.	10	4.20	42.00
Oplismenus compositus (Linn.) P. Beauv.	30	3.80	12.66
Pouzolzia hirta Hasask.	30	2.00	6.66
Erigeron bonariensis Linn.	10	0.80	8.00
Lastrea divida	10	0.60	6.00
Nicus argericanthus	10	0.20	2.00
Remusatia hookeriana Schott.	10	0.20	2.00
Pine forest			
Arundiella nepalensis Trin.	30	19.80	66.00
Selaqinella selaginoides	10	9.80	98.00
Imperata Cylindrica (L.) P. Beauv.	20	7.80	39.00
Achyranthes aspara (Linn.) Hook.	60	7.40	12.33
Cyperus iria Linn.	30	5.20	17.33
Setaria glaucea (Linn.) P. Beauv.	10	4.90	12.25
Ophiopogan intermedia D. Don.	20	2.40	12.00
Carex nubigena D. Don.	10	3.00	30.00
Puzolzia hirta	40	1.80	4.50
Muhlenbergia himalayensis Hack ex Hook.	10	1.80	18.00
Anaphilis busua (Such.-Ham.) Hand.-Maz.	30	1.50	5.00
Desmodium tiliaefolium Baker.	40	1.00	2.50
Oplismenus Compositus (Linn.) P. Beauv.	10	0.80	8.00
Rananculus aryensis Linn.	40	0.80	2.00
Remusatia hookeriana	30	0.70	2.33
Flemengia fruticulosa Wall. ex Benth	10	0.20	2.00
Mixed oak-pine forest			
Commelina paludosa Bl. Var. *mathewii* Rola Rao et Kamathy	100	13.25	13.25
Roscoea alpina Royle	100	11.25	11.25
Ainsiliaea aptera DC.	91.67	6.83	7.45
Cymbopogon distans (Nees) Wats.	75.00	5.17	6.89
Desmodium tiliaefolium	33.33	4.58	13.75
Strobilanthes dalhausianus (Nees) Clarke	83.33	3.58	4.30
Flemengia fruticulosa	75.00	2.42	3.22
Rubia Cordifolia Hook. f.	16.67	2.17	13.00
Hedera nepalensis K. Koch.	33.33	0.92	2.75
Habenaria marginata	8.33	0.33	4.00
Murdannia divergence (Cl.) Buckn.	8.33	0.25	3.00
Ophippogan intermedia	8.33	0.17	2.00
Vitis himalayana Brandis	8.33	0.08	1.00
Mixed oak forest			
Carex nubigena	85.70	77.28	90.17
Carex condensata	78.56	48.71	62.00
Themeda anthera (Nees.)	14.29	0.50	3.50
Viola canescence Wall. ex Roxb.	14.29	0.71	5.00
Cyperus iria Linn.	35.71	1.64	4.60
Smilex parviflora Wall. ex Kunth.	49.99	5.36	10.71
Galium aparine Linn.	14.29	0.84	6.00
Anaphalis busua	28.57	1.79	6.25
Commelina paludosa	14.29	0.57	4.00
Scutellaria angulosa Benth	7.14	0.07	1.00
Artemisia vulgaris Linn.	7.19	1.93	0.07
Roscoes alpina	21.43	0.43	2.00
Arundineria fulcata Needs	21.43	2.28	10.67
Polygalla crotolariodes Buch.-Ham. ex DC.	14.29	1.50	10.50
Valeriaga Wallichii DC.	71.43	10.14	14.20
Arundinella nepalensis	28.57	3.50	12.25
Carex filicina nees ex Wight	57.14	3.36	5.88
Erigeron bonariensis Linn.	57.14	7.00	12.25
Strobilanthes dalhausianus	28.57	0.93	3.25
Rubia cordifolia Hoo. f.	14.29	0.93	6.50
Stachys aspara	21.43	0.50	2.33

species placed at the pine forest site decomposed most slowly. At the sal forest site, *S. robusta* and *Q. leucotrichophora* decomposed completely in 396 days and *M. philippensis* in 365 days. On the pine mixed broadleaf site, *L. ovalifolia* and *Q. glauca* decomposed in 396 days and 365 days, respectively. But, *R. arboreum* and *Q. leucotrichophora* decomposed respectively in 608 and 520 days. At the pine forest site, in *P. roxburghii* 92% decomposition was achieved in 730 days whereas *Q. leucotrichophora* decomposed completely in 609 days. At the mixed oak-pine forest site decomposition was complete in 609 and 639 days, respectively for *Q. leucotrichophora* and *M. esculenta.* At the mixed oak forest site, *Q. leucotrichophora* decomposed completely in 548 days while *Q. lanuginosa* and *Q. floribunda* decomposed completely in 669 days. Differences in the rate of decomposition among species of different forest sites have been reported by several authors including Wiegert and McGinnis (1975) and Gupta and Singh (1977, 1981) and Pandey and Singh (1982)

Edwards (1977) while studying the decomposition of leaf litter species found that the species placed at Ridge site decomposed slowly than on the valley site.

A comparison of rates of leaf litter decomposition for a variety of habitats shows that the present rates lie within the general range of values reported for temperate species (Table 3).

Immobilization and Release of Nutrients

The decomposition of litter is the primary mechanism by which nutrients are returned to the forest soils and the organic matter is incorporated in them. The release of nutrients from litter is a basic process in nutrient cycling within the ecosystem. The dynamics of nutrients are complicated since the nutrients appear in different forms and are subject to many types of transformations such as leaching, immobilization and mineralisation. Increases in concentration of N, P and Na were observed in all species in the annual cycle whereas only *P. roxburghii* and *M. esculenta* showed increase in calcium content for initial periods. There was no increase in K. concentration in any species.

Fastest rates of release of nutrients were ob-

Table 3: Rate of decomposition of leaf-litter in certain forest types of the world

Vegetation	Place	Rate (% day^{-1})	Reference
Oak forests	California, U. S. A.	0.016-0.32	Jenny *et al.* (1949)
Oak forests	Minnesota, U. S. A.	0.018	Reiners and Reiners (1970)
Oak forests (Leaf litter)	Missouri, U. S. A.	0.095	Rochw (1974)
Mixed oak forests	New Jersey, U. S. A.	0.178	Lang (1974)
Quercus patraea	Roudsea wood, England	0.12-0.14	Bocock and Gilbert (1257)
Quercus alba	Eastern United States	0.107	Shanks and Olson (1961)
Quercus alba	Eastern United States	0.126	Witkamp and Olson (1963).
Quercus alba	Tennessee, U. S. A.	0.150	Witkamp (1966)
Oak leaves	Rothamsted, England	0.300	Edwards and Heath (1963)
Quercus robur	Rothamsted, England	0.240	Heath *et al.* (1966)
Quercus robur	U. S. S. R.	0.090-0.096	Zlotin 1970)
Pine forests	California, U. S. A.	0.0027-0.0082	Jenny *et al.* (1949)
Short pine forests	South-east Missouri, U. S. A.	0.036	Crosby (1961)
Pome forests	South Eastern U. S. A.	0.070	Olson (1963)
Pine forests	Minnesota, U. S. A.	0.017	Olson (1963)
Pinus sylvestris	England	0.033	Kendrick (1959)
Pinus alba	Tennessee, U. S. A.	0.110	Witkamp (1966)
Pinus taeba	Tennessee, U. S. A.	0.120	Thomas (1968)
Pine needies	England	0.083	Karenlampi (1971)
Aesculus indica	Naini Tal, India	0.290	Pandey (1979)
Daphane cannabina	Naini Tal, India	0.365	Pandey (1979)
Ilex dipyrena	Naini Tal, India	0.0.329	Pandey (1979)
Quercus floribunda	Naini Tal, India	0.193	Pandey (1979)
Quercus leucotrichophora	Naini Tal, India	0.193	Pandey (1979)
Cedrus deodara	Naini Tal, India	0.158	Pandey (1979)
Cupressus torulosa	Naini Tal, India	0.139	Pandey (1979)
Shorea robusta	Chorgalia, Naini Tal, India	0.253	Present Study
Mallotus philippensis	Chorgalia, Naini Tal, India	0.274	Present Study
Quercus leucotrichophora	Chorgalia, Naini Tal, India	0.253	Present Study
Lyonia ovalifolia	Kalona, Naini Tal, India	0.253	Present Study
Quercus glauca	Kalona, Naini Tal, India	0.274	Present Study
Rhododendron arboreum	Kalona, Naini Tal, India	0.165	Present Study
Quercus leucotrichophora	Kalona, Naini Tal, India	0.192	Present Study
Pinus roxburghii	Baldiyakhan, Naini Tal, India	0.126	Present Study
Quercus leucotrichophora	Baldiyakhan, Naini Tal, India	0.165	Present Study
Quercus leucotrichophora	Ranikhet, Almora, India	0.165	Present Study
Myrica esculenta	Ranikhet, Almora, India	0.156	Present Study
Quercus Lanuginosa	Kilbury, Naini Tal, India	0150	Present Study
Quercus floribunda	Kilbury, Naini Tal, India	0150	Present Study
Quercus leucotrichophora	Kilbury, Naini Tal, India	0.183	Present Study

Table 4: Time (years), required for 99% release of nutrients for species of different forest sites

Site	Species	Organic matter	N	P	Na	K	Ca
Sal	*S. robusta*	1.09	1.83	1.58	2.10	1.22	1.25
	M. Philippensis	1.00	1.85	1.50	1.26	1.00	1.04
	Q. leucotrichophora	1.09	1.18	1.18	1.31	1.48	1.57
	L. ovalifolia	1.09	1.82	2.09	1.82	1.19	1.30
Pine mixed broadleaf	*Q. glauca*	1.00	2.73	2.65	2.97	1.46	1.47
	R. arboreum	1.66	3.44	3.72	3.32	1.87	2.25
	Q. leucotrichophora	1.43	2.18	2.05	2.18	1.48	1.57
Pine	*P. roxburghii*	3.57	5.18	5.91	5.91	2.99	4.80
	Q. leucotrichophora	1.83	4.12	4.52	3.97	2.40	2.62
Mixed oak-pine	*Q. leucotrichophora*	1.67	2.59	1.87	2.99	1.91	2.00
	M. esculenta	1.75	4.39	2.06	5.91	2.04	2.67
Mixed oak	*Q. Lanuginosa*	1.83	3.84	3.03	3.32	2.29	2.39
	Q. floribunda	1.83	4.27	3.32	3.72	1.74	2.28
	Q. leucotrichophora	1.50	1.91	1.57	1.75	1.20	1.39

served at the sal and pine-mixed broadleaf forest sites and slowest at the pine forest sites. The N release was faster in *Q. leucotrichophora* (sal forest), *L. ovalifolia, S. robusta* and *M. Philippensis* and slowest in *P. roxburghii*. In some cases, the P release was faster than N. P release was fastest at the sal forest site and slowest at the pine forest site. There was no immobilisation of K in the decomposing material and K release was faster than the Ca release. Release of both the nutrients was faster at the sal and the pine-mixed broadleaf forest sites and slowest at the pine forest site. Faster release of K compared to other nutrients was also observed by Bocock *et al.* (1961); Gosz *et al.* (1973) and Vogt *et al.* (1983).

Turnover is assumed to follow a negative exponential function $Xt/Xo = e^{-kt}$, where Xo = initial mass, Xt = mass at time t, k is a constant and t = time (Olson, 1963). Time required for the disappearance of 99% of the initial amount of the litter comes to:

$$t\,(99\%) = 4.605/\,(-k)$$

The time for 99% release of litter dry matter and nutrients for the present species is given in table 4. The faster rate of weight loss and nutrient release in general was observed for the species of sal forest site and the pine mixed broadleaf forest site and slower release for the species placed at pine forest site.

Nutrient Release in Forest Floor

Table 5 includes the litter and nutrient inputs and the nutrient release for few species at different forest sites. The leaf litter input values were adopted from Mehra (1984). The total release of nitrogen, phosphorus, sodium, potassium and calcium for the species shown in table 5 was estimated by multiplying the input values with fractional nutrient losses for the bags. Faster dry weight loss as well as nutrient release were observed at the sal forest site followed by pine-mixed broadleaf,

Table 5: Input and release of organic matter, and selected nutrients in the forest soil through selected species.

Forest	Species	Organic matter ($kg\ ha^{-1} yr^{-1}$)		Chemical Components ($kg\ ha^{-1} yr^{-1}$)									
				N		P		Na		K		Ca	
		A	B	A	B	A	B	A	B	A	B	A	B
Sal	*S. robusta*	4505	4152	44.60	41.03	12.61	11.93	1.80	1.60	21.17	20.66	73.43	71.59
	M. Philippensis	316	316	1.64	1.64	0.41	0.41	0.41	0.41	0.79	0.79	6.73	6.75
Pine mixed broadleaf	*Q. glauca*	894	894	8.40	7.56	0.63	0.58	0.72	0.52	7.15	7.15	10.10	10.10
Pine	*P. roxburghii*	5820	2690	38.99	16.18	2.91	1.30	0.64	0.29	7.57	3.61	29.68	12.61
Mixed oak-pine	*Q. leucotrichophora*	3616	2166	41.56	24.67	7.95	4.92	2.53	1.50	24.94	15.40	39.75	29.45
Mixed oak	*Q. lanuginosa*	3641	1987	48.06	25.80	4.37	2.51	2.91	1.23	26.94	16.32	45.15	27.17
	Q. Floribunda	3954	2157	38.35	19.86	4.75	2.67	3.16	1.72	28.47	17.71	52.19	31.61

A = Input, B = release

mixed oak pine, mixed oak and the pine, mixed oak and the pine forest sites. At the sal forest site, *M. Philippensis* decomposed completely at the end of annual cycle and 100% release of nutrient occurred within one year. All the species at the mixed oak and mixed oak-pine forest sites released nutrients at the rate of 50% per year. Potassium release was faster at all sites compared to other nutrients.

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Author's Address: **V.P. Upadhayay**, Ministry of Environment and Forests, Eastern Regional Office, 194, Kharvel Nagar, Bhubaneswar 751 001, Orissa, India

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CHANGE AND MANAGEMENT

R. C. MOHANTY
Department of Botany
Utkal University
Bhubaneswar, Orissa, India

with a Foreword by
U. Schiewer

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