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Application of Aerial Photo-Analysis for Assessment of Vegetation in Kumaun Himalaya. II. Kathgodam to Okhalkanda

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The vegetation and other landuses of Kathgodam to Okhalkanda area in the hilly part of Naini Tal district (Kumaun Himalaya) were studied through aerial photo-analysis. Out of a total area of 44862 ha, 40.1% was under non-forest landuse and 59.9% was devoted to forest landuse. Forests with crown density >40% were recorded in 10.3% of the total study area and only 1.6% land had forests with >60% crown density.

Key Words: Photo-analysis, Landuse, Crown density, Himalayan forests, Altitudinal variation

Introduction

Assessment of vegetation along a transect from Ranibagh to Naina peak-Kilbari in Kumaun Himalaya using aerial photo-analysis technique was presented in the first paper of the series (Tewari & Singh 1983). In the present study 44,862 ha area from another part of Kumaun Himalaya was mapped and assessed for vegetation and landuse pattern.

Study Area

Location

The study area lies between 29°15′ to 29°25′ N lat. and 79°30′ to 79°45′ E long. in the hilly tract of Naini Tal district and covers an altitudinal range of 400m (Kathgodam) to 2300 m (Mukteshwar).

Geology

Geology of the area has been described by Hukku et al. (1974), Raina and Dungrakoti (1975) and Misra (1980). The ground is hilly with varying degree of steepness. Three different rock types i.e., Sedimentary, Meta-sedimentary and Igneous occur in the study area. Structurally the area is very complex. Three major tectonic planes or thrust are observed: (*i*) Main Boundary Thrust, (*ii*) South Almora Thrust, and (*iii*) Ramgarh Thrust.

Climate

The climate varies from monsoon subtropical to monsoon temperate. The mean monthly temperature varies from 9.4°C (in January)–20°C (in June) at Mukteshwar to 13.2°C (in December)–28.2°C (in June) at Kathgodam. Total annual rainfall ranges from 1310 mm at Mukteshwar to 2005 mm at Bhimtal. Severe frosts are usual from December to February and they occur even in lower valleys. In winter (November to February) snow fall commonly occurs at higher altitudes (Mukteshwar, Maheshkhan and Pahar Pani).

Methods

Vertical aerial photographs (1:40,000) taken in 1973 by the Survey of India were interpreted as described earlier (Tewari & Singh 1983). Forests were sub-divided into five classes on the basis of crown density (Tewari & Singh 1983).

Results

The detailed map of the study area as interpreted from the aerial photographs is given in figure 1 and area for different vegetation types and other landuses is estimated in table 1.

Non-Forest Area

A total of 18,000 ha was non-forested land. This represented 40.1% of the total study area of 44,862 ha. Of the non-forested area, 73% (29.3% of the total study area i.e., 13,144 ha) was devoted to agricultural use. Habitation was spread over 382 ha, accounting for 0.9% of the total study area. The townships of Kathgodam, Ranibag and Bhimtal are mainly responsible for this non-forest landuse. Three lakes, viz., Sattal, Bhimtal and Naukuchiatal along with a number of smaller as well as larger streams which drain in the river Gaula are the main water bodies. Wasteland/grassland accounted for 4.7% of the total study area and 11.8% of the non-forest area. This category also includes barren lands and rock-outcrops.

Table 1 *Summary of vegetation and landuse*

Landuse	Area (ha)	% of forest/-non-forest area	% of total area
NON-FOREST:			
Eroded lands	1041	5.8	2.3
Waste/grass land	2127	11.8	4.7
Habitation	382	2.1	0.9
Main roads	392	2.2	0.9
Water bodies	914	5.1	2.0
Agriculture	13144	73.0	29.3
Total non forest	18000	—	40.1
FOREST:			
Shorea robusta	6045	22.5	13.5
Mixed sal	2127	7.9	4.7
Pinus roxburghii	6756	25.1	15.1
Mixed pine-broadleaf	2231	8.3	5.0
Quercus leucotrichophora	4258	15.8	9.5
Mixed oak	3242	12.1	7.2
Scrub vegetation	2203	8.2	4.9
Total forest	26862		59.9
Grand total	44862		

Small patches of eroded lands, which could be identified from the scars of light tone on the aerial photographs in contrast to darker tone of surrounding area, were spreadover covering 2.3% of the total study area. Main (motorable) roads accounted for 392 ha, i.e. 0.9% of the total study area.

Forest Area

A total of 26,862 ha was found under forested land (table 1). Six major forest types could be distinguished in addition to scrub vegetation. They were: *Shorea robusta* Gaertn. f. (Sal), mixed sal, *Pinus roxburghii* Sarg., mixed pine-broadleaf, *Quercus leucotrichophora* A. Camus and mixed oak forest (figure 1).

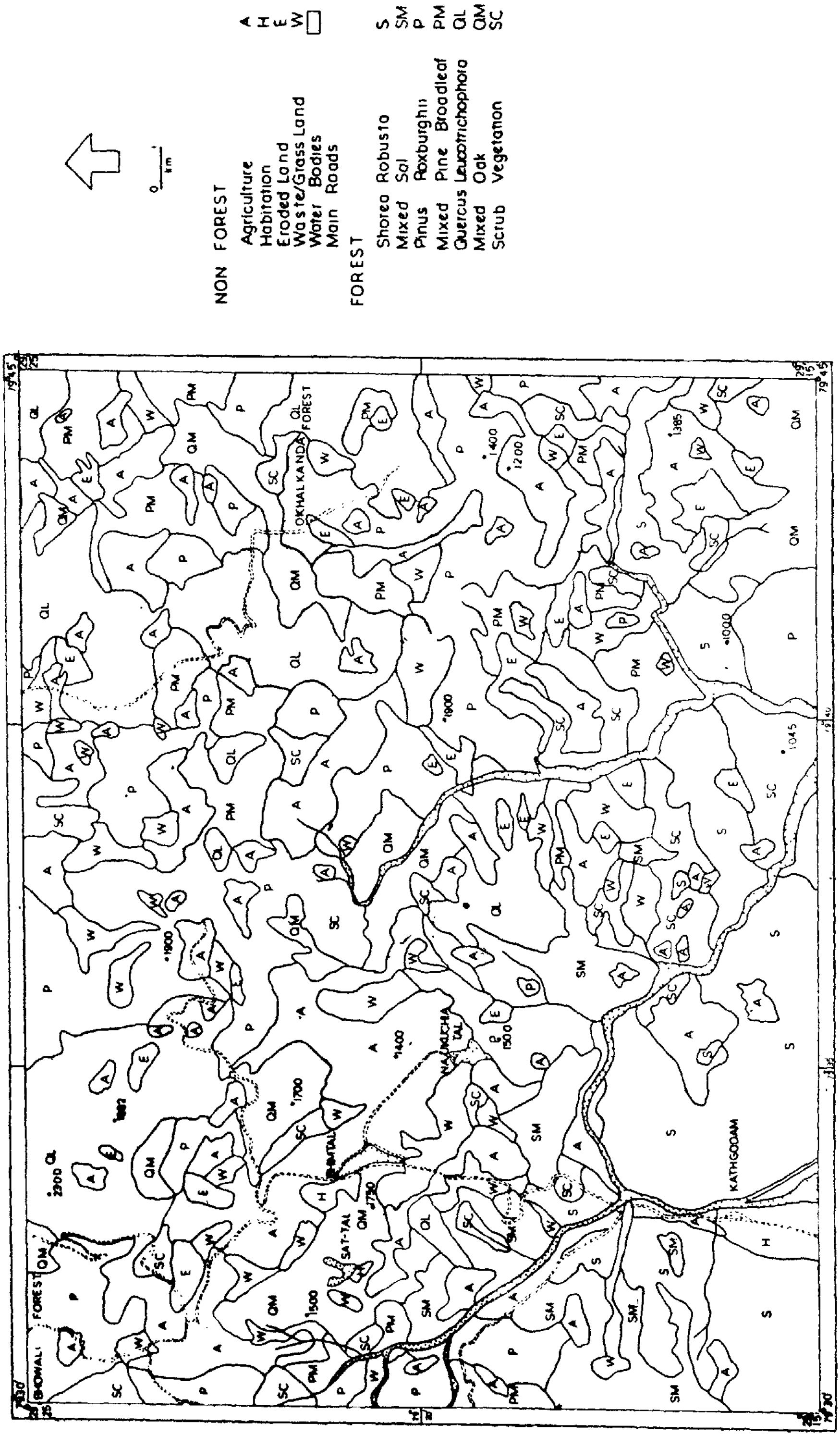

Figure 1 Map of vegetation and other landuses of the study area interpreted from aerial photographs. Altitudes of selected locations are given in meters.

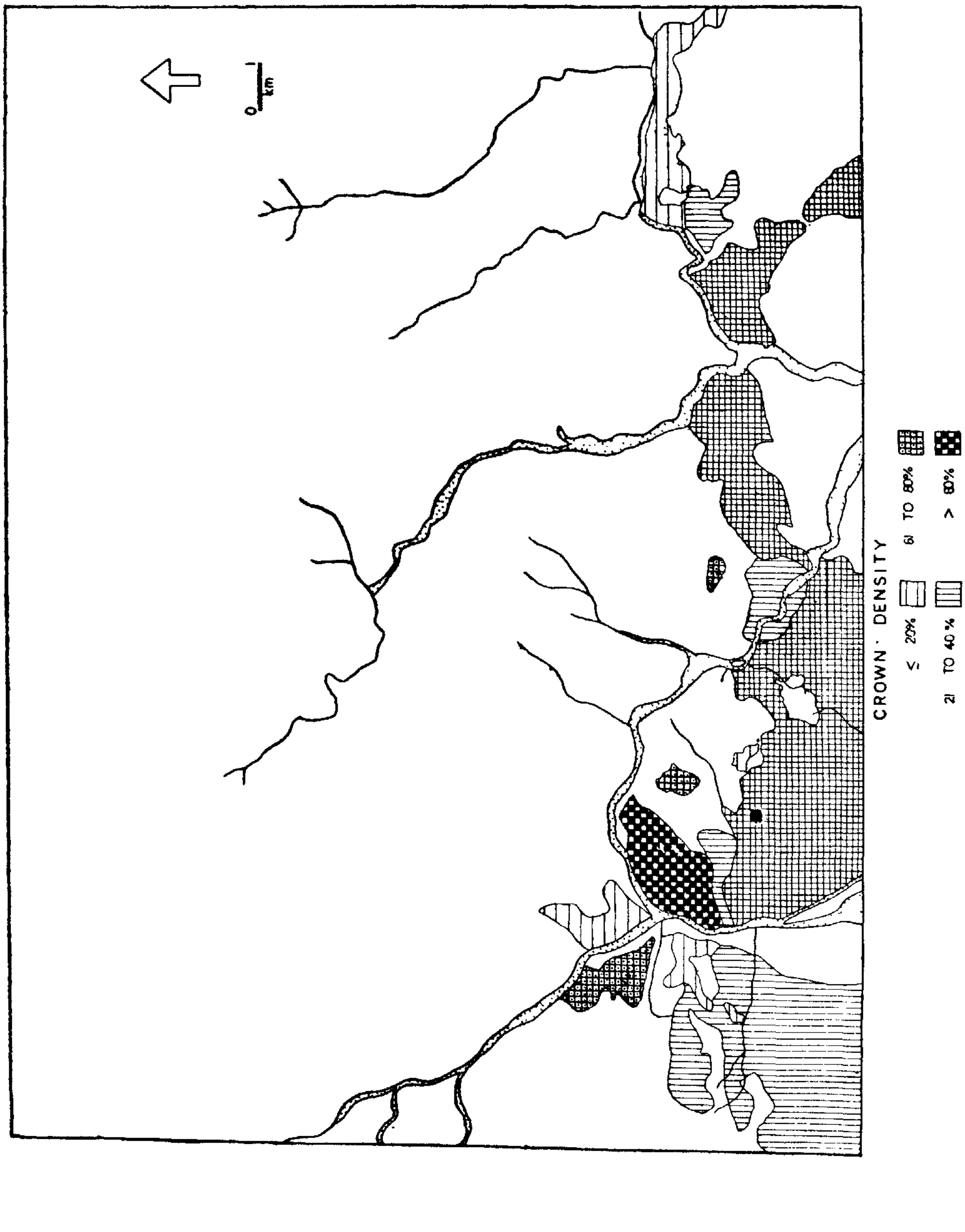

Figure 2 Crown density and distribution of *Shorea robusta* forest

Shorea robusta forest (*figure* 2)

The forest was confined to the area covering a total of 6045 ha i.e. 13.5% of the total study area or 22.5% of the total forested area (table 1). The forest extends from 400 to 900m altitude. A single tall species viz., *S. robusta* was dominant. Field checks revealed that *S. robusta* contributed more than 70% to the plant cover. Associated species were *Mallotus philippensis* (Lam.) Muell. Arg., *Ehretia laevis* Roxb., *Terminalia tomentosa* Wt. and Arn., *Xeromphis spinosa* (Thumb) Keay and *Syzygium cumini* Linn.

Although all five crown density classes were present, 51.8% of the land under this forest type was covered by the forest with≤40 crown density and 39.7% with forest of 41–60% crown density. Only 8.5% of the land was covered by the forest of >60% crown density (table 2).

Mixed Sal forest (figure 3)

Covering a total of 2127 ha (4.7% of the total study area and 7.9% of the total forested land), this forest generally extends from 800 to 1200m altitude. *S. robusta* continued to be the dominant species but the companion species such as *P. roxburghii* and *Toona ciliata* Roem in the upper elevational belt (i.e. between 1000m and 1200m altitude) and *M. philippensis*, *E. laevis* and *T. tomentosa* in the lower elevational range (i.e. between 800 and 1000m altitude) occurred in larger proportion than in the preceding *S. robusta* type.

In 90.3% of its aerial extent crown density was ≤60% and in 9.7% of the area, it was between 61 and 80%. Crown density class >80% was altogether absent (table 2).

Pinus roxburghii forest (*figure 4*)

This forest occupies the largest area (6756 ha), extending from 1000 m to 2000m and overlaps the altitudinal domain of mixed sal forest towards the lower elevation in many places. Throughout the territory of this forest (15.1% of the total study area), single tall tree species viz., *P. roxburghii* was dominant. A total of 98.7% area of this forest had ≤40% crown density and only 1.3%, >60% crown density (table 2).

Mixed pine-broadleaf forest (*figure 5*)

The forest occurred in patches within the altitudinal range of *P. roxburghii* (1000–2000m). *Pinus roxburghii* was the dominant species with a fair share of several associated broadleaf species such as *Q. leucotrichophora*, *Myrica sapida*

Table 2 *Area in each crown density class with in different forest types*

Forest	Crown density									
	≤20		21–40		41–60		61–80		≤80%	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
S. robusta	1188	19.7	1943	32.1	2399	39.7	177	2.9	338	5.6
Mixed sal	805	37.9	576	27.1	539	25.3	207	9.7	—	—
P. roxburghii	3695	54.7	2971	44.0	90	1.3	—	—	—	—
Mixed pine-broadleaf	1185	53.1	653	29.3	393	17.6	—	—	—	—
Q. leucotrichophora	2449	57.5	1633	38.4	176	4.1	—	—	—	—
Mixed oak	957	29.5	1996	61.6	289	8.9	—	—	—	—

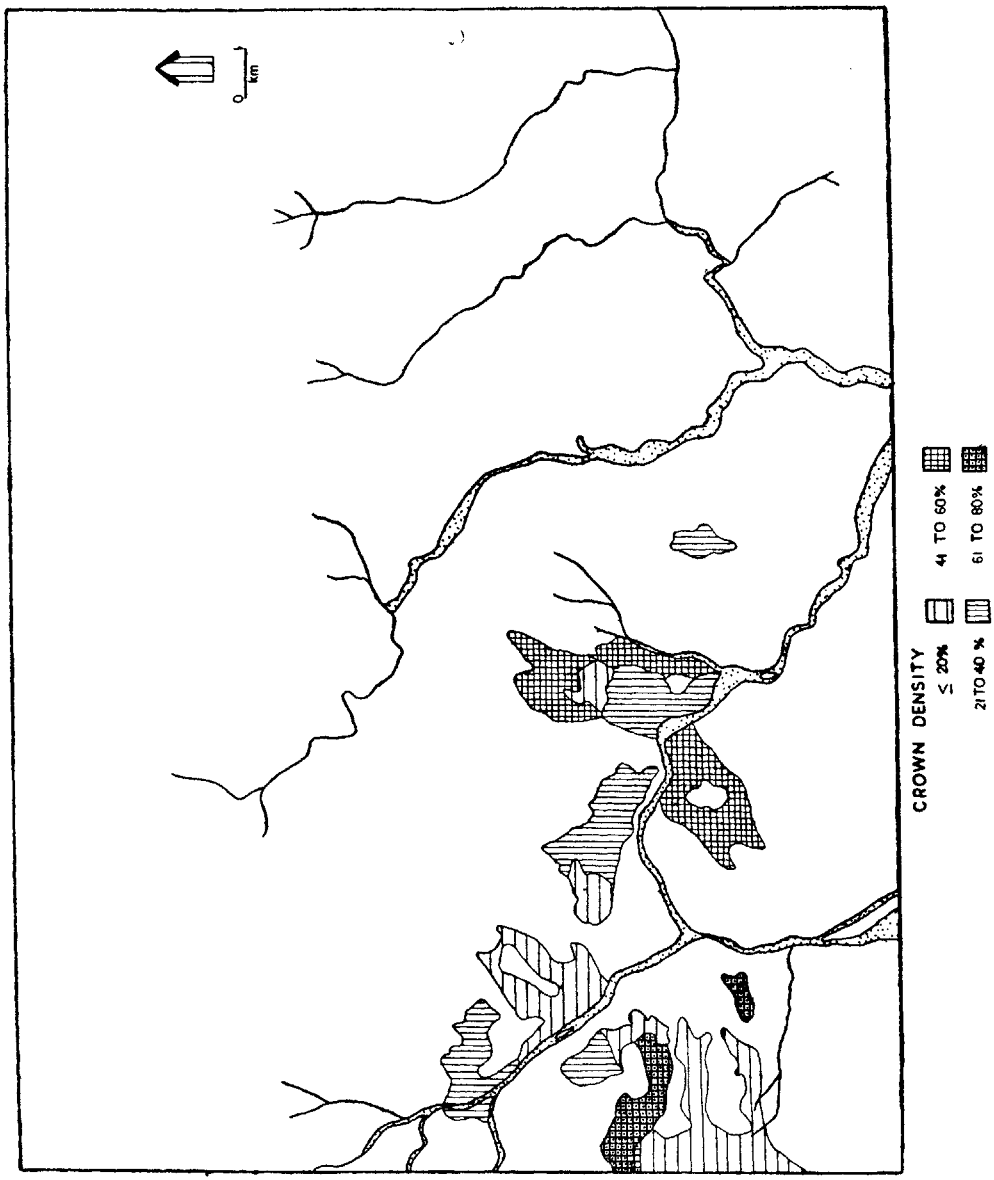

Figure 3 Crown density and distribution of mixed Sal forest

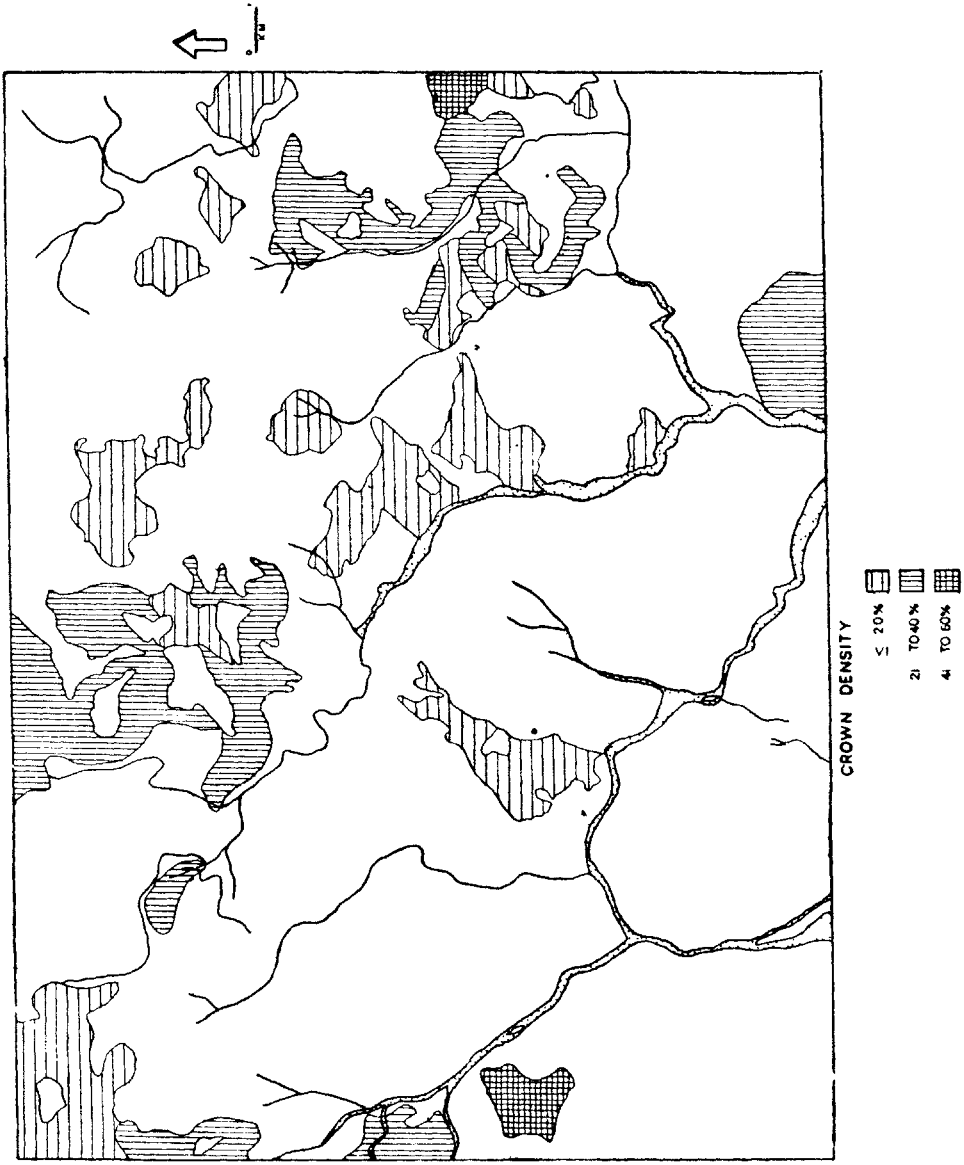

Figure 4 Crown density and distribution of *Pinus roxburghii* forest

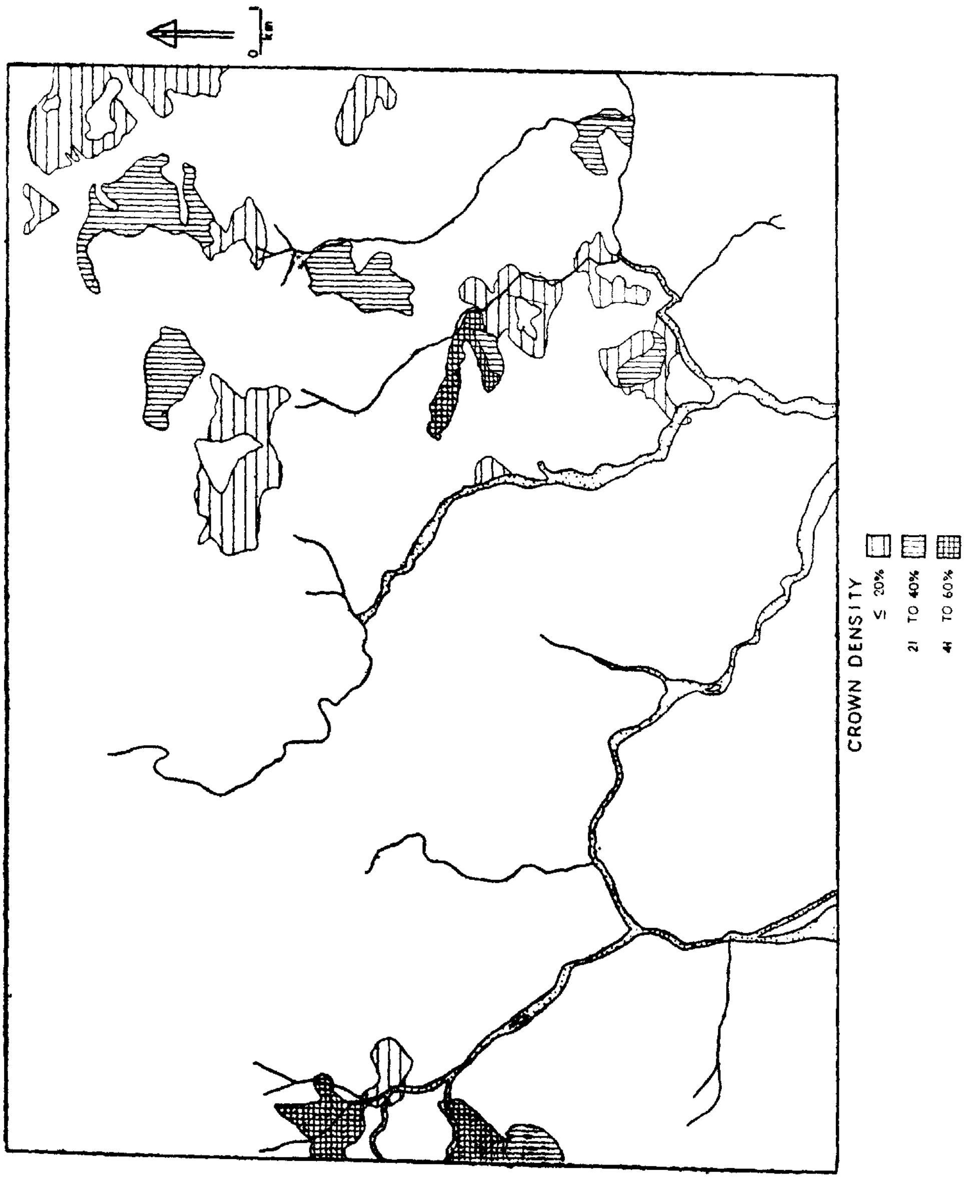

Figure 5 Crown density and distribution of Mixed pine-broadleaf forest

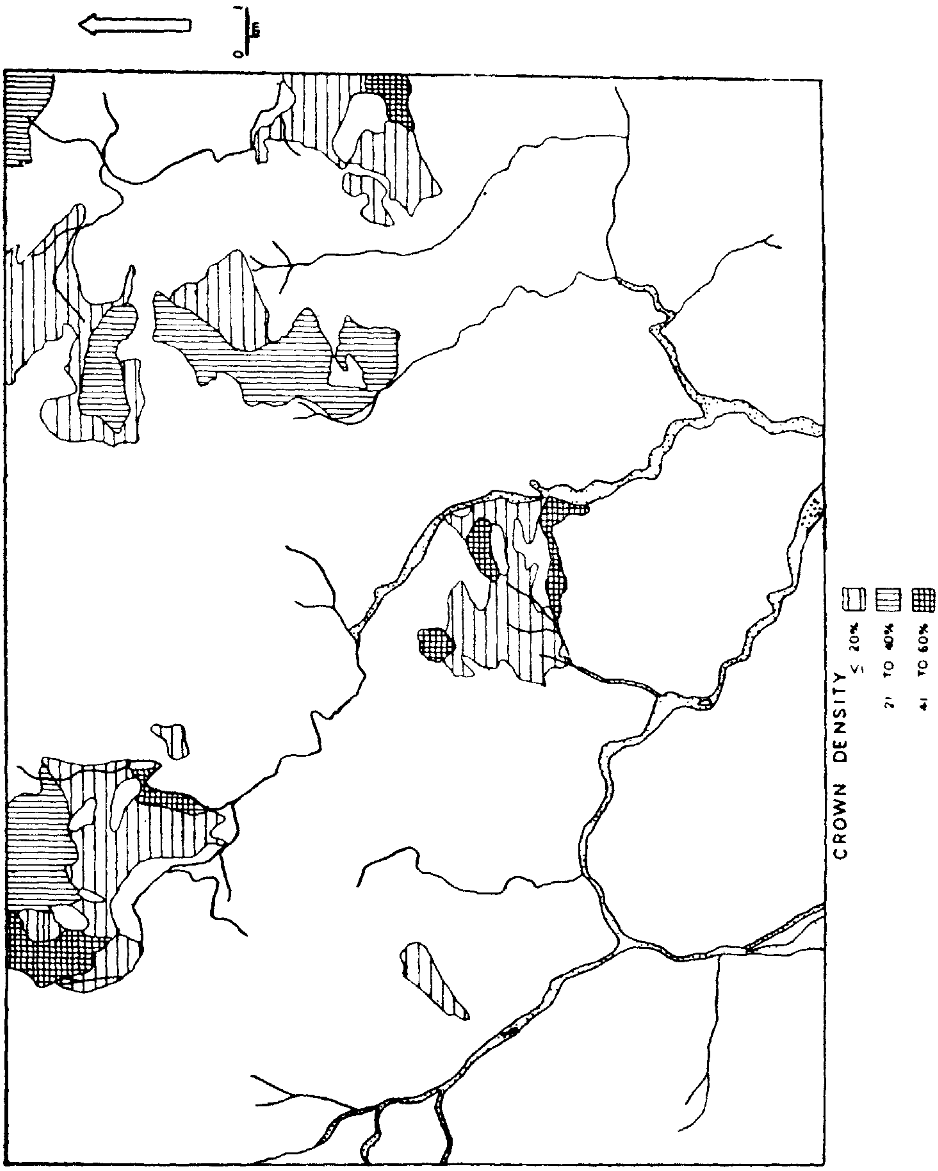

Figure 6 Crown density and distribution of *Quercus leucotrichophora* forest

Wall., *S. cumini* and *Engelhardtia spicata* Leschen ex Bl. var. *Colebrookiana* (Lindl. ex Wall.) O. Ktze. *Pinus roxburghii* and broadleaf species in general, were distinguishable from each other on the aerial photographs. Total area covered by this forest type was 2231 ha, i.e. 5% of the total study area. Within this forest type 82.4% land was covered by the forest with crown density 41–60% (table 2). The relatively dense crown density classes (>60%) were not present.

Quercus leucotrichophora forest (figure 6)

A total of 4258 ha, i.e. 9.5% of the total study area or 15.8% of the total forested area harboured this forest (table 1). In general, altitudinal range enjoyed by this forest varied from 1700 to 2100 m but it also ingressed at places in the altitudinal domain of *Pinus roxburghii* (1000–2000m) and of high altitude mixed oak forest (2100–2300m).

Though *Q. leucotrichophora* was the predominant species, field checks revealed the presence of scattered individuals of *P. roxburghii* and certain other broadleaf species, such as, *M. sapida*, *Rhododendron arboreum* Sm. and *Acer oblongum* Wall. Saxena and Singh (1982) also recognized patches of *Q. floribunda* Lindl. community within the territory of this forest type in Maheshkhan area.

In 95.9% area of the forest, crown density was 40% or less and in the remaining 4.1% area it was between 41–60% (table 2).

Mixed oak forest (figure 7)

The mixed oak forest accounted for 7.2% (3242 ha) of the total study area (table 1). Compared to *Q. leucotrichophora* forest, this mixed oak forest, along with *Q. leucotrichophora*, contains high altitude oaks (viz., *Q. lanuginosa* D. Don. and *Q. semecarpifolia* Sm.) at the upper elevation (2100–2300m) and lower altitude oak (viz., *Q. floribunda* and *Q. glauca* Thumb.) at the lower elevation (about 1100 to 1300m).

Within this forest type 29.5% area was under ≤20% crown density class, 61.6% area under 21–40% crown density class and 8.9% area under 41–60% crown density (table 2). Crown density classes >60% were altogether absent.

Scrub vegetation (figure 8)

Patches of scrub land occurred throughout the study area. Total area occupied by the scrub vegetation was 2203 ha, which was 4.9% of the total study area or 8.2% of the total forested area. This type of vegetation was generally confined to the area between forest and agricultural lands. Species identification was not possible on aerial photographs. However, ground checks revealed that the scrub vegetation was generally dominated by *Lantana camara* Linn. throughout the area but in lower altitudinal zone, i.e. below 1000m, presence of *Clerodendrum viscosum* Vent., *Murraya koenigii* Spreng., *Myrsine semiserrata* Wall., *Pyracantha crenulata* (D. Don) Roem. and *Rubus ellipticus* Smith was also noticed.

Discussion

In the present study although forested land accounted for about 60% of the total area, this statistics is misleading in that only 1.6% of the total area of 44,862 ha had forest with >60% crown density and 10.3% area had forest with >40% crown density (table 3). In comparison to the area described in the first paper of this series (Tewari & Singh 1983), where 16.3% of the total area of 11,900 ha had

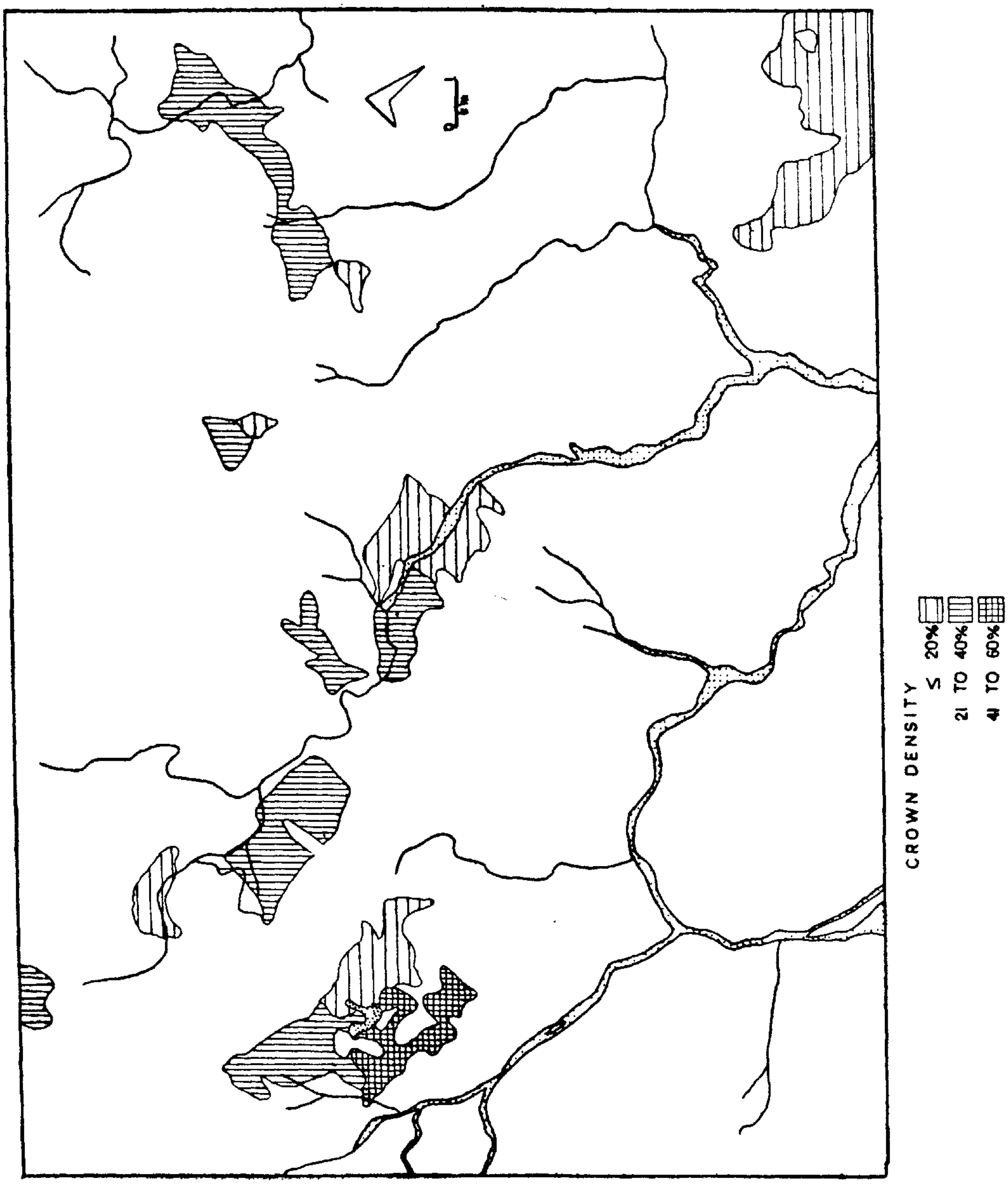

Figure 7 Crown density and distribution of mixed oak forest

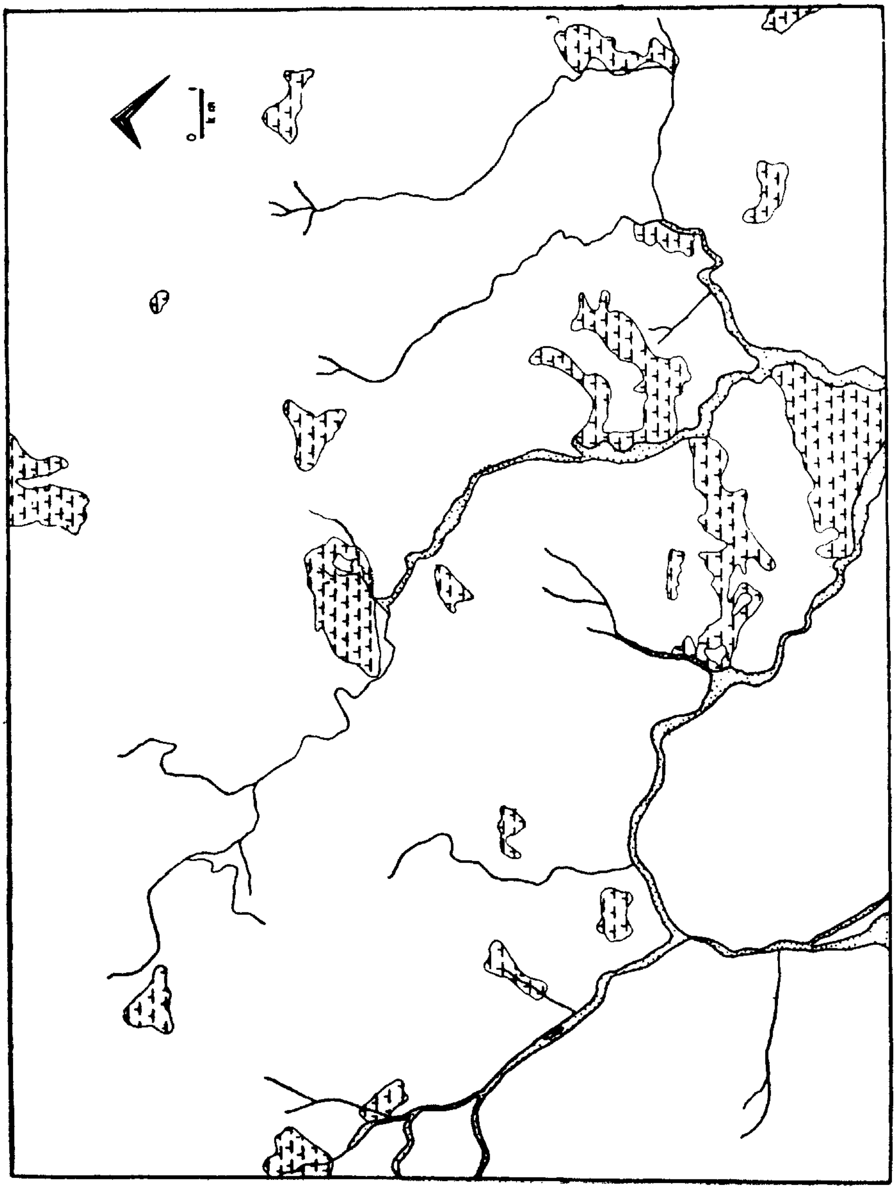

Figure 8 Distribution of scrub vegetation

forest with >60% crown density and 32.1% had forests with >40% crown density, the present tract supports a markedly poorer forest vegetation.

Table 3 *Per cent of total study area with forests of >40% and >60% crown density*

Forest	Percent area with >40% crown density	Percent area with >60% crown density
S. robusta	6.5	1.1
Mixed Sal	1.7	0.5
P. roxburghii	0.2	—
Mixed Pine-broadleaf	0.9	—
Q. leucotrichophora	0.4	—
Mixed oak	0.6	—
Total	10.3	1.6

Among the forest types *P. roxburghii*, *Q. leucotrichophora* and mixed oak forest had more than 90% area under crown density ⩽40%, whereas mixed pine-broadleaf forest had 82.4% area under this category. The prevalence of relatively lower crown density indicates the poor state of forests consequent to over exploitation.

Crown density >60% was recorded only in *Shorea robusta* and mixed Sal forest types located in the lower elevational belt. Although these forests expressed crown density >60% in certain areas, in a large portion (i.e. in >90% area) the crown density in both the forests was ⩽60%. This indicates that the forests under these two types are also subjected to considerable biotic stress. Repeated field checks revealed that these two forests had thick growth of broadleaf climber *Bauhinia vahlii* Wt. & Arn. at places and this may also account for the occurrence of dense crown density classes (>60%) on aerial photographs.

Eroded lands were distributed throughout the area both in non-forested and in poorly forested landuses; however, wasteland/grassland was more concentrated near agricultural lands pointing to their secondary nature.

The study (including Tewari & Singh 1983) revealed an interesting altitudinal pattern in vegetation. *Shorea robusta* which has an absolute dominance below 800m, begins to be replaced by *P. roxburghii* above 1000m in response perhaps to cooler temperatures. The altitudinal belt 800–1000m is a tension zone where a mixture of broadleaf species, such as *Holoptelea integrifolia*, *Mallotus philippensis*, *Ehretia laevis* and *Terminalia tomentosa*, gain local preponderance due to weakening tolerance of *S. robusta* but remain associated with it. *Pinus roxburghii* has maximum expression between 1000 to 2000m. Within this altitudinal belt, however, three other forest types viz., mixed pine-broad leaf, mixed (lower altitude) oak and *Q. leucotrichophora* are also present. Here *P. roxburghii* seems to take advantage of weak tolerance of *Q. leucotrichophora* to relatively higher temperatures and greater biotic stress. The altitudinal range 1400–1800m specially is a zone of tension between the pine and oak, and apparently the more xerophytic and relatively thermophilic pine wins over in extensive areas. Biotic factors such as grazing, lopping, felling and man-induced fire assist the spread and sustenance of pine which has a greater capacity to colonize the exposed and depauperate habitats as compared to the oak. Pine seems to be a seral species. Around 1900m *Q. leucotrichophora* generally attains dominance and gradually gives way to other oak species (*Q. lanuginosa* and *Q. semecarpifolia*) as altitude increases.

Co-examination of geological and vegetation maps as interpreted from aerial photographs indicated a loose relationship between forest types and lithology (Goel & Singh 1981). *S. robusta* forest occurred predominantly on sand stone and shales of the Siwalik system, while mixed sal forest with localized scrub and *P. roxburghii* was present on Nagthat volcanics. *Pinus roxburghii* forest occurred predominantly on Nagthat quartzite and the lower member of Ramgarh group-the Rikhakot schist. The Ramgarh porphyry/gneiss harboured *Q. leucotrichophora* forest and at places mixed pine-broadleaf forest. Shales of Krol group at lower altitude supported *P. roxburghii* or mixed pine-broadleaf forests and at higher altitude *Q. leucotrichophora* forest. Krol limestone was predominantly covered with *Q. floribunda* forest and in a local patch the latter species was mixed with some planted conifers.

Use of aerial photographs in mapping and assessing the vegetation has not gained sufficient momentum in India, although in developed countries remote sensing has proved to be very useful for vegetation and landuse studies (Gaussen 1948, Gaussen & Rey 1947, Rey 1953, 1957, Northtrop & Johnson 1970, Stafford & Landfelder 1971, Zonneveld et al. 1971, Versteegh 1975). One of the aims of the study was to estimate the extent to which the aerial photo-analysis technique can be applied to vegetation and landuse studies in the Himalaya. Area under forest and non-forest landuses could easily be delineated on the aerial photographs. Non-forest landuse such as agricultural lands, habitation, wasteland/grassland, eroded lands, major water bodies and main roads were easily distinguishable. Broad forest types such as broadleaf and conifer forests, and mixed broadleaf-oak forests were easily distinguishable. In the forests with one or two tall dominant tree species, the latter were also recognizable. For example, *S. robusta* could be distinguished from *Quercus* species. However, in mixed forests it was not possible to identify the individual species. Thus the various species of *Quercus* could not be distinguished from each other on aerial photographs at the given scale. Subordinate species were often not recognizable on the photographs. For this purpose field check was necessary. It can be concluded, however, that with selective field checks, the landuse and vegetation can be successfully and rapidly assessed by using aerial photographs.

One of the major difficulties in the use of this technique is the lack of ready availability of aerial photographs. Additionally, when a set of photographs is obtained after a great difficulty it is outdated. For example, in the entire Uttar Pradesh, 29,253 ha of forest under the control of UP Forest Department was converted to non-forest use between 1973–1979 (Anonymous 1981). Both of the papers in the present series are based on 1973 photographs. We did attempt to correct the extents of various landuses by field checks but it was not always possible to do it precisely. Calibration of crown density with the current levels was however possible; the photographs showed a much better crown density level indicating better status of the forest a decade ago. Mechanism must be found to make the recent and preferably large scale (say, 1:15,000) photographs readily available to willing investigators if this technique is to be popularized. Also once a facility (e.g., trained researchers) develops in an institution it should be continually supported and used.

We recognize that colour photography,

highly sensitive infra-red photography, magnetometers, scintillation counters and multispectral scanners provide a more elegant and perhaps better means for landuse and vegetation study but their large scale and routine use will continue to be cost-inhibitive for a long time to come. Problems with the use of Landsat visible and near infra-red data have been pointed out by Ormsby (1982); for example, agricultural area may get classified as residential/industrial, urban as water, bare extractive areas as urban, and cloud shadows as water. Data from thermal scanners can aid in classifying certain themes provided there is good thermal differentiation, but a variety of factors affect the resulting temperature sensed by satellite (Ormsby 1982). Insufficiency of multispectral scanner data and synthetic aperture radar data, and complementarity between the two have been commented upon by Birnie et al. (1982).

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