Chapter 5

FOREST RESOURCES OF SIKKIM

Nature has been particularly generous in her gift of sylvan treasures to the state of Sikkim. With luxuriant forest abounding in all part of state, Forestry has been the major land use in the State and nearly 82% of the total geographical area of the State is under the administrative control of the State Forest Department. The forest cover of the State is 46% of the total geographical area of the state. This proportion is one of the largest in the country.

Table 5.1 Sikkim General

Geographic Area	*7,096 sq. km (0.2 % of country)*
Population	*0.54 million (0.05 % of country)*
Urban	*0.06 Million (11.1 %)*
Rural	*0.48 Million (88.9 %)*
Average Population Density	*76 persons per sq km*
Tribal Population	*22.40 %*
Livestock Population	*0.34 million (0.1 & of country)*
No. of Districts	*4*

Table 5.2 Forest Area Details ***(As per the State Records)***

Total geographical area	--------	7096 sq. kms.	
Recorded forest land:			
1. (A) Reserved Forests	--------	2261 sq. kms.	
(B) Khasmal Forests	--------	285 sq. kms.	
(C) Gorucharan Forests	--------	104 sq. kms.	
Total	**--------**	**2650 sq. kms.**	**(37.34%)**
2. Area under alpine pasture & scrub-(RF)	**---**	**1024 sq. kms.**	**(14.44 %)**
3. Area under perpetual snow cover (RF)	**---**	**2091 sq. kms.**	**(29.50 %)**

Thus the total recorded forest land in the state > 81.28 % of total geographical area and the Revenue area =1643.59 sq kms.

Fig 5.1 Recorded Forest Land

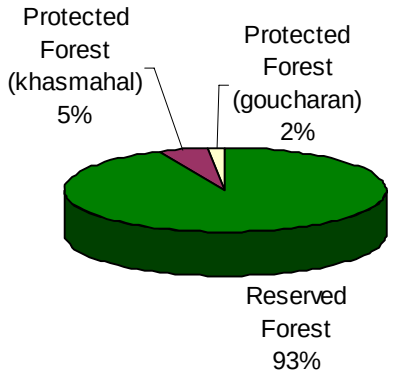


Table 5.3 Recorded Forest Area ***(As per the Forest Survey of India 2005 (FSI)*** **(Area in sq. kms)**

Geographic area	Reserved Forests	Protected Forests (Khasmal)	Protected Forests (Gorucharan)	Recorded Forests of State's Geographic area		Of Country's Forest area
7,096	5,452.39	285	104	5,841.39	82.31 %	0.75 %

The recorded forest area of the State is 5,841 km², constituting 82.31% of the geographical area of the State. Legally this area has been classified into Reserved Forest and Protected Forest, which constitute 93.34% and 6.66% of the forest area respectively.

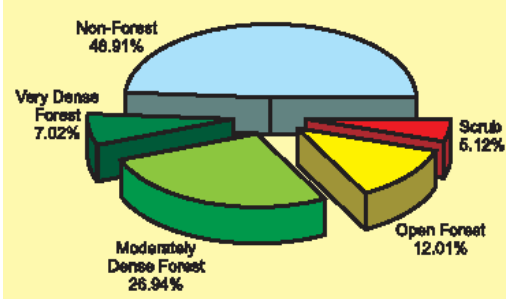
As per the **State of Forest Report** of the Forest Survey of India, Ministry of Environment & Forest, Government of India, the Forest cover assessment status in different reported year is as under:

Table 5.4 Forest Cover in Different Assessments (1987-2005) (Area in sq. kms)

Year	1987	1989	1991	1993	1995	1997	1999	2001	2003
Forest Cover Assessment	2,756	3,041	3,041	3,119	3,127	3,129	3,118	3,164	3262
Percentage of Geographical area	38.84%	42.86%	42.86%	43.95%	44.06%	44.1%	44%	45%	46%

Note: In the State of Sikkim about 44 % of total geographical area is under Alpine pasture & scrub and under perpetual snow cover. Hence, in these areas, it would not be possible to bring the tree cover. The area considered for the tree cover may therefore be excluding these areas.

Fig 5.2 Forest Cover of Sikkim



Map 5.1 Forest Cover of Sikkim

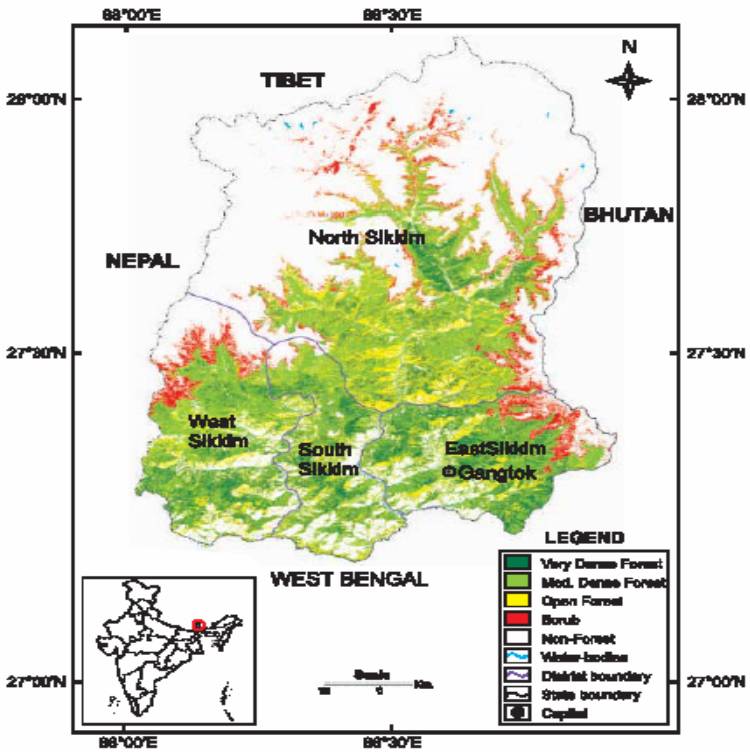


Table 5.5 Forest Cover *(in sq. kms)*

	2003	2005
Very Dense Forest	498	498
Moderately Dense Forest	1,912	1,912
Open Forest	852	852
Total	**3,262**	**3,262**
Of State's Geographic area	45.97 %	45.97 %
Scrub	363	363
Of Country's Forest Cover	0.48 %	0.48 %

Table 5.6 Forest & Tree Cover - 2003

Total Forest & Tree Cover	3,284 sq. kms.
Of State's Geographic area	46.28 %
Of Country's Forest & Tree Cover	0.42 %
Per capita Forest & Tree Cover	0.61 Ha

Table 5.7 Forest & Tree Cover - 2005

Category	Area (in Km²)	% of Geographical Area
Tree Cover	27	0.38
Forest Cover	3,262	45.97
Forest & Tree Cover	**3,289**	**46.35**

Table 5.8 District – wise Forest Cover (Sikkim) (Assessment year 2003) (Area in km²)

District	Geographic Area	Forest Cover				Percent	Change
		Very Dense	Moderately Dense	Open Forest	Total Forest		
East	954	162	396	121	679	71.17	
North	4,226	132	755	439	1,326	31.38	
South	750	95	311	123	529	70.53	
West	1,166	109	450	169	728	62.44	
TOTAL	**7,096**	**498**	**1,912**	**852**	**3,262**	**45.97**	**+98**

Table 5.9 District – wise Forest Cover (Sikkim) (Assessment year 2005) (Area in km²)

District	Geographic Area	Forest Cover				Percent	Change	Scrub
		Very Dense	Moderately Dense	Open Forest	Total Forest			
East	954	162	396	121	679	71.17	0	68
North	4,226	132	755	439	1,326	31.38	0	208
South	750	95	311	123	529	70.53	0	4
West	1,166	109	450	169	728	62.44	0	83
TOTAL	**7,096**	**498**	**1,912**	**852**	**3,262**	**45.97**	**0**	**363**
Net change							**0**	**+3**

Table 5.10 Forest Cover Change Matrix (Sikkim): (2001-2003) (Area in km²)

2001 Assessment	2003 Assessment					Total 2001
	Very Dense	Moderate Dense	Open	Scrub	Non-forest	
Very Dense	498			8	87	**2362**
Moderate Dense		1912				
Open Forest	289		852	36	64	**802**
Scrub	27			236	74	**341**
Non- forest	187			80	3249	**3164**
Total 2003	**498**	**1912**	**852**	**360**	**3474**	**3262**
Net change						**+98**

Table 5.11 Forest Cover Change Matrix (Sikkim): (2003-2005) (Area in km²)

2003 Assessment (Data of Nov, 02)	2005 Assessment (Data of Dec. 2004)					Total 2003
	Very Dense	Moderate Dense	Open	Scrub	Non-forest	
Very Dense Forest	498	0	0	0	0	**498**
Moderately Dense	0	1912	0	0	0	**1912**
Open Forest	0	0	852	0	0	**852**
Scrub	0	0	0	360	0	**360**
Non-Forest	0	0	0	3	3471	**3474**
Total 2005	**498**	**1912**	**852**	**363**	**3471**	**7096**
Net Change	0	0	0	3	-3	

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Vegetation and Flora of Sikkim

The flora of Sikkim Himalaya has partly been studied by the famous Taxonomist Shri J. D. Hooker as early as 1948 as a part of Flora of British India published in 1872 -1897. Since then, the Botanical Survey of India has been exploring the approachable pockets in parts of Sikkim from Botanical point of view (Rolla S. Rao, 1968). However, no comprehensive vegetation type map of the entire Sikkim could be generated due to inaccessibility probably a great constraint for ground survey.

In the present study, six broad vegetation types have been demarcated in Sikkim based on Champion and Seth (1986). They are:

1. Tropical Semi-evergreen Forests
2. Sub-tropical Broad-leaved Hill Forests
3. Himalayan Wet Temperate Forests
4. Sub-alpine Forests
5. Moist Alpine Forests
6. Dry Alpine Forests

A. Tropical Semi-evergreen forest (300m-900m)

The Tropical semi-evergreen Forests with Sal as a dominant species along with a few deciduous components, is the climax type of vegetation in the foot hills of the district. These forests have been influenced by physiographic, edaphic and biotic factors of the region.

B. Sub-tropical mixed broad-leaved hill forests (900m-1800m)

As altitude increases from 900-1800m, the forests also gradually change from Tropical to Sub-tropical forests comprising tree species of *Macaranga, Schima, Eugenia, Sapium, Castanopsis* and these are generally mixed with shrubby species of *Baliospermum, Clerodendrum* and *Emblica.* Generally it is not possible to identify these two vegetation types as separate classes in satellite imagery since the signatures of these mixed composition of species are not distinct, hence classified as Mixed broad leaved hill/Mixed forests.

C. Himalayan wet temperate forests (1800m-2700m)

The vegetation gradually changes from sub tropical to sub-temperate in the altitudinal range of 1800-2400m and beyond that the vegetation becomes that of distinct Temperate forest. In the region between 1800 m to 2400 m, the dominant species are Suaga (Hemlock), *Acer, Michelia, Juglans, Rhododendron, Ilex* associated with *Rosa, Rubus, Berberis and Viburnum.* The typical temperate forests *Quercus* (Oak), *Acer, Populus, Larix* and *Abies densa* predominate the region between 2400 m and 2700m. The Himalayan wet temperate forests comprise of coniferous species with needle shaped leaves easily differentiable from broad leaved species due to their distinct spectral signatures.

D. Sub-alpine forests (2700m3700m

The vegetation from typical temperate type gradually changes to sub-alpine type at higher elevations. The tree species of *Rhododendron* are found predominantly mixed with a ariety of species like *Gaultheria, Euonymus, Vibrunum, Juniperous* and *Rubus.* Under this zone, the extensive *Rhododendron* patches were delineated but further stratification into different density classes could not be done due to their uniform canopy cover.

E. Moist Alpine forests (3700m4000m)

The vegetation in this zone mainly comprises of typical alpine meadows where tree growth is completely arrested. Quite a few stunted bushy growth species of *Rhododendron* mixed with tough clumps of *Juniperous, Salix, Berberis, Rosa* and *Lonicera* are common.

F. Dry Alpine forests (above 4000 m)

The vegetation is practically of scattered scrubs, often barren. Most of the species are of stunted thorny scrubs nature. Some of the common species are *Berberis, Juniperous* and *Salix.* In the present investigation, the alpine zone has been delineated into three categories as alpine barren with no vegetative cover, alpine scrub with scattered bushy vegetation and alpine meadows/pastures with predominantly of grasses.

Spectral reflectance of vegetation

The spectral reflectance of vegetation is very distinct and is influenced by leaf structure, water content, pigments and air spaces within the leaf. These factors mainly influence the visible, near infra-red and middle infra-red region of the electromagnetic spectrum (EMS) incident on the leaf. The low reflectance observed in blue and red regions corresponds to two chlorophyll absorption bands centered around 0.45 um and 0.65 um respectively. A relatively lack of absorption and more of reflectance in the green part of the EMS allows normal vegetation to look green. But in the near infra-red region, there is high reflectance, transmittance of similar magnitude and very low absorption. These three reflectance characters of vegetation depends on the internal structure of leaves whereas younger plantation or new emerging leafy trees show markedly high reflectance values in near infra-red; as leaves grow, inter-cellular space becomes less due to more transportation of photosynthetic materials thereby the reflectance decreases markedly immature plantations or old leaves on a tree canopy.

When the vegetation becomes stressed due to drought or excess of mineral content as in mining areas or senescent period, the amount of chlorophyll pigment decreases thereby the reflectance ion green band decreases considerably and at the same time red reflectance increases. In view of decrease in intercellular spaces reflectance values in the near infra-red will also decrease. These unique reflectance curves help in identifying the disease plant efficiently and also to assess the total biomass of the vegetation under study. In view of this relation, the ratio of the reflectance in near infra-red and red or any derived indices of vegetation data are sensitive indicators of vegetation growth! vigour. In the middle IR reflectance peaks occurs at 1.6 & 2.2 um. It has been shown that total incident solar radiation absorbed in the region is directly proportionate to the leaf water content. With this background, it is pertinent to know the spectral reflectance curves of various forest/land use classes in multi-spectral images for better understanding before subjecting the raw data for classification.

Forest type and density mapping

Realizing the importance of forest cover in the ecological conservation and economic development, the National Forest Policy proposed that the total area under forests in the country be increased steadily to cover at least one third of the total land area, the proportion be distributed 60 percent in hilly areas and 20 per cent in the plains. Thus the forest area and quality are significant aspects for sustainable development of nation and are being monitored using remote sensing techniques ever since the launch of the first satellite of Landsat series in 1972. Recently, Forest Survey of India, Dehra Dun has reported the total forest cover of Sikkim as 3124 sq. km. (42.80 per cent) to the total geographical area of 7300 sq.km. based on visual interpretation techniques using Landsat TM on 1:250,000 scale but district wise analysis has not been given (FSI, 1989). An attempt has also been made to utilize digital classification techniques to delineate different forest classes on South district, Sikkim but due to non availability of satellite data for some portion of south-eastern part, the entire district could not be covered (Jadav et.al,1993).

The utilization of remote sensing techniques in forest resource mapping has been proved to be cost effective and reliable on real time basis. The non availability of cloud free data for different seasons, rugged terrain which generally casts shadow and subsequent loss of information are some of the problems faced with the Sikkim area. Since the classification of forest types are mainly decided on the dominant association of vegetation, structure and phenological behavior, particular season or two seasons data (pre and post monsoon) could generally be of help in delineating one type of forest from the other. In addition, the variation in floristic composition with respect to altitude also effects the overall spectral response of vegetation.

In view of different brightness intensity values of same category within the deep shadow, partial shadow and non-shadow, in the rugged terrain conditions of West district, Sikkim, the classification of different categories through digital techniques pose problems. However, the image ratios do enhance and suppress the effect of shadow (Holben and Justice 1981) and some researchers used multidimensional analysis using digital topographic data as added dimensions and physical models which estimate the reflection of solar radiation from slopes (Lepreur et.al. 1988) However, in the present study different linear contrast stretching parameters were given to red, green and blue filters to IRS band 4, 3 and 2 respectively to extract useful information before identifying the features belonging to forest and non-forest categories. Though the stretching is scene specific, it has helped to identify various forest as well as landuse/ cover classes more precisely than any other enhancement technique including ratios, principal component analysis.

The local acquisition time of the satellite image plays an important role in casting shadow. The Landsat, IRS and SPOT have local acquisition time of 0930, 1025 and 1130 hrs. Respectively. Knowing SPOT has got minimum shadow, however, due to nonavailability of SPOT data at the time of the processing the data, next best available IRS satellite data has been selected. The present approach of classifying problem areas separately helped in controlling the signature extension and also shadow effect becomes localized. However some of the landuse/cover classes of lakes, rock outcrops, built-up areas are obscured on the image due to the influence of deep shadow. Therefore, such categories are located and marked on the survey of India topographical maps and digitized these classes. They were precisely superimposed on to the image to improve the mapping accuracy.

Forest type is defined as a unit of vegetation which possesses broad characteristics in physiognomy and structure sufficiently pronounced to permit its differentiation from other such units.

Forest density gives the numerical strength of the forest area under study and it has got two components:

1. Ground density which denotes number of trees per unit area.
2. Crown density which represents the per cent canopy cover with respect to ground area exposed.

In case of Sikkim forest cover mapping, the following forest crown cover density classes in each of the vegetation type have been segregated based on tonal variations.

1. More than 40% represents crown cover density of the forest as dense/closed canopy.
2. 200/0-40% shows crown cover density of the forest as open canopy.
3. 10%-20% crown cover density of the forest gives the degraded area.
4. Less than 10% crown cover density of the forest comes under the total degraded with scrubs.