FOREST TYPE AND DENSITY CLASSES

Delineation of forest type and density classes

The basic understanding of different forest density/type in relation to remote sensing data has been given in Chapter-3 & 4. The commonly used parameter for identifying density is the relative red tone/hue in false colour composite or a particular variation within the red, green, blue or combination of different tones of these in enhanced images. The procedure for generating forest type and density maps can be divided into four steps as follows:

Preparation of ground truth base scene-Step-I

1. After selecting the proper season, respective CCTs are to be procured from NRSA, Hyderabad.
2. In case of IRS-IA LISS II data, the -paths can be merged after finding out the overlap area.
3. Transformation models for each scene have to be generated to rectify satellite data for geometric corrections.
4. The rectified scene can be subjected to enhancements as explained below for improving the visibility of the image.

Enhancements:

Digital techniques have been found to be more appropriate than the photographic techniques for image enhancement because of the precision and wide variety of digital Processes. The enhancement techniques are extensively used in digital image processing as first step after rectifying the scene to improve the quality of an image for easy recognition of various earth features. For forest cover mapping, two enhancements can be attempted for optimum use in the field studies or ground truth collection.

Contrast enhancement:

This technique expand the range of brightness values in an image so that the image can be efficiently displayed in a manner desired by the interpreter/analyst. It has also been noticed that the identification of different forest type/ density classes needs thorough understanding in the field as well as with the image signatures. After keen observation of certain know areas of different forest categories, one can decide the optimum stretching parameters to locate/identify various earth features correctly. For easy identification of various forest/Land use classes in the rugged terrain of Sikkim State, the optimum stretching parameters have been found using Red, Green and Blue filters (Table-B). Using such optimum stretching parameters, standard false colour composite (FCC) are to be generated and mosaiced for ground truth collection.

Vegetation index map

Vegetation index is a convenient parameter for expressing the multi-spectral response of vegetation.. The vegetation is the only land category known to strongly absorb in visible light and to absorb little or no light in the near infra red spectral region. Spectral reflectance of other materials such as soil or litter generally increases with wave length. Thus the difference of visible and near infra red reflectance represents photosynthetically active vegetation. Therefore, vegetation canopy parameters such as leaf area index, above ground biomass and absorbed photosynthetically active radiation have been correlated with vegetation index. However, these functions are site and species specific since vegetation index is a function of the entire geometry and optics of the vegetation canopy interface.

The Vegetation Index image is the ratio between Near infrared (NIR) and red (R) bands. (VI=NRI/R)

The Normalized Difference Vegetation Index (NDVI) is generated by: NDVI = NIR - R/NIR + R.

The normalization process minimizes the effect of illumination geometry as well as surface topography. The ratio images emphasize difference in slopes of spectral reflectance curves between the two bands (NIR and Red) enabling one to extract reflectance variations. However, the ratio does not eliminate the additive effects due to atmospheric attenuation. Also a disadvantage of ratio images is that that they suppress difference in albedo, i.e earth features that have different albedos but similar slopes of their spectral curves may be indistinguishable in ratios. In view of this, the ratio images of the hilly terrain areas are not of much help in deciding the forest density classes because of various lighting conditions and shadow factor. However, this output can be used in uniform sun light conditions generally found along the south-east facing hills.

5. Mosaic of these two outputs would be helpful in ground truth collection. The aerial photographs and Survey of India topographical map can also be used for inaccessible areas and locating the sample area. The information as required in each of the sample should be incorporated in the "Ground Truth Proforma" enclosed at the end under Appendix-I.

The various phases involved in Step-l are given in Flow-Chart-2

Training computer and classification strategy-Step-II

Supervised classification technique involves "training' the computer to recognize a particular combination of digital number values (DN) representing the reflectance in each of the different wavelength bands in study from a forest cover type/land use class of interest.

In view of different illuminations in hilly rugged terrain conditions of Sikkim, the training of samples to the computer follows a pattern different to that adopted for normal plain areas. In hilly rugged terrain conditions, these different lighting conditions are observed. They are:

1. Bright areas: Most of the east-south facing hills have optimum lighting conditions, therefore, these areas are to be trained separately in each of the forest/land use classes.
2. Partial shadow areas: The hills facing north-west, often other side of the east - south hills generally are not exposed to sufficient lighting condition, hence, the reflected radiations reaching sensor are always poor, rendering different tone/signatures. Therefore, these areas are also to be trained separately under different forest/land use classes.
3. Total shadow areas: Total shadow 'areas are found frequently in the hill cliffs, gorges due to non availability of lighting conditions. These are seen as dark black areas. These total shadow areas are also to be classified separately by assigning different class values.

Care has to be taken to acquire suitable ground truth information from the field or aerial photographs before assigning training areas.

Classification strategy:

The key to successful and accurate classification lies in defining a set of training areas which are truly representative of that particular cover class under study.

The ideal classification for forest management is one which satisfies the needs of the forest administrative planners with up-to-date information at minimum time, cost and also to improve the ability of the planner and appraise him of the condition, characteristics, the resource potential and the environmental constraints in the management of forest. In classifying multispectral data, different classification techniques are available for use to discriminate forest cover types and other land use categories. Among all the supervised classification algorithms, maximum likelihood classifier has been used with considerable success throughout the world. (Rogger M. Hoffer, 1980).

Each of the forest cover class in a particular vegetation type and other land use categories in the area under study have been subdivided into 4 to 5 sub classes within the main class. The statistical information obtained from each of the training set is used to calculate the probabilities of each resolution element (Pixel) of the scene going into every class by employing Gaussian hypotheses.

In case of Sikkim, it has been found that the Agricultural areas (current fallows in November scene) and the forest blanks within the Reserve Forest areas have similar spectral signatures; hence there is every possibility of mixing up of these two classes.

Therefore, it has been decided to extract the Reserve Forest area by masking and convert the Agriculture class to Forest Blanks and reuniting with the original scene by compositing. Most of the rock outcrops, lakes and built-up areas have been observed in the shadow areas and are difficult to- segregate due to overlapping signatures with other land use classes. In view of these problems, it has been decided to digitize these features with the aid of the Survey of India topographical maps and overlay on to the classified image to improve the classification accuracy.

The problem of shadow effect has been successfully solved by assigning different classes of each category in the bright, partial shadow and total shadow areas. The major problem of moderate to deep shadows have also been solved in some test areas by boosting its digital range of each training area by acquiring adjacent class digital values keeping the mean of each of such training sets different. This approach has been worked out to the satisfaction with least overlapping of adjacent forest density classes. The classification has been launched, however, for the full scene and subsequently corrected for those areas having confusion with the ground reality. The basis of such approach is to improve the classification accuracy by utilizing the limited ground truth information for classifying the entire area. This is mainly due to the difficulty in acquiring large amount of the ground truth information.

The launching of classification strategy for Sikkim forest cover categorization has enabled to discriminate the forest area into broad classes on the basis of altitude and transformation of confusion classes into discrete ones.

1. There is a general trend in change of vegetation as altitude varies and most of the temperate forests are restricted above 2700 m altitudinal zone. Keeping this in view, the launching zone for classification has been decided.
2. Most of the Sal forests are restricted to lower reaches in East, West, and South districts of Sikkim, they have been classified separately.

The classification strategy mode and launching are contingent upon altitude, light condition and finally on the distribution of vegetation type within the scene. This enables zonal launching of classification strategy by generating computerized training sets.

Confusion matrix

The confusion matrix of each of the individually classified scenes are to be acquired to find out the accuracy in segregating different classes. A decision can be taken for merging of these classes based on the ground realities. The two or three separately classified scenes are merged to prepare a single scene after merging the classes to cover the entire area of interest.

Preparation of classified full scene

After completing the necessary merging of different classes, the different rows falling under each scene are to be grown to make the base classified scene ready (Flow-Chart-3).

Preparation of mask and overlay scenes-Step-III

Necessary mask files and overlay files are to be digitized using transformation models and these vector files are to be converted to roster files using the base classified scene. Necessary corrections, if required can be done before extracting or overlaying.

Preparation of final forest cover maps showing forest type and density maps-Step-IV

1. Final district map showing different classes pertaining to forest density and type is extracted using District Mask scene. The overlay files that are generated in the step-II should be overlaid on to the image and then subject to smoothening filter using mode techniques.

2. The confusion classes within the Reserve Forest are modified based on the confusion matrix generated in the step-II and statistics pertaining to each of the reserve forest area under each district are generated. After necessary modification, the RF scene is reunited with the original scene by compositing.

3. The statistical data base for the entire district is generated to show aerial extent of each of the forest density classes under each forest type and other land use classes.

4. Now the scene is ready for photo-write generation. The representation of forest cover map (density/type) can be shown either on 1:50,000 scale or 1:100,000 depending on the utility in forest management (Flow-Chart-5).

5. To generate}:50,000 scale, the present spatial resolution pixel on 36 m is zoomed to 30 m and generate a photo-write using 120 x 120 micron size. This gives a negative in the scale of 1:250,000, which can be blown up to five times (5X) to get a scale on 1:50,000. In case of 1:100,000 scale, the scene with 36 m pixel can be used to generate a photo-write with 72 X 72 microns, which gives a original scale negative on 1:50,000. This negative can be blown up to five times (5x) to get a scale of 1:000,000. In case of Sikkim all the forest density maps were generated on 1;50,000 scale whereas forest type maps were generated on 1:100,000 scale. The quality of these photo-write prints are quite good for updating working plan maps, further enlargements can be taken in optical enlargement or PROCOM-II using transparencies through visual techniques.

Accuracy estimation

The digital classification, especially for a large area has been proved to be useful in view of quick appraisal of the real time land use/land cover condition and in depicting the aerial extent of various classes. But there is a need to assess the accuracy by the following approaches before ascertaining the results.

The qualitative approach is one such method through which the overall classification accuracy can be assessed by comparing number of points found correctly on the classified image to that of total number of points checked in the field multiplied by hundred gives the total accuracy of the classified output in percentage.

The quantitative approach is one that estimates the amount of confusion among different training sets defined in the ground truth and the classes in the classified output by generating "confusion matrix" to check the overall classification accuracy. It has been suggested that an accuracy of more than 85 per cent in delineating various forest density classes as well as other land use/land cover categories should be fulfilled for validation.

It is necessary to verify the classified image through sound statistical methods as well as physical verification in the field before asserting the accuracy. Generally the classification accuracy is estimated by generating a confusion matrix between ground truth and classified pixels. However, in the present study emphasis has been given to estimate the accuracy by comparing the different forest, landuse/ cover classes on the classified image and the same classes in the field through systematic sampling methods.

The area under study has been divided into 5 x 5 sq. km grid and verified for each of the classes at 1 km apart. The size of the grid was decided with the assumption that minimum of five samples fall within each category and the number of samples in each category would proportionately be equal to the total area of the category. The sample of each category to be verified in the field were marked on the photo-mosaiced classified image on 1:100,000 scale. Those samples which are easily accessible in the field were physically verified and those samples which fall in remote .and inaccessible areas were verified using aerial photographs and a contingency table was prepared. The overall classification accuracy was estimated through rationing the number of samples correctly classified on the image to that of the total number of samples checked in the field multiplied by hundred (Table-2). In the present study an over all accuracy of more than 85 per cent in correctly delineating forest classes was achieved.

District wise analysis

Generation of a thematic data base at district level is one of the conventional methods yet employed in modern times as a systematically feasible technique, to arrive later at a wider target viz., State and Country level. The exploration and analisation of district floras, conceptualized and implemented by Prof R. S. Rao (formerly Head, Botany Department, Andhra University, Visakhapatnam and Director-in-Charge of Botanical Survey of India, Calcutta) is a pioneering botanical work at district level especially in dealing with the inventory of plant species in the forest and their description. More over district-wise analysis, enables temporal monitoring and generation of data base especially for planners and policy makers.

Hence the present study aims to make district-wise forest study in Sikkim with the following objectives.

1. To map different forest types and four density classes within each type as dense forest with more than 40 per cent canopy cover, open forest with canopy cover between 20 and 40 per cent, degraded with tree canopy between 10 and 20 per cent, the scrubs with less than 10 per cent canopy. It is also proposed to map forest blanks amidst dense/open forests.

2. To map major landuse/cover classes of agriculture areas, sand, river/water bodies, rock outcrops, built-up areas, snow and landslides.

3. To incorporate the forest boundaries for better scientific forest management strategies.

Realizing the capability of satellite remote sensing technology for forest management, the State Forest Department, Sikkim in association with Regional Remote Sensing Service Centre, Kharagpur has taken up a study to map forest type and their density classes of all the four districts of Sikkim using IRS-1A LISS II satellite data pertaining to the period of November, 1988.

Sikkim, the tiny Himalayan State situated between the latitudes 27 N to 28 N and longitude 87 E to 89 E approximately has a total geographical area of 7096 sq. Kms. The Sikkim bounds between the Kingdom of Bhutan in the East and Nepal in the West, and Chinese Tibet in the North and the State of West Bengal in the south. The State has four districts namely East, West North and South.

The floristic exploration that have been made in Sikkim (Hooker, 1872-97), BSI - Rolla S. Rao, 1968) could not cover the whole State, inaccessibility being the main constraint for the ground survey. This also has become bottle neck to generate vegetation type map of the State.

East district, Sikkim

Vegetation and flora of East district, Sikkim

Each vegetation types more or less associated with climate, rainfall, aspect and topographic pattern. The forests of the district can broadly be identified as 1. Lower hill forest 2. Middle hill forests 3. Upper hill forests based on the altitude.

Lower hill forests

The vegetation of this zone confined to an altitude between 300-900 m consists of mainly tropical dry deciduous to semi-evergreen species with sal as a dominant species. Because, the spectral signature of sal is significantly distinguishable from those of the mixed species, the predominant areas of the former are labelled as sal forests and those of the latter as mixed forests. Some of the common tree species are *Terminalia myriocarpa, Albizzia lucida, Callicarpa arborea, Dalbergia sissoo, Anogeissus latifolia, Adina cordifolia* and certain' bamboo species as undergrowth.

Middle hill forests

The tall evergreen species of *Alnus nepalensis, Prunus cerasoides, Shima wallichii, Englehardtia spicata* and associated with other species of *Castonopsis Macaranga, Eugenia, Sapium etc.* are seen in the altitude zone between 900 and 1800 m. No single spectral signature could be demarcated, probably because of heterogeneous floristic composition and absence of any predominant species. In the present investigation, single season (November) datum has been used due to non-availability of cloud free data for other seasons making it rather .difficult to delineate dominant species composition, hence classified under mixed subtropical broad leaved forest.

Upper hill forests

Further, the upper hills can broadly be distinguished into four strata based on altitude and also general species composition as :

Zone 1. 1800-2400m : This zone ,is a transitional zone between subtropical mixed broad leaved to sub-temperate zone with species ranging from *Alnus, Michilus, Quercus* and *Sympocos sp.* The evergreen tree species dominates the region and the undergrowth is mainly of dwarf species of bamboos.

Zone 2. 2400-3000 m: The typical temperate forests consist of species of *Pinus* and *Abies* mixed with *Picea*, *Tsuga* and *Juniperus* covering extensive areas intermixed with species of *OakRhododendron, Betula* and *Michilus sp. Pinus roxburghii* is mostly confined to Rangit valley in East District. *(Abies, Larix, Tsuga* are dominant in North district).

Zone 3. 2700-3700 m : The zone mainly consists of *Rhododendron* species intermixing _with temperate to evergreen species. The vegetation becomes spares as altitude increases and often restricted to grooves of the hills.

Zone 4. 3700-4500 m : This zone harbours scarcely any vegetative cover because of the adverse conditions of less soil cover and high wind coupled with frost. However, bushy vegetation with xerophytic characteristic species is common. Some of the species are *Juniperous, Salix, Barberis.* This zone is called as Alpine but the presence of scrub or without any bush or with grasses makes the terrain look different. Based on the presence or absence of vegetative cover, the alpine zone is further delineated into Alpine barren (without vegetative cover) and Alpine scrub (with bush).

The prime objective of delineating the total forest cover into pure Sal forest, mixed forests (subtropical broad leaved forest), coniferous (temperate forests) forests and four density classes with canopy cover more than 40 per cent as dense forest, between 20 and 40 per cent as open forest, between 10 and 20 per cent as degraded and the canopy cover less than 10 per cent as scrubs, within each forest type has been accomplished in the present investigation. The forest blanks amidst the dense forest cover in the reserve forest and district have also been mapped. Because of uniformity in canopy cover, all the tree Rhododendrons could not be further stratified into density classes based on the canopy cover.

The other landuse/cover classes that could be segregated are agriculture areas, river! streams and snow. In view of deep shadow problem, the classes of built-up areas, rock outcrops and lakes were visually interpreted and delineated using the standard false colour composite and ratioed images. A separate mask scene of these features were generated and overwritten on to the classified image. The present approach of using visual and digital techniques helped to achieve considerable mapping accuracy (Photo-I, 2, 3).

The diagrammatic representation of different forest types and the capability of remote sensing techniques in delineating various forest types are given in Figure 4.

Analysis

The working plan maps are generally prepared to represent the forest types and three density classes as dense/closed with more than 40 per cent, open forests with canopy cover density between 10 and 40 per cent and canopy cover less than 10 per cent under the category of degraded forests. However in the present investigation emphasis has been given to delineate open forests into two more categories as open forest with canopy cover between 20 and 40 per cent and degraded forest with canopy cover between 10 and 20 per cent. In addition to this tree canopy cover with less than 10 per cent has been represented as scrub forests. The present approach would be helpful to the planners to take necessary prescriptions to improve the degraded forest to open forest. The prime objective to delineate forest into pure Sal forest, subtropical broad-leaved hill forests, temperate (conifers), oak/rhododendron and alpine forest types has been accomplished. Four density classes as closed (more than 40 per cent canopy cover), open (canopy cover between 20 and 40 per cent) degraded forests (canopy cover between 10 and 20 per cent) and scrubs with less than 10 per cent tree canopy cover in Sal forests, Subtropical broad-leaved hill forest and Himalayan Wet Temperate forests have been delineated. Further, the alpine forests were distinguished into alpine scrub and alpine barren. It was found that Sal forests, subtropical mixed broad leaved hill/mixed forests, coniferous and alpine forests occupy an area of 0.17, 43.53, 11.78 and 13.89 per cent respectively ofthe total geographical area of the district. The scrubs with less than 10 per cent canopy cover and forest blanks within the reserve forest areas were recorded in 2.12 and 1.36 per cent of the total geographical area of the district reflecting the total wastelands to be developed into vegetative cover. The non-forest categories of snow, lakes, water bodies, sandy area, built-up and landslide areas contribute an area 3.72 per cent and agricultural area is reported to be 23.44 per cent. The total forest cover ofthe district was 55.47 per cent with 17.86 per cent covering closed forest and 37.61 per cent of open forest cover (Table-9, Bar Chart-I).

West district, Sikkim

Vegetation and flora of West district, Sikkim

The vegetation and flora of West district in Sikkim is also categorized into three types depending upon the altitude as 1. Lower hill forests, 2. Middle hill forests and 3. Upper hill forests.

Lower hill forests

The vegetation and flora of this zone at an altitude between 300-900 m consists mainly of tropical dry deciduous to semi-evergreen with Sal as a dominant species. The maximum biotic influence is seen in the lower reaches leading to frequent landslides. In view of significant spectral signature of Sal from other mixed species, the Sal alone can be differentiated from other mixed group of species and those species for which no specific spectral pattern could be ascertained were merged together and labeled-as 'mixed forests'. Some of the common species are *Terminalia myriocarpa, Albizzia lucida, Bombox ceiba* and *Ailanthus grandis.*

Middle hill forests

The tall evergreen species of *Alnus nepalensis, Shima wallichii, Castonopsis hystrix, Prunas cera* so *ides, Saurauja nepalensis* and species of *Macaranga, Eugenia, Sapium etc.* are seen at high elevation between 900 m and 1800 m. In view of no distinct spectral signature from these species, all such mixed group of species are combined together as 'mixed forests'. However, in the present investigation, single season (November) data has been used due to the non availability of cloud free data, hence it was difficult to segregate all the type of species compositions.

Upper hill forests

The upper hills can broadly be distinguished into three strata based on altitude and also into general species composition as:

Zone 1. 1800-2400 m : The Zone-1 is transitional between subtropical broad leaved to sub-temperate zone with species ranging from *Alnus, Michilus, Quercus lanceaefolia,* Q. *Lanmellosa, Symplocos sp.*

Zone 2. 2400-2700 m The typical temperate forests of zone-2 consists of coniferous species with needle like leaves are abundantly covering extensive areas inter mixed with species of *Oak-Rhododendron arboreum, Betula alnoies, Michilus sp.*

Zone 3. 2700 m and above m: In the Zone 3, the lower reaches are occupied by sub alpine species of *Rhododendron* mixed with temperate to evergreen species. As the altitude increases, the vegetative cover becomes sparse because of less soil cover and adverse meteorological conditions, high wind velocity and frost conditions. Nevertheless the region is covered to greater extent by bushy vegetation exhibiting xerophitic features. Some ofthe species are *Juniperous, Salix, Barberis.* This zone is called alpine but the presence of scrub, without any bush or with grasses makes the terrain look different. On the basis of vegetative cover, the alpine zone is further delineated into Alpine barren (without vegetative cover) and Alpine scrub (with bush).

In the present study five broad vegetation types have been demarcated for the State of Sikkim (Champion and Seth 1968). They are:

1. Tropical Moist deciduous-Semi evergreen Forest (alt. 300-900 m) ;
2. Eastern Himalayan Sub-tropical Broad-leaved Hill Forests (alt. 900-1800 m)
3. Himalayan Wet Temperate Forests (alt. 1800-300 m)];
4. Sub-alpine Forests (alt. 3000-3700 m) and
5. Alpine Forests (alt. 3700-4500 m).

At higher altitudes all the tree *Rhododendron* species are distinct due to specific phonological characteristic nature, especially the uniform canopy cover with thick shining leaves. The spectral signature of these *Rhododendrons* are also distinct due to which the entire stretch of Rhododendrons could be separated as a single class. In view of the uniformity in its canopy cover, all the tree *Rhododendrons* could not be further stratified into density classes based on the canopy cover (Phot0-4, 5).

The diagrammatic representation of different forest types and the capability of remote sensing techniques in delineating various forest types are given in Figure-5.

Analysis

The analysis of the generated data base of the forest and vegetation on the basis of spectral responses, vegetational classification and analysis Landuse/ land cover features according to altitude have already been discussed in detail in connection with East district of Sikkim, the same is applied for West district of Sikkim.

The total forest cover of the district was 56.31 per cent of the total geographical area. The detailed analysis of forest cover indicates that 18.77 and 37.54 per cent of area was respectively under dense and open canopy cover. The scrub land and forest blanks cover 0.70 and 1.64 per cent within the reserve forest respectively. Under the non-forest category, the major landuse/cover of Agriculture is 19.02 per cent and all other landuse/cover categories represent 9.07 per cent only. With regard to the forest types, Sal, Mixed, Coniferous and Alpine occupy nearly 0.01, 35.06, 21.24 and 13.27 per cent respectively (Table-10, Bar Chart -2).

South District, Sikkim

In the present study five broad vegetation types have been demarcated ft>r the State of Sikkim (Champion and Seth 1968). They are:

1. Tropical Moist deciduous-Semi evergreen Forest (alt. 300-900 m) ;
2. Eastern Himalayan Sub-tropical Broad-leaved Hill Forests (alt. 900- 1800 m)
3. Himalayan Wet Temperate Forests (alt. 1800-300 m)];
4. Sub-alpine Forests (alt. 3000-3700 m) and
5. Alpine Forests (alt. 3700-4500 m).

The vegetation types are associated with climate rainfall, aspect and topographic pattern. However, the forests can broadly be identified as 1. Lower hill forests, 2. Middle hill forests, 3. Upper hill forests based on the altitude.

Lower hill forests

The vegetation and flora of this zone ranging between 300-900 m consisting of mainly of tropical dry deciduous to semi-evergreen with Sal as a dominant species. The maximum biotic influence is seen in the lower reaches leading to frequent landslides. In view of significant spectral signature of Sal from other mixed species, the Sal alone can be differentiated from other mixed group of species.

Middle hill forests

As spectral reflectance characters could not be delineated species wise, they were considered as mixed group species representing the tall evergreen species of *Alnus nepalensis, Shima wallichii, Castonopsis hystrix* and species of *Macaranga, Eugenia, Sapium etc.* are seen at high elevations between 900 m and 1800 m. However, the dominance of no single species could be "observed because the data were recorded for single season (November, 1988) due to non availability of cloud free data.

Upper hill forests

Further, the upper hill can broadly be distinguished into three strata based on altitude and also into general species composition as:

Zone 1. 1800-2400 m : Zone 1 is distinct as transitional between subtropical broad leaved to sub-temperate zone consisting wide range of species *Alnus, Michilus, Querus lanceaefolia, Q. Lanmellosa, Symplocos sp.*

Zone 2. 2400-2700 m : Zone 2 has typical temperate forests dominated by needle leaved conifer covering extensive areas inter mixed with species of *OakRhododendron arboreum, betula alnoies, Michilus sp.*

Zone 3. 2700-300 m : Thin top fertile soil, high wind and freezing conditions of zone 3 do not favour establishment of free vegetation, but hardy xeric shrubs like Salix, Barberis. The alpine zone may be barren without any green cover or alpine scrub possessing bushy scrubs. Based on the presence or absence of vegetative cover, the alpine zone is further delineated into Alpine barren (without vegetative cover) and Alpine scrub (with bush).

The integrated data base of the forest vegetation of South District of Sikkim has been analyzed and vegetational types are classified on the basis of altitude using spectral reflectance characteristics of landuse/landcover pattern, on the lines similar to those applied for the East and West districts of Sikkim (Photo-6 & 7).

The diagrammatic representation of different forest types and the capability of remote sensing techniques in delineating various forest types are given in Figure 6.

Analysis

The total forest cover of the district was 55.27 per cent of the total geographical area. The detailed analysis of forest cover indicates that 19.33 and 35.94 per cent of area was under dense and open canopy cover. The scrub land and forest blanks cover 1.51 and 2.41 per cent within the reserve forest respectively. Under the non forest category, the major land use/cover of agriculture occupies about 30.92 per cent of the total geographical area of the district. With regard to the forest types, Sal, Mixed, Coniferous and Alpine occupy nearly 1.70, 44.21, 9.36 and 5.82 per cent respectively (Table-ll, Bar Chart-3).

North district, Sikkim

Vegetation and flora of North district, Sikkim

Each vegetation types more or less associated with climate, rainfall aspect and topographic pattern. The forests of the district can broadly be identified as 1. Lower hill forest 2. Middle hill forests 3. Upper hill forests based on the altitude.

In the present study, six broad vegetation types have been demarcated in the North district. Sikkim. 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 and 6. Dry Alpine Forests.

Lower hill-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 suffered greatly due to the effect of physiographic, edaphic and biotic factors operating in the region.

Middle hills-Sub-tropical mixed broadleaved hill forests (900m-1800m)

As altitude increases from 900 - 1800 m, the forests also gradually change from Tropical to Sub-tropical forests comprising tree species of *Macaranga, Schima, ugenia, 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 these are classified as mixed broad leaved hill/mixed forests (Photo-8).

Upper hill-Himalayan wet temperate forests (1800m-2700m):

The vegetation gradually changes from subtropical to sub-temperate in the altitudinal range of 1800m-2400m and beyond that the vegetation becomes that of distinct Temperate forest.

In the region between 1800m 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 comprising tree species of *Quercus (Oak), Acer, Populus, Larix* and *Abies densa* are predominating in the region between 2400 m and 2700 m.

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 (Photo-9).

Sub-Alpine forests (2700 m - 3700 m)

The vegetation from typical temperate type gradually changes to sub-alpine type at higher elevations. The tree species of *Rhododendron* are predominantly mixed with a variety 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.

Moist Alpine forests (3700m-4000m)

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.

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 (Photo-10,11,12, 13).

The diagrammatic representation of different forest types and the capability of remote sensing techniques in segregating various forest types are shown in Figure-7.

Analysis

The working plan maps are generally prepared to represent the forest type and three density classes as dense/closed with more than 40 per cent, open forests with canopy cover density between 10 and 40 per cent and canopy cover less than 10 per cent under the category of degraded forests. However in the present investigation, emphasis has been given to delineate open forests into two more categories as open forest with canopy cover between 20 and 40 per cent and degraded forest with canopy cover between 10 and 20 per cent. In addition to this tree canopy cover with less than 10 per cent has been represented 'as scrub forests. The present approach would be helpful to the planners to take necessary prescriptions to improve the degraded forest to open forest. The prime objective to delineate forest into subtropical mixed broad-leaved hill forests, temperate (conifers) *oak/rhododendron* and alpine forest types has been accomplished. Four density classes as closed (more than 40 per cent canopy cover), open (canopy cover between 20 and 40 per cent degraded forests (canopy cover between 10 and 20 per cent) and scrubs with less than 10 per cent tree canopy cover in Subtropical mixed broad-leaved hill forest and Himalayan Wet Temperate forests have been delineated but Rhododendron forests could not be separated into different density classes due to uniformity in the canopy cover. Further, the alpine forests were distinguished into alpine scrub, barren and pastured areas.

It was found that subtropical broad leaved hill/Mixed forests, conifers and alpine forests occupy an area of 15.35, 14.17 and 36.96 per cent to the total geographical area of the district. The scrubs with less than 10 per cent tree canopy cover and forest blanks within the notified reserve forest were recorded 1.48 and 1.06 per cent respectively to the total geographical area of the district reflecting the total wastelands to be developed into vegetative cover. The non-forested categories of snow, glacier, lakes, water bodies, sandy area, built-up and landslide areas were contributed an area of 28.63 per cent. The agriculture area was reported to be only 2.35 per cent. The total forest cover of the district was 29.52 per cent with 10.43 per cent covering dense forest and 19.09 per cent of open forest cover (Table-12 Bar Chart-4).

National Parks, Wildlife sanctuaries, Proposed Biosphere Reserve

In the present study, Khangchendzonga National Park and proposed Biosphere Reserves in North district, Wildlife sanctuary in Tinjurey forests in East district, proposed Biosphere Reserves in West district and Wildlife sanctuary, proposed biosphere reserve in South district, have been delineated and separate statistical data base has been generated for forest management purpose (Table-13).

Overall analysis

An attempt has been made by NRSA, Hyderabad to map the forest cover of Sikkim using 1972-75 and 1980-82 Landsat MSS data on 1:1 million scale and projected the figures of24.12 and 39.49 per cent of the total geographical area of 7300 sq. km. Subsequently Forest Survey of India, Dehra Dun (1989-91) also made an attempt to map the forest over of Sikkim using Landsat TM on 1:250,000 scale and reported 42.60 per cent to the total geographical area of 7300 sq. km. The present study recorded the total forest cover of the state as 40.13 per cent to the total geographical area of7069 sq. km (Table 14 A&B).

Conclusion

The management of forest is aimed at ensuring environmental stability and ecological balance for sustenance of all life. Keeping this in view, all the working plan/ forest management plan maps are up-dated once in ten to fifteen years. The basic knowledge required for updating the working plan map is the information related to area and volume of species composition on minimum administrative unit wise i.e., compartment, with reliability and minimum cost on real time basis. Such information is ideal for improving the ability of the planners to understand the existing forest stock. The information on regeneration capacity of different species, forest damage assessment and deforestation could be helpful to the forest administrators to make reliable statements about the condition, characteristics, the resource potential and the environment constraints, if any.

According to the system prevailing in India, the whole process of working plan consists of the preparation of three reports as: First preliminary working plan report, Second .preliminary working plan report and the final report.

First preliminary working plan report

Under the first preliminary working plan report, emphasis will be given to review the results of past management prescription for each working circle and modifications, if required. The schedule of field work to be done for the forest stock, field inventory for forest resources and regenerations survey, man power and budgetary requirements are also given in the report. The forest type and density map thus generated through present investigation has a.' great significant role in planning for the above purpose thereby reduces the cost and time to a considerable extent.

The concerned working plan officer would give more attention to those basic& administrative units (compartments/beats in Sikkim) where some forest cover change has been noticed and otherwise the existing information will be taken from the old forest stock maps. The present study helps the forester to prioritize the compartments before starting the field work, thereby reducing the cost and time for forest stock assessment. However, the volume related information could not be carried out in the present investigation but the existing data base on forest type and density will definitely be helpful in identification- and delineating of various homogenous strata thereby reducing the number of plots required for sampling.

Second preliminary working plan report

The purpose of second preliminary working plan report is to take necessary decisions on the formation of various working circles based on the results obtained from the first report. In addition, the information pertaining to geomorphological details like aspect, slope, geology and soil erosion and also damage assessment due to various factors including biotic influence are collected in the field to provide an overview of the entire plan area. Some of these themes could be generated through satellite remote sensing techniques like digital terrain model and digital elevation model with the aid of high resolution with stereo capability and temporal study.

Final working plan report

The data on forest type and density help in writing the final working plan report/ management plan and also in taking an appropriate decision, based on environmental considerations with the plan area for Afforestation programs and also wildlife management planning.

The present study highlighted the usefulness of remote sensing techniques for updating the forest working plan maps and also supplemented the information about the location, aerial extent of different forest types and their density classes. The forest type and density maps thus generated on real time basis help the forest administrators in planning and scheduling the field work for forest stock assessment. In addition it reduced the number of samples required for forest inventory and volume estimation and also time/cost to a considerable extent. Further, the implication of digital elevation model for such a hilly terrain area would definitely help in improving the classification and it is proposed to make use of the same in near future.

The present study highlights that digital classification techniques with limited ground truth could be used for mapping broad categories of forest and their crown density classes. In addition the present study provided the status of forest resources as on November 1988 for the first time with details of different forest types and their density classes along with the statistical data on the area of each category of forest as well as non-forest categories. The statistical data on different forest categories will be the bench mark for subsequent assessment of the forest cover. The present study has also shown the usefulness of remote sensing techniques in providing the information about. the location, aerial extent of different forest types and their density classes. Further, the forest type and density map thus generated on real time basis has helped the forest administrators in planning and scheduling the field work for forest stock assessment and also reduced the number of samples required for forest inventory and volume estimation coupled with time/cost to a considerable extent.

The State Forest Department, Sikkim has also taken policy decision to monitor the forest cover changes at every five years interval. Such change detection map would be of immense help to the forest officials in assessing the forest cover changes within the notified forest areas and also in habitat assessment in the National Parks, Sanctuaries and also proposed Biosphere Reserves.