# CHAPTER – VIII

## Summery and Conclusion

Forests are an integral component of the global ecosystem. Forest vegetation is fundamental to many of the environmental processes. Any degradation of forest, for food, fibre, timber, etc., greatly affects many of the vital environmental processes. Tropical forests are the most fragile and biologically diverse ecosystems of the world. These forests, due to the diverse floral and faunal resources are severely exploited In this regard it is important to study the various dimensions of Alagar hills reserved forest - one of the biodiversity rich tropical forests of south Tamil Nadu.

Alagar hills reserved forest, the present study area, is a part of the Eastern Ghats lying in the Nattam Taluk of Dindigul District, situated in the south central Tamil Nadu State. It is located between North latitudes 10° 5' 30'' to 10° 9' 40'' and East longitudes 78°10' 20'' to 78°17'7'', covering an area about 70 sq.km. On the north and eastern sides, it is bounded by Dindigul District and on the east and southern sides it is bound by Madurai District.

The objectives considered to achieve the aim of studying the landscape ecology of Alagar hills for the conservation and management of forest resources include the evaluation of the terrain characteristics of the study area; to make an inventory of the forest cover and its functional characteristics; to investigate the changes in the health of the forest vegetation through space and time; to analyse and integrate the results obtained to identify habitat suitability for the thriving native plant species and suggesting suitable strategies and conservation measures for the management of Alagar hill environs.

This area is generally hot and dry. The relatively cool season is December, January and part of February. The analysis of rainfall reveals that this area falls under dissymmetric rainfall regime with the bulk of rain occur during

the northeast monsoon (October - December). A considerable amount of rain is also received during the southwest monsoon (June – September). There are a few heavy spells during summer. On an average, the humidity is above 60% for most part of the year. Alagar Hills contains *Khondalite* group of *Quartzite* rocks belonging to *Archaean* period. Scarp faces, valley fills, bajada and structural valley are the predominant geomorphological features of Alagar hills. The soil of Alagar hill is 99.6% red loam and sand and the remaining 0.4% is black clay loam. The socio-economic investigation of Alagar hills using the Census of 2001 reveals that there are 39 households with a total population of 161 persons. Total illiterates were 111 persons - out of this 63 were women. There were about 46 cultivators, 58 agricultural labourers and 55 non-workers.

'Alagar hills' is located amidst a number of urban centres. These urban centres are characterised by high fossil fuel utilization for sustaining the productivity of industries and other urban establishments. Alagar hills acts as a CO2 sinks and maintaining the homeostatic state of the environment. Alagar hill is overloaded with the $CO_2$ dumped by adjacent urban centres and transport networks. This is the landscape context of Alagar hills. Forest cover is the landscape matrix, in which a number of landscape elements – different types of forest patches are embedded. The matrix is the most extensive and most connected landscape element and therefore plays the dominant role in the functioning of the landscape. There are three types of landscape corridors are present in Alagar hills, viz., line corridors composed of road ways and stream corridors composed of streams and network corridors the network developed by the crisscross of road and streams. The pattern detected in any ecological mosaic is a function of scale. For the present study, Landsat TM and ETM data (spatial resolution of 30 m x 30m) have been used. This is the grain size applied to derive the results of the other spatial analyses. Landscape ecology focuses on three important characteristics of landscapes – the structure, function and change.

This study is a synthesis of both the physical terrain characteristics and forest structural characteristics. Hence the study has been carried out in two phases. In the first phase, the terrain characteristic of Alagar hills is studied in detail. This involves the study of topography and its various attributes such as, slope, aspect, and hill shade. In the second phase, the forest structure of Alagar hills is studied. This involves the description of the vegetation and the plant community structure of Alagar hills, in terms of qualitative and quantitative methods.

The terrain characteristics of Alagar hills are studied through analysing the topography. To investigate the influence of topography over the hill environs in GIS a terrain model is required. This requirement has been met out by creating a Digital Elevation Model (DEM). The DEM is used to derive first and second order derivatives which are useful for the characterization of the landscape. Further it is useful for the visualization of Alagar hill environs which is the basis for the processes of hypothesis generation.

The studies on the structural aspects reveal many interesting patterns. From the perspective offered by the *ViSC (Visualisation in Scientific Computing)* the structure of Alagar hills is conveniently divided into two portions, viz., the *right catapult ranges* and *left undulating ridges* for the convenience of description. Study on the relief reveals that the hill abruptly rises in the eastern portion; however the rise is gradual in the western side. From the visualisation offered, it is possible to deduce that the erosion, due to the high elevation and high slope conditions, is more in the catapult ranges than in the undulating ridges. The Alagar hills reserved forest boundary encompasses three different type of forest category, classified according to their crown density, viz., dense forest (> 40% crown density), open forest (10% - 40% crown density) and scrub (< 10% crown density).

The class of gentle slope (<8°) are found in the low-lying area adjacent to the reserved forest boundary and at valley floor. Moderate slope areas (8° – 16°) are found in the mid altitude zone of 300-400 meters elevation. Moderately steep slope (16° – 24°) is found to occur in the high altitudinal zones having 400 – 500 meters of elevation and favour open forest category. Areas of steep (24°- 32°) and very steep slopes (>32°) are predominantly found in the eastern slope of the study area and located between 600 and 800 meters of elevation and favour dense forest category. The analysis of aspect reveals that the west and northwest, east and southeast facing slopes actively participate in the formation of the three prominent valley systems of Alagar hills. West and northwest facing slopes at the end of Periya Aruvi Valley experiences severe structural disturbances, where the general trend of the slope is highly disturbed.

The hillshade developed for the present study using hypothetical azimuth and altitude of Sun's position has been used for preparing maps which gives 2.5 dimensions to the map outputs. To investigate the spatial variations of hillshade of Alagar hills a solar illumination model has been developed. In which the average variation of hill shade in different months has been attempted with the actual azimuth and altitude of sun's position. It is vivid from the model that the east and southeast facing slopes are highly illuminated by sun during the months, January, February, March, October, November and December. However, the West and Northwest facing slopes receive maximum illumination conditions during May, June, July and August in all other months it is under the shadow regime. This may be a reason why this slope category is not supporting the growth of vegetation groups in Alagar hills. East and Southeast facing slopes receive solar illumination in all the four seasons of the year viz., summer, winter, northeast monsoon and southwest monsoon period, when compared to other slope categories and hence inferred as a productive zone in Alagar hill environs.

Studies on the forest structure of Alagar hills shed light on the vegetation of Alagar hills and plant community structure. At the foot of Alagar hills the

vegetation is scrub and at higher elevations it is dry deciduous and still higher it is moist deciduous type. Patches of woodland savannah is noticed in between deciduous forests. Riparian vegetation is found in the valleys. The plant community structure is studied through qualitative and quantitative means. The floristic composition of Alagar hills is well documented. It records about 900 species of plants belong to 526 Genera and 126 families in Alagar hills. Of which 725 plant species belongs to 424 genera and 103 families are dicotyledons. While 175 species of plants belong to 103 genera and 23 families are monocotyledons. The vegetation of Silambar valley is two storied in which the ground vegetation is poor. The Periya Aruvi Valley vegetation shows 3 storied formations. The vegetation of the Bison Valley is very dense and it is of the 2-storied-type. The biological spectral climate of Alagar hill complex is similar to that of Australian and deviates slightly from that of normal or world climate. The investigation reveals that the life form climate of this hill complex is of the *Thero-phanero-phytic* type.

According to the Forest Survey of India (FSI), Alagar hill reserved forest has dense forest covering an area of 22.3 sq.km. The open forest covers an area of 23.1 sq.km. The scrub land cover and non-forested land accounts 20.9 sq.km and 4.5 sq.km, respectively. In Alagar hills tree juveniles are more in number. There are about 11913 tree juveniles and 910 trees are found per hectare. Tree juveniles are the dominant type of vegetation type found in Alagar hills. Their number exceeds the number of other vegetation types such as shrubs, herbs, climbers, lianas and trees. There is, however, a considerable amount of dominance exerted by climbers and lianas over the landscape of Alagar hills. Shrubs, herbs and trees are less dominant.

The study of spectral profiles of digital images of Alagar hills provides insight in to the nature and diversity of vegetation groupings in the area. There were 8 transects constructed in different parts of the Alagar hills, viz., gravelly area, plains, flat topped hill, Bison Valley, Silambar Valley, Periya Aruvi

Valley, east and west facing slopes to study the spectral characteristics. There are heavy undulations in the spectral reflectance curve of the flat topped hill. The gravelly areas at the foot of the ranges, rich in eroded material, sustain ephemeral vegetation. The reflectance curve of the gravelly area is with characteristic periodic undulations. The peaks are attributed to the exposed rock and gravels in the area. In the plains the digs in the curve is not so deep and there are moderate peaks. This pattern is attributed to the grass cover with intermittent trees in the plains. The undulations in the spectral profile of west facing slope is quiet frequent and indicating a diverse mixed forest category. Unlike the west facing slopes, the undulation in the east facing slopes are infrequent and the curve is smooth indicating dominant vegetation groups and prevalent stable environmental conditions.

Among the three valleys Bison valley exhibit infrequent undulations indicating undisturbed stable environmental conditions conducive for vegetation growth. There are drastic undulations found in the reflectance curve of Silambar Valley when compared to other valleys. This indicates the disturbed environmental conditions and diverse nature of vegetation exist in this valley. Periyaruvi Valley have frequently undulating spectral reflectance pattern however, the undulations are not as drastic as the undulations of Silambar valley, and the curve runs to considerable distance with minor undulations. This type of signature indicates the presence of dominant vegetation type with heavy disturbances.

An exploratory attempt on some of the important landscape processes viz., slope process, channel process biological and ecological processes has been made in the present study. This exploration, however, is based on the observed patterns indicative of processes. These indicators are either the derivatives of the Digital Elevation Model or other GIS analysis.

Hill slope processes are studied through two important indicators viz., curvature and rate of down slope movement. Thus in Alagar hills, the valleys are associated with deposition and peaks are associated with erosion. However the pattern is not uniform and there are discontinuities in the erosion offered by the peaks. The intensity of erosion is more at the point of convergence of the two ranges at right catapult ranges. This slowly decreases as the ranges move toward northeast. There is a heavy disturbance to this process at the middle portions of this range. On the other hand erosion as well deposition is active on the top of northwestern portion of the right undulating ridges. On the southwestern portions the deposition is active than erosion. The result of plane curvature indicates a heavy divergence on the top northwestern portion of the left undulating ridges. Further the convergence is active at the channels. On the right catapult ranges at the middle of the right side range there are divergence results due to the poor development of channels.

The result of the study on the rate of down slope movement shows that the northern portions at the fag end of Periya Aruvi Valley shows a faster down slope movement and a slower movement is observed on the east and south east facing slopes of bison valley. A mixed pattern of slow and faster rates is found in the right undulating ridges. The valleys register a very slow down slope movement since the sloping conditions comes to a halt there. The area between 300 to 600 metres of elevation shows a higher rate of down slope movement than the other relief categories.

Channel process involves the corridors of the study area. The channel process indicators considered for evaluations include drainage density, ruggedness number, and length of overland flow. The Silambar valley and Periyaruvi valley has more drainage density than Bison Valley. In the east, north east and south eastern portions of the catapult ranges the density of the drainages are high. However it gradually raises on the portions of the left undulating ridges. The study on the length of overland flow reveals that the flow

length is little more in the case of run off reaching Tirumanimuthar flowing in the Bison Valley when compared to the flow length of run off reaching either Silambar or Periya Aruvi rivulets. Especially the impediments to the flow of run off are high in the place where the two ranges of the right catapult range converge. In the left undulating ridges the places covered by thick forest cover offers considerable impediment to the run off. On other areas at periphery the flow length values are very low; this may be attributed to the well developed channel network.

For the present study the biological processes are studied by employing digital image processing techniques. Apart from that periodicity of flowering pattern of Alagar hill's vegetation is also studied. The Normalised Difference Vegetation Index (NDVI) was one of the widely adopted and applied vegetation indexes. The NDVI is popularly used to assess the vegetation vigour of a vegetation community. The NDVI for Alagar hills has been calculated for two time periods viz., 1990 and 2001. The results indicate that the valleys harbour high yielding; productive vegetation groups while the peripheral areas are inhabited by scrub vegetation and thorny thickets which are not productive in terms of yield. Some of the areas in the periphery especially in the south eastern portions include rock outcrops and gravely areas, in those areas the NDVI approaches zero. In the non forested land over the west facing slopes of catapult ranges the NDVI is very low and indicate its exposed rocky nature with scanty grass cover. There are marked changes in the NDVI of 1990 and 2001.

Periodicity describes the occurrence of various biological processes and their manifestations in plants and animals at fairly regular intervals in time. Such periodic annual rhythm in plants is known as phenology. At Alagar hills the dry season is interrupted by some rain in May giving two rainy seasons. The occurrence of two rainy seasons is reflected in the two flowering seasons in this area. Nearly half of the species flower during the rainy (northeast monsoon) and post monsoon period (51%) less than 50% of the plants flower during summer

and premonsoon (42.4%). The flowering rhythm of a minority of species (3.7%) is inconstant. It varies from year to year and it may be due to the fluctuations in the amount of rainfall. Plants belong to *Stenosiphonium russelianum* of this area bloom once in 5 years in the post monsoon season. On such occasions the whole range of Alagar hills appears in light blue colour and so the local inhabitants call this plant 'Alagar malai Kuringi'.

Landscape metrics especially patch metrics; shape metrics, pattern metrics and spatial autocorrelation have been explored here so as to enhance the understanding of the ecological processes involving landscape elements of Alagar hills. Patch metric analysis indicate that the mean patch size of the landscape elements of Alagar hills varies from 1.0 sq.km to 8.9 sq.Km. The open forest and scrub land patches have more or less equal mean patch size. However, open forest has more number of patches when compared to other patch types. This shows that it is highly fragmented. Patches of non-forested area too have many patches; this is attributed to the effect of slope.

Shape metrics quantify the shape of patches and other landscape elements as area- perimeter ratios. Using this relationship forest continuity index for Alagar hills environs has been calculated. The peripheral area of Alagar hills reserved forest has a very good continuity. The valley's of this hill system too shows a good continuity. As the elevation increases the continuity starts being disturbed. The highest disturbance to continuity is found in the left undulating ridges than the right catapult ranges. Non forest patches act as a prime factor in disturbing the forest continuity at higher altitudes. At lower altitudes on the western periphery the disturbance to the continuity may be attributed to the proximity of the forest ranges to the zone of human interactions.

The landscape pattern metrics viz., dominance and diversity indices and spatial statistics are attempted for the present study. The result of dominance and diversity indices indicates that vegetation found in the left undulating ridges

dominate the landscape of Alagar hill as a whole and the western slopes of the right catapult ranges are found to have the heterogeneous land cover in the landscape of Alagar hill environs.

The landscape patches of Alagar hills have been used to study the spatial statistics of Alagar hills environs. The cluster analysis has been used as a spatial statistics tool to investigate the landscape elements of Alagar hills. Two types of forests (dense forest and open forest), scrub land and non-forested area constitute the landscape patches of Alagar hills. The intention of the present study is to investigate how various landscape patches are clustered together. From the results the *dense forest* is highly clustered with *open forest* category. However with the *scrub* land the pattern is neither clustered nor dispersed. The open forest category is randomly clustered with scrub. However, with the non-forested area it is highly clustered. The *scrub land* is randomly clustered with *dense forest, open forest and non-forested land.* The pattern is neither clustered nor dispersed.

There are two types of tourist activities witnessed by Alagar hill environs viz., religious tourism and eco-tourism. The religious tourism is associated with the devotees who visit the temples in the Alagar hill environs while eco- tourism involves the local people from the vicinity who visit the hills for values other than religion. Apart from the two types of tourism, Alagar hill provide ample opportunities for exploratory tourism for bird watchers and taxonomist for exploring and enriching the knowledge.

The changes that have happened over a period of time in the structural and functional aspects of Alagar hills between 1990 and 2001 have been studied. The changes in spectral characteristics of Alagar hill environs has been observed for the present study using the temporal images of Landsat TM of 23$^{rd}$ April 1990 and 15$^{th}$ May 2001. The changes in the spectral characteristics indicate changes in the forest structure. The study pointed out changes in the histogram

of green band (band 2). There is a drastic change in the upper limit (the maximum) of the reflectance value in Red band. The histogram of Infra red is the most significant one with reference to the studies related to vegetation. The higher reflectance in infrared indicates good vegetation vigour. The histograms of the two time periods are more or less similar, however, there is a change in the mean value. The mean value of 1990 is 80.4 and the mean value 2001 is 76.7. Though it appears to be an insignificant change, it is very important. The decline in the mean value indicates a disturbance. This may be attributed to the lose of ground cover vegetation during dry summer months.

Changes in the vegetation vigour are brought out by comparing the NDVI, dominance and diversity indices of two time periods. The Normalised Difference Vegetation Index of the two periods (23$^{rd}$ April 1990 and 15$^{th}$ May 2001) of Alagar hill environs show significant changes in the vegetation surface of the landscape. Most of the changes have happened in the peripheral area of the reserved forest. The higher ranges of Alagar hill environs fall in the NDVI class with the value >0.17. At 1990 most of the higher ranges and mid altitude zones were in this class. This indicates a vigourous vegetation growth. At 2001 only the high altitudinal zones (600m – 800m), characterized by the dense forest cover, show high NDVI values (> 0.17). Even in the high altitudes the loss of thickness is vivid. The non-forested lands during 2001 are exposed and devoid of grass cover. The west, south west and northwest facing slopes show much degradation.

The results of the observation of the changes in the dominance and diversity indices indicates that vegetation found in the left undulating ridges dominate the landscape of Alagar hill as a whole at 1990. The scenario has not entirely changed at 2001. Though the vegetation groups of left undulating ridges continue to dominate the landscape, its intensity is lessened over the period of time. This is not a good sign and indicates that the dominant landcover are slowly loosing their strong hold and pave way for other land covers such as open

forest category or non-forested area to dominate. At 1990, the western slopes of the right catapult ranges were found to have the heterogeneous land cover in the landscape of Alagar hill environs. By 2001, the diversity has increased much in the west facing slopes. Most of the mid altitudinal zones especially the western slopes of the left arm of right Catapult Ranges indicate a diverse landcover. Further a similar trend started peeping in the vicinity of the higher altitudes of the left undulating ridges. This is not a healthy trend and indicates that those lands which are diverse at 2001 were once dominated by the dense forest category. From this it could be envisaged that the higher altitudes characterized by the dense forest cover of left undulating ridges could be replaced by open forest category, if a similar trend continues.

Further an exploratory attempt to find out the possible factors causing these changes has also been attempted through observing the Moisture Stress Index (MSI) and visual inspection of temporal satellite images of Alagar hill environs. The visual inspection of satellite images clearly indicates that Alagar hill environs are not entirely devoid of human disturbances. The results indicate that some forested area of about 10 hectares has been cleared atop Alagar hills in the year 2001. The shape of the clearance is more or less rectangle; this clearly indicates the human interferences. Changes in climatic conditions may be a prominent factor apart from the human interferences for the drastic changes that have happened in Alagar hills. In the years 94, 95, 99 and 2001 the rainfall is less than the normal. This may result in the moisture stress and would have led to the changes observed in the vegetation vigour. From the evaluation it could be inferred that climatic changes and human interferences hold the key for the changes observed in the forest cover of Alagar hill environs.

The results thus obtained in the studies on the structure and function are integrated so as to arrive at a habitat suitability map for thriving suitable native species, endangered and threatened species. To achieve this objective a spatial model has been developed. The spatial model integrates a number of factors

including NDVI, MSI and FCI (Forest Continuity Index), physical factors such as slope, aspect and the landscape elements (the forest categories). The result shows different classes of landcover belongs to different percentage of habitat suitability. The most suitable classes in the range of 90 – 100 % of suitability is found to be distributed in the majority of the eastern slopes of the right Catapult Ranges where the Bison Valley is located and in the higher altitudes of the left undulating ridges. The area comes under the Bison Valley is the more preferred location, since it is inaccessible to human beings and naturally protected, for thriving endangered and native plant species. The higher reaches of the left undulating ridges are the next most preferred spot for thriving threatened or endangered species of flora.

Several management strategies have been proposed for the better management and conservation of forest resources of Alagar hills. It has been suggested that the Alagar hills reserved forest boundary should be divided into a number of habitat suitability zones, viz., *core zone, restoration zone, manipulation forestry zone* and *zone of ecotourism,* based on the habitat suitability values. The areas of best habitat suitability fall under the core zone with habitat suitability values of 80% to 100%. Thus, the peaks of the Bison Valley, Periya Aruvi Valley and left undulating ridges comes under this zone. In the core zone human interferences should be totally banned with the aim of preserving the biological community in a natural state.

The areas with a habitat suitability of 60% to 80% are considered as *restoration zone.* The eastern slopes Silambar Valley and open forest areas of left undulating ridges and Bison Valley are grouped under this category. Here the human interferences should be as least as possible. The aim of the *restoration zone* is to function like a buffer to protect the core zone from the external interferences.

The areas with a habitat suitability of 40% to 60% may function like a *manipulation forestry zone,* where harvest of natural resources is permitted to a minimal level. The areas of religious importance in Alagar hills viz., Alagar temple, Pazhamudhir Cholai, Nupura Gangai and Southern Peripheral area, the Silambar Valley up to Nupura Gangai are confined to the *zone of ecotourism.* In this zone activities may be allowed.

Tourism is a major revenue generating functions in Alagar hills. In view of improving the revenue, it has been suggested to introduce Rope car way, like in other eco-tourist places to view the natural environment of the Alagar hills.

The conservation and management of forest resources of Alagar hills require a coordinated effort of a number of agencies. In this regard an Administrative Advisory Council, represented by various Government Departments, scientists, Professors from University Departments and colleges and eminent persons may be formed. In order to effectively protect the existing forest cover, it is suggested that the Reserved Forest boundary of Alagar hills should be revised to exclude Silambar Valley. The Silambar Valley could be promoted as an eco-tourism spot.

Long-term monitoring of a variety of environmental parameters is essential for an adequate understanding of ecological processes. So it has been suggested that the satellite images have to be obtained regularly to monitor a wide range of hydrological, geological, biological and ecological parameters. Further as proposed in this thesis various landscape ecological metrics, such as dominance and diversity indices and forest continuity index should be included in the monitoring list so as to ensure the ecological resilience.

The present study sincerely attempts to understand the realities of hill area management by using the data obtained from the modern techniques like remote sensing and GIS along with conventional data. However, still there exists wider

scope for studies with greater depth on various themes. The present study has been attempted amidst several limitations, including the non availability and restricted availability of several secondary data for Alagar hill environs the one like data on climatic variables. Further, yearly remote sensing data due to the financial constraints were not procured. The temporal images on yearly basis would highly be useful in monitoring closely the changes happening in the structural aspects. If attempted with such a vast data base, the study would have attained a different depth.