5.1. Introduction

An understanding of the flows and interactions within and between landscape components is the focus of any landscape analysis. It is essential to know how a component works, and the interaction of its parts in the overall system of the landscape, since throughout evolution, physico-chemical and biological patterns and processes have shaped the structure and function of terrestrial landscapes and their subsystems (Forman and Godron, 1986; Bastian, 2001).

In the present study important landscape processes viz., slope process, channel process, biological process and ecological processes occurring in the Alagar hills are focused. This exploration, however, is based on the sequential observed patterns indicating the processes. These indicators are either the derivatives of the Digital Elevation Model or other GIS analyses. Using GIS, slope and channel processes could be studied with clarity. The functional capability of GIS in data processing, surpass the limitations of the conventional studies related to the processes of landscapes. Further, it is possible to see the results interpolated spatially giving better visualisation of an area in-turn helps in understanding the processes.

Slope processes are processes related to the slopes and involve the landscape patches. Channel processes are associated with the corridors of the landscape such as drainages in the landscape. Channel processes, though considered as a separate process, are closely linked with the slope process. Both of these processes together contribute to the process of denudation.

In slope process the elements of curvature, profile and plan form of curvature of the landscape have been attempted. In channel processes, drainage
density, flow accumulation and length of overland flow are attempted. Curvature, flow direction, flow accumulation, length of overland flow are second order derivatives of DEM (Digital Elevation Model), while, drainage density is calculated separately. The biological process is studied through image processing techniques. The Normalized Difference Vegetation Index (NDVI) is calculated for this purpose. Landscape metrics such as patch, shape and pattern metrics are attempted to understand the ecological processes. Further, Alagar hill is associated with religious tourism and ecotourism, which has also been studied as a functional aspect.

5.2. Methodology

Topographic elements of a landscape computed directly from a DEM and these are often classified into primary and secondary attributes (Moore et al., 1991). Primary attributes are calculated directly from the digital elevation data. Secondary attributes combine primary attributes and the new indices describe or characterise the spatial variability of specific processes observed in the landscape (Moore et al., 1991). Slope, aspect, plan curvature, and profile curvature are all examples of primary attributes. These attributes are usually computed using directional derivatives of a topographic surface either by using second-order finite difference schemes or by fitting a bivariate interpolation function $z = f(x,y)$ to the DEM and then computing the derivatives of the function. Secondary attributes are computed using two or more primary attributes and offer the ability to describe pattern as a function of process (Huggett and Cheesman, 2002). Rate of downslope movement and length of overland flow falls under this category. Table 5.1 lists the process indicators and their applications used for the present study.
### Table 5.1. Process Indicators and their Applications

<table>
<thead>
<tr>
<th>S. No</th>
<th>Process Indicator</th>
<th>Definition</th>
<th>Process</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Profile curvature</td>
<td>Rate of change of slope</td>
<td>Slope Process</td>
<td>Geomorphology — flow acceleration, erosion/deposition patterns and rate, soil and land evaluation indices, terrain unit classification</td>
</tr>
<tr>
<td>2</td>
<td>Plan curvature</td>
<td>Rate of change of aspect</td>
<td>Slope Process</td>
<td>Converging/ diverging flow, soil water characteristics, terrain unit classification.</td>
</tr>
<tr>
<td>3</td>
<td>Rate of Downslope Movement</td>
<td>sine of the slope angle ( (S_d = W \sin \beta) .)</td>
<td>Slope Process</td>
<td>To analyse the rate of downslope movement of weathered debris and rock rubbles.</td>
</tr>
<tr>
<td>4</td>
<td>Drainage Density</td>
<td>Length of streams per unit area.</td>
<td>Channel Process</td>
<td>One of the important parameters for assessing the groundwater potential in an area.</td>
</tr>
<tr>
<td>5</td>
<td>Length of overland flow</td>
<td>Maximum distance of water flow to a point in the catchment.</td>
<td>Channel Process</td>
<td>Erosion rates, sediment yield, time of concentration.</td>
</tr>
<tr>
<td>6</td>
<td>NDVI (Normalized Difference Vegetation Index)</td>
<td>( \text{NDVI} = (\text{NIR-Red}) / (\text{NIR} + \text{Red}) )</td>
<td>Biological Process</td>
<td>Studies related to Vegetation Vigour</td>
</tr>
<tr>
<td>7</td>
<td>Landscape metrics</td>
<td>Patch metrics Shape metrics Pattern metrics</td>
<td>Ecological Processes</td>
<td>Spatial statistics vital to understand forest stability and disturbances.</td>
</tr>
</tbody>
</table>

*(after Huggett and Cheesman, 2002)*

### 5.3. Hill Slope Process and Process Indicators

Hill slope processes (Plate.2) are studied through two important indicators viz., curvature and rate of down slope movement. The slope curvature is derived from DEM of Alagar hills and the rate of down slope movement is calculated using raster calculator function of Arc GIS.
5.3.1. Curvature

The evolution of the slope through time by creep, raindrop impact and slope wash can be described by the diffusion equation:

$$\frac{dy}{dt} = c\left(\frac{d^2y}{dx^2}\right)$$

At any point on the initial slope the rate at which the elevation 'y' changes with time 't' is the product of a diffusion constant 'c' and the local slope curvature (Bloom, 2002). Further, curvature is an important indicator of flow acceleration, erosion/deposition patterns, converging and diverging flow. A positive curvature indicates that the surface is upwardly convex at that cell, while negative curvature indicates it is upwardly concave. A value of zero indicates that the surface is flat. Curvature can also be used to understand erosion and runoff processes. While the slope affects the overall rate of movement down slope, the aspect defines the direction of flow. Hence there are two types of curvatures viz., profile curvature and plan curvature. Profile curvature is the slope of the slope. Plan curvature is the rate of change of aspect. The profile curvature affects the acceleration and deceleration of flow, and therefore influences erosion and deposition. The planform of curvature influences convergence and divergence of flow (Moore et al., 1991; Zeverbergen and Thorne, 1987).

The curvature of Alagar hills shows (Fig.5.1) a summit convexity and channel concavity. Higher curvature values (around 8.2) are observed at the peaks and summit of Alagar hills indicating a summit convexity. The low curvature values (around -6.3) are associated with valleys indicating concavity. The concavity is helpful in the process of valley development. Since, it has been an established fact that the erosion occurs on a portion of the scarp that is convex upward and deposition on the portion that is concave upward. Mass wasting, especially soil creep, largely controls the upper convex and straight segments of slope profiles. Slopes controlled by seepage, rain wash, sheet wash or rill wash are generally concave skyward. At some position on a slope, rain-wash becomes
Alagar Hill Environs

CURVATURE

Legend

High : 8.2
Low : -6.3

Fig. 5.1
dominant over soil creep, and the slope profile inflects from convex near the top to concave near the base (Bloom, 2002).

The summit convexity of Alagar hills could well be supported by the explanation offered by Horton (1945). He observed a reasonably uniform thickness of soil or regolith over the convex surface and assumed that in a given interval of time a uniform thickness of the weathered material is removed from the entire summit area. With the stated assumption, the amount of material that creeps past any point is proportional to the distance of the point from the summit. Since creep is primarily a gravitational phenomenon, the slope angle increases radially from the summit in order to move the progressively great amount of debris. The summit curvature becomes convex to the sky.

As the value of the profile curvature (Fig.5.2) increases the deposition increases. Thus in Alagar hills, as is elsewhere, 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 (acceleration) of erosion is more at the meeting point of the two ranges at the right Catapult Ranges. This gradually 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. Divergence is active on the right Catapult Ranges at the middle of the right arm of the catapult.

Valleys with high values of plan curvature (Fig.5.2) indicate convergence and peaks showing low values associated with divergence. The occurrence of majority of a low values (convergence) at left undulating ridges may be due to
the presence of many peaks. However, the structure of the Catapult Ranges is simple and thus predictable convergence (low values) and divergence (high values) are associated with valleys and peaks respectively.

5.3.2. Rate of Downslope Movement

According to Strahler (1956), the shear stress acting parallel to a slope, which causes a particle to move downslope, is proportional to the sine of the slope angle \( (Sd = W\sin\beta) \). It could be expected that the rate of downslope movement of small, loose rock fragments responding to that stress would also be proportional to the sine of the slope angle. This particular parameter is useful to assess the speed of the denudation process.

Rate of downslope movement (Fig.5.3) has been derived for the present study using the raster calculator function of Arc GIS, where sine of degree slope raster has been calculated. The rate of down slope raster has values range between -1 to +1. The negative values indicate a slow rate of movement and the positive values indicate a faster movement of debris through slopes. The result shows a mixed pattern of slow and faster rates. However, most of the values are centred on the value 0, indicating a moderate down slope movement. Yet there are a few exceptions - the northern portions at the far end of Periya Aruvi Valley shows a faster down slope movement and a slower movement is observed on the east and southeast facing slopes. A mixed pattern of slow and faster rates are found in the right undulating ridges. The Valleys register a very slow down slope movement since the sloping conditions halt there. The area between 300 to 600 metres of elevation shows a higher rate of down slope movement than the other relief categories. This is vivid when the rate of down slope movement raster is overlaid with the contours (Fig.5.3).

5.4. Channel Process and Process Indicators

Channel process involves channels (Plate.2) of the study area. The process indicators considered for evaluation of the process includes drainage
Alagar Hill Environs

RATE OF DOWNSLOPE MOVEMENT

Legend
Contour

High
Low

Fig. 5.3
density and length of overland flow. Drainage density is calculated separately while flow length is derived from DEM of Alagar hills.

5.4.1. Drainage Density

Drainage density is a measure to analyse the length of different streams per unit area and it is obtained by dividing the total stream length by the total area. The simplest way to calculate drainage density on a regional scale is to divide the study area into grid squares of one sq.km. each and the measure the total stream length in each grid square and to group the derived in drainage density categories (Savindra Singh, 2000).

Jawahar Raj (2001) has observed that the areas of high drainage density is the result of erosion and dissection by over land flow, low drainage density areas are the product of run off process dominated by infiltration and subsurface flow. By considering the above view, it is observed from the results (Fig. 5.4) that the Silambar Valley and Periya Aruvi Valley has more drainage density than Bison Valley. In the east, northeast and southeastern portions of the Catapult Ranges the density values of the drainages are high. It ranges from 1 to more than 3 km/sq.km. However on the portions of the left undulating ridges it is gradual, ranging from less than 1 km/sq.km to more than 3 km/sq.km.

5.4.2. Length of Overland Flow

The length of overland flow is a measure of stream spacing or degree of dissection. This term refers to the length of the runoff rainwater on the ground surface before it gets localized into definite channels. Smaller the values of length of overland flow, quicker the surface run off enter the stream. In a relatively uniform terrain, therefore less rainfall is sufficient to contribute a significant volume of surface runoff to stream discharge (Jawahar Raj, 2001). However, in a rugged terrain with undulating slopes, like Alagar hills, calculating flow length is little difficult since there are impediments to the flow of water to the channels. There are two prominent impediments envisaged in the
Alagar Hill Environs

LENGTH OF OVERLAND FLOW

Legend
(Values in Km)

- 0.00 - 0.04
- 0.04 - 0.08
- 0.08 - 0.12
- 0.12 - 0.16
- 0.16 - 0.20

Fig. 5.5
The present study viz., slope and forest cover. These two impediments were given due weightages in the calculation of flow length in Arc GIS environ. table.5.2 shows the weightages assigned to different slope and forest categories of Alagar hills.

Table.5.2. Impediments and their weightages for flow length calculations

<table>
<thead>
<tr>
<th>S.No</th>
<th>Slope</th>
<th>Forest Type</th>
<th>Impediment</th>
<th>Weightages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 16</td>
<td>Dense Forest</td>
<td>High</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>16 – 24</td>
<td>Scrub Jungle</td>
<td>Moderate</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>24 - 32</td>
<td>Open Forest</td>
<td>Low</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 32</td>
<td>Non Forested Area</td>
<td>Very low</td>
<td>1</td>
</tr>
</tbody>
</table>

The dense forest has a characteristic undergrowth of shade loving shrubs and climbers in Alagar hills. And thus, dense forest and a slope of 0 to 16 degrees offer high impediment to the run off and assigned a weightage value of 4. Scrub vegetation and thorny thickets offer a considerable impediment to the flow of water. Scrub vegetation and slope category 16 – 24 are considered to impose moderate impediment and assigned a value of 3. As the slope increases the impediment it offers is nullified by the increasing gravitational force. Thus higher slopes are assigned low and very low impediment values viz., 2 and 1. Open forest which lacks under growths and non forested area having a thin layer of grass offers low and very low impediments to the run off and are given weightages of 2 and 1 respectively.

The length of overland flow values for the present study varies from 0.04 to 0.20 (Fig.5.5). This estimation indicates that the rain water has to run over 0.04km to 0.20 km before it gets concentrated into stream channels. It is clear from the results that the flow length is little more in the case of run - off reaching Thrumanimuthar rivulet flowing in the Bison Valley when compared to the flow length of run off reaching either Silambar or Periya Aruvi rivulets. The impediments are higher where the two ranges of the right Catapult Range
converge. In the left undulating ridges the surface is covered by thick forest cover leading to considerable impediment to the run off. In other areas especially at periphery the flow length values are very low; this may be attributed to the well developed channel network.

5.5. Biological Process and Process Indicators

Satellite sensors provide continuous flow of data on the amount of reflected and emitted radiative energy from the Earth. For studies of vegetation dynamics, the most important part of the spectrum is the visible and near infrared region (0.4 – 0.7 μm), usually referred to as Photosynthetically Active Radiation (PAR). Since the 1960s, scientists have extracted and modeled various vegetation biophysical variables using remotely sensed data. Much of the effort has gone into the development of vegetation indices - defined as dimensionless, radiometric measures that function as indicators of relative abundance and activity of green vegetation, often including percentage green cover, chlorophyll content, green biomass, and Absorbed Photosynthetically Active Radiation (APAR) (Running et al., 1994; Huete and Justice, 1999).

There are more than 20 vegetation indices in use. Many are functionally equivalent (redundant) in information content (Perry and Lautenschlager, 1984). Rouse et al. (1974) developed what is now called the generic Normalized Difference Vegetation Index (NDVI), which is calculated using the following expression:

\[
\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}
\]

where, NIR and Red is the amount of reflected light of visible red and near infrared wavelengths respectively (Jensen, 2004). A number of studies, from ground based measurements as well as to satellite based ones, have confirmed a linear relationship between NDVI and APAR.

In the present study the biological processes have been studied through evaluation of vegetation vigour by employing digital image processing.
techniques to calculate NDVI and periodicity of flowering pattern of Alagar hills.

5.5.1. The Vegetation Vigour of Alagar Hills Reserved Forest

The NDVI index is one of the widely adopted and applied vegetation indices. The NDVI is popularly used to assess the vegetation vigour of a vegetation community. The values of NDVI range from -1 to +1. The values of NDVI change according to the seasonal variations in the reflectance from leaves. The variations in the reflectance pattern of leaves largely depend on climatic variations, stress and diseases.

The NDVI for Alagar hills has been calculated from the Landsat image of 23 May 1990 (Fig.5.6). The NDVI values calculated for Alagar hills range between < 0.03 and 0.52. For the present study, the NDVI values have been divided into four classes of equal interval for the purpose of interpretation.

The three valleys and east and southeastern slopes fall under the category of vegetation having NDVI values greater than 0.17. The peripheral areas, predominated by scrub vegetation, register low NDVI values viz., < 0.03 to 0.10. There are marked changes in the NDVI of 1990 and 2001 which has been elaborately dealt in the next chapter. From the results, in short, the following observations were made:

1. The vegetation of dense as well as open forest category registered a vigourous growth in 1990.
2. The vegetation vigour of the scrub vegetation is little less than the other types of forest in Alagar hill environs.
3. The non - forested area registered a very low NDVI value indicating the scanty vegetation cover over there.
Alagar Hill Environs

NORMALISED DIFFERENCE VEGETATION INDEX

Fig. 5.6
4. In west facing slopes there are discontinuities in vegetation cover caused by the intermittent non-forested area resulting in moderate vegetation vigour in the adjoining areas to it.

5. In all the three valleys, the vegetation found at the east facing slopes registered maximum vegetation vigour.

6. 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.

7. In the non-forested land, over the west facing slopes of Catapult Ranges, the NDVI is very low and indicates the exposed rocky nature with scanty grass cover.

8. In some of the areas in the periphery especially in the southeastern portions with rock outcrops and gravely areas, the NDVI approaches to zero indicating its barren nature.

5.5.2. Periodicity

Periodicity is ecology describes the occurrence of various biological processes and their manifestations in plants and animals at fairly regular intervals of time. The processes are often internal, such as active cell division, cell enlargement, increased or decreased photosynthesis or a change in hormone or enzyme action. The manifestations may be expressed as loss of leaves, formation of new leaves, flowering, fruiting and dispersal of fruits and seeds, as well as by the breeding and migration patterns of certain animals. The periodicity results from intrinsic genetic characteristics of species populations, which are under the influence of a particular combination of environmental factors. Such periodic annual rhythm in plants is known as phenology. For the present study the phenomenon of flowering alone is considered for the analysis of periodicity. A flowering period is taken as the period from the first opening of the flower buds to the time when the last flower ceases to present anthers or stigma.
5.5.2.a Phenology

Tropical plant communities with their high levels of species diversity display phenological events spread over a period of time and space. Understanding of such behaviour of the communities is useful in evolving proper management strategy. Information on phenology is helpful in predicting the interactions of plants and animals to the changing environment. Studies from different parts of the world have shown climatic factors are found mainly responsible for vegetative and reproductive phenology, at both community and species levels. Studies have reported that various phenological events are triggered by rainfall, water availability, temperature, photoperiodism, duration of dry spell, and changes in day-length and temperature (Bhat and Murali, 2001).

In the tropical climatic zones, phenology seems to present a number of features that are peculiar when compared with those of the temperate regions. In temperate climates the seasons are well marked in terms of temperature and day length, and most plants and animals react in distinct ways in response to these changes during the year. In tropics, however, the situation is different. Temperature and day length do not vary nearly as much throughout the year. In spite of this, different species of plants and animals show distinct periodicity at specific times of the year. The remarkable thing about tropical communities is the apparent absence of synchronization between many different species in most of the phenological phenomena. At almost any time of the year a few species may be flowering, fruiting, losing leaves or producing a flush of leaves. It is this continuity and overlap which makes tropical phenology different from elsewhere. Phenology in the tropics is more a population than a community phenomenon, unlike the situation in temperate climates where most of the phenological activities of plant appear to be synchronized.

5.5.2.b. Phenology of Alagar Hills

The phenology of Alagar hill environs was studied by Sriganesan (1984). From the study he observed that nearly half of the species flower during the
northeast monsoon and post monsoon season (51%) less than 50% of the plants flower during summer and premonsoon (42.4%) (Table.5.3). The flowering rhythm of a minority of species (3.7%) is inconsistent (Fig.5.7). It varies from one year to another and it may be due to the fluctuations in the amount of rainfall. A very low percentage (0.9%) of plants flower round the year.

Phenology of *Stenosiphonium russelianum* and *Bambusa arundinaceae* is not included in any one of the category because of their flowering is not an annual feature. A majority of *Stenosiphonium russelianum* (Plate.2) plants 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’. However, stray flowering is seen in the same season every year. No mention has been made of this phenomenon in the local floras (Sriganesan, 1984).

### Table 5.3. Phenology of Alagar Hills through Seasons

<table>
<thead>
<tr>
<th>Phenology of Alagar Hills through Seasons</th>
<th>Monsoon and Pre Monsoon</th>
<th>Monsoon period only</th>
<th>Post Monsoon only</th>
<th>Monsoon and Post Monsoon season</th>
<th>Summer only</th>
<th>Pre Monsoon only</th>
<th>Monsoon and Summer season</th>
<th>Round the Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 (3.7%)</td>
<td>285 (31.4%)</td>
<td>147 (16.2%)</td>
<td>30 (3.3%)</td>
<td>119 (13.1%)</td>
<td>266 (29.3%)</td>
<td>19 (2.1%)</td>
<td>8 (0.9%)</td>
<td></td>
</tr>
<tr>
<td>432 (47.6%)</td>
<td></td>
<td></td>
<td></td>
<td>385 (42.4%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>462 (51.1%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the case of Alagar hill environs the northeast monsoon season (October to December) and post monsoon season (January to February) is the primary period and the pre monsoon (March to May) and southwest monsoon season (June to September) as the secondary or subsidiary one. It appears that in topical woody species, which flower twice a year, the flowering is not at the same level of importance on both occasions. The period that lasts for a longer time of flowering is considered as primary period of flowering, while the second and shorter period is regarded as a secondary or subsidiary one. The longer-flowering period is regarded physiologically as the first flowering of the species in a year. This is because the longer period of flowering must go with the presence of a greater storage of energy, which might take place during the rainy period (Ewusie, 1969, 1980). Flowering frequency may also be of use in determining the age of a tree. Thus a tree which flowers twice a year is expected to show two seasonal rings per annum if the species is sufficiently sensitive to the seasonal changes in the weather and hence grows in between flowering periods (Kormondy, 1969).
5.6. Landscape Metrics

Landscape metrics such as patch metrics, shape metrics, pattern metrics and spatial autocorrelation have been explored here so as to enhance the understanding of the ecological processes which involve the interaction between landscape patches (the different vegetation communities) of Alagar hills.

5.6.1. Patch metrics

Patch metrics relates to the size of patches of the landscape. Patch size, the area covered by each patch and the number of patches, have considerable influence over the stability of the landscape. In areas with natural vegetation influenced minimally by human activities, patches are highly variable in size, with the average patch size probably quite large and are highly irregular in shape, where factors such as fire, weather, erosion, and other geological processes are major controls on the extensiveness of patches. The progressive modification of the landscape by agriculture and urbanization process tend to eliminate irregularly curved projections, into straight patch edges resulting them as rectangular polygons (Godron and Forman, 1983). Studying the patch size and shape has considerable importance since the individual patches of different types in a landscape typically associate with a local increase in wild life (O’Connor et al., 1999). However, any habitat surrounded by different ones are in effect create, an island for the species that live there. Such habitat islands shrunken to become too small to support the minimum breeding populations of species (Miller, 1994).

In Alagar hills reserved forest, four types of patches are found, viz., dense forest, open forest, scrub land and non-forested land (Fig. 3.1). The table 5.4, shows the patch metrics of Alagar hills. The open forest patch is the dominant among all other landscape patches in Alagar hills forest environ. Dense forest as well as scrub land patches are, however, equally dominant. Their areal extent does not vary appreciably. But their influence is confined to different altitude zones. Scrub land is dominant in the lower altitudes. Open forest patches are
dominant in the mid-altitude and dense forest patches are dominant in high altitudes of Alagar hills.

Table 5.4. Patch Metrics of Alagar Hill Environs

<table>
<thead>
<tr>
<th>S. No</th>
<th>Patch Type</th>
<th>Patch Area (Sq.Km.)</th>
<th>Mean Size of Patch Area Polygons (Sq.Km)</th>
<th>Number of Patches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dense Forest</td>
<td>22.3</td>
<td>8.9</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Open Forest</td>
<td>23.1</td>
<td>5.1</td>
<td>64</td>
</tr>
<tr>
<td>3</td>
<td>Scrub Land</td>
<td>20.9</td>
<td>5.3</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>Non Forest Land</td>
<td>4.5</td>
<td>1.0</td>
<td>47</td>
</tr>
</tbody>
</table>

The mean patch size is an indicator of the vegetation fragmentation (Armando et al., 2000). The mean patch size of the landscape element of Alagar hills varies from 1.0 sq.km to 8.9 sq.km. The mean patch size indicates how the patches spread over the landscape. 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 open forests are highly fragmented. Patches of non-forested area are too many and reason for it is attributed to the effect of slope. A higher mean patch size and relatively less number of dense forest patches are good signs of its undisturbed nature when compared to other patches.

5.6.2. Shape Metrics

Shape metrics quantify the shape of patches and other landscape elements as area- perimeter ratios. Vogelmann (1995) used the natural logarithm of forest area to perimeter ratio to assess the patterns and trends in forest fragmentation, which is called as forest continuity index. Many species, particularly bird species, are unable to continue as breeders in dissected habitats,
largely because predators and parasites can more easily penetrate small forests when compared to large forests (O’Connor et al., 1999).

In the present study, forest continuity index (Fig. 5.9) for Alagar hills environs has been calculated, through GIS, by applying the following expression:

\[
\text{Forest continuity index} = \ln \left( \frac{\text{Area}}{\text{Perimetre}} \right)
\]

It could be interpreted that an increasing value of the index increases the continuity of the forest patch. The peripheral area of Alagar hills reserved forest has a very good continuity index with a value more than 4.5. The valley’s of this hill system too shows a good continuity. As the elevation increases the forest continuity starts leading to undisturbed nature. The highest disturbance to continuity is found in the left undulating ridges of the study area than the right Catapult Ranges registering values between 3.5 and 4.5. At higher altitudes values, the values are less ranging between 3 and 3.5. This may be attributed to the non-forested patches and co-existing small patches of different forest types. At lower altitudes on the western periphery, the heavy disturbances to the continuity are attributed to the proximity of the forest ranges to the zone of human interactions.

5.6.3. Pattern Metrics

Pattern metrics are intrinsically more complex (O’Connor et al., 1999). Spatial pattern of landscapes is a primary focus of landscape ecology. The quantitative indices of spatial pattern can be used to enhance the understanding of relationships between spatial patterns and ecological process (Forman and Godron, 1986). For the present study dominance and diversity indices are attempted, as pattern metrics, using digital image processing techniques. Pattern analyses of patches are carried out using spatial statistics tools offered by ArcGIS.
Alagar Hill Environs
FOREST CONTINUITY INDEX

Legend
Continuity Index
- < 3
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- > 4.5

Fig. 5.9
5.6.3.a Dominance and Diversity indices

*Dominance* specifies the proportion of area covered by the largest single land cover, irrespective of its identity. *Diversity indices* provide complementary measures of dominance, indicating the diversity of patch types within a spatial unit of analysis. Clearly, landscapes with high dominance are likely to be permeable to species that can use the dominant habitat, and unfavorable to those that cannot. Specialised filters can be used to quantify the patterns for preparing thematic maps or classifications (O'Connor et al., 1999).

The dominance and diversity indices of Alagar hill environs are attempted using filters available in the GIS Analysis of interpreter module in ERDAS IMAGINE - 8.6 image processing software. The Neighborhood Tools are used to assess the indices. The dominance and diversity filters are applied on the first order principle component image of Landsat TM, 1990. The results are shown in the figure.5.10.

In dominance index map the brightest values represent the classes with the greatest number of pixels. The brightest spots are found evenly in the peaks of the ranges of Alagar hills. However, the concentration of the bright spots is more on the side of the left undulating ridges than the right Catapult Ranges. This indicates that vegetation found in the left undulating ridges dominate the landscape of Alagar hill as a whole.

The brightest values in the diversity index map represent areas with the most heterogeneous land cover. The western slopes of the right Catapult Ranges are found to have heterogeneous land cover units in the landscape of Alagar hills. This may be attributed to different type of vegetation categories and the presence of non-forested area.
5.6.3.b Spatial Statistics and Pattern Analysis of Patches

Identifying geographic patterns is important in understanding how geographic phenomena behave in an area. Maps give a sense of pattern of features or values simply by cartographically represent them, calculating a statistic and quantify the pattern. This offers a possibility to compare the patterns of different distributions and also to calculate the probability that a pattern is not simply due to chance. Calculating this probability is important if one needs to have a high level of confidence in taking any decisions.

An important difference between spatial and traditional (aspatial) statistics is that spatial statistics integrate space and spatial relationships directly into analysis. Consequently, most of the tools in the spatial statistics toolbox of Arc GIS require the user to select a conceptualization of spatial relationships. The conceptualization of spatial relationships will depend very much on what is being measured. Measuring clusters of a particular species of tree in a forest, for example, inverse distance is probably most appropriate. For some analyses, space and time might actually be less important than more abstract concepts like familiarity (the more familiar something is the more functionally near it is) or spatial interaction.

A number of methods are available for analysing the patterns in the spatial structure of data (Mueller and Ellenberg, 1974). Most of the methods are designed to describe point data, assuming that patterns can be compared to a poisson distribution, including the variance/mean ratio, nearest neighbour and even Morisita's Index. These methods are primary first-order statistics, which test whether the mean spatial trend is significantly different from a random pattern. First-order statistics distinguishes whether the units in a study area exhibit an overall spatial structure (clumped or regular) or random. Second-order statistics (measurement of the square deviation to the mean) are developed for the purpose of quantifying small-scale pattern intensity and scale. Such methods test the spatial autocorrelation of variables (everything is related to
everything else, but near things are more closely related than distant things) and spatial pattern significance. They also used to model the spatial patterns. Techniques designed to analyze point data are not suitable for describing the spatial patterns of habitat patches or canopy cover (Bartlett, 1978). However, this problem could be overcome by calculating centroid for habitat patches or canopy cover and calculate spatial autocorrelation with other landscape elements in the vicinity.

Spatial autocorrelation measures attempt to deal simultaneously with similarities in the location of spatial objects and their attributes. If features that are similar in a location are also similar in attributes then the pattern as a whole is said to exhibit positive spatial autocorrelation. Conversely, negative spatial autocorrelation is said to exist when features which are close together, in space tend to be more dissimilar in attributes than the features which are further apart. Zero autocorrelation occurs when attributes are independent of location (Longley et al., 2001).

The pattern analysis tool available in Arc GIS - Spatial Statistics Module measures spatial autocorrelation (feature similarity) based not only on feature locations or attributes values, but on feature locations and feature values simultaneously. Given a set of features and an associated attribute, it evaluates whether the pattern expressed is clustered, dispersed or random. The result of the analysis is a Moran's Index Value. When the Moran's Index Value falls near +1.0 indicates clustering; an index value near -1.0 indicates dispersion. Further, Z score is also calculated to assess whether the observed clustering/dispersion is statistically significant or not.

5.6.3.c Spatial Statistics of landscape patches of Alagar Hills

The landscape patches of Alagar hills have been used to study the spatial statistics of Alagar hill environs. Two types of forests (dense forest and open forest), scrub vegetation and non-forested area constitute the landscape patches
of Alagar hills. They are amalgamated within the reserved forest boundary of Alagar hills. The dense forest is found in the elevated regions surrounded by the open forest type. The area with very high slope did not support the growth of shrubs, climbers and lianas or trees and are exposed with little grass cover. These areas are termed or classified as non-forested land within the reserve forest boundary. At the lower altitude the scrub vegetation is found. The intention of the present study is to investigate how various landscape patches are clustered together. The result of the cluster analysis is shown, in the table 5.5, below:

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From the results (Fig.5.11) the dense forest patches are highly clustered with open forest category, with the Moran's Index value of 0.15 and with a Z score of 7.4 standard deviations. There is less then 1% likelihood that this clustered pattern could be the result of random chance. However with scrub vegetation the pattern is neither clustered nor dispersed. Non-forested land is somewhat clustered, having the Moran’s Index value of 0.01 and Z score of 1.3 standard deviations, with dense forest. But this may be due to random chance.

The open forest category is randomly clustered with scrub vegetation. The pattern is neither clustered nor dispersed with a Moran’s Index value of 0 and Z score of 0.7 standard deviations. However, with the non-forested area it is highly clustered, with a Moran’s Index value of 0.1 and Z score of 7.1 standard
Fig. 5.11. Cluster Analysis

Dense Forest Vs Open Forest

There is less than 1% likelihood that this clustered pattern could be the result of random chance.

Dense Forest Vs Scrub

The pattern is neither clustered nor dispersed.
Dense Forest Vs Non-Forested Area

While somewhat clustered, the pattern may be due to random chance.

Open forest Vs Scrub

The pattern is neither clustered nor dispersed.
Open forest Vs Non-forested land

There is less than 1% likelihood that this clustered pattern could be the result of random chance.

Non-forested land Vs Scrub

The pattern is neither clustered nor dispersed.
deviations. There is less than 1% likelihood that this clustered pattern could be the result of random chance. The *scrub vegetation* is randomly clustered with *dense forest, open forest and non-forested land*. The pattern is neither clustered nor dispersed. From the cluster analysis the following were envisaged:

1. The dense forest category and open forest category are highly clustered, so any changes that happen in either of the forest categories could affect the flora and fauna of both.

2. The open forest is highly clustered with the non-forested area. In Alagar hills the non-forested area is associated with the steep slope conditions; the factors responsible for denudation would be active in the barren, exposed, rocky non-forested land than in the vegetated open forest.

3. The progressively changing non-forested area invariably influence and induce changes in the open forest category, which in turn affect the dense forest ecosystem.

4. The scrub vegetation category is randomly clustered with all other forest types. This zone experiences high human interferences. Due to its random clustering there is no immediate threat expected to be imposed from this vegetation category to other forest types. However, the human interference from this zone to other forest types cannot be ruled out.

5.7. **Tourism**

There are two types of tourist activities observed in Alagar hill environs viz., religious tourism and eco-tourism. The religious tourism is associated with the devotees who visit the Hindu temples in the Alagar hill environs while eco-tourism involves the local people from Madurai who visit Alagar hills for taking a break from their regular routines and also for refreshment from fatigue. Apart from the above mentioned reasons, it is a local tourist spot for city dwellers; with a cool climatic condition quiet contrary to the weather conditions prevailing in the urban centres nearby.
Alagar hill environs are the abode of the two prominent temples of Shiva and Vaishnava traditions of Tamil culture. Alagar Koil (Plate.4), the Vishnu temple is situated at the foot of the hills (275m) and a temple of Muruga (350m), regarded as the son of Lord Shiva, is situated in the middle of the Silambar Valley. The ‘Pazhamudhir Cholai’, the name of the place where Murugan temple is located, is considered to be the one among the six prominent temples of Murugan in Tamil Nadu. There are quiet a number of auspicious days in a year, especially during ‘Krithigai’, the Murugan temple would be thronged by the devotees of Shiva origin.

Alagar Koil would be the centre of cyclone during the ‘Chitrai’ festival celebrated in April every year. It is reported that several lakh people used to club during this festival at Alagar temple. It is one of the colourful festivals celebrated in Tamil Nadu. Apart from these festivals there would be regular tourist flow through out the year, for these temples which is one of the major tourist attractions in Madurai. Devotees consider taking bath in the springs flowing in the vicinity of these temples could cure their diseases of the body, mind and spirit. There are two springs, Garuda Thirtham (350m), a seasonal one, and the other, the perennial Nupura Gangai (425m) (Plate.4). There is a motorable road from the foot of the hills to Nupura Gangai enroute ‘Pazhamudhir Cholai’. The Governing Body of the temples plies buses to reach the Murugan temple atop Alagar hills regularly.

Apart from the two types of tourism, Alagar hill provides ample opportunities for exploratory tourism for bird watchers and taxonomist for exploring and enriching the knowledge.