In 1995, the Indian Ministry of Rural Development initiated new guidelines to ensure that all area development programmes be implemented on a watershed basis (Paul and Radhika, 1999). This new approach had a long term perspective to rejuvenate and sustain depleting water resources as opposed to initiating small scale projects to deal with the short term demand. An emphasis was placed on taking measures, to create a sustainable watershed in the near future. A definition of watershed management from an Indian resource was “the wise use of soil and water resources within a given geographical area so as to enable sustainable production and to minimize floods” (Tideman, 2002).

One problem leading to the degradation of water resources in India is deforestation, where the per capita availability of forests is only 0.8 hectare (Lal, 2002). The felling of trees has forced the topsoil to be directly exposed to the runoff, increasing soil erosion and thus causing high turbidity in the water. The Indian Government has initiated restoration methods as a key component of watershed management, and has created awareness programmes to educate the community on the importance of preserving forest lands.

The Kallar sub-watershed is home to native ‘Shola’ forests that has reached equilibrium with local environmental conditions. ‘Shola’ forests are encountered in altitudes greater than 1500 meters and are restricted to the valleys or folds in the hills, while the surrounding hill slopes should ideally be covered with grasses. The ‘Shola’ Forests provide a natural setting for water conservation. Unfortunately, many of these forests have been converted into man-made Eucalyptus or Acacia forests, which have a negative effect on the environment. The Eucalyptus species not only extract all rainfall
that enters the soil, but utilize an additional 100 millimetres of groundwater for every meter depth of soil the roots penetrate (Puri and Nair, 2004). The photograph below provides a visual example of the differences between the ‘Shola’ and man-made forests.

Since the acacia root system restricts the ability of other vegetation to grow, leaving the ground with less vegetative cover whereby causing runoff and uprooting of trees. A forest should be capable of checking the erosion on any type of soil, on any slope, and under all types of climatic conditions. This will be accomplished by a forest with the following characteristics:

- dense population of trees;
- variety of trees;
- water availability; and
- healthy wild life and ecological balance.

Keeping in mind the conservation of forests and the role of watershed in ecological balance, this thesis has been initiated with the core aim to assess the changes
in the Kallar sub-watershed by integrating remote sensing and GIS and to suggest conservation measures.

The first section (5.1) of the thesis deals with analyzing the land use and land cover changes in and around the Kallar sub-watershed. The magnitude of impact due to land use change was identified for a three year period over a span of 13 years. The overall estimated change from 1989-2002 has been identified. The results reveal that the area under forest cover has changed enormously (Evergreen forests-1.39%, moist deciduous forests-1.36%, riparian vegetation-4.16% and rocky with sparse vegetation-6.12%). There is also a steady increase in the number of settlements of the study areas, especially the areas that are associated with the land use practice areas, which have shown significant increase.

The Kallar sub-watershed has lost its forest wealth of both evergreen and moist deciduous forests. These forests have been replaced by tea and coffee (beverage crops), which are grown in this area to gain foreign exchange little knowing their consequences on the hydrological regimes of the watershed. Among these two crops, tea is being cultivated at an altitude greater than 1000 meters. Consequently this area has become more urbanized because of the revenue arising from these crops and their high yield. Similar changes in land use and depletion of forest cover have been reported by several authors (Dai et al., 1996; Yeh and Li, 1996, 1997, 1999; Chen et al., 2000).

Research shows that human-induced conversions (e.g. deforestation) and modifications (e.g. changing land use management such as fertilizer use and irrigation practices) of land use have great significance in the functioning of the earth system with an impact on the biogeochemical cycles (Turner et al., 1994). Apart from the direct
impacts of climate change on crop yields, climate change may also result in migration of agro-ecosystems in ways that can affect global food production.

The rapid conversion of vegetated lands into fallow or urban settlements has a considerable change in the climate of the region. The relationship between the changing vegetation cover and the climate has been estimated in the next section (5.2).

Extreme variations in climatological inputs often have the most rapid and significant impacts on vegetation state. This was clearly illustrated in the Midwest in 1988 when dry climate conditions prevailed and in 1993 when very wet climate conditions profoundly affected landscapes and ecosystems (Lillesand and Kiefer, 1994). The study used MVC AVHRR data will be used to assess and evaluate changes in vegetation state after extreme hydrologic events.

These changes in global climate have significant implications on the hydrological regimes of the Kallar sub-watershed. The NDVI results show that climate and vegetation are closely correlated. The results of the overall change in the vegetation cover of the Kallar sub-watershed reveal that during the span of 13 years, only 4.84% of the area remained unchanged whereas the rest of the areas have undergone changes in the vegetation cover. A major portion of the study area is under scrub land (19.91%) followed by 18.06% under sparse vegetation, 9.32% under dense vegetation 83.69% under shrubs and 4.84% under wetlands. The results from the NDVI studies were kriged and it was found that the climatic variables rainfall and climate are closely correlated with vegetation. The areas of the watershed, which experienced higher rainfall patterns, had good vegetation cover than the rest of the region.
The depletion of vegetation and erratic conditions has caused significant changes on the soil profiles, distribution and characteristics. This has initiated the need to study the soil aspects of the watershed through GIS and identify the soil capability, irrigability, suitability and productivity as in section 5.3.

The results reveal that the soils Fine loamy, Typic Dystropepts; Fine, Typic Dystropepts and Fine, Ultic Tropudalfs fall under the land capability class IIIe. They are moderately good cultivable lands on moderate slopes. These slopes have limitations of moderate erosion, soil depth, soil salinity, soil texture. They have vertic characteristics or drainage problems that reduce the choice of crop. In general, these areas have varying suitability for different crops. They are unsuitable for growing vegetable crops. Fine loamy, Fluventic Dystropepts fall in the capability class IIs. They are also good cultivable land on gentle slopes that have slight limitations of soil depth, salinity, texture, drainage or erosion that reduce the choice of crops.

The results for soil irrigability reveal that Fine loamy, Typic Dystropepts, Fine, Typic Dystropepts and Fine, Ultic Tropudalfs are under the land irrigability class 4t. These are lands that are marginal for sustained use under irrigation and they have severe limitations of sustained use under irrigation. One other limitation is topography. The soil Fine loamy, Fluventic Dystropepts is under the soil irrigability class 2s. These are soils that have moderate soil limitations for sustained use under irrigation. One other limitation of this soil type is the stratification of the layers.

The crop suitability for the various crops (Tea, Coffee, Banana, Paddy, Pepper cardamom, Cole vegetables and forest trees) were divided into four types viz highly
suited, moderately suited, poorly suited and unsuited. The details of the soil suitability results are presented in Table 5.3.7 of section 5.3.

The results of the present productivity of the crops grown on the soils Fine loamy, Typic Dystropepts, Fine Typic Dystropepts, Fine loamy, Fluventic Dystropepts and Fine, Ultic Tropudalfs are 22.40, 24.35, 26.40 and 28.50 respectively. The potential productivity and co-efficient of productivity was also calculated which reveal that they could be improved by the implementation of land improvement techniques.

The potential controlling factor for the changes in the soil morphology has been identified as the slope. The steepness of the slope increases the runoff of the streams, leading to deposition and sediment transport. The land use practices and slope are dependent on each other and act as the two sides of a coin. Slope is another most important terrain characteristic and plays a vital role in soil land use planning, soil erosion and geomorphologic and runoff processes (Sankar et al., 2001). Hence the second part of this chapter has been initiated to identify the land use practice areas at various altitudes and the impact of slope on the changes. It is seen that beverage crops are grown on very steep slopes which are unsuitable for tea plantation and suitable only for forest trees. It is seen that at an altitude of greater than 1000 mts these beverage crops are grown. The results reveal that such cropping practices on sloppy areas cause soil erosion during rainy periods. The results obtained are in tune with that of Kandasamy and Venugopal, (2002) in a study on the Nilgiri district, Tamil Nadu.

From a land use perspective, agricultural activities have been identified as major sources of nonpoint source pollution (sediments, animal wastes, plant nutrients, crop residues, inorganic salts and minerals, pesticides) (Viessman and Hammer, 1993) and
known to impact water quality. Residential/urban/built up land are other dominant factors in generating large amounts of non-point source pollution from stream water discharge, and even small rains are capable of washing accumulated pollutants into surface waters.

Development and interpretation of morphometric maps are important tools in studies related to (Zuchiewicz, 1991) drainage patter and runoff. The changes in the slope features have an impact on the morphological characters of the study area. This is as a result of the influence of various factors of the watershed. Based on this the quantitative morphometric analysis methods were used to evaluate the stream characters and qualitative methods were used to enumerate the water quality of the Kallar sub-watershed which is presented in section 5.4

The results obtained from the study reveal that the Kallar sub-watershed is experiencing severe water problem. The quality of water is below the permissible limits prescribed by the WHO, 1993. The results are presented in table 5.4.6, 5.4.7 and 5.4.8. Many villages with the incidence of water borne diseases have been reported. The villages immediately affected by the pollution problem are Kunjappanai and Burnside II high levels of water pollution. The villages Donnington, Kolikarai, Semanarai, Vagappanai, Aracodu and Karriykur are moderately villages and Robroy Mamaram, Mullur, Quinshola and Burnside I show moderate pollution. The study also shows that there are many springs and streams, which have dried up due to changes in the climate and changes in land use.

There is a crucial linkage between shola patches and water resource availability. Wherever sholas exist, existence of water is assured. Due to the decrease in the sholas the water sources have been depleted. There are severe monsoon failures, which have a
negative effect on the Kallar sub-watershed. Hence the final chapter (5.5) deals with the biodiversity study of the Longwood shola, which is the chief source of water supply to several villages. In this chapter the Diversity indices were calculated for the tree, shrub, lianas and climbers, epiphytes and ferns of the watershed (Table 5.5.10). The results reveal that the rich biodiversity of the shola is the reason for the maintenance of the micro-climate of the entire watershed. The human impact of the shola was also found by mapping the habitations residing closer to the shola and it was found that the fringes of the shola are the areas which are worst affected.

When viewed from all perspectives, it is concluded that the chief cause of the deterioration in the health of the Kallar sub-watershed is the changes in the land use and land cover. In conjunction changes in the shola forests which ultimately affect the climate. This has triggered off the other problems faced in the watershed right from the depletion of forests, change in climate, loss of soil fertility and increased pollution levels due to the use of fertilizers. Hence it is recommended that immediate actions be taken to restore the Kallar sub-watershed for the betterment of the residents of not only the Kallar sub-watershed but also the Kotagiri town as a whole.

The table (Table 7.1) lists the possible application of the maps derived from the study on the Kallar sub-watershed using RS and GIS.

Land managers could use these data sets and maps in erosion control, emergency flood management, land use planning, and management. City and town planners can use these data for residential and commercial storm-drain and sewer inlet locations and for pipe size to be able to drain off large rain events. Industries can use this data and maps to
be able to handle chemical spills and pesticide levels in the water in order to produce environmental impact statements.

Table 7.1. Potential Users of the data sets and maps

<table>
<thead>
<tr>
<th>Organizations</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land developers</td>
<td>Storm drain design, pollution control, infrastructure planning, fertilizer and pesticide runoff</td>
</tr>
<tr>
<td>Town Planners, Public utility managers</td>
<td>Sewer design, storm drain size, infrastructure design.</td>
</tr>
<tr>
<td>Local Government</td>
<td>Land Use, Planning and Management</td>
</tr>
<tr>
<td>Environmental Engineers</td>
<td>Land use, Planning and Management</td>
</tr>
<tr>
<td>Soil conservation planners</td>
<td>Development control, Soil conservation, Erosion control, Vegetation sedding locations, Land Management</td>
</tr>
<tr>
<td>Environmental Protection Agency</td>
<td>Toxic site management and prevention</td>
</tr>
<tr>
<td>Department of Agriculture/Farming</td>
<td>Fertilizer and pesticide runoff effects</td>
</tr>
<tr>
<td>State Environment/Natural Resources Agencies</td>
<td>Wet Land Conservation/preservation</td>
</tr>
<tr>
<td>Industry</td>
<td>Monitoring and reporting for environmental impact statements</td>
</tr>
<tr>
<td>Forest Department</td>
<td>Forest conservation</td>
</tr>
</tbody>
</table>

Hence the study on the Kallar sub-watershed has proved to be a productive one, which can be used by several organizations and institutions for the betterment of the hill dwellers.