METHODOLOGY
4.0 METHODOLOGY

4.1 Data Used

The data gathered from several government sectors and field surveys are mapped using GIS technique and Remote Sensing data are used for further analysis to study the Kallar sub-watershed.

The following data and maps were obtained from several sources:

a) The climatological data (rainfall and temperature) were obtained from four tea estates (Kilmelfort, Burnside, Kotada, and Deepdale) of the Kallar sub-watershed for a period from Jan 1989 to Dec 2003.

b) The socio-economic data of the watershed were retrieved from the Kotagiri Taluk office and also from the Census data for the years 1980-1990 and 1990-2000 maintained at Chennai.

c) Taluk map with the village panchayat boundaries were obtained from the District Survey Department, Ooty.

d) Land use map was obtained from the Horticulture Department.

e) Watershed boundary map was obtained from Anna University, Chennai.

f) Forest working plan was obtained from the Forest Department of The Nilgiris.

g) Toposheets 58 A15 and 58 E3 with a scale of 1:50,000 was obtained from the Survey of India, Govt. of India, Bangalore.

h) IRS LISS III satellite imageries pertaining to the study area of the years 1989 Jan, 1993 March, 1999 Feb and 2002 Feb were purchased from the National Remote sensing Agency (NRSA), Hyderabad.

i) A questionnaire was prepared to collect the village information on water resources and their uses (Appendix 1).

4.2 Soil Survey Methods

The standard soil survey procedure laid down in the soil survey manual prepared by the All India Soil and Land Use Survey Organization and the Soil Survey Manual (USDA Hand Book) were followed during the soil survey work. The soil survey includes
(a) identifying the type of soil
(b) describing the type of soil and
(c) classifying the same

4.2.1 Profile Studies

Soil profiles were opened to a depth of two meters or up to the parent material or up to the water table which ever was shallower to study and record the physicochemical properties of the soils. “Guidelines for Profile Description” by FAO (1967) and terms in Soil Survey Staff (1999) were referred to, for describing the soil classification units. Soil taxonomy (Soil Survey Division Staff, 2000) was referred to and soils were classified at family level.

The soil profile samples, representative of each soil family were collected for physical and chemical analysis in the laboratory to supplement the morphological observations of the field.

4.2.2 Laboratory Studies

During the conduct of survey, horizon-wise soil samples were collected from typical soil profiles and analyzed in the laboratory. Physical analysis of soils comprises particle size distribution. Chemical analysis includes the estimation of EC, pH, CaCO$_3$, Organic Carbon (OC), Cation Exchange Capacity (CEC) and Exchangeable Cations.

International Pipette method was employed for determining particle size distribution. The soil was analysed for mechanical composition of coarse sand (2 to 0.2 mm) fine sand (0.2 to 0.02 mm) silt (0.02 to 0.002 mm) and clay (< 0.002 mm). Chemical analysis was done according to standard procedures (Soil Survey Division Staff, 2000).
4.3 Habitat Quality Assessment

The habitat quality evaluation can be accomplished by characterizing selected physicochemical parameters in conjunction with a systematic assessment of physical structure. Through this approach, key features can be rated or scored to provide a useful assessment of habitat quality.

Physical characterization includes documentation of general land use, description of the stream origin and type, summary of the riparian vegetation features, and visual interpretation of the stream parameters. The water qualities discussed in these protocols are in situ measurements of standard parameters that can be taken with a water quality instrument. These are generally instantaneous measurements taken at the time of the survey. Measurements of certain parameters, such as temperature, pH dissolved oxygen, and turbidity, were done in the field. In addition, water samples were collected for selected chemical analysis. These chemical samples are transported to an analytical laboratory for processing. The combination of this information (physical characterization and water quality) will provide insight as to the ability of the stream to be used for drinking purposes.

4.3.1 Equipment/Supplies Used For Habitat Assessment and Physical/Water Quality Characterization

- Physical Characterization and Water Quality Field
- Data Sheet
- Habitat Assessment Field Data Sheet*
- clipboard
- pencils or waterproof pens
- camera
- In situ water quality meters
- Global Positioning System (GPS)
4.3.2 Visual-Based Habitat Assessment

The methodology adopted here is the Rosgen (1996) method which is detailed in chapter 5.5.

4.4 Analysis of Water Quality:

Table I. Water Quality Parameters Analysed and the Procedures Followed

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameters</th>
<th>Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Temperature</td>
<td>Thermometer</td>
</tr>
<tr>
<td>2.</td>
<td>pH</td>
<td>pH meter</td>
</tr>
<tr>
<td>3.</td>
<td>Total Dissolved Solids</td>
<td>TDS meter</td>
</tr>
<tr>
<td>4.</td>
<td>Dissolved Oxygen</td>
<td>Titration against potassium dichromate</td>
</tr>
<tr>
<td>5.</td>
<td>Electrical Conductivity</td>
<td>Conductivity meter</td>
</tr>
<tr>
<td>6.</td>
<td>Total Hardness</td>
<td>EDTA Trimetric Method</td>
</tr>
<tr>
<td>7.</td>
<td>Turbidity</td>
<td>Nephelometer</td>
</tr>
<tr>
<td>8.</td>
<td>Sodium</td>
<td>Flame Photometer</td>
</tr>
<tr>
<td>9.</td>
<td>Phosphate</td>
<td>Flame Photometer</td>
</tr>
<tr>
<td>10.</td>
<td>Potassium</td>
<td>Flame Photometer</td>
</tr>
<tr>
<td>11.</td>
<td>Magnesium</td>
<td>Difference of total hardness and Ca hardness</td>
</tr>
<tr>
<td>12.</td>
<td>Calcium</td>
<td>Titration against EDTA</td>
</tr>
<tr>
<td>13.</td>
<td>Chloride</td>
<td>Titration against Silver Nitrate</td>
</tr>
<tr>
<td>14.</td>
<td>Sulphate</td>
<td>Nephelometer</td>
</tr>
<tr>
<td>15.</td>
<td>Nitrate</td>
<td>Ion Selective Electrode Method</td>
</tr>
<tr>
<td>16.</td>
<td>Copper</td>
<td>Neocuproine Colorimetric Method</td>
</tr>
<tr>
<td>17.</td>
<td>Cadmium</td>
<td>Dithizone Colorimetric Method</td>
</tr>
<tr>
<td>18.</td>
<td>Arsenic</td>
<td>Atomic Absorption Spectrophotometer</td>
</tr>
<tr>
<td>19.</td>
<td>Iron</td>
<td>Colorimetric Thiocyanate Method</td>
</tr>
<tr>
<td>20.</td>
<td>Coliform</td>
<td>Most Probable Number Technique</td>
</tr>
</tbody>
</table>

Water samples were collected from 23 locations of the Kallar sub-watershed and the parameters analysed with their respective methodology are given below. The latitude and longitude of the sampling points which were noted through the GPS (GARMIN) were used for mapping. The parameters analysed and the relevant methodologies adopted are given in the Table I. The parameters analysed were compared with the standards produced by the WHO (1993) and are presented in Table II.
Table II. Drinking Water Quality Standards prescribed by the WHO (1993)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Permissible limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (units)</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>TDS (Mg/l)</td>
<td>1000</td>
</tr>
<tr>
<td>DO (Mg/l)</td>
<td>5</td>
</tr>
<tr>
<td>EC (Micromhos/cm)</td>
<td>1400</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>5</td>
</tr>
<tr>
<td>N (Mg/l)</td>
<td>200</td>
</tr>
<tr>
<td>P (Mg/l)</td>
<td>0.1</td>
</tr>
<tr>
<td>Mg (Mg/l)</td>
<td>150</td>
</tr>
<tr>
<td>Ca (Mg/l)</td>
<td>100</td>
</tr>
<tr>
<td>Cl (Mg/l)</td>
<td>250</td>
</tr>
<tr>
<td>SO4 (Mg/l)</td>
<td>250</td>
</tr>
<tr>
<td>NO3 (Mg/l)</td>
<td>50</td>
</tr>
<tr>
<td>Fe (Mg/l)</td>
<td>0.50</td>
</tr>
<tr>
<td>Cu (Mg/l)</td>
<td>0.05</td>
</tr>
<tr>
<td>Cd (Mg/l)</td>
<td>0.003</td>
</tr>
<tr>
<td>Ar (Mg/l)</td>
<td>0.05</td>
</tr>
<tr>
<td>Coliform</td>
<td>10/100 ml</td>
</tr>
</tbody>
</table>

4.5 Mapping in GIS

4.5.1 Extraction of the different layers from 1:50,000 scale digital maps

The toposheets 58/A15 and 58/E3 of 1:50,000 scale were appropriately registered and layers such as the watershed boundary, mini and micro watersheds of the Kallar sub-watershed, stream networks, contours, roads and reserve forest boundaries were digitized in the GIS environment using MapInfo 6.0 version. Stream orders were classified and drainage network maps were prepared in MapInfo 6.0 version.

4.5.2 Morphometric Analysis

The drainage basin analysis was carried out quantitatively. The quantitative drainage analysis is done aspect wise such as linear aspects and aerial aspects. In the linear aspects, stream order, stream length, bifurcation ratio and mean length of streams
of orders were analyzed. In the aerial aspects, the factors like drainage density, stream frequency and basin area were evaluated.

**Linear Aspects**

**i) Stream Order (U)**

The first step in drainage-basin analysis is designation of stream orders (Horton, 1945), which is not only the index, the size and scale, but they also afford and approximate the index of the amount of stream flow, which can be produced by a particular network. Stream order number is directly proportional to the size of the contributing watershed, to channel dimensions, and to stream discharge at that place of in the system.

**ii) Stream Number (N_u)**

The count of stream channel in its order is known as stream number. The number of the stream segments decreases as the order increases. The higher amount stream order indicates lesser permeability and infiltration. Stream number is directly proportional to size of the contributing watershed, to channel dimensions. It is obvious that the number of streams of any given order will be fewer than for the next lower order but more numerous than for the next higher order. Each segment of the stream was numbered starting from the first order to the maximum order.

**iii) Bifurcation Ratio (R_b)**

Horton (1945) and Strahler (1958) had defined Bifurcation ratio as number of streams of one order to the number of the next higher order.

\[
R_b = \frac{N_u}{(N_u+1)}
\]

where,

\[R_b = \text{Bifurcation ratio}\]
The bifurcation ratio will not be precisely the same from one order to the next, because of possibility of variations in watershed geometry and lithology, but tends to be a constant throughout the series. Bifurcation ratios characteristically range between 3.0 and 5.0 for watersheds in which geologic structures do not distort the drainage pattern. The theoretical minimum value of 2.0 is rarely approached under natural conditions. Because the bifurcation ratio is dimensionless property and to display geometric similarity, it is not surprising that ratio shows only small variations from region to region.

Abnormally, higher bifurcation ratios might be expected in regions of steeply dipping rock strata where narrow strike valleys are confined between hogback ridges.

iv) Stream Length ($L_u$)

Mean length $L_u$ of a stream-channel segment of order $u$ is a dimensional property revealing the characteristic size of components of a drainage network and its contributing basin surface. Channel length was measured with the help of Arcview GIS 3.2a software. To obtain the mean length of channel $L_u$ of order $u$, the number of segments $N_u$ of that order divides the total length, thus:

$$
\bar{L}_u = \frac{\sum_{i=1}^{N} L_{u_i}}{N_u}
$$

where,

$L_u = \text{Stream length}$

$N_u = \text{Stream Number}$
As expected, mean of channel segments of a given order is greater than that of the next lower order but less than that of the next higher order. Horton (1945) postulated that the length ratio RL (which is ratio of mean length $L_u$ of segments of order $u$ to mean length of segments of the next lower order $L_{u-1}$) tends to be constant throughout the successive orders of a watershed.

**Arial Aspects**

**i) Basin Area ($A_n$)**

The drainage basin area is one of the important parameters like that of the length of draining the basin. The area of a given order is defined as the total area projected on a horizontal plane contribution overland flow to the channel segments of the given order, which includes all tributaries of the lower order.

**ii) Stream Frequency ($F_n$)**

Horton (1945) introduced stream frequency as the number of stream's segment per unit area and discusses the importance to ground water recharge characteristics in a river basin. It is obtained by dividing the total number of stream to the total drainage basin area.

**vi) Drainage Density ($D_d$)**

An important indicator of the linear scale of land-form elements in stream eroded topography is drainage density $D_d$. Drainage density is the total length of all the streams in the basin to the area of whole basin (Strahler., 1958). It is a measure of average length of the streams per unit drainage area, and describes the spacing of the drainage ways. Drainage density has been interpreted to reflect the interaction between climate and geology (Ritter *et al.*, 1995). In general, low drainage density is favored in regions of highly resistant or highly permeable subsoil materials, under dense vegetation cover, and
where relief is low. High drainage density is favoured in regions of weak or impermeable surface materials, sparse vegetation, and mountainous relief. Mathematically it is expressed as:

\[ D_d = \sum \frac{L_u}{A_u} \]

where,

- \( D_d \) = Drainage Density
- \( L_u \) = Stream length
- \( A_u \) = Basin Area

4.6 Mapping using Remote Sensing

4.6.1 Preprocessing of Images

Preprocessing is a process of image rectification and restoration. It precedes further manipulation and analysis of image data to extract specific information. The image rectification and restoration operations correct image data for distortions or degradations that stem from the image acquisition process. The images were pre-processed in ERDAS IMAGINE 8.4. The procedures followed are as follows:

i) Subsetting

The images of the years 1989, 1993, 1999 and 2002 were subset specifying the study area using the AOI tool.

ii) Mosaicing

The toposheets pertaining to the study area were mosaiced to aid in further analysis.
iii) Reprojection

The images were projected from Universe Transverse Mercator (UTM) reference system to Polygonic reference system. Nearest Neighbourhood was selected for resampling as this method uses the value of the closest pixel to assign the output pixel value without altering the DN value.

iv) Georectification

Map to image georectification process was adopted for mosaic, where ground control points were obtained from Survey of India (SOI) 1:50,000 scaled toposheets. Selection of points was done by referring to the image and choosing prominent landmarks. Several georeference points were chosen that consisted of permanent structures like roads, railway line, bridges, mountains, peaks etc.

4.6.2 Image Processing

i) Extraction of NDVI from imagery

The Normalized Difference Vegetation Index (NDVI) approach is based on the fact that healthy vegetation has a low reflectance in the visible portion of the EMS due to chlorophyll and other pigment absorption and has high reflectance in the NIR because of the internal reflectance by the mesophyll spongy tissue of a green leaf (Campbell, 1987).

The NDVI is calculated as IR-R/IR+R, where ‘IR’ is the infrared reflectance and ‘R’ the red band reflectance. It is believed to largely eliminate the scene-to-scene differences arising out of solar-target-sensor variations in geometry. NDVI can be calculated as a ratio of red and the NIR bands of a sensor system and is represented by the following equation:

\[
\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}
\]
Where NIR is the spectral radiance in the near infrared band and RED is the spectral radiance in the red band. The index normalizes the differences between the bands so that the values range between -1 and +1.

The NDVI has been widely used for global land cover mapping over large areas, especially with the NOAA/AVHRR sensors (Teillet et al., 1982). Hence, NDVI was computed by using cloud-free IRS 1C LISS III images of the years 1989, 1993, 1999 and 2002, with a spatial resolution of 23.5 m, to distinguish vegetative and non-vegetative areas of the Kallar sub-watershed using ERDAS IMAGINE 8.4 software.

The influence of climate on the vegetation was obtained using kriging. Interpolation methods, such as ordinary kriging, or cokriging may allow the biophysical model simulations to be done for a minimal number of points, and then a surface map of the simulation output could be created for a region. These surface maps could then be used in any type of analysis that requires spatially explicit vegetation reduction across a region. As an interpolation method, ordinary kriging can provide estimates for unknown points by using the weighted linear average of the available samples (in this case model simulation output). Kriging is often described as the Best Linear Unbiased Estimator (B.L.U.E.). It is "best" because the variance of the errors is minimized, linear because the estimates are weighted linear combinations of the sample data, and unbiased in that the average error is equal to zero (Davis, 1973). Hence kriging was performed for the temperature and rainfall variables and their effect on vegetation cover was analysed.

This is an estimate of a theoretical function calculated from a finite number of points which correspond to all pairs of observations separated by distance $h$. In practice, the kriging estimator is given by the formula:
where \( Z_k(x) \) is the study random function at point \( x \) and \( \lambda_i \) and \( Z(x_i) \) are the kriging coefficients and the measurements of the function in the \( N \) observations, respectively. Kriging was applied to interpolate the residuals of the study parameters of rainfall and temperature for all pixels using an exponential semi-variogram model. Finally, the study parameters for each pixel were obtained, reintroducing the systematic trend due to rainfall and temperature.

**ii) Classification Techniques**

Image classification is the process of assigning pixels to classes. Usually each pixel is treated as an individual unit composing of values in several bands. By comparing pixels with one another and pixels of known identity, it is possible to assemble groups of similar pixels into classes that match the information categories of interest to users of remotely sensed data. These classes form regions on a map or an image; after classification, the digital image is presented as a mosaic of uniform parcels, each identified by a colour or symbol.

**a) Unsupervised Classification**

Unsupervised classification can be identified as identification of natural groups or structures within an image. The advantages of unsupervised classification are that no prior knowledge of the region is required, the opportunity for human error is minimized and unique classes are recognized as distinct units (Campbell, 1996).

Different number of classes were allotted for unsupervised classification of land use and land cover of the study area.
b) Ground Truthing

The Kallar sub-watershed was surveyed to classify the vegetation types and land use pattern. Different elements of vegetation and its structures were identified using differences in type of land cover/land use, tree species composition, canopy cover, land feature description and the degree of disturbance in the land. The latitude and longitude was noted during ground truthing using the Global Positioning System (GPS) (GARMIN). Ground truthing is a common procedure for all types of classification and other analyses in Image processing.

c) Supervised Classification

Supervised classification is the process of using samples of known identity to classify pixels of unknown identity. Samples of known identity are those pixels located within training areas. The training areas are defined by identifying regions on the image that can be clearly matched to areas of known identity on the image. Pixels located within these areas form the training samples used to guide the classification algorithm to assign the specific spectral values to appropriate informational classes. The advantage of this method is that we have control of a set of selected menu of informational categories tailored to a specific purpose and geographic region. Thus this type of classification is important to generate a classification for the specific purpose of comparison with another classification of the same area at different time periods (Campbell, 1996).

Based on the data collected from ground truthing, the images were classified into seven classes. The pixels were resampled using Maximum Likelihood algorithm. The advantage of Maximum Likelihood algorithm is that it is the most accurate. Every spectral response has a probability of belonging to a class and no pixels are left
unknown (Lillesand and Kiefer, 1994). From the spectral information obtained from each of these signatures, the Kallar sub-watershed was divided into several land use classes.

d) Post Classification Smoothing

To remove the speckled appearance of the classified images, majority filter (3*3) was applied. When majority filter passes a window over dataset, it compares the central pixel with all neighbours and assigns the majority value to the central pixel.

e) Evaluation of Classification

Accuracy assessment for supervised classification was done by generating random points on the image. Classes falling on these points were then cross-checked with sample test points collected from field and SOI toposheets.

4.6.3 Analysis of change

The goal of change detection is to discern those areas on digital images that depict change features of interest (e.g. forest clearing or land cover / land use change) between two or more image datasets. The changes in land use were calculated in percentage using matrix method in ERDAS Imagine 8.4 version.

4.6.4 Preparation of Digital Elevation Model (DEM)

Surfaces such as the surface of the earth are continuous phenomena rather than discrete objects to fully model the surface, would need an infinite amount of points. The spatial database models that are used for continuous surfaces are digital elevation model which is one way of representing surfaces and will examine some important algorithms based on Digital Elevation Models (DEM’s). The term digital elevation model or DEM is frequently used to refer to any digital representation of a topographic surface. The DEM is the simplest and common form of digital representation of topography.
The Digital Elevation Model (DEM) of the watershed was generated using contour maps. The scanned topographic map was exported to MapInfo 6.0 version for digitization after registration. The latitude and the longitude of the ground control points were converted to actual ground co-ordinates. The drawing tools were used to digitize all the 20-meter contours and editing was also performed for all the contour lines and stored in a single layer. The contours were then assigned attribute values (actual elevation of the contours). These contour lines were exported to ERDAS IMAGINE 8.4 to perform surfacing. The output obtained after processing is the DEM.

4.6.5 Preparation of Slope Map

Slope is defined by a plane tangent to a topographic surface, as modelled by the DEM at a point (Burrough, 1986). Slope is classified as a vector; as such it has a quantity (gradient) and a direction (aspect). Slope gradient is defined as the maximum rate of change in altitude (tan Θ), aspect (ψ) as the compass direction of this maximum rate of change (Cf. Fig.1). More analytically, slope gradient at a point is the first derivative of elevation (Z) with respect of the slope (S), where S is in the aspect direction (ψ). At the same time the first derivative of a function (i.e. S stands for slope) at a point can be defined as the slope (angular coefficient or trigonometric tangent) of the tangent to the function on that particular point, hence:

\[ \tan \Theta = \frac{\text{rise}}{\text{run}} = \frac{\partial Z}{\partial S} \]
Although Digital Elevation Models (DEM’s) were originally developed for modelling relief, they are also used to model the continuous variation of any other attribute $Z$ over a dimensional surface better known as digital terrain model (DTM). It is useful for three dimensional displays of land forms, for statistical analysis and comparison of different kinds of terrain; for computing slope maps, aspect maps and slope profiles that can be used to prepare shaded relief maps, assist geomorphological studies or estimate erosion and run-off (Arya et al., 2002).

Elevation and slope were achieved using Digital Elevation Model. Elevation classes map considering 20-meter classes were obtained through the classification of Digital Elevation Model. Slope classes map was achieved by classifying the slope into various classes. The maps thus derived were overlayed and the improper land use practice areas were identified.
4.7 Sampling Approach

The major species of the area have been identified for generating a base line information of the shola. The habitat level characteristics have a direct or indirect influence over the vegetation types have been taken up in the forested areas.

A total of 30 plots were sampled across the study area of 116 hectares covering the entire shola, which were selected through stratified random selection enroute for the general vegetation distribution pattern study across the Longwood shola. A total of 18 plots were distributed in the peripheral zone of the shola while the remaining 12 plots were made in the core portion of the shola.

4.7.1 Modified Whittaker Method

Proper care was taken during the sampling to enumerate trees, shrubs, epiphytes, lianas and climbers and ferns of the Longwood shola. Plots of different sizes were laid for all the strata. The nested plot of size 12*12m was selected for sampling, wherein the trees and epiphytes were sampled in 12*12m, shrubs and lianas and climbers in 6*6m and ferns in 1*1m. The species were identified by their local names or scientific name. Samples of the unidentified species were preserved as herbarium and brought to the laboratory for identification.

Overall presentation of vegetation cover of the plot i.e floral species list in the study area was compiled with their families, generic and species names. The species were identified with the help of relevant taxonomy books (Champion and Seth, 1968)

4.7.2 Indices of Diversity

Diversity is often represented in the form of indices. Diversity indices attempt to incorporate both richness and abundance into a single numerical value. These are
therefore referred to as heterogeneity indices. A given value of diversity index can result from different combinations of species richness and abundance or evenness.

Species richness can be described as the number of species in a sample or habitat per unit area. Indices can be generated to bring them to similar scale. The simplest species richness index is based on the total number of species and the total number of individuals in the sample or habitat. Higher the value greater the species richness.

4.7.3 Shannon Wiener information theory Index

Shannon Wiener Index \( (H) \) represents the average degree of uncertainty in predicting to which a particular species, an individual chosen at random from a sample will belong.

\[
H = - \left[ \frac{n_i}{N} \log_2 \left( \frac{n_i}{N} \right) \right]
\]

where \( H \) is the Index Value

\( n_i = \) importance value or number of species

\( N = \) total number of species in that habitat type

Evenness value ranges higher in cases where all species are equally distributed across the sample, and near zero when the abundance of the species are very different from each other.

4.7.4 Preparation of Distance Class Maps

Distance from roads and residential areas were the two other important data layers used in the last chapter of the study. They were prepared considering the distance from roads and residential areas using the toposheets and roads from the Taluk map in MAPINFO 6.0.
The data have been prepared and used in different sections and the methodologies adopted are briefed in a flowchart (Fig II)
Fig 4.1 Flowchart showing the methodology adopted for the study on the Kallar Sub-watershed of The Nilgiris