CHAPTER 3
STUDY AREA, MATERIALS AND METHODS

3.1 Study area

Unlike other disasters, drought is a large scale phenomenon. The extent of area can be as small as a few districts (0.5 – 1 Mha) and in severe cases it may extend across a continent. Drought incidents may last for few months and may extend to several years. Hence to study drought from a broader perspective it is appropriate to choose a larger area as the study area. In this study, depending on the objective and the data used, the extent of area under study varies. For the first objective which investigates the soil moisture changes before and after the onset of monsoon using passive microwave sensor data, entire country has been chosen as the study area. This is due to the fact that variation in monsoon and monsoon rainfall distribution is a large scale phenomenon. Further, the passive microwave AMSR-E data which was used in the study has a resolution of 25 x 25 km. Hence, considering the entire country as the study area may be more appropriate for this objective. The second objective of our study deals with the early season drought assessment using the moderate resolution remote sensing data. The study area chosen for this study is the state of Andhra Pradesh. For the third objective of deriving the soil moisture using soil water balance model for assessing the early season agricultural drought, the study area is the states of Andhra Pradesh and Tamil Nadu.

India, with 329 million hectares of the geographical area presents a large number of complex agro-climatic conditions. India is mainly a tropical country but due to great altitudinal variations, almost all climatic conditions from hot deserts to cold deserts exist. There are four seasons: (i) Winter (December-February), (ii) Summer (March-June), (iii) South-west monsoon season (June-September), and (iv) Post monsoon season (October-November). However, the south-west or the summer
monsoon is the main source of rainfall in the country, providing 80% of the precipitation. India receives annually about 4000 cubic kilometers of water through precipitation. Most of this rainfall is confined to few months in a year and the country remains dry for almost the rest of the year. To monitor rainfall at a regional level India Meteorological Department (IMD) has divided India into 36 meteorological (met) sub-divisions. The study on soil moisture changes before and after the onset of monsoon using passive microwave sensor data, considers met sub-divisions as a basic unit for this study.

For the study on early season agricultural drought assessment using the SWIR based index and modeled soil moisture, two contiguous states of Andhra Pradesh and Tamil Nadu are considered. Andhra Pradesh is located in the Indian peninsular; it is the fifth largest state of the country with a total geographic area of 27.44 million hectares. The forest covers 22.6% of the state and the net sown area is about 39%. The state has diverse vegetation types like the forested districts in the north to the dry arid districts in the south. The summer monsoon season (June – September) is the major cropping season. The state receives about 68.5% of the total annual rainfall during this period. During summer monsoon season the majority of the agriculture is dependent on the monsoon as 65% of the 13.02 million hectare gross cropped area is under rainfed condition (Mishra et al 2005). 45% of the state is prone to drought (Seth, 1998). The state has 22 agricultural districts with an average geographical area of 4000 to 5000 km² per district. Districts are further subdivided into Mandals (roughly 250 km²) and then into villages. Due to constraints in getting the field data on weather and other related observations at sub-district and village level, district level data was considered for this study. Hence, all the data generated and analyzed in this study was at the district level.

Tamil Nadu is the southern most main land state of India and is geographically located between 8°5' and 13°35' North latitude and between 76°14'
and 80°21' East longitude. The total geographical area of the state is 13 million hectares out of which 7 million hectares is cultivable. Fifty five per cent of the cultivable area is dry land. The red soil is the dominant soil type in Tamil Nadu, followed by black and alluvial soils. It has semi arid climate, which is influenced by both the south west and north east monsoons. The south-west monsoon (June-September) contributes around 32 per cent mostly in the western and northern districts of the state. The dominant monsoon however is north-east monsoon (October - December) which contributes 42 to 48 per cent of total annual rainfall. Coastal districts of the state get nearly 60% of the annual rainfall and the interior districts get about 40-50% of the annual rainfall (http://www.imdchennai.gov.in/northeast_monsoon.htm). Hence the major cropping season in the state of Tamil Nadu and southern Andhra Pradesh (adjacent northern state) is during the north east monsoon season. Monitoring the early season agricultural drought during both the monsoons is more appropriate for this region. Figure 1 shows the location of the study area.

3.2 Data used

3.2.1 Soil moisture data

The AMSR-E gridded Level-3 land surface product (AE_Land3) has been used in this study. The product is available in the Earth Observation System Data Gateway(EOSGateway)webpage(http://delenn.gsfc.nasa.gov/~imswww/pub/imswebcome/). The basic theory behind microwave remote sensing of soil moisture is based on the large contrast between the dielectric properties of liquid water (~80) and dry soil (<4). The dielectric properties of wet soil was studied by several investigators (e.g., Wang and Schmugge, 1980; Dobson et al., 1985; Ulaby et al., 1986). As the moisture increases, the dielectric constant of the soil-water mixture increases and this change is detectable by microwave sensors (Njoku and Kong, 1977). The emission of microwave energy is proportionate to the product of the surface
temperature and the surface emissivity, which is commonly referred to as the microwave brightness temperature ($T_B$).

For typical soil moisture applications, using longer microwave wavelengths at low altitude, temperature contributions from the atmosphere and the sky can be neglected. Thus, the brightness temperature of an emitter of microwave radiation is related to the physical temperature of the source through the emissivity such that

$$T_B = (1 - R) \cdot T_{\text{eff}} = e \cdot T_{\text{eff}}$$

(4)

where

R - hemispherical-directional reflectivity from the surface,  
$T_{\text{eff}}$ - effective radiating temperature of the surface, and  
e = (1-R) - effective emissivity,
Which, depends on the dielectric constant of the medium (Schmugge, 1990). Although the relationship between emissivity and $T_B$ is linear, the relationship between emissivity and dielectric constant is nonlinear because the water content of the media has a nonlinear effect on the dielectric constant. Reflectivity is described by the Fresnel equation (5) and (6) that defines the behaviour of electromagnetic waves at a smooth dielectric boundary. For horizontal and vertical polarized waves (H, V) at non-nadir incidence ($\theta$), the Fresnel reflectivity may be derived from electromagnetic theory (Kong, 1990) as:

$$R(H,\theta) = \left| \frac{((\cos\theta - \sqrt{\varepsilon_H} - \sin^2\theta)) / (\cos\theta + \sqrt{\varepsilon_H} - \sin^2\theta))}{((\varepsilon_H \cos\theta - \sqrt{\varepsilon_H} - \sin^2\theta)) / (\varepsilon_H \cos\theta + \sqrt{\varepsilon_H} - \sin^2\theta))} \right|^2 \quad (5)$$

$$R(V,\theta) = \left| \frac{((\varepsilon_V \cos\theta - \sqrt{\varepsilon_V} - \sin^2\theta)) / (\varepsilon_V \cos\theta + \sqrt{\varepsilon_V} - \sin^2\theta))}{((\varepsilon_V \cos\theta - \sqrt{\varepsilon_V} - \sin^2\theta)) / (\varepsilon_V \cos\theta + \sqrt{\varepsilon_V} - \sin^2\theta))} \right|^2 \quad (6)$$

Where,

$\varepsilon_p$ - polarization-dependent complex dielectric constant of the emitter.

Because the contribution of the imaginary part of $\varepsilon_p$ is relatively small, inversion of equations (5) and (6) can be simplified if we consider only the real part of the complex dielectric constant, or permittivity. Application of the Fresnel equation requires remote observations of reflectivity and assumptions that the dielectric and temperature properties of the soil are uniform throughout the emitting layer, that emissivity is related principally to the permittivity, and that the soil depth emitting the energy being measured is known. Through inversion of the Fresnel equation, we obtain an estimate of the effective permittivity of the emitting layer. For H-polarization we obtain from equations (5):

$$\varepsilon_{H,\text{eff}} = \sin^2\theta + \cos^2\theta \left( \frac{\sqrt{R} + 1}{\sqrt{R} - 1} \right)^2 \quad (7)$$

and for V-polarization from equations. (3):

$$\varepsilon_{V,\text{eff}} = a^2 + a(a^2 - 4b^2 \cos^2 \Theta \sin^2 \Theta)^{1/2} / 2b^2 \cos^2 \Theta \quad (8)$$
Where, $a = R_V^{1/2} + 1$ and $b = R_V^{1/2} - 1$.

Volumetric soil moisture content is determined from $\varepsilon_{\text{eff}}$ by inverting the soil dielectric mixing model of Dobson et al. (1985) using known dielectric properties of soil, water and air.

### 3.2.2 Assumptions

Although it is desirable to use complete and physically based models to determine soil moisture from microwave remote sensing instruments, it is rarely possible to obtain the ancillary data that these models require (Jackson, 1993). Consequently, application of the Fresnel equation requires assumptions that the dielectric and temperature properties of the soil are uniform throughout the emitting layer, that emissivity is related principally to the real part of the complex dielectric constant, and that one has knowledge of the soil depth emitting the energy being measured. There are several additional considerations that also should be incorporated in a retrieval algorithm. Jackson et al. (1997) provides a comprehensive review of many of these issues.

The AMSR-E products used in this study includes daily measurements of surface soil moisture of the top few centimeters of soil and vegetation/roughness water content interpretive information, as well as brightness temperatures and quality control variables. The ancillary data include time, geo-location, and quality assessment. This product offers coverage of the global land surface, excluding snow-covered and permanent densely vegetated areas. It is provided in global cylindrical equal area projection at a nominal grid spacing of 25 x 25 km (true at 30° N & S), with 1383 columns and 586 rows.

The daily AE_Land3 products obtained from the web were processed and multiplied with the scales factor to convert the digital number to surface soil
moisture values. The range of soil moisture measured is 0 to 0.5 g/cm³ with an estimated accuracy of 0.06 g/cm³. The quality control flags were used to remove the unwanted pixels.

3.2.3 Rainfall data

The weekly rainfall data supplied by the India Meteorological Department (IMD) was used in the study. Apart from the conventional data supplied by the IMD the rainfall products of the Tropical Rainfall Measuring Mission (TRMM) 3B42 product was also used. The 3B42 algorithm produces TRMM-adjusted merged-Infrared (IR) precipitation and Root-Mean Square (RMS) precipitation-error estimates (NASA, 2010). These gridded estimates are on a 3-hour/daily temporal resolution and 0.25° by 0.25° spatial resolution. Details regarding the product can be found in the Algorithm 3B-42 User’s guide (URL:http://tsdis02.nascom.nasa.gov/tsdisDocuments/3B42_Users_Guide).

The daily TRMM 3B42 product was used to investigate the soil moisture changes before and after the onset of monsoon using the passive microwave sensor data and also as the input driver in the soil water balance model to estimate the daily soil moisture. The daily TRMM 3B42 product was obtained in ASCI format during the study period. The ASCI file was used to create the rainfall surface by incorporating the geo-location information and scale factors using the ARCGIS and ERDAS software. The IMD standard weekly spatial weighted average precipitation of each met-subdivision was extracted and used for analysis.

For the study on derivation of soil moisture using the soil water balance model, the TRMM 3B42 Rainfall product is the most important input driver. The daily rainfall surfaces was derived from the TRMM 3B42 product and used in the model. More details of the TRMM 2B42 algorithm are explained on http:/
3.2.4 MODIS Vegetation Index (VI) Product

The MODIS instrument is operating on the Terra and Aqua spacecraft. It has a swath width of 2330 km with 36 spectral bands. MODIS, standard VI products include the Normalize Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI) to effectively characterize bio-physical/biochemical states and processes from vegetated surfaces. There exists a complete, global time series record of 6 VI products from each of the Terra and Aqua MODIS sensors, at varying spatial (250m, 1km, 0.05 degree) and temporal (16-day, monthly) resolutions to meet the needs of the research and application communities. The VI products are validated with accuracies depicted by a pixel reliability flag and with globally averaged uncertainties of 0.015 units (http://modis.gsfc.nasa.gov/data/dataprod/dataproducts.php?MOD_NUMBER=13).

The MODIS Terra/Aqua 16 days Vegetation Index (VI) product (http://LPDAAC.usgs.gov) was used in the analysis. The layers used from the vegetation index product were the Normalized Differenced Vegetation Index (NDVI), quality assurance flag for NDVI, reflectance of near infrared (858 nm) and shortwave infrared (2130 nm). These products were computed from atmospherically corrected bi-directional surface reflectance that have been masked for water, cloud, heavy aerosols and cloud shadows (http://tbrs.arizona.edu/project/MODIS/userguide-doc.php). The data were processed through appropriate image processing software to derive the NDVI and the reflectance of near infrared and shortwave infrared. Using equation (3), NDWI\(_{2130}\) was derived from the near and shortwave infrared reflectance. Using the quality assurance flag layer, the cloud contaminated pixels were identified and excluded. During the first two months of the season the cropped area would have
low NDVI/NDWI value due to lesser vegetative cover, but if a district had considerable area under forest, the district average NDVI/NDWI value tends to be high. To remove this noise the non agricultural area including the forest and uncultivable land in each district of the state was masked by using the Land use/Land cover layer generated by the National Remote Sensing Centre (NRSC) under the programme titled “Natural Resources Census (NRC)”. The NRC envisages generating spatial information on (i) Land use / land cover (ii) Land degradation (iii) Soils (iv) Geomorphology (v) snow cover or glaciers (vi) wetland and (vii) vegetation cover at 1:50000 scale using high resolution satellite data.

3.3 Theoretical overview of the Soil Water Balance Model

A simple book-keeping, bucket-type, water tight model based on law of conservation of mass is used in this study. The basic assumptions of the model are i) The effective rainfall on any day is redistributed instantaneously and uniformly over the root zone, ii) The abstraction from the soil is also uniform through the entire root zone, iii) The runoff, deep percolation and evapotranspiration are sinks, iv) Since we are considering the early stage of the cropping season no interception losses are considered, v) Agriculture lands are prepared and ready for sowing before the start of the season and vi) Only the un-irrigated rainfed agricultural areas are considered.

Figure 2 presents the overview of the soil water balance model. Since the objective is to derive the area conducive for sowing focusing on the early stage of the crop, the soil profile was divided into two layers. The top layer is the initial active root zone with a depth of 30 cm while the bottom layer 90 cm thick is called the passive root zone. This model considers the initial root depth of 30 cm throughout the season to capture the soil water scenario for crops sown and germinating during any part of the cropping season. The soil water balance in the upper layer is governed by daily values of rainfall, runoff, evapotranspiration (ET) and drainage to the second
layer. When the upper layer saturates in excess of Field Capacity (FC) due to rainfall, the excess water percolates to the lower passive root zone and is instantaneously redistributed in that zone. The excess soil water in the passive root zone moves out as deep percolation. Since the upper 30 cm is considered for the soil water assessment, the lower limit of soil water is the residual water content of the soil as the upper layer is exposed to the atmosphere and subjected to upward flux due to the direct solar radiation. The components of a generic hydrological model include rainfall, irrigation, runoff, infiltration, evapotranspiration, percolation and deep percolation. Each of the components is described hereunder.

![Figure 2: Overview of the Soil Water Balance Model](image)

Figure 2: Overview of the Soil Water Balance Model
3.3.1 Rainfall

Rainfall is the most important input driver for any hydrological model. This study used the daily near real time TRMM 3B42RT spatial rainfall product which gives accumulated daily rainfall at a spatial resolution of 0.25° x 0.25°. This data is available from the http://disc2.nascom.nasa.gov/Giovanni/tovas/realtime.3B42RT_daily.shtml web link and more details about the data are also given here. The ASCII data which was downloaded from the web location, imported using commercial GIS software and rainfall surface was created with a spatial resolution of 1 km x 1 km.

3.3.2 Potential Evapotranspiration

Accurate and reliable evapotranspiration (ET) datasets are crucial in regional water and energy balance studies. The daily global potential evapotranspiration data was downloaded from http://earlywarning.usgs.gov/fews/global/web/dwnglobalpet.php web page. This daily global Potential Evapotranspiration (PET) is calculated from climate parameter data that is extracted from Global Data Assimilation System (GDAS) analysis fields. The GDAS data are generated every 6 hours and then summed up to obtain daily totals by the National Oceanic and Atmospheric Administration (NOAA). The GDAS fields used as input to the PET calculation include air temperature, atmospheric pressure, wind speed, relative humidity, and solar radiation (long wave, short wave, outgoing and incoming). The daily PET is calculated on a spatial basis using the Penman-Monteith equation (the formulation of Shuttleworth (1992) for reference crop evaporation is used). These equations were standardized in accordance with the FAO publication 56 for the 6-hourly calculations (Allen et al, 1998). The data was downloaded and imported through appropriate software and sub-sampled to 1 km x 1 km resolution. Since this study deals with the early crop stages of sowing, germination and establishment, the initial stage crop coefficient
(K_c) was adopted using the dual K_c approach proposed by Allen et al. which is defined by

\[ \text{ET}_c = (K_{cb} + K_e) \text{ET}_o \]  

(9)

Where K_{cb} - basal crop coefficient (0.15) and K_e – is the soil evaporative coefficient. The K_e varies from 0.15 to 1.00 depending on the antecedent soil moisture condition. If the soil is dry K_e takes the lower value towards 0.15 and if the soil is wet it takes the higher value towards 1.00.

### 3.3.3 Runoff

Daily runoff (Q, mm) was estimated from spatial rainfall data using the USDA Soil Conservation Service (SCS, 1985) Curve Number (CN) technique with appropriate modification for Indian conditions based on Ministry of Agriculture (1972) & Sahu (1990) with respect to soil type. The soil information was derived from the 1:1 million scale NBSS&LUP soil map which has three textural classes namely sandy, loamy and clayey. The parameters like the FC and the Permanent Wilting Point (PWP) were derived for each textural class using the Saxton et. al. soil triangle.

The values of the CN vary with Antecedent Moisture Conditions (AMC). AMCI, AMCII, and AMCIII, correspond to dry, average, and wet catchment conditions respectively. These conditions are identified empirically based on the cumulative rainfall of the 5 preceding days. If this rainfall is < 36.6 mm, then AMCI applies; if it is more than 53.3 mm, AMCIII applies; and if it is in between, AMCII applies. For soil regions of India except for the black soil region with AMCII and AMCIII condition, the runoff is given by:
\[ Q = \frac{(R - 0.3S)^2}{(R + 0.7S)}, \text{ if } R > 0.3S \] \hspace{1cm} (10)

\[ Q = 0, \text{ if } R \leq 0.3S \]

and for black soil region with AMCII and AMCIII conditions

\[ Q = \frac{(R - 0.1S)^2}{(R + 0.9S)}, \text{ if } R > 0.1S \] \hspace{1cm} (11)

\[ Q = 0, \text{ if } R \leq 0.1S \]

Where

\[ S = 254\left(\frac{100}{CN} - 1\right) \] \hspace{1cm} (12)

The values of the CN for average AMC (CN for AMCII or CN = CN2) are tabulated for various soil, land use, and management conditions by the Ministry of Agriculture (1972). The corresponding values of CN for dry CN1 and wet CN3 catchment conditions are given by:

\[ CN1 = CN2 - \left\{20(100 - CN2)/[100 - CN2 + \exp(2.533 - 0.0636(100 - CN2))]\right\} \] \hspace{1cm} (13)

and

\[ CN3 = CN2 \exp[0.00673(100 - CN2)] \] \hspace{1cm} (14)

However, in real situations, the AMC value is not restricted to the three discrete conditions identified empirically for the cumulative rainfall but can vary over a continuous range, and the value of \( S \) can be directly related to the soil moisture content in the active layer by the equations of Sharpley and Williams (1990).

In real situations, the AMC value is not restricted to the three discrete conditions identified empirically for the cumulative rainfall but can vary over a
continuous range, and the value of $S$ can be directly related to the soil moisture content in the active layer by the equations of Sharpley and Williams (1990):

$$S = S1\{1 - \frac{FFC}{[FFC + \exp(w1 - w2 \times FFC)]}\}$$  \hspace{1cm} (15)

Where, $S1$ is the value of $S$ associated with CN1 ($S2$ for CN2 and $S3$ for CN3), $FFC$ is the fraction of FC and $w1$ and $w2$ are called the shape parameters. The value of $FFC$ is given by:

$$FFC = \frac{(MC1 - PWP)}{(FC - PWP)}$$  \hspace{1cm} (16)

The shape parameter area defined as

$$w1 = \ln\left[\frac{1.0}{1 - \frac{S3}{S1}} - 1.0\right] + w2$$  \hspace{1cm} (17)

$$w2 = 2\left[\ln\left[\frac{0.5}{1 - \frac{S2}{S1}} - 0.5\right] \ln\left[\frac{1.0}{1 - \frac{S3}{S1}} - 1.0\right]\right]$$  \hspace{1cm} (18)

The average condition CN (CN2) was decided on the basis of hydrologic soil group and land use pattern. The CN1 and CN3 were calculated from equation (13) & (14) respectively. Corresponding $S1$, $S2$ and $S3$ values were calculated from equation (12) using the CN1, CN2 and CN3 values. The shape parameters $w1$ and $w2$ were calculated using (17) and (18). The retention parameter $S$ was calculated from equation (15) using the fraction of FC (equation 16) value, which depended on soil type and $w1$ and $w2$ values. Daily runoff was calculated using $S$ and daily rainfall data from equation (10).

### 3.3.4 Top Layer Soil Moisture ($\theta_{1i}$)

The top soil layer considered is 30 cm thick which is the initial stage root depth for most of the crop. The soil moisture in the top layer of the soil is very critical in the sowing, germination and establishment of the crop. The top layer soil moisture is derived at the end of each day using the daily soil water balance equation (19) for this layer given by
\[ \theta_{i} = (\theta_{i-1} \times RD_{i-1} - R_{i} - Q_{i} - P_{i} - ET_{i}) / RD_{i} \]  
for \( i = 1, 2, \ldots, N \),

Where

\( \theta_{i} \) - Top layer soil moisture (m³/ m³)

\( RD \) - the root depth (mm) during the initial stage (300 mm)

\( R \) - rainfall (mm)

\( Q \) - runoff (mm)

\( P_{i} \) - percolation out of the top layer (mm)

\( ET \) - evapotranspiration (mm/day)

\( N \) - the number of days in the crop season

### 3.3.5 Percolation (\( P_{i} \))

Percolation is the amount of water that leaves the upper soil layer and enters the bottom passive root zone. Percolation is given by

\[ P_{i} = R_{i} - Q_{i} - (FC - \theta_{i-1}) RD_{i-1} \]  
(20)

If \( P_{i} < 0 \), then \( P_{i} = 0 \) For the passive root zone

### 3.3.6 Passive Layer Soil Moisture (\( \theta_{2i} \))

It is the soil moisture that is present in the bottom layer of the passive root zone which is 90 cm in this study. The bottom layer soil moisture is derived by:

if \( P_{i} = 0 \)

\[ \theta_{2i} = \theta_{2i-1} \]  
(21)

Otherwise,

\[ \theta_{2i} = \theta_{2i-1} + P_{i} / (RDM - RD_{i}) - DP_{i} \]  
(22)

Where RDM is the maximum root depth (mm) and DP is the drainage out of the passive root zone layer (bottom layer) as deep percolation.
3.3.7 Deep Percolation (DP\textsubscript{i})

Deep percolation is the amount of water that leaves the bottom soil layer and enters the soil beyond the root zone. Deep percolation is given by

\[ DP_{i} = P_{i} - (FC - \theta_{2_{i-1}}) (RDM - RD_{i}) \]  

If \( DP_{i} < 0 \) then \( DP_{i} = 0 \)

Where RDM is maximum root depth (mm) and DP is the drainage out of the passive root zone layer (bottom layer) as deep percolation.

The SWB model was developed using the Spatial Modeler module of the ERDAS Imagine software. The model was run on a daily time step basis giving daily spatial inputs of rainfall and PET.

3.4 Area Conducive for Sowing (ACS)

Farmers of the dry land region depend on the rainfall for cultivating their land. In these regions, rainfall is the life saver commanding all agricultural operations. In the states of Andhra Pradesh and Tamil Nadu the onset of south west monsoon (June-September) during the \textit{kharif} and north east monsoon (October-December) during the rabi season is very crucial for the success of the crop. The first soaking rain creates conducive environment for sowing of the seed for the crop. There are instances where the monsoon had commenced on time but the first soaking rain which helps sowing would occur several weeks later. The sowing of seed happened close to the surface of the soil which is subject to rapid fluctuation of soil moisture around the seed, especially during the warmer \textit{kharif} period. Under this circumstance it is crucial to know when the top layer of the soil gets enough soil moisture which renders the land conducive for sowing. Different types of crop require various degrees of soil moisture for germination. It is generally known that there is maximum germination if the soil moisture is anywhere between 50% to 80% of the FC. This study considers 60% of FC as the germinating soil moisture. Hence any region with soil moisture above 60% of FC for a continuous period of 7 days
was considered as conducive for sowing. The soil moisture is continuously monitored for this condition from June with a moving window of 7 days to find out the area conducive for sowing. In order to derive the ACS of agricultural area, the forest and the non agricultural area were masked using the Land Use Land Cover (LULC) map generated at National Remote Sensing Centre (NRSC), Hyderabad.