Drought Assessment of Nagarjuna Sagar Command Area using Geospatial tools

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In

Spatial Information Technology

By

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CERTIFICATE

This is to certify that the dissertation entitled "**Drought Assessment of Nagarjuna Sagar Command Area using Geospatial tools"** submitted by **Mr. PITTAMUDUSULA LINGAIAH** to Jawaharlal Nehru Technological University, Hyderabad for the award of the degree of Master of Technology (M. Tech) is a record of bona fide research work carried out by him under my supervision and guidance. **Mr. PITTAMUDUSULA LINGAIAH** has worked on this topic for about ten months and the dissertation, in our opinion, is worthy of consideration for the award of Master of Technology in accordance with the regulations of the institute. The results embodied in this thesis have not been submitted to any other university or Institute for the award of any Degree or Diploma.

Signature of supervisor,

Mr. J. VENKATESH

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This is to certify that the dissertation entitled **“Drought Assessment of Nagarjuna Sagar Command Area using Geospatial tools”** Submitted by **Mr. Pittamudusula Lingaiah** in partial fulfillment of the requirement of the Master’s Degree in **Spatial Information Technology** of **Center for Spatial Information and Technology (CSIT)** department is bonafide work and may be placed before the examination board for their consideration.

Head of the Department

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DECLARATION

I, **Pittamudusula Lingaiah** bearing HT.No. **03031D3206** hereby declare that the project work entitled "**Drought Assessment of Nagarjuna Sagar Command Area using Geospatial tools"** is an authenticated work carried out by me at ICRISAT under the guidance of **Mr. J. VENKATESH (Assoc. Professor, CSIT, JNTUH)** for the fulfillment of the requirement for the award of the degree of **Master of Technology in Spatial Information Technology.**

Date:

Place: HYDERABAD **Pittamudusula Lingaiah**

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ABSTRACT

The Krishna River Basin is frequently affected basin to drought due to climate change. Nagarjuna Sagar is one of the most important dams under Krishna river basin. Water imbalance and failure of monsoon are the major reasons for Drought.

The main aim of the present study is to prepare a land use/land cover (LULC) maps for study years including irrigated areas and assessment of drought in the command area of Nagarjuna Sagar Project. LULC maps are prepared using continuous time series of MODIS data. The drought methodology was developed with coarse resolution data set like MODIS 250m time series and other secondary data.

Remote sensing-based assessments of a perennial Krishna river basin, which flow through many states in India helps in understanding the effect of abiotic stress like drought. MODIS time series products can be used to understand cropland changes at the basin level due to abiotic stresses, especially water scarcity.

The identification of land use/land cover (LULC) areas for two crop years, 2013-14 (a normal year) and 2015-16 (a drought year) using Spectral matching technique. Based on the NDVI and intensity of damage, Drought affected crop areas were categorized into three classes -- severe, moderate and mild. Ground survey data were collected to find the accuracy of spatial products. Water inflows and outflows from the Krishna basin i.e. Nagarjuna Sagar dam during the study period shows the water level in the Krishna Basin during the drought year. The spatial distribution of individual years with nine LULC classes shows the overall accuracies of 79% for the year 2013-14 and 85% for the year 2015-16 and Kappa values for 2013-14 and 2015-16 are 0.78 and 0.82 respectively. The cropland classified areas obtained from MODIS data were compared with national statistics for the year 2013-14 with a R^2 value of 0.87. Results indicates that changes in irrigated areas in 2015-16 compared to 2013-14 shows the impact on food security.

Key words: Nagarjuna Sagar; Water stress; drought; Remote sensing; ground survey data; spatial and statistics data; NDVI

Chapter – 1

INTRODUCTION

1.1 Remote Sensing- Definition

Remote sensing refers to making observation about an object or feature or phenomenon without coming in physical contact with it.

Remote sensing is 'the measurement or acquisition of some property of an object or phenomenon, by recording device that is not in physical or intimate contact with the object or phenomenon under study'

Scope of Remote Sensing

Remote sensing involves the collection of data or making measurements on the object/feature, analyzing/ interpreting and deriving information about it.

In practice, remote sensing encompasses a host of activities right from development of sensor, making spectral measurements of the earth's surface, atmosphere, and extra-terrestrial planets, interpretation/analysis of such measurements, deriving information about them, and its dissemination to the concern users.

In the event of any requirement with respect to decision on the planning or implementation of the management of earth's natural resources like minerals/, soils, water resources, etc. integration of information on natural resources in a Geographical Information System (GIS) and modelling tools are required.

1.2 Advantages and Limitations of Remote Sensing

Advantages

Remote sensing is unobtrusive, if the sensor is passively recording the electromagnetic energy reflected from or emitted by the phenomenon of interest. Consequently, the passive remote sensing does not disturb the object or area of interest.

Under carefully controlled conditions, remote sensing can provide fundamental biophysical data, including x, y, location, z elevation or depth, biomass, temperature, moisture content, etc. In this sense, it is much like surveying, providing fundamental data that other sciences can use when conducting scientific investigations. However, unlike much of surveying, the remotely sensed data may be obtained systematically over very large geographical areas rather than single point observation.

Unlike other mapping sciences such as cartography or GIS which rely on data produced elsewhere, remote sensing yields fundamental scientific information. Remote sensing-derived information is now critical to the successful modelling of numerous natural (e.g. water supply estimation, eutrophication; non-point source pollution); and cultural processes (e.g. Land-use conversion at urban fringe, water demand estimation, population estimation). A good example is DEM which is so important in many spatially distributed models.

Limitations

Remote sensing science has limitations. It simply provides some spatial, spectral, and temporal information of value. Its utility is often oversold. Human beings select the most appropriate sensors to collect the data, specify resolution of the data, calibrate the sensor, select the platform to carry the sensor, determine when data will be collected, and specify how the data are processed. Thus human-produced errors may be introduced as the various remote sensing instrument and mission parameters are specified.

Active remote sensor systems, such as laser or radar that emit their own electromagnetic radiation, can be intrusive and affect the phenomenon being investigated. Lastly, remote sensing instruments like n situ instrument may be expensive to collect and interpret or analyse.

1.3 Role of Remote Sensing in monitoring Agriculture

In developing countries like India, the Crop statistics plays a vital role in understanding the crop production and food security. This comes into role because India is a country where majority of the food security depends on monsoon rainfall. It is very difficult to estimate the crop production, types of crop and crop acreage by field surveys and it will take lot of time and human effort. In this case, Monitoring agriculture using remote sensing is best alternate to estimate acreage under the crop, crop yield per unit area and also crop condition assessment. Now a days, the free availability of satellite data helps in large scale of research in agriculture sector.

The forecasting of crop production using remote sensing increases and spread all over the world. Acreage estimation using RS data has been verified in different parts of the world and also number of studies and research have been carried on remote sensing for crop acreage estimation in India Work carried out so far in India has demonstrated that even with single-date satellite data. It is possible to estimate pre-harvest acreages of major crops, particularly in single crop dominated regions, with sufficient accuracy. Many carried various studies on land use statistics through integrated modelling using GIS, integrated approach for estimation of crop acreage using remote sensing data and GIS, field survey for hilly region and spectral data used visual interpretation technique.

Crop yield estimation surveys based on several experiments estimated the accurate average yield for all major crops. Various yield models were developed by different researches like yields and weather, soil or biometrical characters, spectral reflectance and the crop yield. Several studies also measured parameters like vegetation vigour and some agronomic quantities such as leaf area index, wet or dry biomass or grain yield. Several vegetation indices were developed for the identification of different parameters.

The real time forecast of crop production helps in economic system and the development in remote sensing technology had an immense potential to improve the existing pre-harvest forecasting models.

1.4 Crop condition assessment

Monitoring of Crop condition in the early stage is essential for crop monitoring and crop yield prediction as well as the status and trend of their growth. Monitoring the crop condition at early stages of crop growth is very important in acquiring the exact production after harvest time. The real time statistics shows the great influence on the policymaking on the price, circulation and storage.

The field survey statistics are often expensive, with some errors, and cannot provide real-time, and also delay in forecasting of crop condition. Remote sensing based satellites will provide temporally and spatially continuous information of crop. Many studies helps in improving the methodology in finding crop rotation, cropping area or crop phenology, cropped/fallow land which is integrated to increase the accuracy of crop condition monitoring. International organizations like USDA of U.S. and VI of EU, as well as FAO, all have their own remote sensing based crop monitoring systems.

1.5 Drought Definitions

The drought has no precise definition. Diversified hydro-meteorological variables, socio-economic factors and different water demands in different regions have kept researchers away from compiling/modifying any precise definition of drought. The definition of drought which is good enough for one field does not help its implementation in another field. However, some broad definitions are sited below:

(i) The World Meteorological Organization (WMO, 1986) describes "drought means a sustained, extended deficiency in precipitation."

(ii) The UN Convention to Combat Drought and Desertification (UN Secretariat General, 1994) defines "drought means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems."

(iii) The Food and Agriculture Organization (FAO, 1983) of the United Nations defines a drought as a hazard, "the percentage of years when crops fail from the lack of moisture."

(iv) The encyclopedia of climate and weather (Schneider, 1996) defines a drought as „an extended period – a season, a year, or several years – of deficient rainfall relative to the statistical multi- year mean for a region."

However, its definition varies according to the causes and transaction phases for which it occurs and the fields which it effects. Hence, the definitions of drought can be organized into the categories generally known as type of droughts.

Types of Drought

The droughts are broadly classified in three categories. They are Meteorological drought, Hydrological drought and Agricultural drought. Any one of these categories or combinations of these could generate a fourth category of drought called as Socio economic drought.

Meteorological Drought

The occurrence of any category of drought is considered to be started with the deficiency in precipitation. The Meteorological droughts are based on deficits in precipitation Whenever the actual rainfall over a region is less than 75% of the long term climatological mean, the resulting drought is known as Meteorological drought. This category is estimated as a region specific matter because the occurrence of precipitation highly varies from region to region.

Hydrological Drought

The occurrence of Hydrological drought is noticeable from the available water in the surface water resources due to reduced precipitation events or quantity. Hydrological droughts are often lagged compared to Meteorological droughts. Hydrological drought occurs when there is marked depletion of surface water causing very low stream flow and drying of lakes, reservoirs, rivers etc.

Agricultural Drought

The deficiency of water from either meteorological or hydrological sources lessens the irrigation water for crop production. This water is supposed to be stored in soil as soil moisture which is ultimately affected as well. As a result, scarce soil moisture leads to Agricultural drought occurrence due to serious crop stress and affects the crop productivity. Hence, Agricultural drought refers to a period with declining soil moisture content and consequent crop failure (Gumma et al., 2019a).

Socio-Economic Drought

Socio-economic drought is associated with failure of water resources systems to meet water demands and thus associating droughts with supply of and demand for an economic good (water) (AMS, 2004). It occurs when the demand for an economic good passes ahead of its supply due to weather related deficit in water supply. It can result from either of the three categories discussed above or their combined effects for an extended term.

1.6 Impact of Drought

Drought is one of the costliest disasters as compared to other natural disasters. It has a negative impact on various sectors of the society (e.g., economy, energy, recreation, agriculture, water resources, ecosystems and human health). Some of the major dire effects of drought are discussed below.

Impact on Economy

The impact of drought on sectors like agriculture, forestry and fisheries, can blow on economy of the country. These sectors have their basic requirements dependent on the surface and ground water supplies. The occurrence of a drought event can become the basis for the losses in yields in crop and livestock production. As a result, the GDP of a country finally reduces and hence the economy also.

Impact on Environment

The impact of drought to environment is seen as damages to flora and fauna including different species, wildlife habitat, forests; degradation of landscape quality, loss of biodiversity, and soil erosion. Normal conditions are reestablished in case of short-term effects. But when these effects linger for long term, the damages may even become permanent. For example, increased soil erosion due to degradation of landscape quality, may result into an everlasting loss of biological productivity.

Impact on Society

The social impact of drought is due its length of persistency and extremity. The shortage of crop production resulting in suicides of farmers is a common nuisance around India. It can also cause loss of human lives due to food shortages, which can create panic and violence in the society as well. Water user conflicts are common during extreme drought, which are mostly political, social and industrial in nature. Social unrest can cause public dissatisfaction with government regarding drought response. The most common concern in developing countries like India is drought directly or indirectly hits to poverty.

Drought scenario - India

Indian economy mainly depends upon the agriculture as nearly 70 % of its population depends directly or indirectly on agriculture based occupation. About two thirds of the land receives uneven distribution rainfall and also less rainfall (less than 1000mm). Drought is frequent phenomenon over many parts of India, out of net sown area nearly 65 percent of the land are vulnerable to drought. Even after post-independence, about one thirds of irrigated area got affected by droughts. Every year, there is some area in India which affected by drought. In India, it is necessary to achieve 350 million metric tons of food production to meet its food security.

Drought Scenario - Globally

All the developing countries are very much depending on the agriculture related business. These countries are almost drought prone. In most of the tropical countries, severe drought occurs for every five years. It depicts that fifty percent of worlds total population are affected by drought and nearly 33 percent of land under desertification.

For proper planning and efficient utilization of the land, it is necessary to understand the crop period, necessary types of crops to be cultivated in the suitable areas. As the technology is improving in the field of agriculture it became easy for off and on farm activities. Use of mathematical models for extracting the crop characteristics using Remote sensing and Geographical Information System (GIS) with high speed computers is aiding tools and techniques for it.

In this study, we demonstrated how satellite imagery can be displayed, processed and analyzed using digital techniques in a popular digital image processing software programme Erdas Imagine and GIS software ArcGIS. The classification of data is analyzed using advanced methods like spectral matching techniques, Google Earth are ideal for quantifying associated land use changes, and are useful for decision makers.

Chapter -2

OBJECTIVES OF THE STUDY

The main objectives of the research are to

1. Deriving a methodology for the drought assessment:

   A methodology was designed for the assessment of drought.

2. Identification of Irrigated areas for the years 2013-14, 2015-16 using MODIS 250 m resolution data:

   Mapping Spatial distribution for normal year and water- deficit year using MODIS 250m resolution

3. Observing the changes of agriculture land use for the study years

   Identifying the drought affected areas by comparing normal and drought year spatial distribution

4. Accuracy Assessment and Comparison with National statistics available
5. Assessment of drought areas

   The intensity of the drought was identified spatially considering different parameters into three categories mainly mild, moderate and severe drought

Chapter – 3

STUDY AREA

Nagarjuna Sagar (NJS) Project (16°34′24″ N, 79°18′47″ E) is the world's largest masonry dam built across Krishna River in Nagarjuna Sagar, Nalgonda District of erstwhile Andhra Pradesh, India, between 1955 and 1967. The dam contains the Nagarjuna Sagar reservoir with a capacity of up to 11,472 million cubic meters with 150 m tall and 1.6 km long with 26 gates which are 13 m wide and 14 m tall. Nagarjuna Sagar was the earliest in the series of large infrastructure projects initiated for the Green Revolution in India and also one of the earliest multi-purpose projects in India called as 'modern temples'. The dam provides irrigation water to the Nalgonda District, Prakasam District, Khammam District and Guntur District and also generates hydroelectric power of 815.6 MW and contributes to the national grid. The right canal is 203 km long and irrigates 1.113 million acres (4,500 km^2) of land. The left canal is 295 km long and irrigates 0.32 million acres (800 km^2) of land.

Nagarjuna Sagar started to supply water (33 Mm^3) to Hyderabad, Capital city of Telangana which is expected to increase to 370 Mm^3 by 2030. This expected demand of Hyderabad is equivalent to 4% of the water allocated to the Nagarjuna Sagar irrigation project. Releases from Nagarjuna Sagar are made in the following priority: Hyderabad water supply, Krishna Delta and Nagarjuna Sagar canals. The command area is divided in to five sub regions based on the districts in which they fall.

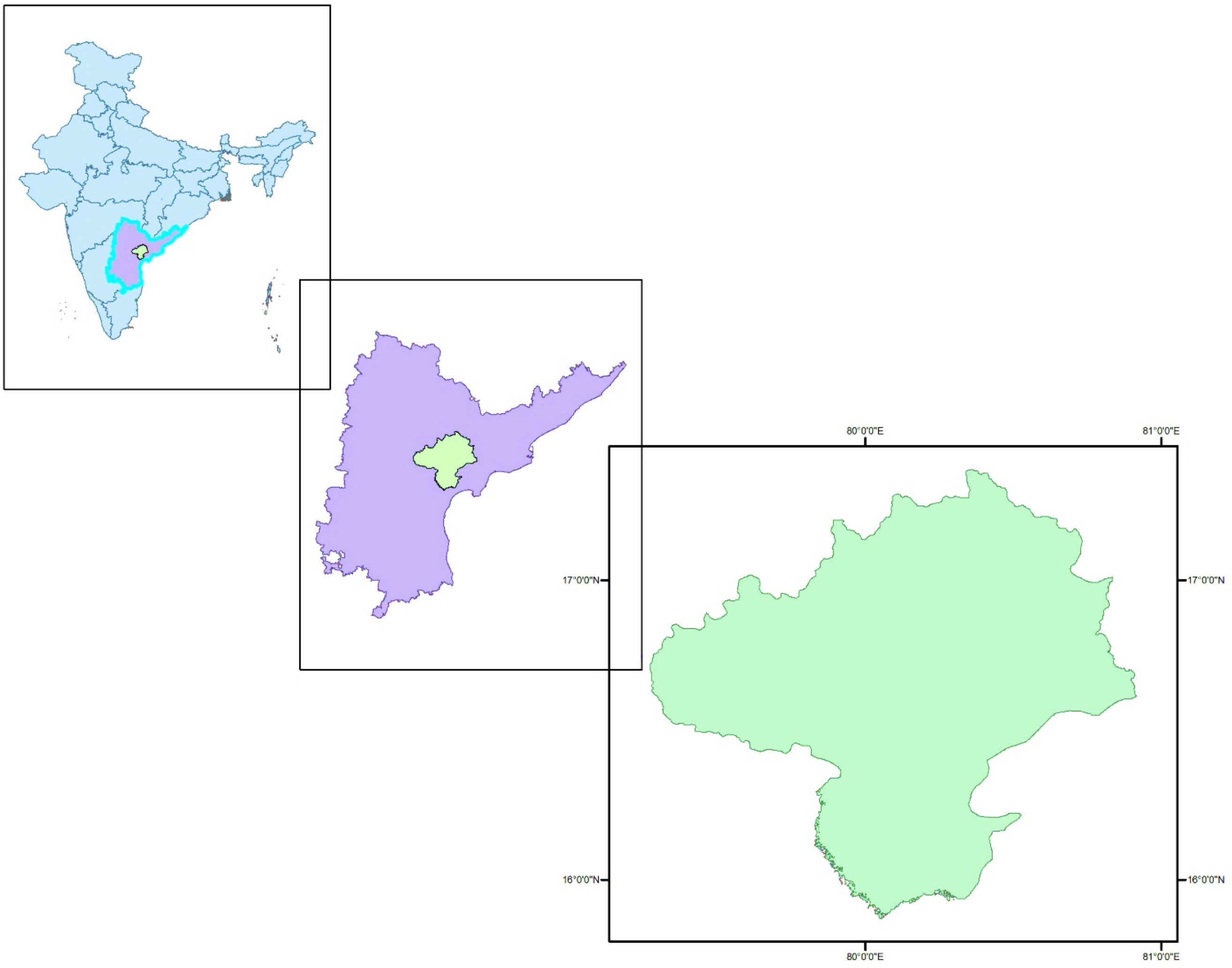

Figure 3.1. Location map of the Nagarjuna Sagar (NS) command area in southern India.

3.1 Physiography

The erstwhile Nalgonda district is in the Southern part of the Telangana Region lies in 16°25' and 17°50' of the Northern Latitude and 78°40' and 80°05' of Eastern longitude covering an area of 14,240 Sq. Kms. The District is bounded by Medak and Warangal districts in the North, Guntur of Andhra Pradesh and Mahbubnagar districts in the South, Khammam and Krishna district of Andhra Pradesh in the East and Mahbubnagar and Rangareddy district in the West.

3.2 Climate and Temperature

The region has a hot and dry summer throughout the year except during the South West monsoon season. A year may broadly classify into four seasons mainly cold season from December to mid-February, summer season from mid-February to first week of June, South West monsoon season from June to September and the past monsoon season during October to November. Cold season extending from December to February is followed by summer when both day and night temperatures increase sharply. May month is the hottest month with mean daily maximum temperature of about 40^o C and minimum is about 28^o C. December is the coldest month with the mean daily maximum and minimum temperature is 35^o C and 20^o C respectively.

3.3 Rainfall

The average rainfall in this region is about 772 mm in which 71% of the annual rainfall is received during south west monsoon (i.e. June to September). The variation in the annual rainfall in the district from year to year is large. On an average there are 46 rainy days per year.

3.4 Drainage

The Nagarjuna Sagar is drained by river Krishna with its tributaries mainly Musi, Aler, Dindi etc. Musi river, a tributary of the Krishna is next in importance in this region. The Aler river flows in Bhongir taluk before joining the Musi river.

3.5 Soils

The soils in around the study reservoir are mostly loamy sands, sandy loams and sandy clay loams. In the areas of flat topography and alongside the river Krishna and most of its tributaries comprises mainly of black cotton soil.

3.6 Forest

The reservoir region contains dry mixed deciduous forest with characteristic species commonly are Anogeissus Latifolia (Chirumanu), Chloroxylon swieknia (Billudu) and Harduickia binata (Eppa). Southern Tropical Thorn Forest also most common type found in Nalgonda district with thin density and absence of a canopy. It occupies very poor and rocks soils subject to over grazing and over exploitation.

3.7 Agriculture

Agriculture is the main occupation for 70% of the population and the land under cultivation is nearly 50% of the geographical area. The major crops in the district are Paddy, Jowar, Cotton, Bajra, Maize, Greengram, Redgram and oil crops like Sesamum, Groundnut and Castor.

Chapter -4

DATASETS AND MATERIALS

4.1 MODIS 250m

The 16-day composite images in the MOD13Q1 dataset are available in the public domain and are pre-calibrated (http://modis-sr.1tdri.org/html) and also contains surface reflectance for each band at ground level with no atmospheric scattering or absorption. MODIS data are acquired in 12-bit (0 to 4096 levels) directly from satellites, and then later it is stretched to 16-bit (0 to 65,536 levels). Before processing the datasets, it will go through the Cloud removal approaches and the preparation of mega data files using MODIS Re-Projection Tool(MRT).

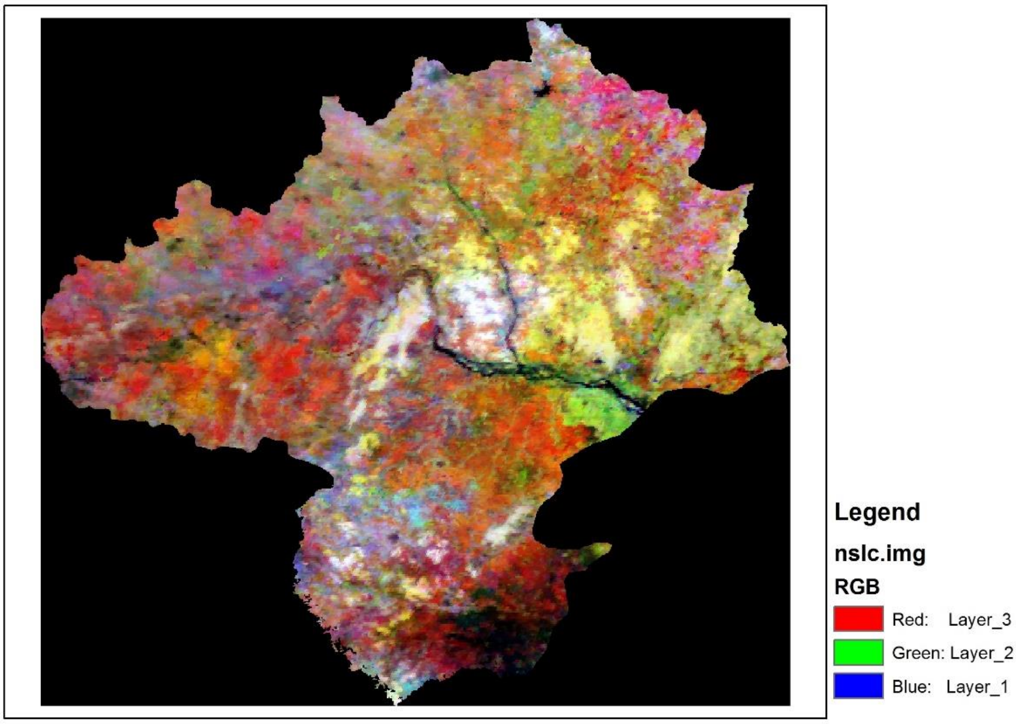

Fig 4.1: MODIS 250m monthly Maximum Value Composite (MVC)

Table 4.1. MODIS 250m with usage and Band Width

Primary Use	Band	Bandwidth(nm)
Land/Cloud/Aerosols Boundaries	1	620 – 670
	2	841 – 876

4.1.1 Cloud removal algorithm

The location of Nagarjuna Sagar (16°34′24″ N, 79°18′47″ E) is located on Tropical Convergence Zone where most of the region is under monsoons and high change in vegetation cover during the monsoon season in which cloud cover is also maximal. In order to obtain cloud free time-series images we have downloaded only which: (a) obtain all images with < 5% cloud cover and (b) passing through cloud-masking algorithm. Out of the 46 images only 14 images with 25-40% cloud cover. It is required to get cloud free areas to get maximum temporal coverage and monitoring. To achieve this, the images obtained are required to pass through the Cloud removal algorithm.

4.1.2 Minimum reflectivity threshold for cloud removal

In the cloud removal algorithm, the MODIS bands (b1 and b2) in which the one with maximum cloud cover is removed using minimum reflectivity threshold. If the reflectance value in b1 is greater than or equal to 18 or null value, then the values in b1 are replaced with a zero value else b1 value remained as it is.

4.1.3 Preparation of Mega data sets

The continuous time-series analysis of MODIS data requires the preparation of mega data sets using multiple bands using ERDAS ER Mapper software. In which, the 16-day NDVI images were stacked into a 23-band file for each crop year (two images per month) and followed by the monthly maximum value composites were created using 16-day NDVI MODIS data to minimize cloud effects. The single mega-files help in preparing and analysis of monthly MVC NDVI with 12 monthly images per year.

4.2 Secondary Data Sets

4.2.1 Ground truth datasets

Ground survey data was collected for class identification and labelling and the remaining 81 points were used to assess accuracy. Using pre-classified output, Google Earth imagery, GPS tracking attached to the image processing software and also random points from images for ground survey data. The required information was collected during ground data for points which are used for class identification and labelling. The required information includes land use categories, land cover percentages, cropping pattern during different seasons (through farmer interviews), crop types, and watering method (irrigated, rainfed). Samples were obtained within large contiguous areas of a particular LULC because of 250 X 250 m size. Available Landsat 8 products were also used as additional ground survey information in identification of LULC class. The ground truth form contains parameters like

1. GT Point no, Country, province, District
2. Coordinates (Using GPS), date
3. Crop calendar
4. Crop intensity
5. Topographic position

6. Land use land cover parameters: (% cover): trees, shrubs, grasses, barren land/soil, rock, water, built-up, farmland, and others.

7. Crop parameters

8. General description (land use land cover at particular location)

9. Soil condition (soil moisture, soil type and soil erosion)

10. Cropping pattern (Previous/present including season wise)

11. Crop growth / crop health

12. Agriculture technique (Rainfed, Irrigated, and etc.)

13. Irrigation techniques \ watering methods like

- Shallow tube well irrigated areas during dry season
- Surface irrigated areas (canal/river)
- Combined dug well and dug out irrigated areas during dry season

Other data is non remote sensing data which is collected during field visit helps in remote sensing analysis including class identification, labelling (ex: source of irrigation, crop information and etc.) for accuracy assessment.

1. Plot name:
1.1 Latitude:
1.2 Longitude:
1.3 Easting:
1.4 Northing:
1.5 UTM Zone:
2.Elevation (meters):
2.1Plot Size:
2.2Date of collected sample: (MM/DD/YY)
2.3Classified class (original):
2.4Digital Photo Name:

3. *Land Cover type* *Percent cover (%)*
3.1 Tree ☐
3.2 Shrubs ☐
3.3 Grass ☐
3.4 Built up ☐
3.5 Water ☐
3.6 Fallow land ☐
3.7 Weeds ☐
3.8 Wheat ☐
3.9 Rice ☐
3.10 Cotton ☐
3.11 Water vegetation ☐
3.12 Rock ☐
3.13 Snow ☐
3.14 Sand ☐
3.15 Other :
3.15.1
3.15.1.2
3.15.1.3
3.15.1.4

4. *Topographic position*
4.1 Upland ☐
4.2 non-hydromorphic valley fringe ☐
4.3 hydromorphic valley fringe ☐
4.4 valley bottom ☐

5. *LULC type Level I* *Percent cover (%)*
5.1 Cropland ☐
5.2 Forests ☐
5.3 Wetlands ☐
5.4 Rangelands ☐
5.5 Barren lands ☐
5.6 Snow or ice ☐
5.7 Settlements ☐
5.8 Water ☐
5.9 Roads ☐
5.10 Desert lands ☐
5.11 Other:
5.11.1.
5.11.2
5.11.3.
5.11.4
Notes:
Level I LULC class name and description:

6. *LULC type Level II* *cover (%)*
6.1 Crop
6.11 -irrigated ☐
6.12 -rain fed ☐
6.13 -supplemental ☐
6.14 -other
6.2 Forest
6.21 -deciduous ☐
6.22 -evergreen ☐
6.23 -mixed ☐
6.24 -other
6.3 Wetland
6.31 -forested ☐
6.32 -nonforested ☐
6.33 -other
6.4 Rangeland
6.41 -herbaceous ☐
6.42 -shrub and brush ☐
6.43 -mixed ☐
6.44 -other
6.5 Barren land
6.51 -dry salt flats ☐
6.52 -sand ☐
6.53 -beaches ☐
6.54 -exposed rock ☐
6.55 -other
6.6 Snow or ice
6.61-Glacier ☐
6.62 -perennial snow ☐
6.63 -other
6.7 Natural vegetation
6.71 -long grass ☐
6.72 -short grass ☐
6.73 -other
6.8 Urban ☐
6.81 Water
6.82 -rivers ☐
6.83 -canals ☐
6.84 -lakes/reservoirs ☐
6.85 -ocean ☐
6.9 Other:
6.91 Proposed class:
Level II LULC class name and description

7. *Level III* *Cover (%)*
7.1 Irrigated
7.11 -ground water /crop 1 ☐
7.12 -ground water /crop 2 ☐
7.13 -ground water /crop 3 ☐
7.14 -ground water /crop 4 ☐
7.21 -surface irrigated/crop 1 ☐
7.22 -surface irrigated/crop 2 ☐
7.23 -surface irrigated/crop 3 ☐
7.24 -surface irrigated/crop 4 ☐
7.3 Rain fed
7.31 -crop 1 ☐
7.32 -crop 2 ☐
7.33 -crop 3 ☐
7.34 -crop 4 ☐
7.4 Supplemental
7.41 -crop 1 ☐
7.42 -crop 2 ☐
7.43 -crop 3 ☐
7.44 -crop 4 ☐
Notes:
Level III LULC class name and description

Fig 4.2: Ground truth form used during the field visit to record databased on physical observation and farmer interviews.

v

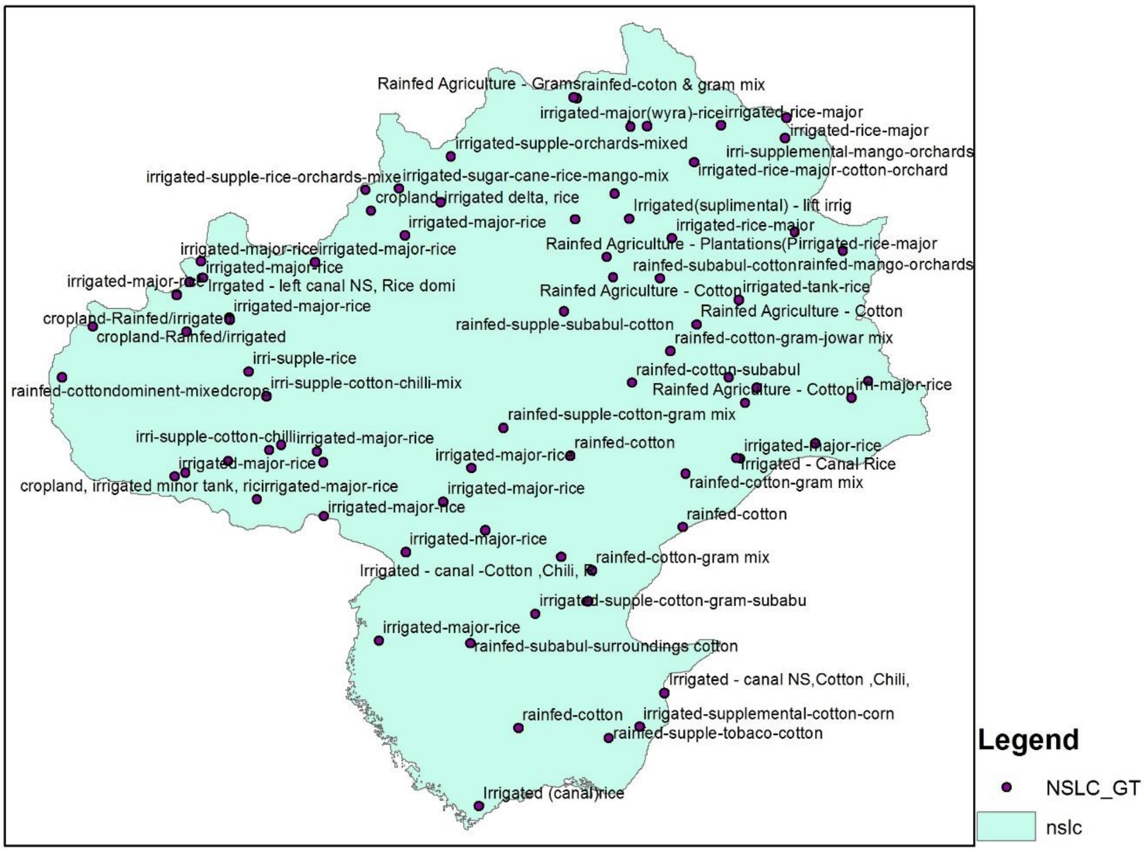

Figure 4.3. Ground survey locations in the Krishna River Basin

4.2.2 National Statistics & Secondary Data

The Statistics related to cultivated area, production, crops and other related data for the study years were collected from the India-stat(DIP, 2015). Using tropical rainfall measuring mission (TRMM), daily rainfall data was processed as monthly mean rainfall data to compare with 11 years (from 2005 to 2016). Due to missing of official statistics for drought-affected areas, the rainfall data was not used to identify drought areas but as an accumulation of evidence of water stress occurrence.

Chapter – 5

METHODOLOGY

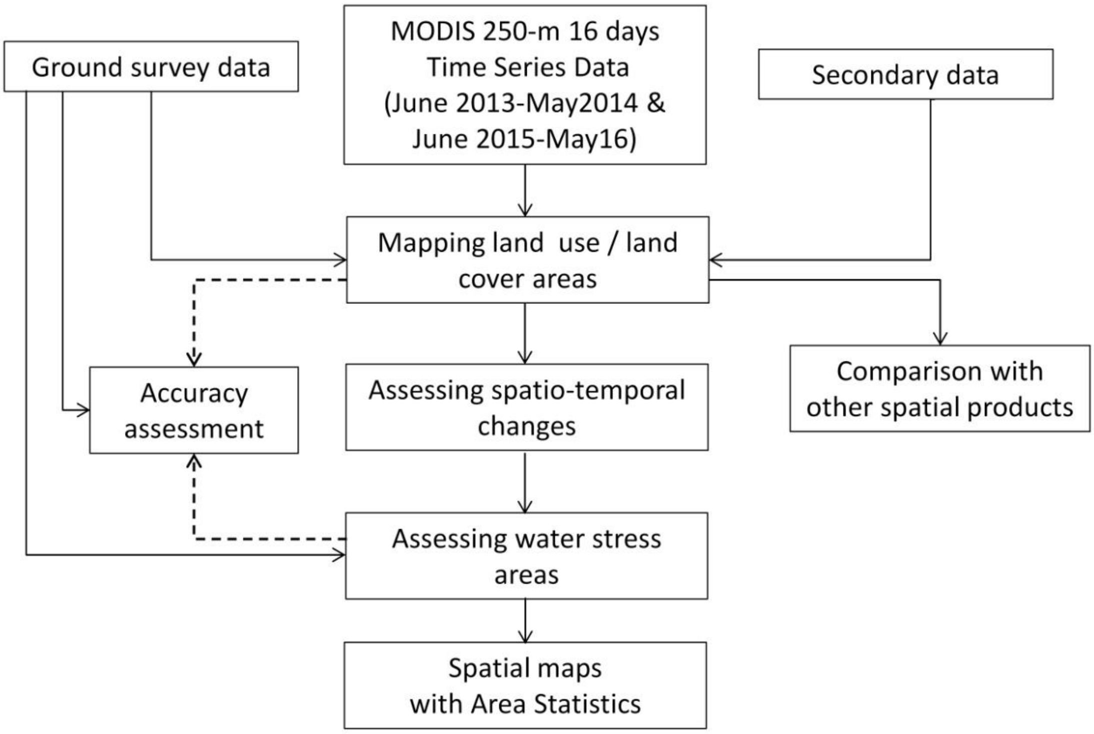

Figure 5.1. Methodology-flow chart of the study

5.1 MODIS data pre-processing

5.1.1 Blue band minimum reflectivity threshold for clouds

India is one of the south Asian country which is subjected to the influences of the oscillating subtropical convergence zone leads to flood mainly in monsoon season i.e. June to September. During this monsoon season of the year, we will observe the significant change in vegetation cover, dynamics of vegetation, and biomass accumulation. Due to high cloud coverage in monsoon season, it is difficult to retain the required number of pixels in the time-series.

In order to rectify the problem of cloud cover up to some extent, the following approach was adopted(Thenkabail *et al.*, 2005): (a) retain all the images with <5 percent cloud cover (b) apply a cloud-masking algorithm to the eliminate areas with cloud cover and retain the rest of the image in an unchanged form(Thenkabail *et al.*, 2005; Gumma *et al.*, 2011a; Gumma *et al.*, 2019b). The cloud-masking algorithm runs with a threshold value of 18% (1800 when MODIS pixel values are scale to a 0-10000 range) for band 3 and set to make all other bands to null if this is exceeded. A detailed description of cloud removal algorithms for MODIS, available with(Thenkabail *et al.*, 2005; Gumma *et al.*, 2011a).

5.1.2 NDVI and monthly maximum value composite (MVC)

A normalized difference vegetation index (NDVI) was created using surface reflectance values of red and NIR bands (equation 1). For every month, two 16-day composites were available. A total of 23 16-day composites for every crop year, forms Monthly maximum value composites (MVCs) by combining two 16-day composites for every month from June 2013 through May 2014 and 2015-16 were created in order to minimize cloud effects during the monsoon season in equation 2. The created monthly MVCs were stacked into a 12-band mega-file data cube (MFDC).

$$NDVI = \frac{\lambda_{NIR} - \lambda_{red}}{\lambda_{NIR} + \lambda_{red}} \qquad (1)$$

$$NDVI_{MVC_i} = Max(NDVI_{i1}, NDVI_{i2}, NDVI_{i3}, NDVI_{i4}) \qquad (2)$$

Where, MVC_i is the monthly maximum value composite of the i^{th} month.

i_1, i_2, i_3, and i_4 are every 8 days' data in a month.

5.1.3 Mega-file data cube composition

The combination of many bands of data of a study area into a single file after cloud removal referred to as mega-file data cube. These mega datacube has no limitation for size or dimension of a mega-file.

5.1.4 Unsupervised classification

Unsupervised classification (et al Cihlar et al. 1998) was used to classify the image. The unsupervised ISOCLASS cluster algorithm (ISODATA in ERDAS Imagine 2014™) run on the NDVIMVC file with an inputs of initial 40 classes with a maximum of 40 iterations and convergence threshold of 0.99. Using unsupervised classification, depending upon the inputs, it will classify the nearly homogenous NDVI values as classes. It is recommended to use unsupervised techniques for large areas with unknown range of vegetation types, and identification of homogeneous sites (Cihlar, 2000; Biggs *et al.*, 2006; Gumma *et al.*, 2011c). It is very difficult to Identify training sites for small, heterogeneous irrigated areas.

5.1.5 Creation of ideal spectra

Ground data is required to create Ideal spectral signatures for LULC classes. The precise locations of the ground data were recorded by a Garmin GPS unit. Ideal spectra names are assigned based on a) major types of crops b) the dominant crop and c) type of irrigation with their individual spatial distribution. For generating ideal spectra, we used 52 locations for 2013-14 image and 63 locations for 2015-16 image to cover major irrigated classes. Ideal spectra were created for every known land use using ground data.

Even though the ideal spectra differ from one location to location because of the duration of the crop, variety of the seed, the eco-systems and other factors. Due to same ideal spectra, the possibility of matching arises. Even though, there is difference in magnitude with in irrigated and rainfed based crops. The field-plot data shows the crop dominance (mixed crops occupying smaller fractions of the area) than any single crop. In such cases, ideal spectral signatures for crop dominance were generated in irrigated and rainfed conditions. The approach involves the selection of classes with similar cropping patterns by characterizing their ideal spectral and grouped based on similarity in their spectral signatures.

5.1.6 Generation of class spectra

Using unsupervised ISOCLASS k-means classification using the MODIS NDVI MVC 250m MFDC i.e. the 12 layer NDVI stack is classified using unsupervised classification with 40 classes initially. The obtained signature file obtained is used to plot the signature of each LULC class over time shows the profile of vegetative intensity and this will help in identification of the LULC classes.

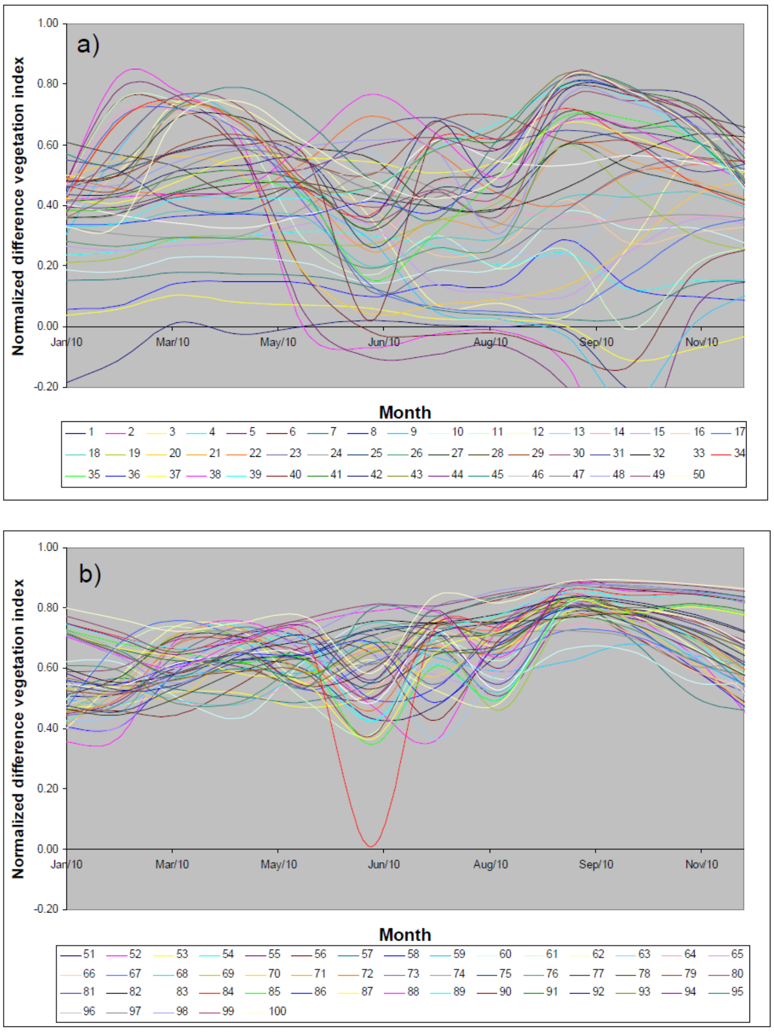

Figure 5.2: Class spectral signatures of unsupervised classes derived using MODIS 250m mega-file data-cube (MFDC)

The crop growth along with cropping calendar was derived from these time series curves as explained by Thenkabail et al. (2005) to identify the classes with similar spectral graphs throughout the cropping year. Same procedure was used to identify the entire class and labelling the classes.

5.2 Mapping of Land Use and Land Cover

5.2.1 Class Identification and Labelling Process

Class identification and labelling is a step-by-step process which is based on NDVI temporal signatures with the help of ground survey data. The observation of crop growth stages and cropping pattern from temporal signatures mainly

(a) Start of cropping season (e.g., monsoon and winter)

(b) Length of cropping season

(c) Magnitude of crops during different seasons (e.g., water stress and normal years)

(d) End of cropping season

Using spectral matching techniques, (Gumma *et al.*, 2014; Gumma *et al.*, 2016), the obtained class spectra graph was compared with ideal spectra bank and identifying the class with same patterns. If the similar NDVI time series and pattern was observed, then they combined into a single class. if there is mixing of different land cover, then the class is clipped out and reclassified using the same ISOCLASS algorithm. Landsat imagery and ground survey data through spatial modeling techniques such as overlay matrix, recode and proximity analysis. After the classification, the respective classes were merged and labelled into nine required classes.

In the present study, MODIS 250 m spatial resolution was used for classification where average land holding size is less than a pixel and there is a possibility of different LULC classes in one class with 250 m × 250 m pixel (6.25 ha). Full pixel areas are not an accurate representation, in order to increase the accuracy of the classification, cropland fraction was calculated using the methodology in which Sub-pixel areas are separate from other LULC classes (e.g., grasses, trees, shrubs, etc.).

5.2.2 Ground Survey data

Ground truth data required information contains the cropland fraction and irrigated area fractions which helps in sub-pixel area (King *et al.*) calculations, ideal spectra creation and also in accuracy assessment of identified classes.

5.2.3 Spectral matching techniques

Spectral signature matching techniques are mainly developed for hyperspectral data analysis of minerals and later same principle was also applied for identification of LULC classes from MODIS time-series satellite imagery.

Spectral signature matching (van Ittersum *et al.*) techniques group the similar classes by comparing with the ideal spectral data bank for class identification and labelling process.

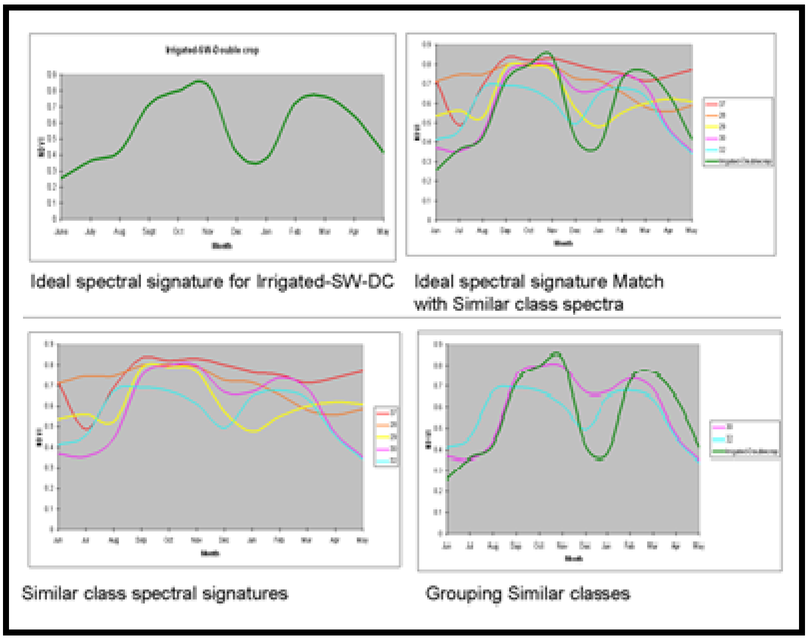

Figure 5.3: Class spectral signatures matching with ideal spectral signatures for grouping and identifying the class.

5.2.4 Google Earth data

Google Earth verification is used for class identification and labeling because of its high resolution imagery (http://earth.google.com/) with spatial resolution of 0.61-4 m helps the user to look into required areas from a base of 30 m resolution data to sub-meter resolution for free and easy access through the Web. Using google earth, the visual interpretation of class is possible by considering shape, size, pattern, and texture. Google earth data was also used for class identification and verification because it helps in identification of the LULC where it is difficult to know during field visits. It does not have an accurate information, but the zoom-in views of high-resolution imagery helps in identifying the rice bunds, irrigation and vegetation conditions. But analyzing the previous year's data with the current study year shows the supportive results. From the year 2000, the Google earth data shows the high resolution imagery from one to three years old. In this study, Google Earth data were used to identify and label the classes and deriving irrigated area fractions that helped in sub-pixel area (King *et al.*) calculations and accuracy assessment of irrigated area classes and verifying the classified image by overlaying in Google earth.

5.2.5 Actual or sub-pixel area calculations

The composite MODIS pixels cover an area of (250 X 250 m) i.e. nearly 6.25 hectares, which is larger than average land holding in the study area. In this case, many pixels contain more than one land cover class i.e. mixed classes. The accurate identification of the crop can be obtained only by computing SPAs (Thenkabail *et al.*, 2005; Thenkabail *et al.*, 2009; Gumma *et al.*, 2011b), as

$$SPA_n = FPA_n \times CAF_n$$

where, SPA_n is the sub-pixel area of class n,

FPA_n is the FPA of class n

CAF_n is the crop area fraction of class n as derived from the field-plot observation data.

The RAF's of individual class were calculated based on a large sample size of points which are spatially well distributed in such class. The RAFs were observed by considering the combination of ground data and very high resolution i.e Google earth data(less than 5 m) data. The SPA of each class is calculated by multiplying the FPA of such class with the CAF of class. Later, the SPAs of all classes are combined to obtain the actual areas from all the classes.

5.3 Accuracies and errors

Ground survey points which were collected during the study years are used to assess the accuracy of the classification results. The accuracy assessment was carried out using standard procedure includes generation of an error matrix and accuracy measures for each LULC map. Error matrices and Equation (1)'Cohen'skappa coefficient (κ)'are commonly used for accuracy assessment and helpful in building models during prediction of discrete classes. κcan be used as a measure of agreement between model predictions and reality which is computed as:

$$\kappa = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}$$

where, *N* is the total number of sites in the matrix,

r is the number of rows in the matrix,

x_{ii} is the number in row I and column i,

x_{+i} is the total for row i, and x_{i+} is the total for column i

5.4 Water Stress Mapping and Categorization

Water stress was measured based on NDVI signatures and field survey data. The areas are classified into three categories based on intensity/crop condition.

1. Severe water stress areas - no crop throughout the cropping season due to water shortage.

2. Moderate stress areas - a fraction of the plot was used to grow rice or partial damage had occurred

3. Mild water stress areas - a fraction of the plot was used to grow and the rest was left fallow

The Farmers' responses which were obtained during ground survey were used along with the NDVI signatures to identify ideal spectral signatures (temporal signatures) for water stress and non-water stress areas. During the ground survey, it was observed that the year 2015–2016 was one of the severe water stress year and large agricultural areas including irrigated command areas were left fallows.

Chapter – 6

RESULTS AND DISCUSSIONS

This section deals with results obtained from classification of LULC areas including major croplands, changes in irrigated area, water stress areas and accuracy assessment based on ground survey data and a comparison of irrigated areas from the present study and national statistics.

6.1 LULC Classification of the Krishna River Basin at 250m using MODIS.

6.1.1 Spatial Distribution of LULC

The spatial distribution and identification of LULC was performed using the 16-day time series NDVI stack and the spectral signatures (temporal signatures) generated from for sampled locations and class signatures obtained using spectral matching techniques . Image is classified into nine LULC classes for the normal year (2013–2014) and water-deficit years (2015–2016).The identification of Classes were based on spectral matching techniques along with ground survey data and field observations.

The cropland areas in the Nagarjuna Sagar command area for 2013–2014 and 2015-16 are shown in Table 6.1. The full pixel area of rainfed croplands were 8930 ha shows the rainfed croplands mixed with other land cover areas i.e. the actual rainfed agriculture area was 7520 ha, and remaining was mixed with other LULC classes. The total amount of irrigated area was about 110 thousand ha which includes groundwater, tank irrigation, and major canal irrigation during 2013–2014. Water bodies was about 266.7 thousand hectares.

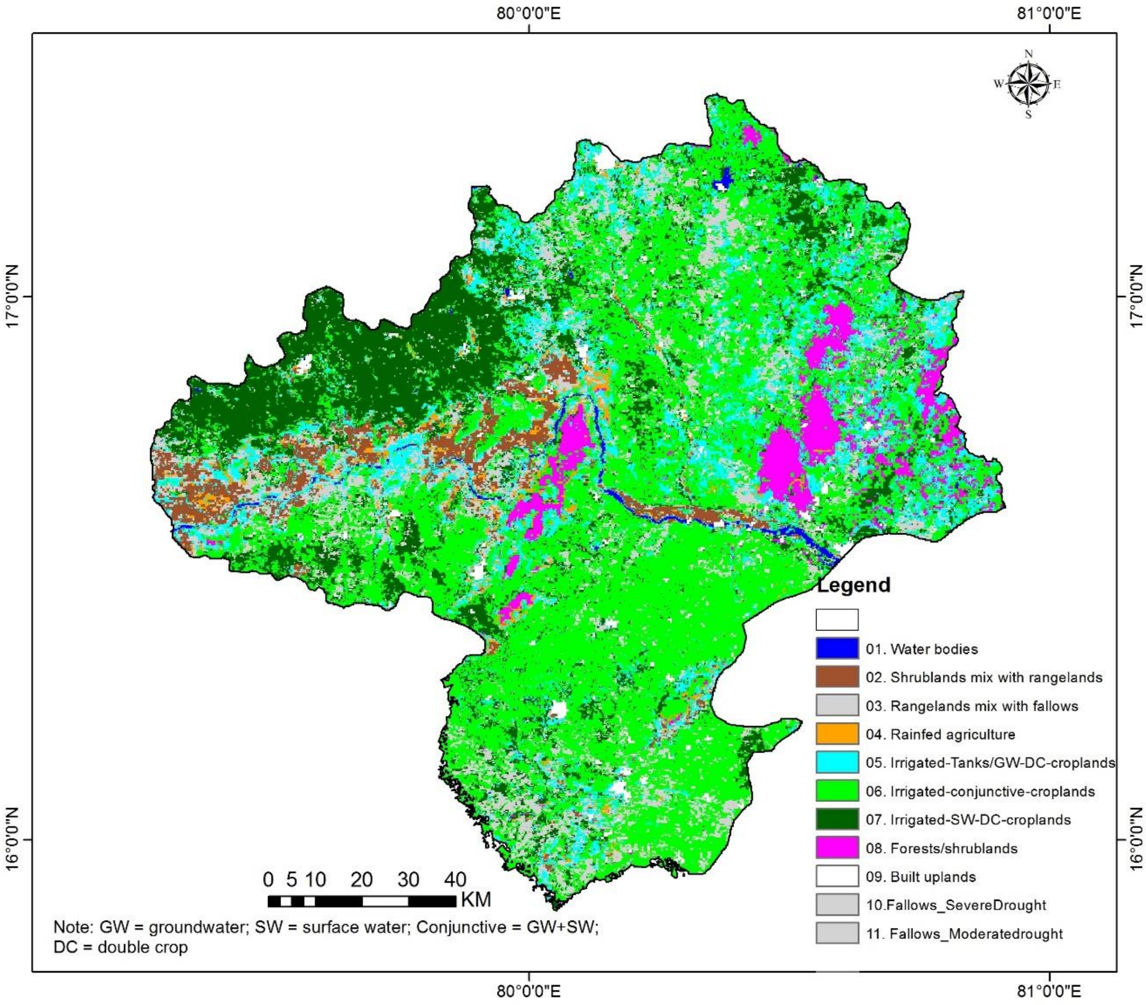

Figure 6.1. Spatial distribution of land use/land cover (LULC) (derived from 2013–2014 MODIS composite).(Note: GW = groundwater; SW = surface water; DC = double crop)

Table 6.1. Irrigated, rainfed, and other LULC areas.

	Full Pixel Area (FPA) (000′ha)		Crop Area Fraction (%)		Actual Cropland Area (000′ha)	
	2013–2014	**2015–2016**	**2013–2014**	**2015–2016**	**2013–2014**	**2015–2016**
01. Rainfed croplands	8.93	8.88	84.20	70.50	7.52	6.26
02.Irrigated-Tanks/GW-DC-croplands	56.67	54.71	86.50	76.30	49.02	44.03
03. Irrigated-conjunctive-croplands	25.26	25.11	89.20	83.60	22.53	20.99
04. Irrigated-SW-DC-croplands	28.71	28.22	92.60	86.10	26.58	24.30
05. Rangelands mixed with fallows	183.32	165.33	21.50	12.50	39.41	20.67
06.Shrublands mixed with rangelands	644.50	516.26	8.50	9.10	54.78	46.98
07. Water bodies	266.70	161.42	-	-	266.70	161.42
08. Forests/shrublands	66.95	66.38	-	-	66.95	66.38
09. Built-up areas	23.25	22.41	-	-	23.25	22.41

Note: GW = groundwater; SW = surface water; DC = double crop.

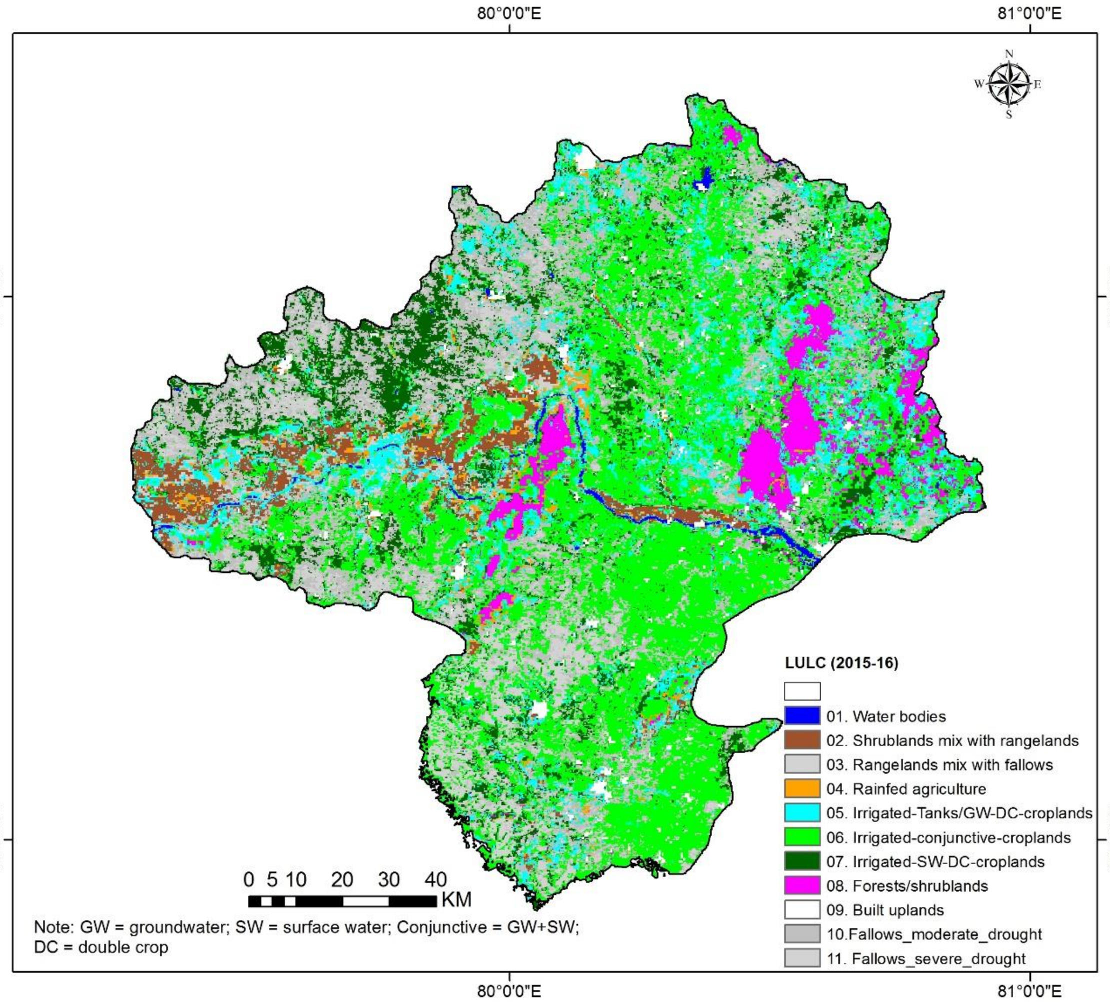

Figure 6.2. Spatial distribution of LULC (derived from 2015–2016 MODIS composite).

The spatial distribution of LULC in the Krishna River Basin for 2015–2016 is shown in Figure 6.2 and areas shown in Table 6.1. Altogether nine classes were identified in which four were croplands and five were other LULC. Rainfed croplands covered 8800 ha and the total irrigated area was 108 thousand ha, which included groundwater irrigated, tank irrigated and major canal irrigated areas during 2015–2016. Water bodies was about 161.4 thousand hectares.

6.1.2 Water Scarcity and Crop stress

During the water stress year (2015–2016) land uses decreased from 111 thousand ha in a normal year (2013–2014) to 108 thousand ha. These arises mainly due to water scarcity in reducing cropping intensity and conversion of crop lands to fallow. Rainfed croplands in the Nagarjuna Sagar were reduced during water stress year, and also significant reduction in the irrigated croplands. There was also decrease in water bodies from 266 thousand hectares to 167 thousand hectares during water stress year.

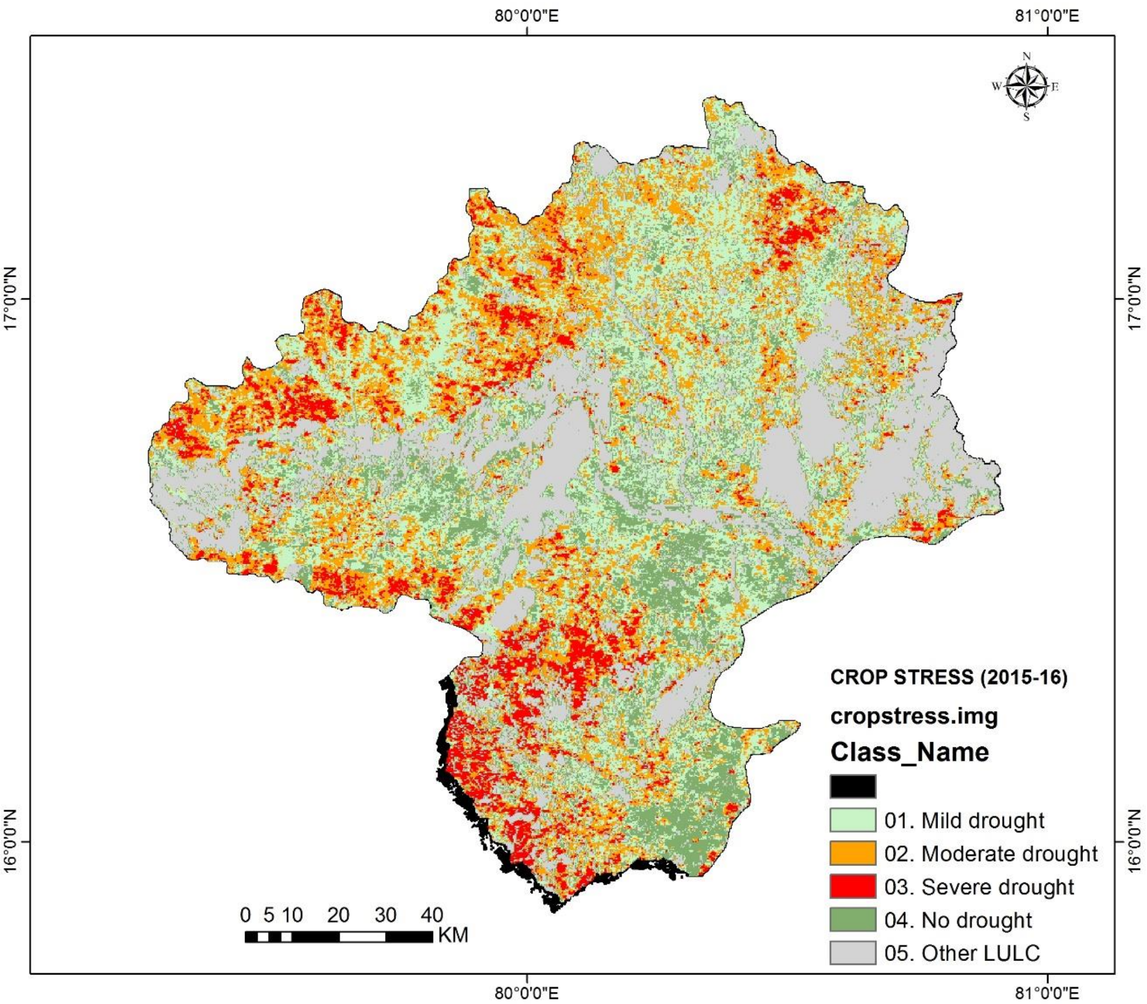

Figure 6.3. Spatial distribution of water stress during 2015–2016 (derived from 2015–2016 MODIS composite).

Table 6.2. MODIS-derived water stress areas across the Nagarjuna Sagar Command area. The table shows full-pixel area (FPA), crop area fraction (CAF), and sub-pixel area (King *et al.*) or actual area. SPA = FPA × CAF.

Water Stress Class	Full Pixel Area (FPA) (000′ha)	Cropland Fraction (%)	Actual Cropland Area (000′ha)
01. Mild water stress	73.732	81.1	59.79665
02. Moderate water stress	58.593	78.1	45.76113
03. Severe water stress	21.723	88.1	19.13796
04. No water stress	47.499	84.7	40.23165
Total water stress area	-	-	164.9274

The above shows the amount of area under water stress. It was observed about 120 thousand hectares of land was under water stress in which mild stress was 56 thousand, moderate was 45 thousand and about 20 thousand hectares under severe stress.

An unexpected decline in food production due to drought affected market leads to high costs and also food insecurity. These arises due to change in climate scenario and growing water efficient crops during a water deficit year. Water scarcity is a frequent reality faced by farmers in the semi-arid tropics, even in the basin command areas which leads to a chain of events affecting crop production, cropping pattern changes and eventually reduced in incomes to farmers. To sustain food security, one should adopt new adaptation strategies such as the use of climate smart varieties and water related management practices along with advanced mechanisms to remunerate the crops during such times.

6.2 Accuracy Assesment and Comparison with Other Published Data Sets

A quantitative accuracy assessment is to examine whether a known LULC was identified as the same LULC or not using error matrix. The ground survey data was collected during the kharif season for the crop years 2013–2014 and 2014–2015 throughout the Nagarjuna Sagar command area. Classification accuracy was performed on two classified products (LULC maps of 2013–2014 and 2015–2016) using 81 points that were not used in the classification.

Tables 6.3 and 6.4 show the error matrices of each classified product of year 2013-14 and 2015-16. In LULC 2013–2014, the overall accuracy assessment was about 79 % i.e. about 64 points were correctly plotted against 81 points. The accuracy for the year 2015–2016 with 81 sample points, of which 69 matched correctly with the present classification with an overall accuracy of 85%.

Table 6.2: Accuracy Assessment for the Classification year 2013-14

	01. Rainfed croplands	02.Irrigated-Tanks/GW-DC-croplands	03. Irrigated-conjunctive-croplands	04. Irrigated-SW-DC-croplands	05. Rangelands mixed with fallows	06.Shrublands mixed with rangelands	07. Water bodies	08. Forests/shrublands	09. Built-up areas	10. Other LULC	**Reference Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
01. Rainfed croplands	3	0	0	0	0	0	0	0	0	0	3	3	100%	100%
02.Irrigated-Tanks/GW-DC-croplands	0	5	0	0	0	0	0	0	0	0	5	5	100%	100%
03. Irrigated-conjunctive-croplands	0	0	2	0	0	0	1	0	0	0	2	2	100%	67%
04. Irrigated-SW-DC-croplands	0	0	0	6	1	0	2	0	0	0	7	6	86%	67%
05. Rangelands mixed with fallows	0	0	0	1	4	1	1	0	0	0	6	4	67%	57%
06.Shrublands mixed with rangelands	0	0	0	0	1	11	0	1	0	0	13	11	85%	85%
07. Water bodies	0	0	0	0	0	1	17	0	1	1	25	17	68%	85%
08. Forests/shrublands	0	0	0	0	0	0	2	7	0	1	8	7	88%	70%
09. Built-up areas	0	0	0	0	0	0	1	0	3	0	4	3	75%	75%
10. Other LULC	0	0	0	0	0	0	1	0	0	6	8	6	75%	86%
Column Total	3	5	2	7	6	13	25	8	4	8	81	64		

Table 6.2 :Accuracy Assessment for the Classification year 2015-16

	01. Rainfed croplands	02.Irrigated-Tanks/GW-DC-croplands	03. Irrigated-conjunctive-croplands	04. Irrigated-SW-DC-croplands	05. Rangelands mixed with fallows	06.Shrublands mixed with rangelands	07. Water bodies	08. Forests/shrublands	09. Built-up areas	10. Other LULC	**Reference Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
01. Rainfed croplands	3	0	0	0	0	0	0	0	0	0	3	3	100%	100%
02.Irrigated-Tanks/GW-DC-croplands	0	5	0	0	0	0	0	0	0	0	5	5	100%	100%
03. Irrigated-conjunctive-croplands	0	0	2	0	0	0	1	0	0	0	2	2	100%	67%
04. Irrigated-SW-DC-croplands	0	0	0	6	1	0	2	0	0	0	7	6	86%	67%
05. Rangelands mixed with fallows	0	0	0	1	4	1	1	0	0	0	6	5	84%	57%
06.Shrublands mixed with rangelands	0	0	0	0	1	11	1	1	0	0	13	12	85%	85%
07. Water bodies	0	0	0	0	0	1	17	0	1	1	25	18	72%	85%
08. Forests/shrublands	0	0	0	0	0	0	2	7	0	1	8	7	88%	70%
09. Built-up areas	0	0	0	0	0	0	1	0	3	0	4	3	75%	75%
10. Other LULC	0	0	0	0	0	0	0	0	0	8	8	8	100%	100%
Column Total	3	5	2	7	6	13	25	8	4	8	81	69		

The district-wise statistics collected from the Directorate of Economics and Statistics (DES), Andhra Pradesh and Telangana were compared with the final MODIS-derived cropland areas statistics of the Nagarjuna Sagar command area. This data contains district-wise area covered in the Nagarjuna Sagar command area to study the comparison with the MODIS derived data. The majority of the district level statistics from DES matched with the MODIS derived statistics varies between −35% and+35% and R^2 value was 0.8686.

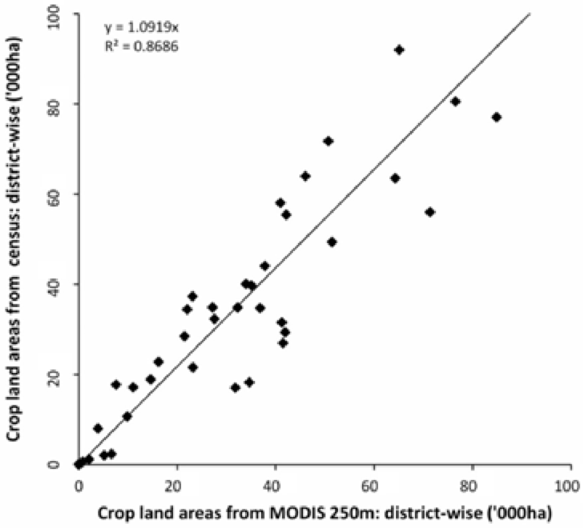

Figure 6.4: A comparison of district-wise cropland area from the MODIS classification and national statistics

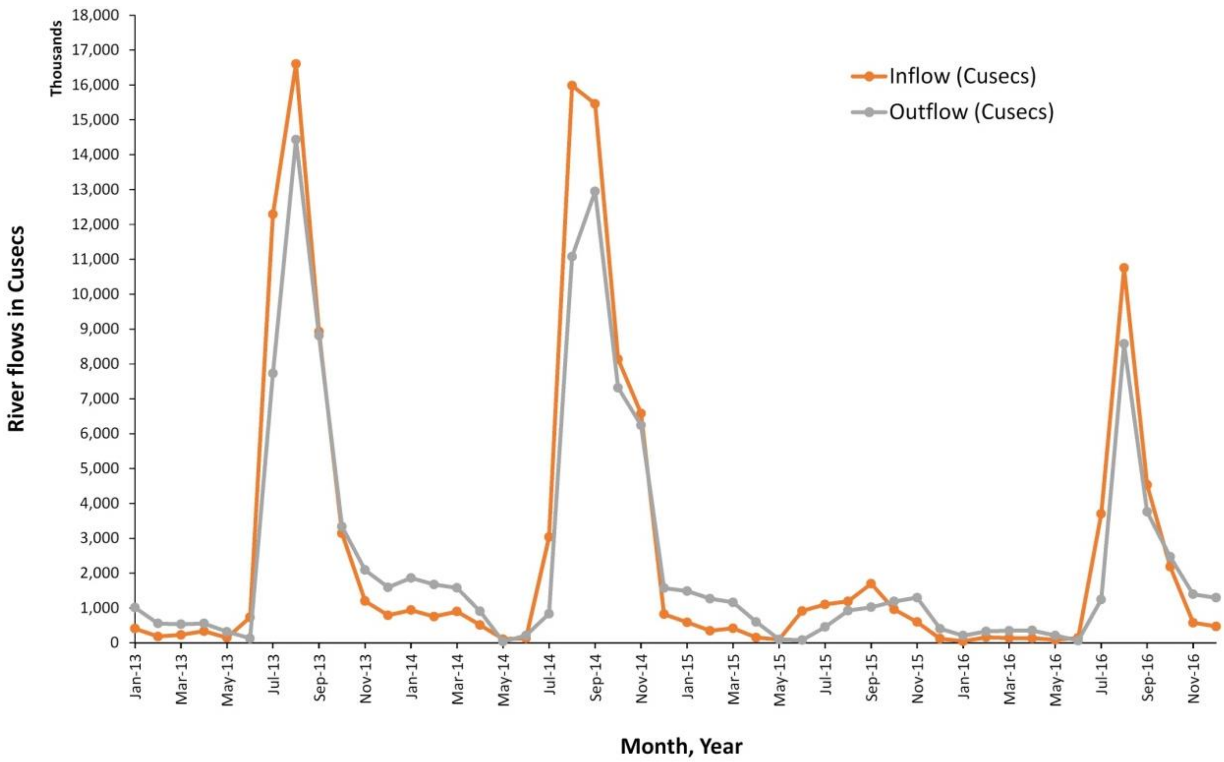

Figure 6.5: Inflows into and outflows from the Krishna Basin between 2013 and 2016

6.3 Discussion

This study identified the changes in irrigated areas including other cropland areas and also drought assessment in a Nagarjuna Sagar command area due to water scarcity. A baseline irrigated area map of the study area was produced for 2013–2014 with an estimation of cropland area. Using thefield-plot information and sub-national statistics obtained from the Ministry of Agriculture, accuracy assessment was done by correlating the MODIS-derived land use/land cover areas. MODIS imagery plays a vital role in this type of study, where time series (composites of every 16 days) imagery not only helps in identifying a land use type but also monitors the dynamics of such land use. Mainly in identification of crop and its growing period. It has an advantage of minimizing the cloud by creating maximum value composite. The spectral matching technique used in identifying a specific land use where the spectral profile follows the phenology (Thenkabail et al., 2007).

This study applied spectral matching techniques which is based on paper by Thenkabail et al. (2007) for mapping irrigated areas using AVHRR time-series imagery along with intensive field-plot information. The purpose of this study is to map changes in cropping patterns in a region with two crop seasons per year. It is a significant new information of mapping spatial and temporal complexity in land use changes due to water stress. The methodology starts with unsupervised classification of NDVI MVCs and follows. In the class identification and labelling process, the 16-day dataset as well as monthly MVCs are used. The main advantage of this approach during classification is to obtain the monthly cloud-free or near-cloud-free images with maximum value composites. MODIS 16-day temporal resolution data helps in identification of cropping systems across different cropping pattern and changes (irrigated, rainfed, etc.). Spectral matching techniques were successful in distinguishing cropping patterns such as mild-water stress, moderate water-stress, severe water-stress areas by comparing the spectral signatures.

The study showed the significant changes in agricultural land use as a result of water stress during 2015–2016. Rainfed and irrigated areas for study years 2013-14, 2015-16 were mapped with classification accuracy between 77–85% using MODIS 250 m time series images and spectral matching techniques (SMTs). The MODIS-based irrigated cropland statistics for the districts obtained for study years were highly correlated (R^2value of 0.86) with the figures reported by the Directorate of Economics and Statistics. We can improve present

The basin-level water inflow and outflow estimates are highly useful in understanding the water balance in the basin. It also presents a realistic picture of the effects of water scarcity during a low rainfall year on crop production and food security of the population in the basin. The result of this research recognizes the value of using MODIS time series 250 m data and advanced methods such as spectral matching techniques to study changes in the agricultural cropland in large river basins. It also contributes considerable amount to the knowledge base of earth observation groups involved in monitoring irrigated areas.

6.4 Conclusions

Chapter 1 deals with the introduction related to the study like Role of Remote sensing in monitoring Agriculture and the described the advantages of using remote sensing in monitoring, crop condition assessment, Drought definitions in view of different authors, Types of Drought and Impact of Drought on society. The Drought Scenario and its effects throughout globe and India. This section also studied about Importance of drought monitoring and previous studies.

Chapter 2 illustrates the objectives of the study and also described the entire study area in terms of its geographical features, climate and population.

Chapter 3 deals with the literature supporting the current study. This sections includes the literature of drought, drought assessment using the remote sensing, GIS and multi variants. This also deals with the different drought indices used by different authors to monitor or to calculate drought and its related study.

Chapter 4 contains the datasets used for the study and its preprocessing techniques to get accurate data like minimizing cloud removal algorithms etc. This also included the materials like ground survey data for classification as well as accuracy assessment and national statistics.

Chapter 5 deals with the methodology of the study which explains the flow and process of the study. The study follows these procedures like mapping, classification, identification of the classes through datasets. Comparison of different datasets and procedure of finding the drought areas was explained in this section. Later on accuracy assessment was done on the classified image.

Chapter 6 shows the results of the chapter 5 and explains the results with their corresponding values. It's also shows the classified images of the study areas in their study areas, accuracy assessment values. The drought areas map also showed here with their respective values.

Overall, provides a comprehensive strategy on the methods and approaches of mapping irrigated areas and also drought assessment using 250m resolution da

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