Change Detection of Sri Ram Sagar Project-1 Command Area using Geospatial tools

A report submitted to

Jawaharlal Nehru Technological University, Hyderabad

For the award of Degree of
Master of Technology

In

Geo Informatics and Surveying Technology

By

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December, 2017

CERTIFICATE

This is to certify that the dissertation entitled "**Change Detection of Sri Ram Sagar Project-1 Command Area using Geospatial tools"** submitted by **Mr. Panjala Pranay** 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. Panjala Pranay** 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.

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Signature of supervisor,

Mr. J. VENKATESH

Assoc. Professor, CSIT

IST, JNTUH

DECLARATION

I, **Panjala Pranay** hereby declare that the report entitled upon **"Change Detection of Sri Ram Sagar Project-1 Command Area using Geospatial tools"** is an authenticated work carried out by me at ICRISAT under the guidance of **Dr. G. Murali Krishna, Scientist-GIS/Geospatial Science (RS and GIS Laboratory), at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India,** during the period of my study as a part of curriculum in **Master of Technology in Geo Informatics and Surveying Technology.**

Date:

Place: HYDERABAD

Panjala Pranay

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Title: Change Detection of Sri Ram Sagar Project-1 Command Area using Geospatial Tools

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ABSTRACT

Sri Rama Sagar Project is I is a multipurpose project constructed across the Godavari River near Pochampad (V) Balkonda (M) Nizamabad (District) during 1964 which is envisaged to irrigate an ayacut of 9, 68,640 Acres covering erstwhile four Districts viz, (Nizamabad, Adilabad, Karimnagar and Warangal) of Telangana and the dam was also meant for generating (4*9 MW) 36MW power of which 3*9MW are already constructed and operational. The main of this study to assess and mapping the changes of crop intensity (i.e., double crop or single crop) under SRSP command area during the irrigated (2000-01, 2010-11) and non irrigated years (2004-05, 2015-16) using coarse resolution multispectral temporal satellite data (MODIS 250m) and their change detection using Geo Spatial Tools. This classification is mainly done by using spectral matching techniques i.e., comparing ideal spectral signatures with NDVI values and Google Earth. This work will help for decision makers to estimate the amount of crop and cropping intensity under the command area.

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Chapter 1
INTRODUCTION

Sri ram sagar project is described as life line of "telangana" as it supplies water for both drinking and irrigation purpose which is envisaged to irrigate an ayacut of 9, 68,640 Acres covering erstwhile four Districts viz, (Nizamabad, Adilabad, Karimnagar and Warangal) of Telangana and the dam was also meant for generating (4*9 MW) 36MW power of which 3*9MW are already constructed and operational. The cropping intensity of command area depends upon the release of water from SRSP.

According to world bank, 70% of total global water accounts for Agriculture. Total land irrigated is globally 20% of total agriculture land but had a production of 40% of total agricultural production. This shows the importance of irrigation in agriculture production.

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.

1.2 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’

1.3 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.

1.4 Sensors

Sensors used for remote sensing can be classified as **passive sensors** and **active sensors.**

Sensors which record the natural radiation, either reflected or emitted from the object are called passive sensors. Photographic camera, optic-mechanical scanner, push broom scanner and imaging spectrometer are examples of this category of sensors.

Sensors which produce their own electromagnetic radiation are called active sensors. The examples of active sensors include **S**ynthetic **A**perture **R**adar (SAR), scatter meter and **Li**ght **D**etection and **R**anging (LiDAR)

1.5 Remote Sensing Platforms

Sensors- meant for making spectral measurements, need to be placed on a suitable observation platform and lifted to a predefined altitude. Platforms can be stationary-like a tripod stand for field observation or mobile like aircraft or spacecrafts depending upon the needs of the observation and constraints. Aircrafts are mainly useful for surveys of smaller areas or limited regional interest.

1.6 Electromagnetic spectrum

Electromagnetic spectrum, the entire distribution of electromagnetic radiation according to frequency or wavelength. Although all electromagnetic waves travel at the speed of light in a vacuum, they do so at a wide range of frequencies, wavelengths, and photon energies.

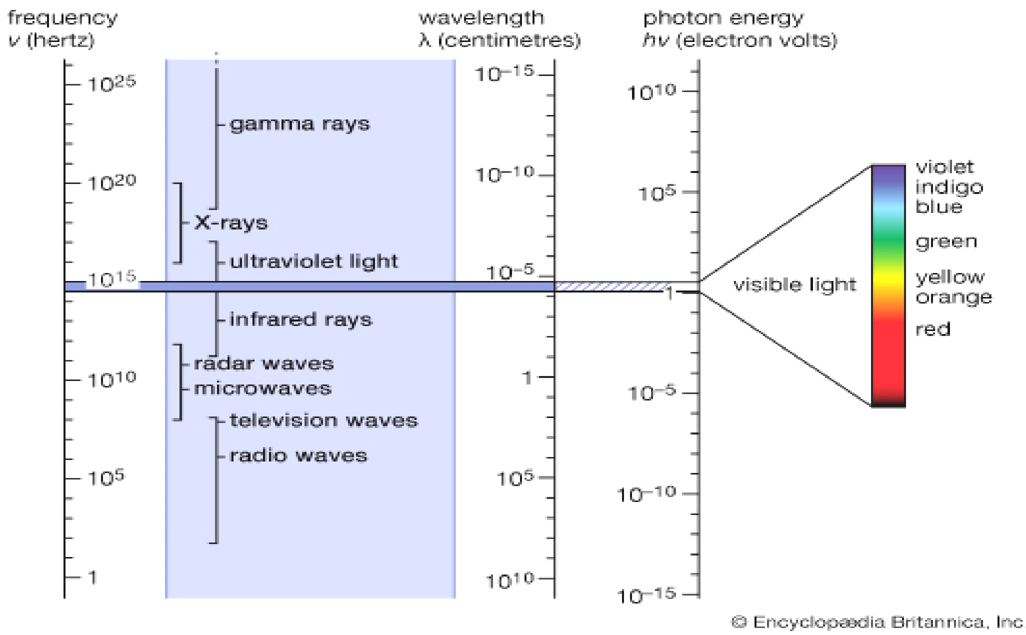


Figure 1-1:Electromagnetic Spectrum

Optical Infrared (OIR) Region

Visible	0.4-0.7 µm
Near infrared (NIR)	0.7-1.5 µm
Shortwave infrared (SWIR)	1.5-3.0 µm
Mid-wave infrared (MWIR)	3.0-8.0 µm
Thermal infrared (TIR)	8.0-15 µm
Far infrared (FIR)	Beyond 15 µm

Visible region

Violet	0.4 - 0.446 mm
Blue	0.446 - 0.500 mm
Green	0.500 - 0.578 mm
Yellow	0.578 - 0.592 mm
Orange	0.592 - 0.620 mm
Red	0.620 - 0.7 mm

1.7 Interactions with the Atmosphere

Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of **Scattering** and A**bsorption**.

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path.

There are three (3) types of scattering which take place.

Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. These could be particles such as small specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day is because of this phenomenon.

Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud conditions are overcast.

The final scattering mechanism of importance is called **Non Selective Scattering**. This occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering.

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents which absorb radiation.

Ozone serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight.

You may have heard **carbon dioxide** referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere.

Atmospheric Windows

Portions of the spectrum that transmits radiant energy effectively are called atmospheric windows. Atmosphere is practically in visible e-m region 0.38 - 0.78 µm. Remote sensing utilizes the transparent regions known as windows to avoid the effects of absorption of radiation.

Atmospheric Windows Spectral region(µm)

- 1 0.3-1.3
- 1.5-1.8
- 2.0-2.6
- 3.0-3.6
- 4.2-4.5
- 7.0-15.0

1.8 Reflectance

Reflectance is the process whereby radiation bounces off an object like Earth's surface, cloud top, etc. In fact, the process is more complicated, involving re-radiation of photons in unison by atoms or molecules in a layer of approximately one-half wavelength deep.

Reflectance refers to the ratio of the total amount of radiation, as of light, reflected by a surface to the total amount of radiation incident on the surface.

There are different type of reflecting surfaces.

Specular reflection occurs when the surface from which the radiation is reflected is essentially smooth. That is the average surface profile height is several times smaller than the wavelength of the radiation striking the surface. Several features, such as calm water bodies, act as *near –perfect specular reflector*.

1.9 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.

1.10 Satellite characteristics

Satellite is an object which revolves around another object. For example, moon revolves around earth it is called as a natural satellite of earth. In similar fashion earth has many manmade satellite which revolves around earth in different orbits continuously those are called artificial satellites.

Depending upon the purpose different orbit are chosen. Following are the orbits in which satellite revolves around the earth.

Orbit

A path followed by a satellite is called as its orbit. Satellite orbit are matched according to the objectivity and capability of sensor it carries. Orbits selection can vary in terms of its altitude, orientation and rotation with respect to earth.

Geostationary orbit: satellites in this orbit are at very high altitude, they see the same portion of earth at all times. It means that satellites in this orbit looks stationary relative to earth, so they are called as Geostationary orbit. And altitude of this orbit is 36,000 km above the earth surface. They revolve around earth exactly above the equator with same speed of earth rotation. Satellites which uses this orbit are communication satellites, weather satellites etc.

Swath

As satellites revolves around the earth sensors sees a portion on the earth surface and that area is called as swath. It may vary from one sensor to another sensor in kilo meters.

Figure 1-2: Swath

1.11 Resolution

A quality of a sensor to detect or record finest details is called a resolution. They are four types:

- Spatial resolution
- Spectral resolution
- Radiometric resolution
- Temporal resolution

Spatial resolution

The smallest possible area that can be detectable by a sensor is called as spatial resolution of that sensor. In other terms we can say area on the ground represented by a pixel in the image.

Spectral Resolution:

Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

Radiometric resolution

Every time an image is acquired on film or by a sensor, its sensitivity to the magnitude of the electromagnetic energy determines the **radiometric resolution**. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy the finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy

1.12 Image Characteristics

Image

An image is a two-dimensional representation of objects observed from a scene. Remote sensing images are the representation of earth surface and its features observed from space. Remote sensing images can be analog or digital. Images taken from aircraft or aerial photographs are analog in nature whereas satellite images taken with the help sensors are digital.

Digital image is represented by two-dimensional matrix of pixels, where each pixel holds information about the intensity value and its location in image.

Pixel

Pixel is short form for picture element. A two-dimensional array of pixels represents a digital image. Every pixel has some value that is called pixel value or grey value or mostly digital number. This DN number shows the intensity level of that pixel in Image. And in that array each pixel has its location value as in which row and column pixel is present. When an image is taken from satellite, it records the reflectance value from earth surface. And every pixel represents some of the area on the earth surface and pixel DN value is the reflectance recorded by the satellite sensor. How much area a pixel can represents is depends on the spatial resolution of that sensor. Following is the example of digital image and pixel.

Scale:

The ratio of distance in an image or map to the actual distance on earth surface is called as scale. For example, if we have scale 1:1000 cm, it means 1 cm of distance in image is equal to 1000 cm distance on earth surface. If the scale is larger then that scale is called large scale (1:500), if the scale ratio is small then it is a small scale (1:10000). So, small scale images cover more area on earth surface compared to large scale images for same image size. Following are some of the types of scales

- Dimension less scale

In this type of scale, the ratio is unit less or both have same units. For example: 1:1000, or 1 cm: 1000 cm.

- Dimensional scale

In this type each size has its own unit. For example, 1cm: 1 km.

This means that one cm on image is equal to one km on earth surface.

Multi-Layer images

When satellite scans a ground area it takes several types of measurements of that area, and each measurement is stored as separate image. When all these layers or images of same area combined is called as multi-layer images. Where each pixel has different measured values at same location. Following are some of the types of multi-layer images.

Multi spectral images

Sensors record the coming information in single band or more than single band. Like panchromatic sensors stores or receive the information in single band only, so its images are of single band only. Some sensors have multiple bands like LISS IV sensors. When a sensor has multiple bands, each band receive the reflectance value in a particular spectral range. When all these different spectral or bands are combined we call it as multi spectral images. Compared to single band images multispectral images have finer details.

A multispectral IKONOS image has four bands. Blue, Green, Red, Near infrared. From all these bands or spectra's reflectance value are recorded and displayed as a multispectral image.

Hyper spectral Images

With the advancement of Remote sensing its application is spreading in all sectors. With this advancement more finer details are expected. So, to achieve more finer and more detailed images Hyperspectral images concept is introduced. We already discussed that in multispectral images we use more than bands but in hyperspectral we use thousands of narrow wavelength bands. So, each band in hyperspectral has narrow bandwidth compared to that of multispectral images. With the increase in number of bands by manifolds, information collected will have finest details which is huge advantage over multi spectral in current scenario. But it comes with a cost, computation becomes complex and it require more storage. As bandwidth of each band is very less they vulnerable to some pseudo features.

Data formats

In above section we discussed about the multispectral images which have multiple bands, for each band separate image is recorded. But when we save this image we save as single image in memory. How we store the data from each band is discussed in this topic. Following are some of the data formats in which multispectral images are stored.

- Band sequential (BSQ).
- Band interleaved by line (BIL).
- Band interleaved by pixel (BIP).

However, each of these formats are preceded by "header" , which contains the information about altitude of sensor from earth surface, sun angle so on.

Band sequential format

In this format each band is stored as separate file, whenever we want to extract information about scene we need all the files. Number of files depends on the number bands. Researcher like this format because there is no need to extract all information sequentially, sometimes some band information is not required, in this format we can select the bands which are required. Which saves time and energy.

Band interleaved by line

In this format bands are written line by line on to same tape. (For example, line1 band1, line1 band2, line1 band3 …). This format is useful when all bands information is necessary. If some bands are not required, then this format is inefficient as it extract all bands information.

Band interleaved by pixel

In this format data for pixel from all bands written together that suppose we are writing pixel (1,1). The data format looks like following pixel(1,1) band 1, pixel(1,1) band2, pixel(1,1) band 3,… after completion of pixel(1,1) all band information next pixel information or data is recorded.

1.13 Objectives of the Study

- The main objective of the project is to assess and show the land use land cover changes of SRSP command area during irrigated (2000-01, 2004-05) and non-irrigated years (2010-11, 2015-16)

Chapter 2
STUDY AREA

Sriramasgar Project Stage-I is a multipurpose project constructed across the Godavari River near Pochampad (V) Balkonda (M) Nizamabad (District) during 1964. The project is envisaged to irrigate an ayacut of 9, 68,640 Acres covering four Districts viz, Nizamabad, Adilabad, Karimnagar and Warangal. Sriramasagar Project, Comprises the following:

i) Sriramasagar Dam across Godavari River

ii) Lower Manair Dam across Manair River

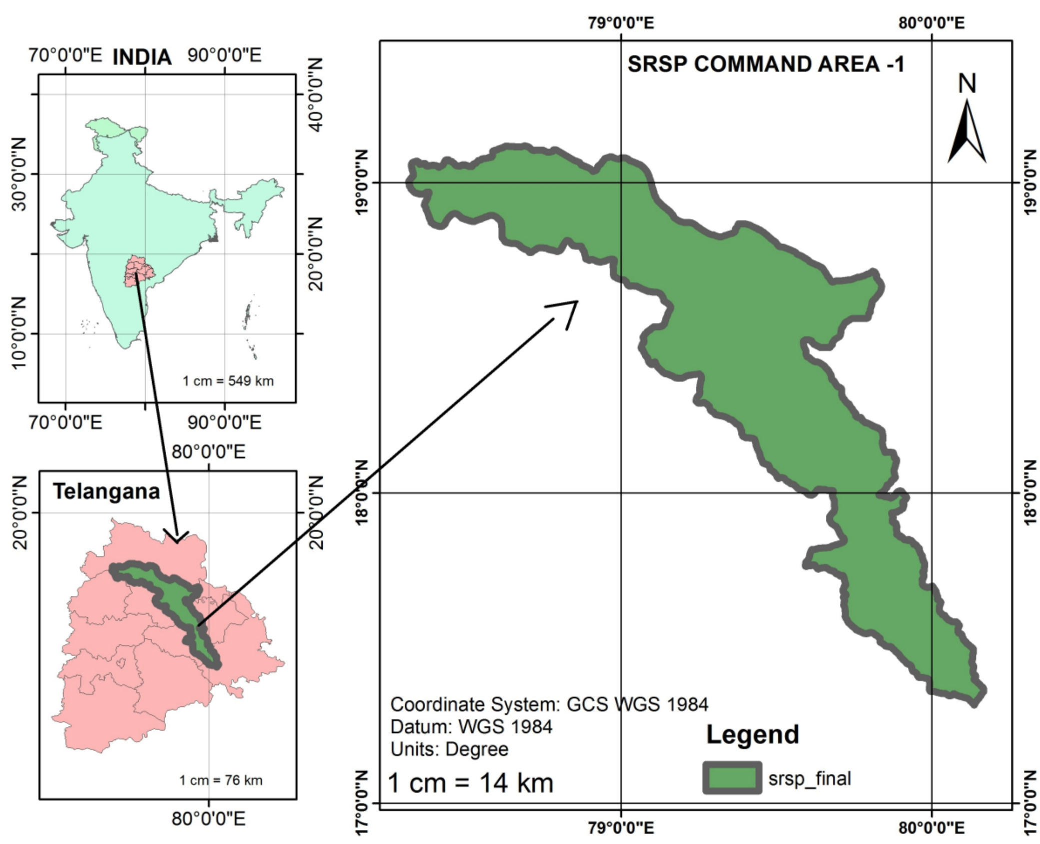


Figure 2-1: SRSP Command Area

Prof.G.V.Sudhakar rao Lower manair Dam was constructed on manair river tributary of river Godavari is situated in Karimnagar District of telangana State. The dam is commissioned during the year 1985.

Source And Location

Source: Godavari River at Pochampad Village.

2.1 Location:

Table 2-1: Location of SRSP & LMD

	SRI RAM SAGAR PROJECT	LOWER MANAIR DAM
Latitude	18^{o} 58' N	18^{o} 24' N
Longitude	78^{o} 28' E	79^{o} 08' E

Table 2-2: SRSP Description

Description	SRSP	LMD
Catchment Area at Dam Site	91,750 Sq.Kms.	6,465 Sq.Kms.
Flood Discharge (observed)	25,740 Cumecs	9,910 Cumecs
Designed Discharge	(45,300 Cumecs	(14,158 Cumecs

2.2 Components

The components of Sri Ram Sagar Project Stage-I are as follows:

1. Sri Ram Sagar Project dam a gravity dam with FRL + 332.54M (1091 ft) and TBL+337.72 M across the river Godavari near Pochampadu (v) with original reservoir capacity of 112 TMC and now revised to 90.313 TMC after allowing for siltation and sedimentation.

2. Lower Manair dam a balancing reservoir across Manair River with reservoir capacity 24.074 TMC.

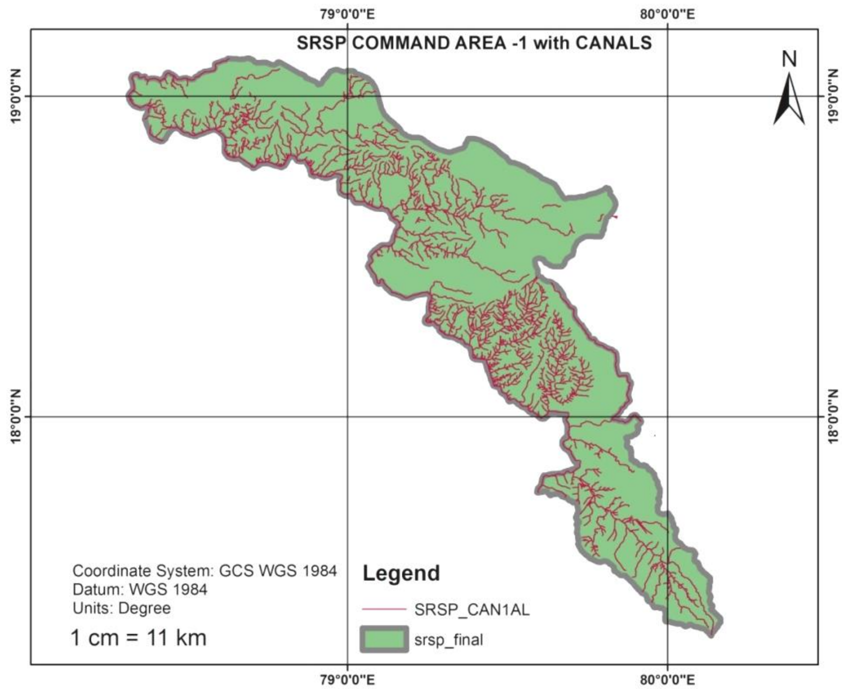


Figure 2-2: SRSP with its Canals

3. Kakatiya canal from 0 to 284 Km and its Distributory system include LMD.

4. Saraswathi canal from km 0.0 to km 47.0 and its Distributory system.

5. Laxmi canal up to Km 3.50 and its Distributory system.

Chapter 3
LITERATURE REVIEW

1. Gumma M.K (2016) mapped rainfed and irrigated *rice-fallow* cropland areas across South Asia, using MODIS 250 m time-series data and identify where the farming system may be intensified by the inclusion of a short-season crop during the fallow period. The study established cropland classes based on the every 16-day 250 m normalized difference vegetation index (NDVI) time series for one year (June 2010–May 2011) of Moderate Resolution Imaging Spectroradiometer (MODIS) data, using spectral matching techniques (SMTs), and extensive field knowledge. Map accuracy was evaluated based on independent ground survey data as well as compared with available sub-national level statistics

2. Gumma, M.K(2014) describes an approach to accurately separate out and quantify crop dominance areas in the major command area in the Krishna River Basin. Classification was performed using IRS-P6 (Indian Remote Sensing Satellite, series P6) and MODIS eight-day time series remote sensing images with a spatial resolution of 23.6 m, 250 m for the year 2005. Temporal variations in the NDVI (Normalized Difference Vegetation Index) pattern obtained in crop dominance classes enables a demarcation between long duration crops and short duration crops. The NDVI pattern was found to be more consistent in long duration crops than in short duration crops due to the continuity of the water supply. Surface water availability, on the other hand, was dependent on canal water release, which affected the time of crop sowing and growth stages, which was, in turn, reflected in the NDVI pattern. The identified crop-wise classes were tested and verified using ground-truth data and state-level census data. These results suggest that the methods, approaches, algorithms and datasets used in this study are ideal for rapid, accurate and large-scale mapping of paddy rice, as well as for generating their statistics over large areas. This study demonstrates that IRS-P6 23.6-m one-time data fusion with MODIS 250-m time series data is very useful for identifying crop type, the source of irrigation water and, in the case of surface water irrigation, the way in which it is applied. The results from this study have assisted in improving surface water and groundwater irrigated areas of the command area and also provide the basis for better water resource assessments at the basin scale

3. Gumma, M.K.(2015) determined the spatial extent of the stress-prone areas to effectively and efficiently promote proper technologies (e.g., stress-tolerant varieties) to tackle the problem of sustainable food production. This study was conducted in Odisha state located in eastern India. Odisha is predominantly a rainfed rice ecosystem (71% rainfed and 29% canal irrigated during kharif-monsoon season), where rice is the major crop and staple food of the people. However, rice productivity in Odisha is one of the lowest in India and a significant decline (9%) in rice cultivated area was observed in 2002 (a drought year). The present study analyzed the temporal rice cropping pattern in various ecosystems and identified the stress-prone areas due to submergence (flooding) and water shortage. The spatial distribution of rice areas was mapped using MODIS (MOD09Q1) 250-m 8-day time-series data (2000?2010) and spectral matching techniques. The mapped rice areas were strongly correlated (R2 = 90%) with district-level statistics. Also the class accuracy based on field-plot data was 84.8%. The area under the rainfed rice ecosystem continues to dominate, recording the largest share among rice classes across all the years. The use of remote-sensing techniques is rapid, cost-effective, and reliable to monitor changes in rice cultivated area over long periods of time and estimate the reduction in area cultivated due to abiotic stress such as water stress and submergence. Agricultural research institutes and line departments in the government can use these techniques for better planning, regular monitoring of land-use changes, and dissemination of appropriate technologies.

4. Gumma, M.K(2011) mapped the rice areas of six South Asian countries using moderate resolution imaging Spectroradiometer (MODIS) time-series data for the time period 2000 to 2001. The population of the region is growing faster than its ability to produce rice. Thus, accurate and timely assessment of where and how rice is cultivated is important to craft food security and poverty alleviation strategies. We used a time series of eight-day, 500-m spatial resolution composite images from the MODIS sensor to produce rice maps and rice characteristics (e.g., intensity of cropping, cropping calendar) taking data for the years 2000 to 2001 and by adopting a suite of methods that include spectral matching techniques, decision trees, and ideal temporal profile data banks to rapidly identify and classify rice areas over large spatial extents. These methods are used in conjunction with ancillary spatial data sets (e.g., elevation, precipitation), national statistics, and maps, and a large volume of field-plot data.

5. Gumma, M.K.(2008) prepared a comprehensive land use/land cover (LU/LC) map using continuous time-series data of multiple resolutions. A methodology is developed to map irrigated area categories using LANDSAT ETM+ along with coarse resolution time series imagery from AVHRR and MODIS, SRTM elevation, and other secondary data. Major stress was towards discrimination of ground-water irrigated area from surface-water irrigated area, determining of cropping patterns in irrigated area using MODIS NDVI time- series, and use of non-traditional methods of accuracy assessment using, ancillary datasets like SRTM-DEM, precipitation and state census statistics.

5. Pardhasaradhi Teluguntla (2016) generated standard and routine cropland products, year-after-year, over very large areas through the use of two novel methods: (a) quantitative spectral matching techniques (QSMTs) applied at continental level and (b) rule-based Automated Cropland Classification Algorithm (ACCA) with the ability to hind-cast, now-cast, and future-cast. Australia was chosen for the study given its extensive croplands, rich history of agriculture, and yet nonexistent routine yearly generated cropland products using multi-temporal remote sensing. This research produced three distinct cropland products using Moderate Resolution Imaging Spectroradiometer (MODIS) 250-m normalized difference vegetation index 16-day composite time-series data for 16 years: 2000 through 2015. The products consisted of: (1) cropland extent/areas versus cropland fallow areas, (2) irrigated versus rainfed croplands, and (3) cropping intensities: single, double, and continuous cropping. An accurate reference cropland product (RCP) for the year 2014 (RCP2014) produced using QSMT was used as a knowledge base to train and develop the ACCA algorithm that was then applied to the MODIS time-series data for the years 2000–2015.

Chapter 4
DATABASE AND METHODOLOGY

4.1 Satellite Data

- MODIS (250 m resolution) time series NDVI multi-spectral data `during 2000-01, 2004-05, 2010-11, 2015-16

4.2 Software used for the research

For Classification

- MRT (Modis Reprojection Tool)
- ERDAS 14 (along with ER Mapper)
- ArcGIS 10.4
- Google Earth Pro

For Documentation

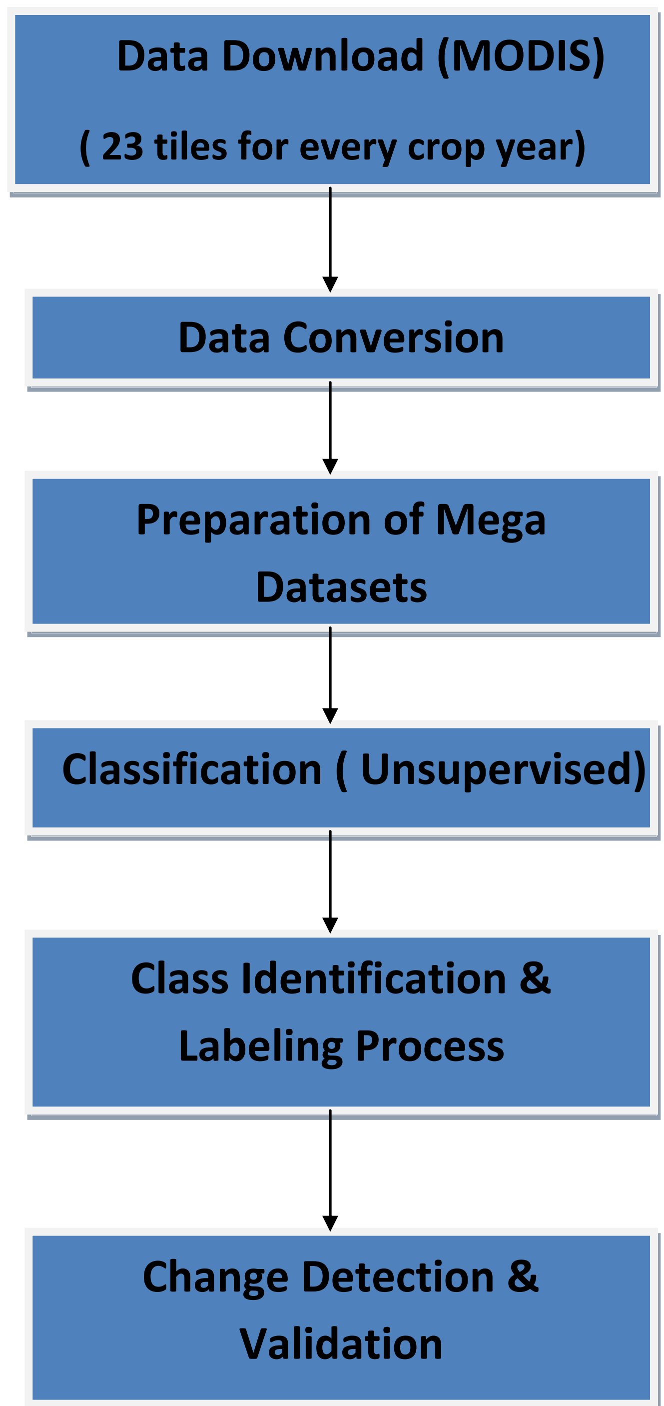
- MS Office

The present research used MOD13Q1 temporal data to identify the irrigated areas. MODIS captures imagery over the earth on a daily basis, which makes it possible to get cloud free data when available immediately after a rainfall event or cloudy day. The 16-days composites from the daily acquisitions bundle up to make a time series dataset over a crop year or a calendar year. This type of dataset provides temporal profiles of crop growing locations to identify the start of season, peak growth stage and harvest date during each season. The values of NDVI as function of time also help in identifying the type of crop in an eco-region based on certain peak thresholds for that crop. This study applies spectral matching technique which is found to be ideal in mapping irrigated areas Thenkabail et al., (2007) and mapping rice areas Gumma et al., (2011). Mapping spatial distribution of rice fallows using MODIS 250m 16-days' time series and ground survey information with spectral matching techniques is significant new advancement in the use of this technique.

Some discrepancies were also found during the comparison of national statistics and MODIS derived irrigated areas. The mismatch occurred in high rainfall zones, where there was misclassification with irrigated areas due to similar growing conditions during cropping season. Most of the areas were corrected using rainfall data and spatial modeling techniques.

Irrigated area fractions (the proportion of irrigated/rice area in a pixel) were assigned based on land use proportions in each class to estimate the MODIS pixel area accurate to the real irrigated/rice area. Also, this method relies on ground survey information that is a truly representative sample of the fragmented rice systems. Higher resolution imagery could be used to more accurate estimate of pure classes, but with a lot more mixed classes coming up. Results clearly show that present methods and MODIS time series data has many advantages such as capturing large scale cropping pattern. But to minimizing errors, additional research will be attempted with multi-sensor images with advanced fusion techniques (Gumma et al., 2011c).

4.3 Methodology



4.3.1 Data Download

The data required like MODIS 250m was downloaded from USGS link. We can download the data as per our requirement. Then the data conversion is done using Modis Reprojection Tool (MRT).

MODIS

MODIS (or Moderate Resolution Imaging Spectro radiometer) is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MODIS is playing a vital role in the development of validated, global, interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment.

Specifications of MODIS are:

- **Orbit:** 705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun- synchronous, near-polar, circular
- **Scan Rate:** 20.3 rpm, cross track
- **Swath Dimensions:** 2330 km (cross track) by 10 km (along track at nadir)
- **Telescope:** 17.78 cm diam. off-axis, focal (collimated), with intermediate field stop

- **Size:** 1.0 x 1.6 x 1.0 m
- **Weight:** 228.7 kg
- **Power:** 162.5 W (single orbit average)
- **Data Rate:** 10.6 mbps (peak daytime); 6.1 mbps (orbital average)
- **Quantization:** 12 bits
- **Spatial Resolution:** 250 m (bands 1-2), 500 m (bands 3-7), 1000 m (bands 8-36)
- **Design Life:** 6 years

Moderate Resolution Imaging Spectro radiometer (MODIS) 250 m spatial resolution time-series data offers one of the best opportunities to study various cropland variables given its: (1) daily acquisition, (2) surface reflectance of 16-day composite time-series that are time-composited into normalized difference vegetation index (NDVI) maximum value composites, and (3) sophisticated cloud removal algorithms that further enhance MODIS applicability.

Table 4-1: MODIS Land use Bands

Primary Use	Band	Bandwidth	Spectral Radiance	Required SNR
Land/Cloud/Aerosols Boundaries	1	620 – 670nm	21.8	128
	2	841 – 876nm	24.7	201

4.3.2 Data Conversion

MRT 2011 (MODIS Reprojection Tool, Version 4.1), used it was developed to support higher level MODIS Land products which are distributed as Hierarchical Data Format (.hdf) -Earth Observing System (HDF-EOS) files projected to a tile-based Sinusoidal grid(.tif) and extracted the NDVI (Normalized Difference Vegetative Index).

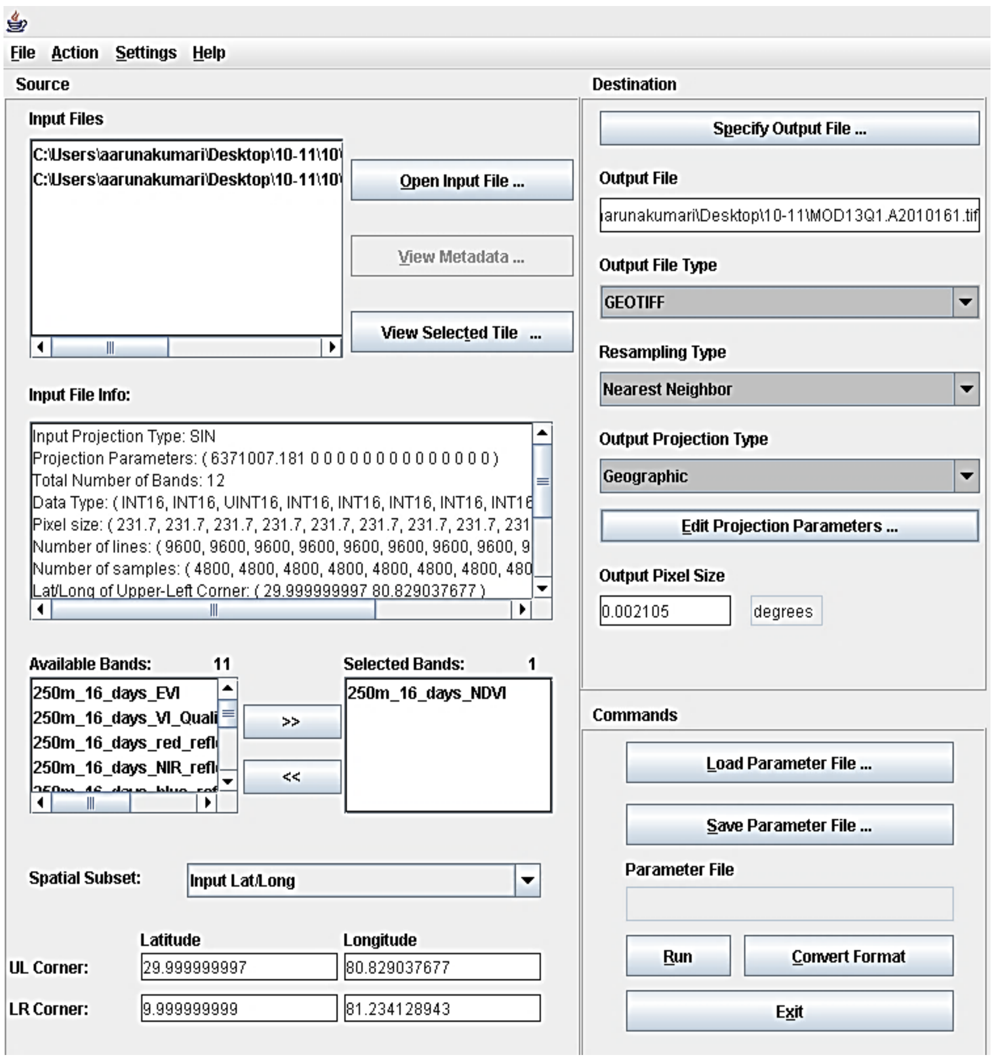


Figure 4-1: MRT Application Interface

Process of MR Tool

1. Open the MR Tool file.

1. **Add .hdf files:** Insert the data of downloaded modis .hdf files **Open Input File**. We have to select the single day images at a time. Two tiles are covered the entire Odisha area, so we selected 2 .hdf files of the same date.
2. **Band selection:** By default, all available bands are selected and appear in the box to the right (Selected Bands). We need only **NDVI** band. To separate certain bands from processing, click on the unwanted bands and use the “**<<”** button to deselect them (below figure). This will move it to the box on the left (Available Bands). To move bands from the Available box to the Selected box, click on the desired band and use “**>>”** button.
3. **Output file:** It is very important to include the file extension as part of the file name. The file extension indicates the file format of the output image. If we add **“.hdf”** it will give **HDF-EOS**, **“.tif”** will give **GeoTIFF** and **“.hdr”** will give **raw binary**.

    In Output File Type, we have selected GEOTIFF which is a standard image format in image processing software.

4. **Resampling:** Selected the Resampling Type as “**Nearest neighbour”.**
5. **Reprojecting:** It transforms the sinusoidal equal area projection of the input .hdf into the geographic coordinate system.
    - The **Output Projection Type** is selected from the list as **Geographic**
    - For the parameters we have to open Edit projection parameters and select **WGS 84** as datum.

6. **Output Pixel Size: 0.002105 degrees.** It should be defined as our outpt image will be in geographic coordinates, the pixel resolution is measured in degrees. MOD13Q1 is 250m resolution, this is equivalent to 0.002105 degrees at the equator.

4.3.3 Preparation of Mega File Datasets

Land use for the crop years are prepared using MODIS Time-Series Mega files of Normalized Difference Vegetation Index (NDVI) downloaded from the USGS website (https://earthexplorer.usgs.gov/).

Mega Cube file i.e. multi date, multi sensor data preparation are done using ERMAPPER software for **MODIS** 250m dataset.

Many bands of data of a study area are combined from numerous dates into a single file referred to as mega-file. These mega data sets have no limitation for size or dimension of a mega-file.

A time series of MODIS 16-day composite reflectance images of 250 m resolution was obtained for June to May (MOD13Q1 data product). The 16-day composite images in the MOD13Q1 data set are free of cost and pre-calibrated. The large- scene size and daily overpass rate of MODIS make it attractive for crop mapping of large areas, and NDVI derived from MODIS has high fidelity with biophysical parameters. The composites are created using the maximum NDVI method on the daily MODIS data to minimize cloud effects (Holben, 1986). The 16-day composite images were downloaded for the year starting Julian day 161. There were one to two 16-day composites per month for a total of 23 16-day composites. Monthly MVCs for June to May for years were created using the 16-

day images to minimize cloud effects during the monsoonal season. The monthly MVCs were stacked into a 12-band NDVI MVC mega-file image (MFI). ERDAS

The above process was done in ERDAS ER Mapper and Imagine 2014.

- ER Mapper involves in advanced image processing and compression capabilities.

- ERDAS Imagine is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications. Imagine is aimed mainly at geospatial raster data processing and allows users to prepare, display and enhance digital images for mapping use in geographic information system (GIS) and computer-aided design (CAD) software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions. By manipulating imagery data values and positions, it is possible to see features that would not normally be visible and to locate geo-positions of features that would otherwise be graphical. The level of brightness or reflectance of light from the surfaces in the image can be helpful with vegetation analysis, prospecting for minerals etc. Other usage examples include linear feature extraction, generation of processing work flows (spatial models in Imagine), import/export of data for a wide variety of formats, ortho rectification, mosaicing of imagery, stereo and automatic feature extraction of map data from imagery.

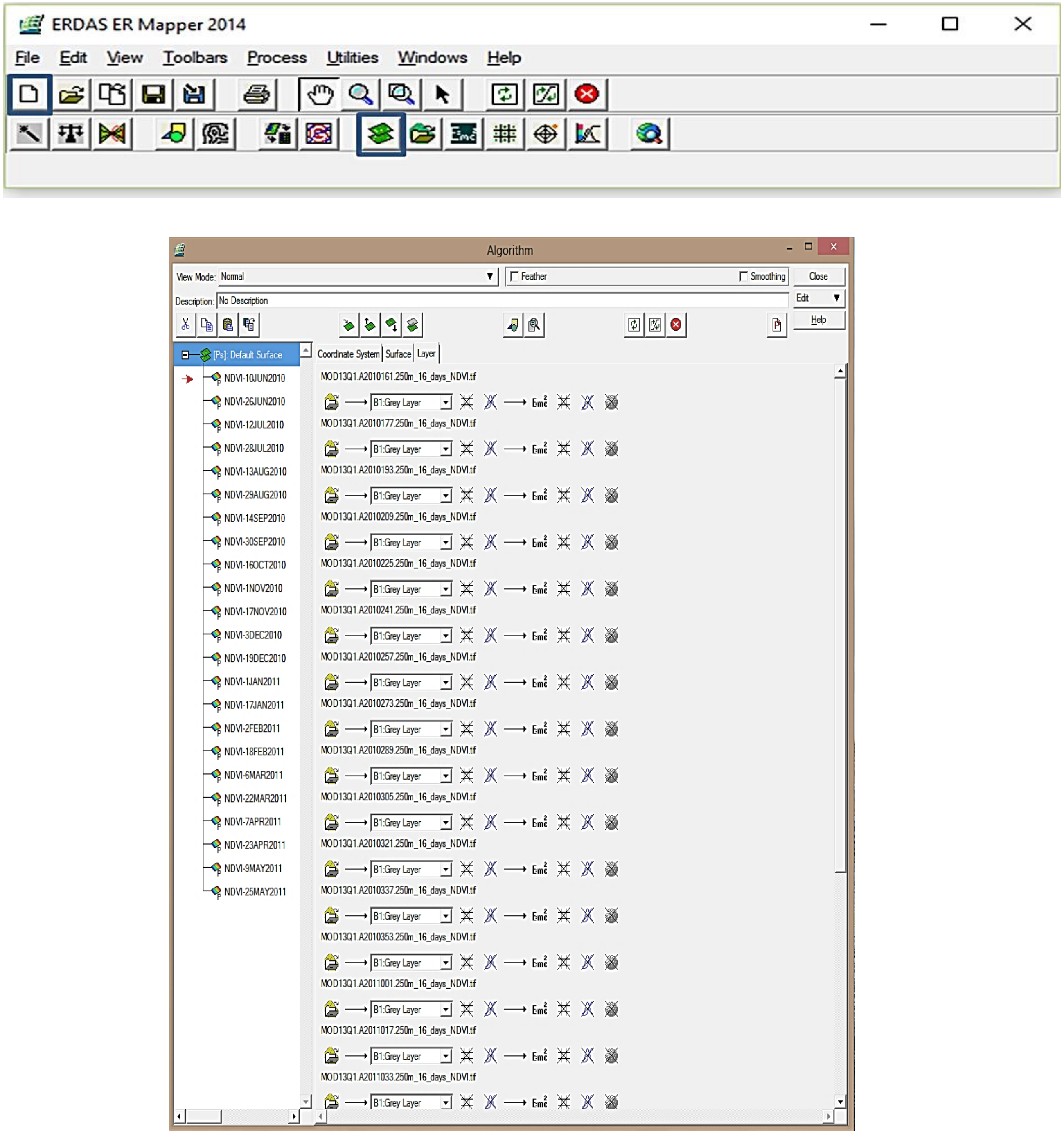


Figure 4-2: ER Mapper 2014 Interface

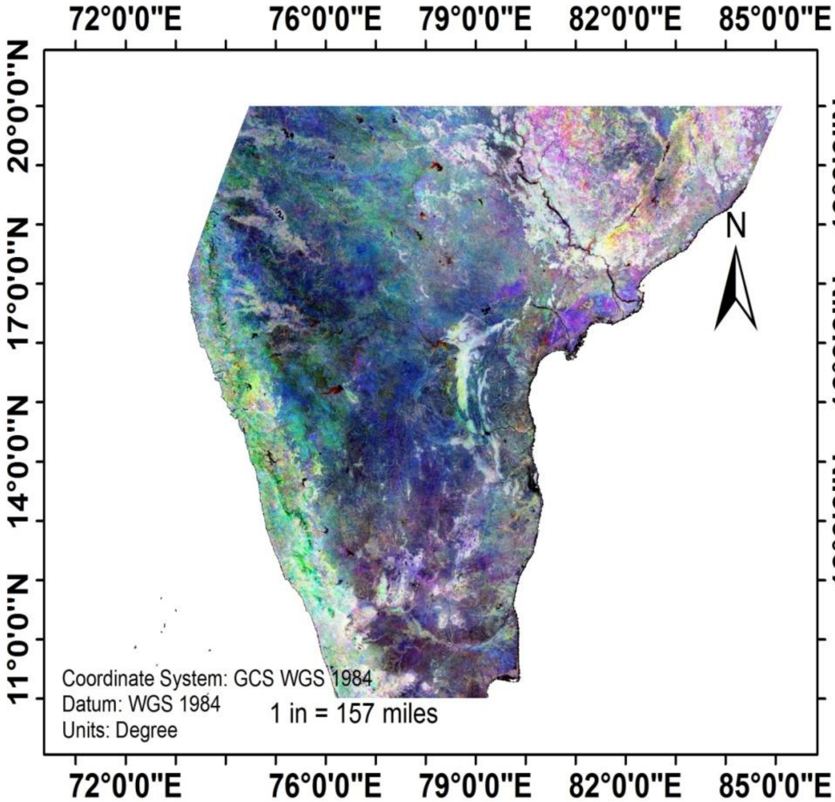


Figure 4-3: Stacked File

A mega file is a composite of time-series MODIS data involving Normalized Difference Vegetation Index (NDVI), and the NDVI Maximum Value Composites (MVC). MVC gives the highest NDVI/spectral value in a particular time span. 16 day MODIS NDVI spectral images are composited to get monthly maximum value composites using MODIS Re-projection Tool (MR Tool).

$$NDVIMVC_i = Max(NDVI_{i1}, NDVI_{i2})$$

Where MVC_i is Monthly maximum value composite of i^{th} month (eg: "i" is Jan-Dec). i_1, i_2 are every 16day composite in a month. The NDVI data was further processed to create monthly maximum value composites (NDVIMVC) for each of the crop year using equation

12 NDVI MVCs (one for each month) of the study area are layer stacked into a single file and this single file is called mega file data cube.

4.3.3.1 NDVI

The **Normalized Difference Vegetation Index** (**NDVI**) is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not. NDVI is calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light.

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$

where NIR is 'Near infrared' and VIS is 'Visible'. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

4.4 Unsupervised Classification

After the generation of mega files, land use/ land cover for the years of study are mapped using ERDAS Imagine 2014 and Google earth. Land use classification is done with the help of 'unsupervised classification' tool in ERDAS. Using this tool, 30 classes were divided and average NDVI values are calculated for the mega files. Based on the average NDVI curves and ideal curves, the land use is classified into crop, water, built-up, forest, etc., and the similar classes are merged.

LU mapping involves various protocols such as unsupervised classification (Kreuter n.d., Levien 1999) and spectral matching techniques. In unsupervised classification, image processing software classifies an image based on natural groupings of the spectral properties of the pixels, without the user specifying how to classify any portion of the image. Conceptually, unsupervised classification is similar to cluster analysis where observations (in this case, pixels) are assigned to the same class because they have similar values. The user must specify basic information such as which spectral bands to use and how many categories to use in the classification or the software may generate any number of classes based solely on natural groupings. Common clustering algorithms include K-means clustering and ISODATA clustering.

Unsupervised classification yields an output image in which a number of classes are identified and each pixel is assigned to a class. These classes may or may not correspond well to land cover types of interest, and the user will need to assign meaningful labels to each class. Unsupervised classification often results in too many land cover classes, particularly for heterogeneous land cover types, and classes often need to be combined to create a meaningful map.

Unsupervised classification using ISOCLASS cluster algorithm (ISODATA in Imagine 2014^{TM}) followed by progressive generalization, was used on 12-band NDVI MFDC constituted for the crop years. The classification was set at a maximum of 30 iterations and convergence threshold of 0.99. In all 30 classes were generated for each segment. Use of unsupervised techniques is recommended for large areas that cover a wide and unknown range of vegetation types. The 30 classes obtained on time series composite from the unsupervised classification were merged using rigorous class identification and labeling using protocols.

4.4.1 Ideal spectra generation

Ideal spectra signatures were generated using 16-day NDVI time-series composite and precise ground survey information which was also used for class identification process (Gumma et al., 2016). Ideal spectral signatures were based on ground survey information, these samples were grouped according to their unique categories and grouped major rice systems. The samples were chosen to generate ideal spectra signatures refer crop intensity, crop type and cropping systems. Each signature was generated with group of similar samples.

The following graphs show the ideal NDVI curves for different classes of land use:

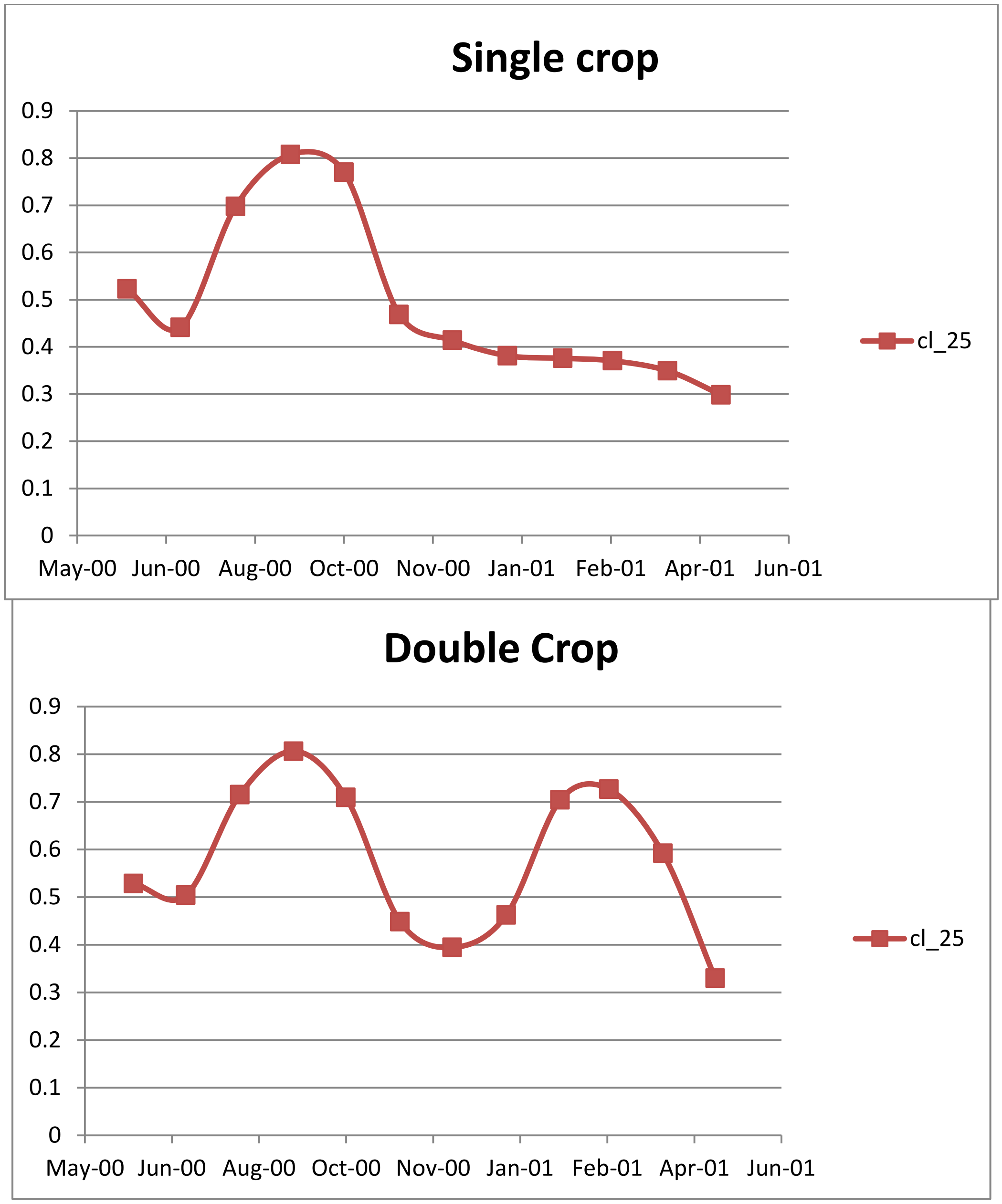


Figure 4-4: Ideal NDVI curves for some land use classes

The NDVI plots are ideal for understanding the changes within and between cropping seasons and between classes and exhibits the length of growing period. Temporal NDVI signature clearly elicits the planting time, peak growth and harvesting stage.

NDVI time series plays a major role in class identification and determining crop growth stages season wise. Separation of rice growing areas from other land use land cover classes is based on annual average NDVI values and timing of the onset of 'greenness'. The annual NDVI of double cropped and triple cropped rice areas was higher than the other crops, meanwhile the difference between irrigated and rainfed rice areas is also clearly seen in the study area.

4.4.2 Class spectra generation

Crop type mapping of data is performed using **spectral matching techniques** (Thenkabail P.S. 2007). SMTs are innovative methods of identifying and labeling classes. For each derived class, this method identifies its characteristics over time using MODIS time-series data. NDVI time-series (Biggs 2006, Thenkabail 2005, Dheeravath V 2009) are analogous to spectra, where time is substituted for wavelength. The principle in SMT is to match the shape, or the magnitude or both to an ideal or target spectrum (pure class or "end member"). The spectra at each pixel to be classified is compared to the end-member spectra and fit is quantified using the following SMTs (Thenkabail P.S. 2007); (1) spectral correlation similarity – a shape measure; (2) spectral similarity value (SSV) - a shape and magnitude measure; (3) Euclidean distance similarity (EDS) - a distance measure; and (4) modified spectral angle similarity (MSAS) - a hyper angle measure. The first two SMTs are used very often (Thenkabail P.S. 2007).

Spectral matching techniques (SMTs) match the class spectra derived from classification with an ideal spectra-derived from MODIS MFDC (Mega file data cube) based on precise knowledge of land use from specific locations. In SMTs, the class temporal profiles (NDVI curves) are matched with ideal temporal profile (quantitatively based on temporal profile similarity values) in order to group and identify classes.

- Using Signature file, the mean values of NDVI of every layer i.e., resembles every month is calculated using signature editor of ERDAS 10.4
- Spectral Matching Techniques is used for mapping LULC which means ideal signatures are matched with spectral signatures and classified accordingly

2000-01														
	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01		
cl_1	0.37	0.3819	0.3494	0.3991	0.3543	0.2759	0.2915	0.2561	0.2564	0.2708	0.2659	0.2504	water	1
cl_2	0.2322	0.2448	0.1919	0.1943	0.1704	0.1353	0.1537	0.1384	0.1441	0.1695	0.1819	0.1837	water	1
cl_3	0.4474	0.4006	0.3658	0.5341	0.531	0.4236	0.4383	0.3977	0.4142	0.4126	0.3829	0.3132	shrubs	4
cl_4	0.4843	0.5208	0.5327	0.5689	0.4726	0.3722	0.3557	0.3252	0.2983	0.3039	0.2953	0.2766	shrubs	4
cl_5	0.4871	0.5256	0.5697	0.6518	0.5828	0.462	0.4489	0.3998	0.3648	0.348	0.3187	0.2858	shrubs	4
cl_6	0.4699	0.575	0.5615	0.6497	0.627	0.5839	0.6261	0.5971	0.5344	0.4563	0.3524	0.2897	sc	3
cl_7	0.4736	0.471	0.5927	0.6703	0.5989	0.4272	0.4036	0.3967	0.4843	0.5217	0.4226	0.3055	dc	2
cl_8	0.5671	0.5936	0.6285	0.6709	0.5878	0.4663	0.4387	0.4175	0.4157	0.4416	0.4161	0.3403	shrubs	4
cl_9	0.5138	0.6409	0.6591	0.6793	0.5672	0.466	0.5331	0.6276	0.6661	0.6366	0.4829	0.3397	dc	2
cl_10	0.6035	0.6519	0.6713	0.6833	0.5662	0.4508	0.4116	0.37	0.3219	0.3203	0.3231	0.3013	shrubs	4
cl_11	0.4392	0.4839	0.5779	0.689	0.6616	0.5603	0.5694	0.5041	0.4456	0.3956	0.3324	0.28	sc	3
cl_12	0.5415	0.6451	0.6562	0.6927	0.6334	0.5485	0.5329	0.4625	0.3882	0.3681	0.3342	0.2914	sc/shrub:	3
cl_13	0.5288	0.6241	0.6695	0.7014	0.631	0.5238	0.5052	0.4837	0.4882	0.5185	0.4611	0.3426	sc	3
cl_14	0.5033	0.4677	0.5885	0.7224	0.6935	0.5604	0.5428	0.5021	0.5298	0.5481	0.4744	0.3366	dc	2
cl_15	0.4148	0.4592	0.5878	0.7125	0.7137	0.6727	0.6857	0.6238	0.5438	0.4719	0.3737	0.2938	dc	2
cl_16	0.5316	0.5377	0.6767	0.7434	0.6506	0.4508	0.4178	0.4615	0.5999	0.6258	0.4771	0.3228	dc	2
cl_17	0.6298	0.6202	0.6677	0.7401	0.6914	0.5709	0.5325	0.51	0.5438	0.575	0.5469	0.414	dc	2
cl_18	0.4809	0.4898	0.6287	0.7498	0.7244	0.6468	0.6528	0.615	0.6003	0.5901	0.5047	0.3384	dc	2
cl_19	0.5469	0.5702	0.6461	0.7436	0.7196	0.6111	0.6032	0.5428	0.4887	0.4393	0.3743	0.313	sc	3
cl_20	0.5295	0.6006	0.6978	0.7517	0.6701	0.5163	0.4972	0.553	0.6627	0.6839	0.5935	0.372	dc	2
cl_21	0.5267	0.5496	0.6651	0.751	0.7132	0.5172	0.4736	0.4279	0.4137	0.4022	0.3506	0.2914	sc	3
cl_22	0.6473	0.6781	0.7146	0.7438	0.6737	0.5534	0.506	0.4516	0.3989	0.3893	0.3923	0.3592	shrubs	4
cl_23	0.5718	0.4899	0.5798	0.7761	0.7775	0.6303	0.5303	0.4228	0.4019	0.3791	0.3588	0.3075	sc	3
cl_24	0.3992	0.4492	0.629	0.7597	0.7672	0.7498	0.7582	0.7018	0.625	0.5375	0.4243	0.3098	sc	3
cl_25	0.5637	0.517	0.6399	0.7883	0.7532	0.5762	0.4743	0.4387	0.6211	0.6976	0.6441	0.3822	dc	2
cl_26	0.5496	0.5165	0.6869	0.7861	0.7384	0.5133	0.4285	0.4077	0.4916	0.5466	0.4944	0.3345	dc	2
cl_27	0.7541	0.729	0.7706	0.7715	0.6801	0.5377	0.4738	0.4088	0.3329	0.3096	0.3214	0.3266	shrubs	4
cl_28	0.5285	0.5038	0.715	0.8061	0.7088	0.4483	0.3942	0.462	0.7037	0.7263	0.5915	0.3293	dc	2
cl_29	0.523	0.4413	0.6974	0.8076	0.7703	0.4686	0.4138	0.3812	0.3758	0.3704	0.3491	0.2983	sc	3
cl_30	0.7478	0.7692	0.7969	0.8127	0.7576	0.645	0.5917	0.5136	0.4059	0.3424	0.3628	0.3828	forest	4

Figure 4-5: NDVI mean values for every month in crop year 2000-01

4.5 Class Identification and Labeling process:

The class identification and labeling process involves the use of Spectral Matching Techniques, location wise spectral signatures, ground survey data (Murali Krishna Gumma 2014) and Google Earth images. After grouping classes based on SMT, class names were assigned for each class.

Google Earth verification is used for class identification and labeling, since Google Earth provides very high-resolution images from 30 m to sub-meter resolution for free and is accessible through the web. This data set was also used for class identification and verification, especially in areas that are difficult to access during field visits (Gumma 2014). Though Google Earth does not guarantee pinpoint accuracy, the zoom-in views of high-resolution imagery were used to identify the presence of any agriculture bunds, vegetation conditions, and irrigation structures (e.g., canals, irrigation channels, open wells). It was observed from the digital globe option on Google Earth that most of the high-resolution images were acquired after 2000.

4.6 Change Detection and validation

Change detection analysis, describe and quantify differences between images of the same scene at different times.

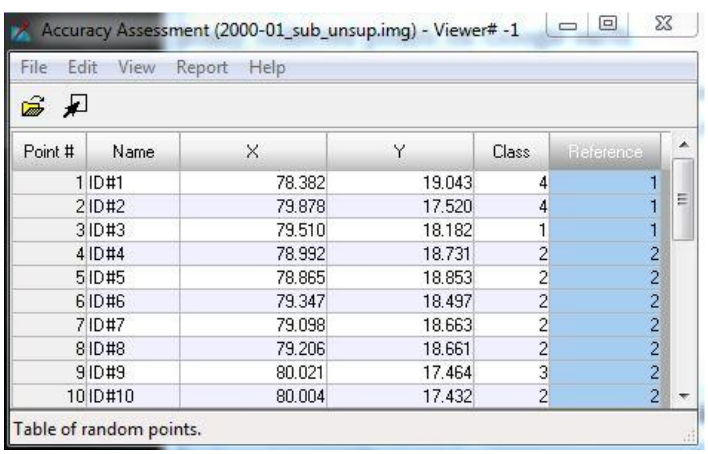
- It was done by considering two sets of irrigated and non irrigated years

i.e. {2000-01, 2004-05}, {2010-11, 2015-16}

Validation is the calibration of the data which we have done and calculating accuracy assessment using

- The ground truth points which is collected
- Some randomly collected points on Google earth

The principle of Accuracy assessment is verifying the class values with the reference class values and finding the accuracy of their correctness.



Point #	Name	X	Y	Class	Reference
1	ID#1	78.382	19.043	4	1
2	ID#2	79.878	17.520	4	1
3	ID#3	79.510	18.182	1	1
4	ID#4	78.992	18.731	2	2
5	ID#5	78.865	18.853	2	2
6	ID#6	79.347	18.497	2	2
7	ID#7	79.098	18.663	2	2
8	ID#8	79.206	18.661	2	2
9	ID#9	80.021	17.464	3	2
10	ID#10	80.004	17.432	2	2

Table of random points.

Figure 4-6: Accuracy Assessment & Random Values

4.7 Ground Truth Values

Table 4-2: Ground Truth Values

Class	Longitudes	Latitudes
Water bodies	78.381589	19.043058
Water bodies	79.878161	17.520383
Water bodies	79.510419	18.182197
Double crop	78.991908	18.730867
Double crop	78.865275	18.853394
Double crop	79.346553	18.497033
Double crop	79.098369	18.663467
Double crop	79.206394	18.660664
Double crop	80.021336	17.4641
Double crop	80.004119	17.431978
Single Crop	79.927489	17.5285
Single Crop	79.930261	17.5245
Single Crop	79.87215	17.532178
Single Crop	79.868922	17.533042
Single Crop	80.041658	17.485767
Single Crop	79.811633	17.755
Single Crop	79.815983	17.747306
Single Crop	79.570928	18.210219
Single Crop	79.532703	18.286856
Single Crop	79.733097	18.014219
Single Crop	79.731331	18.063503
Single Crop	79.780961	17.998831
Single Crop	79.777275	17.982692
Single Crop	79.783367	17.975094
Single Crop	79.196517	18.379906
Other LULC	79.24505	18.691428
Other LULC	78.838408	19.004258
Other LULC	79.651708	18.101547

Chapter 5
RESULTS AND CONCLUSION

In this chapter, the results are discussed by considering the classification done before.

5.1 Land Use Land Cover Classification

The classification is done by taking mainly four classes. They are Water Bodies, Single crop, Double crop, Other LULC

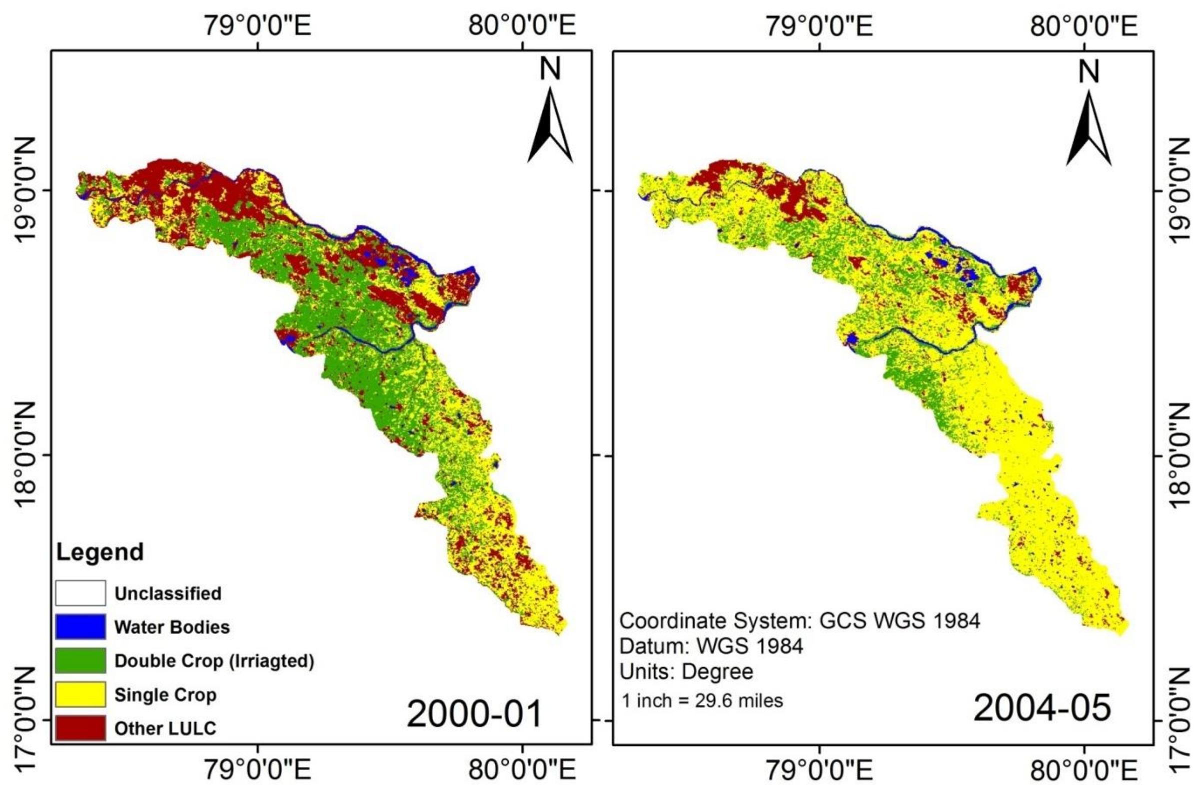


Figure 5-1: Classification images 2000-01 and 2004-05

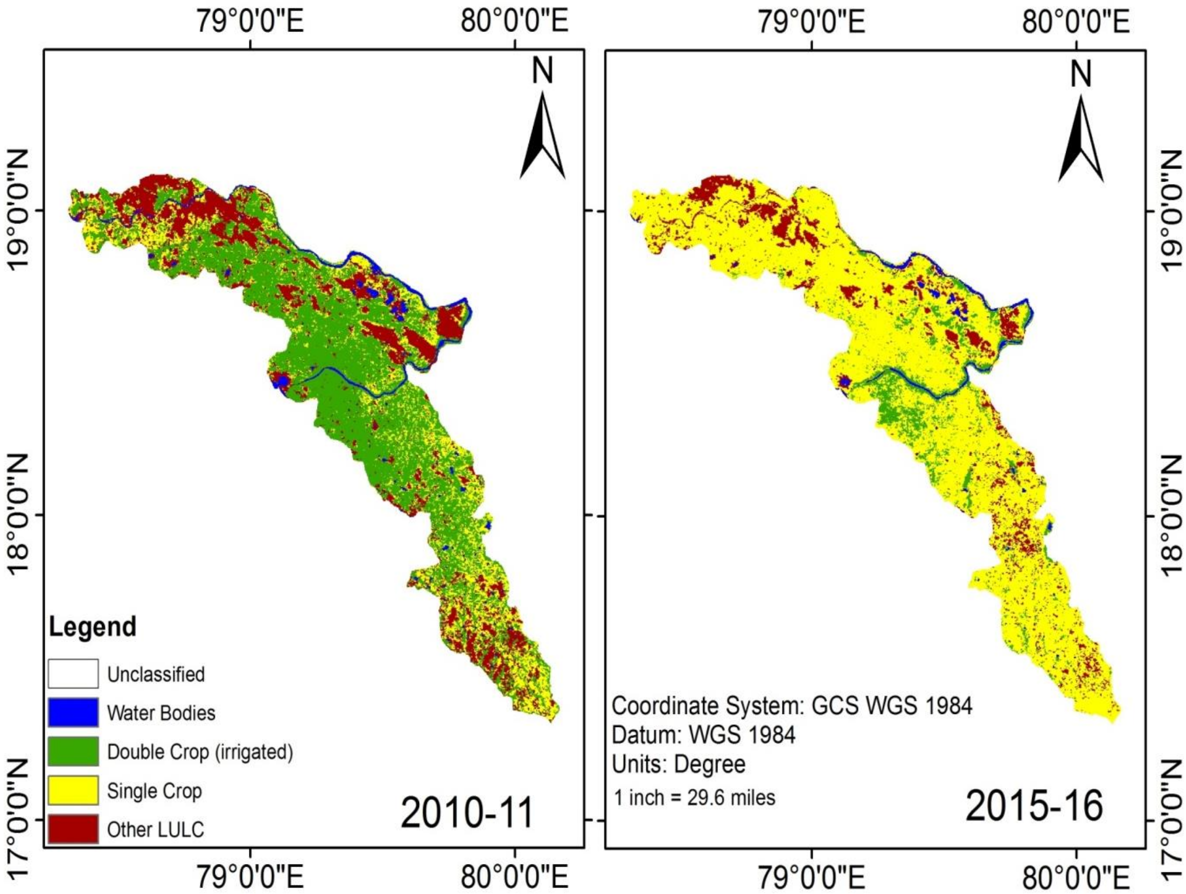


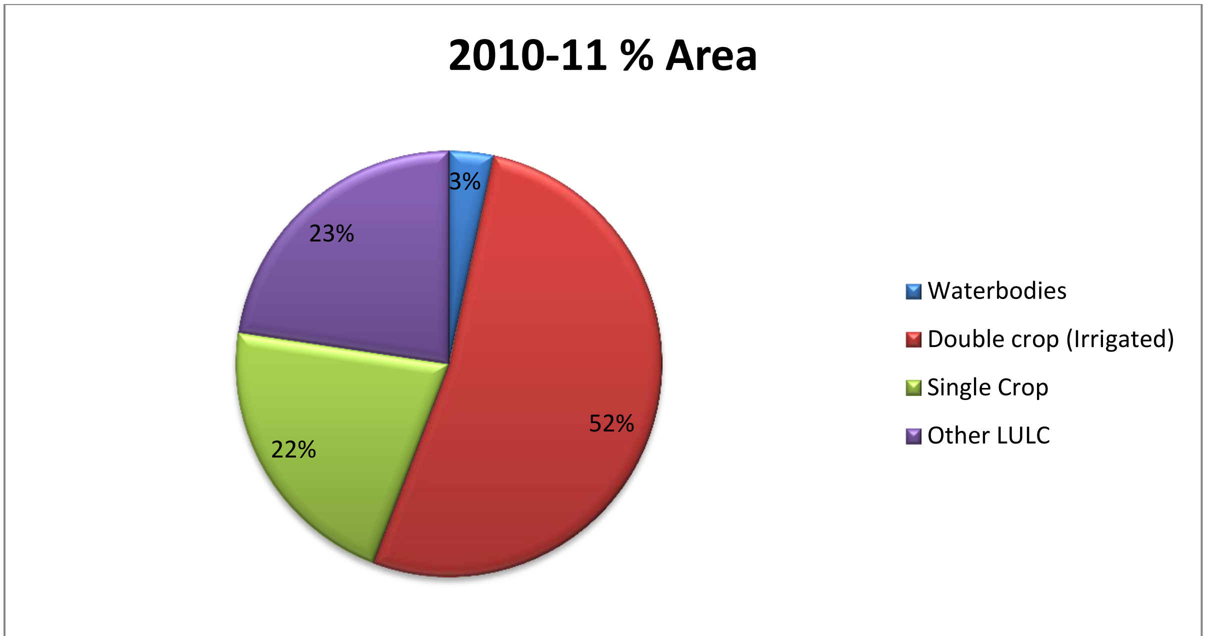
Figure 5-2: Classification images 2010-11 and 2015-16

The images above show the classification of respective years 2000-01, 2004-05, 2010-11, 2015-16

Table 5-1: Class wise area for all years

	Area (Hectares)			
Classes	**2000-01**	**2004-05**	**2010-11**	**2015-16**
Water Bodies	30860.7	33245.6	32132.6	20648
Double Crop (Irrigated)	345197	167606	499240	86980.2
Single Crop	297610	652171	205224	732023
Other LULC	278382	99031.9	215463	112387

5.4 Area wise Classification 2010-11 and 2015-16



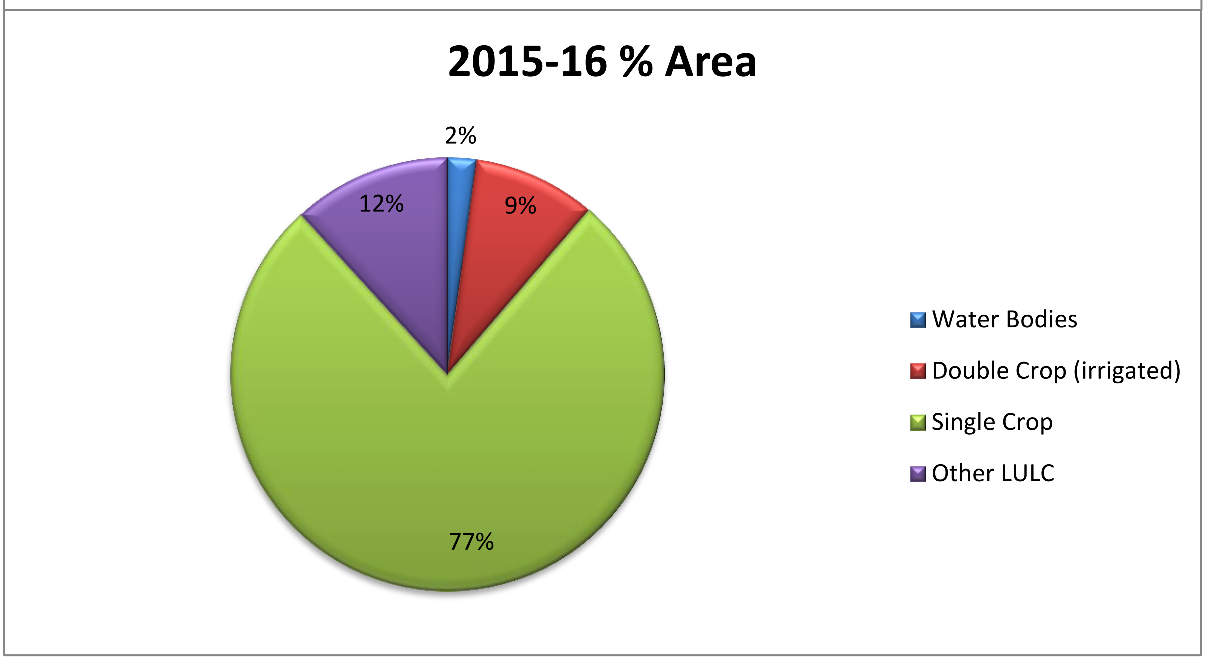
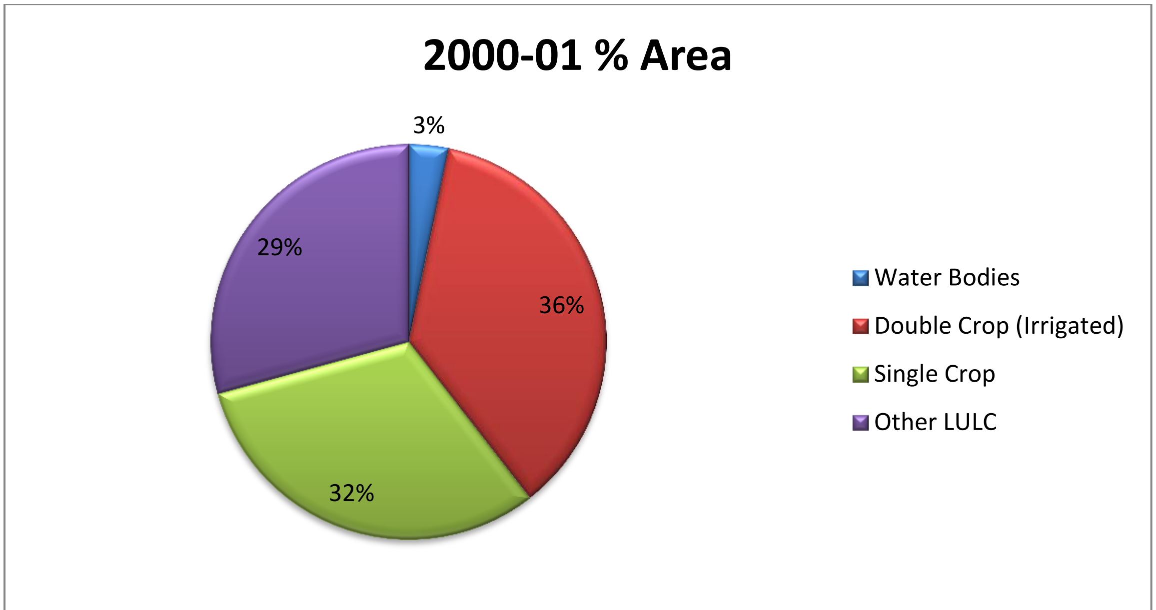


Figure 5-3: Area Wise percentage of LULC during the years 2010-11 and 2015-16

- The above shows the Area Wise percentage of LULC during the years 2010-11 and 2015-16

5.5 Area wise Classification 2000-01 and 2004-05



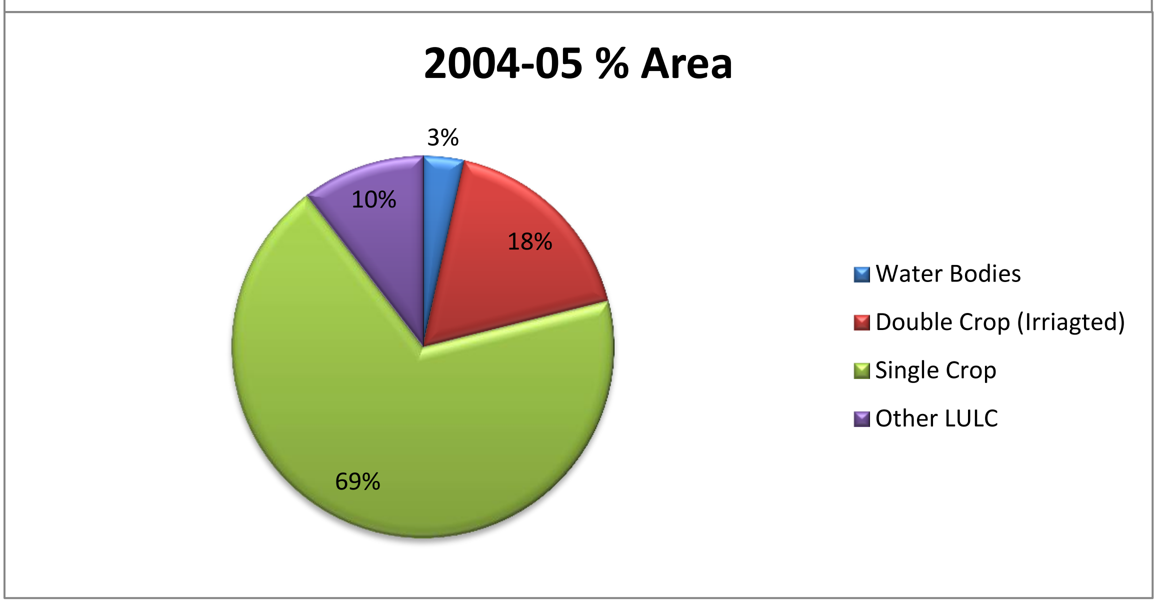
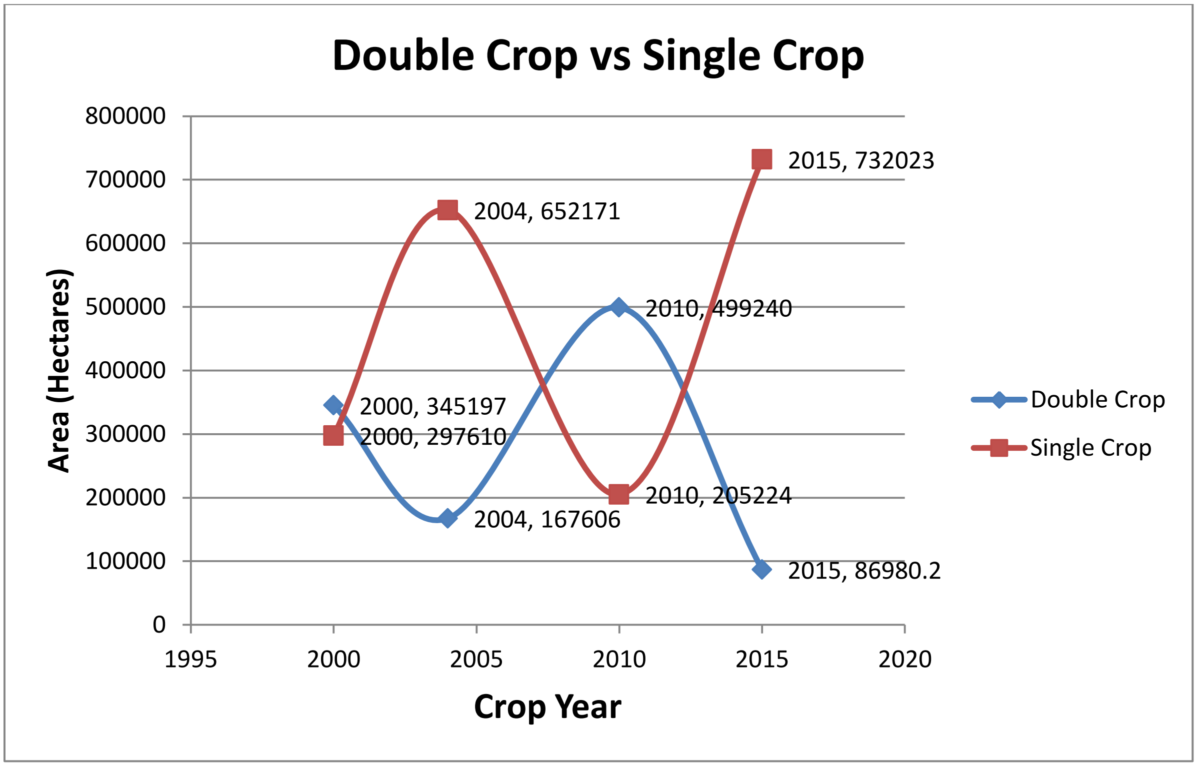


Figure 5-4: Area Wise percentage of LULC during the years 2000-01 and 2004-05

- The above shows the Area Wise percentage of LULC during the years 2000-01 and 2004-05

5.3 Double Crop Vs Single Crop



Graph 5-1: Double Crop Vs Single crop

- Considering the Sri Ram Sagar project command area crop intensity i.e. Double Crop and Single Crop during the irrigated (2000-01, 2010-11) and non irrigated years (2004-05, 2015-16).
- We can see the changes in the above graph that in the non irrigated years there is less double crop compared to double crop in irrigated years.
- Less single crop in irrigated years compared to non irrigated years because as single crop is also included in double crop in irrigated years.

5.2 Change Detection

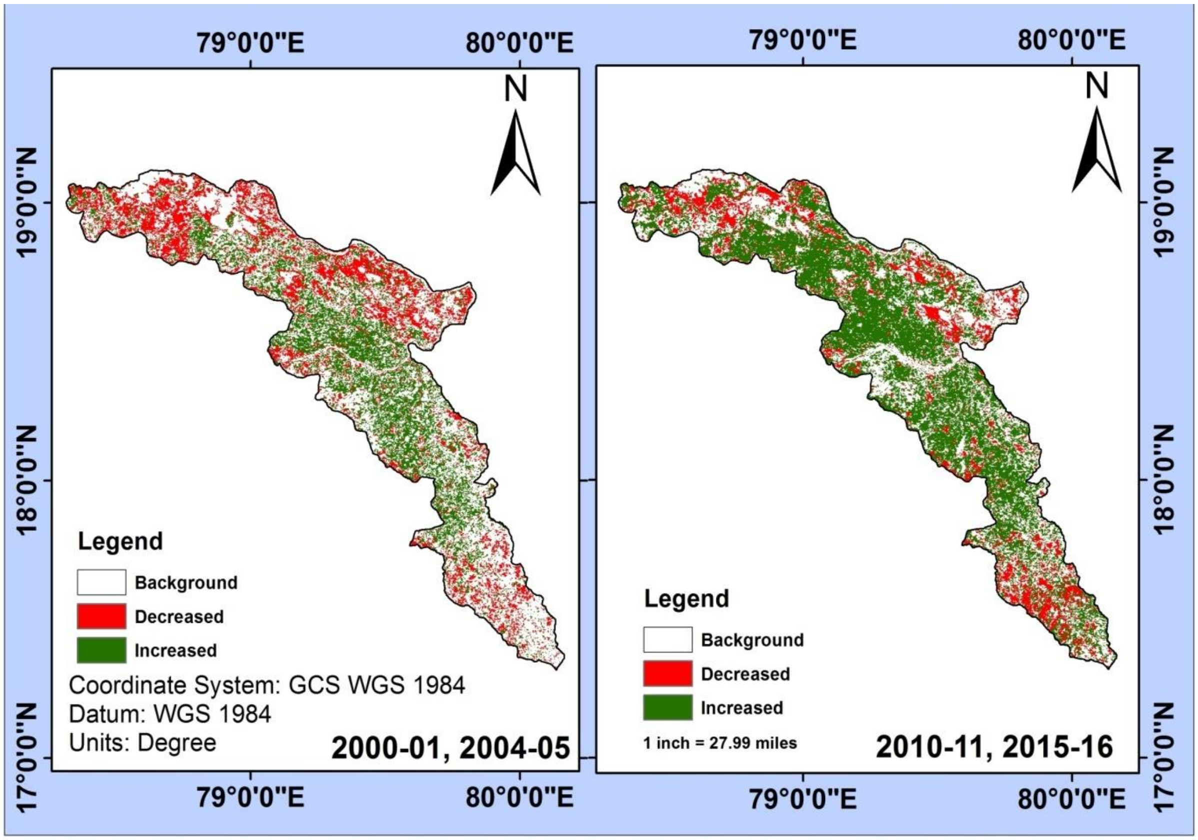


Figure 5-5: Change Detection

- The above image shows the change detection for the two set of years i.e.(irrigated and non irrigated years) for {2000-01, 2004-05} and {2010-11, 2015-16}
- The above change detection is done by considering the 30 percentage change i.e. it shows the values of both 30% decrease areas and 30% increased areas

5.6 Accuracy Assessment

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
Water Bodies	3	1	1	33.33%	100.00%
Double Crop (Ir	7	10	6	85.71%	60.00%
Single Crop	15	12	11	73.33%	91.67%
Other LULC	3	5	3	100.00%	60.00%
Totals	28	28	21		

Overall Classification Accuracy = 75.00%

Figure 5-6: Accuracy Report for the year 2000-01

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
Water Bodies	3	2	2	66.67%	100.00%
Double Crop (Ir	7	4	4	57.14%	100.00%
Single Crop	15	19	15	100.00%	78.95%
Other LULC	3	3	3	100.00%	100.00%
Totals	28	28	24		

Overall Classification Accuracy = 85.71%

Figure 5-7: Accuracy Report for the Year 2010-11

- The above images show the accuracy report for the irrigated years i.e. 2000-01 and 2010-11
- As data collected is based on the irrigated years . so, here I done the accuracy for the irrigated years only

5.7 Conclusion

- It has been observed from the above study that the irrigational water plays a vital role in crop intensity and crop production
- In years 2000-01 and 2010-11, there was release of water from SRSP Which helps in high double crop in command area
- But in years 2004-05 and 2015-16, there was no release of water from SRSP due to which there was less double crop in command area

Chapter 6
REFERENCES

1. Lillesand, T. M., and Kiefer, R. W., 1994. Remote sensing and image interpretation. 3rd edition. John Wiley & Sons, New York.

2. Textbook of Remote sensing and Geographical Information Systems by M. Anji Reddy.

3. Gumma, M., Pyla, K., Thenkabail, P., Reddi, V., Naresh, G., Mohammed, I., Rafi, I., 2014a. Crop Dominance Mapping with IRS-P6 and MODIS 250-m Time Series Data. Agriculture 4, 113-131.

4. Gumma, M., Thenkabail, P., Teluguntla, P., Rao, M., Mohammed, I., Whitbread, A., 2016b. Mapping Rice Fallow Cropland Areas for Short Season Grain Legumes Intensification in South Asia using MODIS 250m Time-Series Data. International Journal of Digital Earth.

5. Gumma, M.K., 2008. Methods and approaches for irrigated area mapping at various spatial resolutions using AVHRR, MODIS and LANDSAT ETM+ data for the Krishna river basin, India. http://publications.iwmi.org/pdf/H042567.pdf. ; Jawaharlal Nehru Technological University, Hyderabad.

6. Gumma, M.K., Mohanty, S., Nelson, A., Arnel, R., Mohammed, I.A., Das, S.R., 2015b. Remote sensing based change analysis of rice environments in Odisha, India. Journal of Environmental Management 148, 31-41.

7. Gumma, M.K., Nelson, A., Thenkabail, P.S., Singh, A.N., 2011b. Mapping rice areas of South Asia using MODIS multitemporal data. Journal of Applied Remote Sensing 5, 053547.

8. Gumma, M.K., Thenkabail, P.S., Gautam, N.C., Gangadhara Rao, T.P., Velpuri, N.M., 2008. Irrigated area mapping using AVHRR, MODIS and LANDSAT ETM+ data for the Krishna River Basin. Technology Spectrum, 2(1), 1-11.

9. Gumma, M.K., Thenkabail, P.S., Maunahan, A., Islam, S., Nelson, A., 2014b. Mapping seasonal rice cropland extent and area in the high cropping intensity environment of Bangladesh using MODIS 500m data for the year 2010. ISPRS Journal of Photogrammetry and Remote Sensing 91, 98-113.

10. Gumma, M.K., Thenkabail, P.S., Nelson, A., 2011e. Mapping Irrigated Areas Using MODIS 250 Meter Time-Series Data: A Study on Krishna River Basin (India). Water 3, 113-131.

11. Pardhasaradhi Teluguntla, Prasad S. Thenkabail, Jun Xiong, Murali Krishna Gumma, Russell G.2017 Congalton Spectral matching techniques (SMTs) and automated

cropland classification algorithms (ACCAs) for mapping croplands of Australia using MODIS 250-m time-series (2000–2015) data International Journal of Digital Earth.