MONITORING RICE CROPPING PATTERN AND FALLOWS IN CENTRAL AND WESTERN PART OF INDIA

A Project thesis submitted to partial fulfillment of the requirements for the Award of the Degree of

MASTER OF TECHNOLOGY
IN
SPATIAL INFORMATION AND TECHNOLOGY

By

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CERTIFICATE

This is to certify that the project work entitled ***"Monitoring Rice Cropping Pattern and Fallows in Central and Western Part of India"*** has been successfully completed by **Ms. P.VINEETHA (Roll No: 17031D3211).** During the academic year 2017-2019 as a partial fulfillment of the academic requirement of the Master's Degree in Spatial Information Technology of Center for Spatial Information and Technology (CSIT) from Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad.

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CERTIFICATE

This is to certify that the dissertation entitled "***Monitoring Rice Cropping Pattern and Fallows in Central and Western Part of India***" **has** been carried out by **Ms. P.VINEETHA** in partial fulfillment for the award of M.Tech, Spatial Information Technology, is a record of work carried out by her under my guidance and supervision.

The results embedded in this report have not been submitted to any other university or institute for the award of any degree or diploma.

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DECLARATION

I hereby declare that the dissertation entitled "***Monitoring Rice Cropping Pattern and Fallows in Central and Western Part of India***" is submitted by me in partial fulfillment of the requirements for the award of **Master of Technology in Spatial Information Technology** from **Jawaharlal Nehru Technological University Hyderabad,** and is a record of bonafide work carried out by me at ICRISAT as a student of **Centre for Spatial Information Technology, IST, JNTU Hyderabad** under the guidance of **Sri. B. Harish** and **Dr. Murali Krishna Gumma, Senior Scientist, Head- RS&GIS Lab, ISD, ICRISAT, Patancheru.** The results embodied in this project work have not been submitted to any other University/Institution for the award of any degree or diploma.

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ABSTRACT

India has the largest area under rice cultivation and holds the second position all over the world as it is one of the principal food crops. Rice-fallow croplands areas are those areas where rice is grown during the Kharif growing season (June- October) followed by fallow during Rabi season (November-February). These croplands are not suitable to grow in Rabi season rice due to their high water needs, but are suitable for short season (≤ 3months). According to national statistics there is an increase in the rice areas in Central and Western states of India. The goal of this project is to monitor the rice-fallow cropland areas & mapping the expansion of rice areas. This study is conducted in Central and Western states of India where different rice eco-systems exist. Time series Moderate Resolution Imaging Spectroradiometer (MODIS) 16days Normalized Difference Vegetation Index (NDVI) at 250m spatial resolution and season wise intensive ground survey data was used. We have applied hierarchical classification and Spectral Matching Techniques (SMT) to map rice areas and the fallows there after (rabi-fallows), in Central and Western states of India. And change detection was carried during 2000-2015 and 2010-2015. The resultant rice maps are compared with available national and sub-national level statistics.

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CHAPTER-1

INTRODUCTION

1.1 General

Agriculture is the backbone of Indian economy and the crucial sector for ensuring food security and unquestionably the largest livelihood provider in India, more so in the vast rural areas. It supports 58% of the population. Around 51% of India's geographical area is under cultivation. It also contributes a significant figure to the Gross Domestic Product (GDP). Sustainable agriculture, in terms of food security, rural employment, and environmentally sustainable technologies such as soil conservation, sustainable natural resource management and biodiversity protection, are essential for holistic rural development. Timely availability of information on agriculture is vital for taking informed decisions on food security issues. India is one of the few countries in the world that uses space technology and land-based observations for generating regular updates on crop production statistics and providing inputs to achieve sustainable agriculture. Satellite-based optical and radar imagery are used widely in monitoring agriculture. Radar imagery is especially used during monsoon season. Integrated use of geospatial tools with crop models and in- situ observation network enables timely crop production forecasts and monitoring.

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. The reliable prediction of crop for remote and inaccessible areas is tedious and time consuming by conventional or traditional methods. 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.

Rice is one of the chief grains of India. India is one of the leading producers of this crop. Moreover, this country has the largest area under rice cultivation and holds the second position all over the world as it is one of the principal food crops. Rice is grown in approximately 34% of the overall cropped territory of the country. Rice production comprises 42% of the overall food crop production in the country. Rice is the basic food crop and being a tropical plant, it flourishes comfortably in hot and humid climate. Rice is mainly grown in rainfed areas that receive heavy annual rainfall. That is why it is fundamentally a kharif crop in India. It demands temperature of around 25 degree Celsius and above and rainfall of more than 100 cm. Rice is also grown through irrigation in those areas that receives comparatively less rainfall

Rice is an important crop for food security in many countries, especially in Asia where it dominates overall crop production and overall food consumption to a much greater extent than elsewhere in the world. Stable and sustainable rice production requires information on where, when and how rice is grown. Considering the extent and significance of rice cropping patterns, it is necessary for farming systems researchers as well as agriculture planners and land managers to collect and monitor spatial information of cropping patterns. The traditional way, which involves high cost and labor, is to gather such information over large areas by the ground survey. However, this method is not applicable to current demands which require rapid and timely updates on the distribution and area per rice cropping pattern. Fortunately, multi- or hyper-temporal remote sensing techniques can offer a cost-effective way to detect cropping patterns on a large-scale landscape, due to the sensitivity of remote sensors to crop texture variations and their capability to capture the temporal signature of crops.

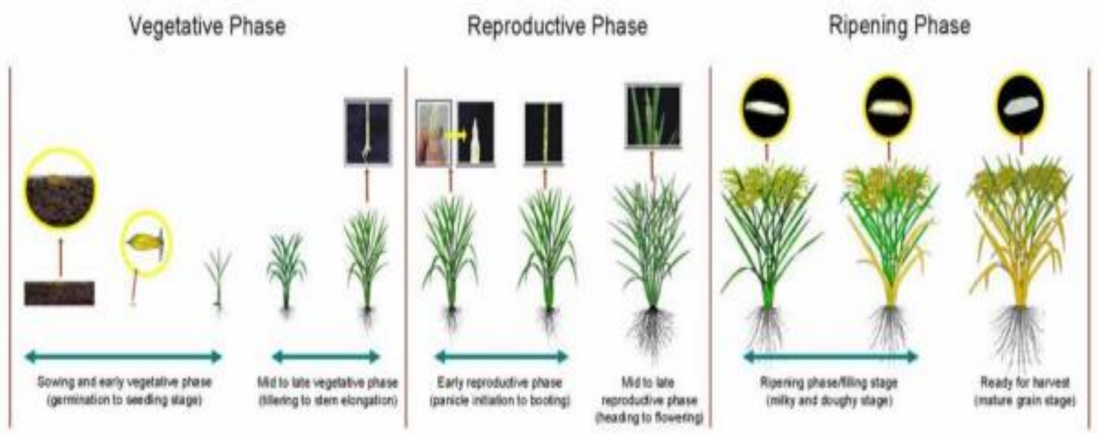

Figure1.1 - Rice growth phases (source: http://www.knowledgebank.irri.org/step-by-step-production/pre-planting/crop-calendar)

The first phase is the vegetative phase (from 45 to 100 days) which consists of the germination, seedling, tillering and stem elongation stages. Germination starts when the seeds are sown in the wet soil and it results in the formation of the seedling. Tillering starts about 15 days after sowing and continues until flowering. At the later stage of tillering, towards the panicle initiation stage, stem elongation begins and contributes to a rapid increase in the vertical expansion of the rice canopy. It is followed by the reproductive phase (around 35 days) which includes the panicle initiation, heading, and flowering stages. During this phase, the plant is characterized by a decrease of the number of tillers, the development of paniculate leaf, panicle formation, and grain development. Ripening is the final phase (around 30 days) with its milk, dough and mature grain stages. Irrigation is stopped in the field from ripening up to harvest and the overall plant water content decreases. Rice fields are usually inundated during the planting and vegetative stage, and detection of this is a key element of most remote-sensing rice detection algorithms. However, for other crops, wheat, for example, is not flooded by irrigated water during the vegetative phase, but the growth duration and phases can be similar to rice. As for fallow land that remains unplanted between two cultivations, there is usually little or no vegetation.

These crop phases coincide with spatial and temporal changes in plant growth. Changes in plant growth can be detected due to changes in the interaction of the plant with light and microwaves and thus can be observed by remote sensing data That means that each crop (such as rice, wheat, maize, bean, vegetable) has distinct growth phases and that the changes in the crop biomass, canopy, water content over time can be used to distinguish different crops. Given the diversity of cropping patterns, it is difficult to discriminate the different cropping patterns using one single-date image Detecting rice cropping patterns requires analysis of dense time series to distinguish rice from other crops or fallow as such, a rice-rice pattern would be different from rice-fallow because of the distinct temporal pattern. Passive remote sensing data from optical sensors have been utilized to delineate rice cropping systems and crop patterns using time series images. Regarding the application of optical sensors to map rice-based cropping systems, most studies were conducted in countries or regions with very large rice growing areas. For example, Gumma et al. (2014) mapped rice cropping intensity in Bangladesh using MODIS 8-day composite data with 500 m spatial resolution. Manjunath et al. (2006) derived the rice rotation map In India using IRS WiFS data with 188 m spatial resolution and 5-day revisit capability, Nguyen et al. (2012) mapped the Mekong Delta rice cropping patterns using 10-day SPOT VGT NDVI 1 km spatial resolution imagery. Also in the Philippines, Asilo et al. (2014) used 8-day composite MODIS NDVI data to map rice cropping patterns in Nueva Ecija and Pangasinan provinces. Similar works have also been done using Landsat TM (Martínez-Casasnovas et al., 2005) and IRS-1A & IRS-1B images (Panigrahy & Sharma, 1997). Gumma et al. (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.

1.2 Role of Remote Sensing in the field of Agriculture:

Remote sensing is the acquisition of information about an object or any phenomenon without making any physical contact with the object. It is a phenomenon that has numerous applications including photography, surveying, geology, forestry and many more. But it is in the field of agriculture that remote sensing has found significant use. There are many applications of remote sensing in the agricultural sector. Below is a summary of these applications

A major problem in the agriculture is the inadequate field measured data to describe the process. Remote Sensing has been identified as a tool to produce information in spatial and temporal domain, instead of point measurement, in digital form, with high resolution. The remotely sensed data acquired from space borne platforms, owing to its wide synoptivity and multi spectral acquisition provides spatial information about the various processes of the cropland. This spatial information can be used as input data for crop models. Remote Sensing techniques can produce high spatial coverage of important terms for large areas, but at the cost of rather sparse temporal resolution.

Applications of remote sensing in agriculture:

1. Crop identification
2. Crop diversification
3. Yield estimation and prediction
4. Crop acreage estimation
5. Crop condition assessment and stress detection
6. Identification of planting and harvesting dates

7. Crop yield modeling and estimation
8. Soil moisture estimation
9. Irrigation monitoring and management
10. Soil Mapping
11. Monitoring of droughts.
12. Identification of pest and disease infestation
13. Land cover and land degradation mapping
14. Identification of problematic soils.

1.3 Problems of Remotes Sensing for Indian conditions:

1. Small size of plots
2. Diversity of crops sown in a particular area
3. Variability of sowing and harvesting dates in different fields
4. Inter cropping and mixed cropping practices
5. Extensive cloud cover during the rainy season

1.4 Objectives of the study:

1. To identify and map the rice cropping pattern in Central and Western part of India
2. To map Rice-Fallow areas in Central and Western part of India
3. To asses the changes in the Rice-Fallow areas during 2000-2010-2015.

CHAPTER 2
STUDY AREA

2.1 Central and Western India

Central and Western India consists of Madhya Pradesh, Gujarat, Maharashtra and Rajasthan. Since this area covers a large part on India with tropic of cancer passing thorough midway, this region consists of areas ranging from hot arid regions to areas of Western-Ghats with heavy rainfall.The total study area lies between the latitudes-15°55' & 30°32'N and longitudes- 68°40' & 82°9'N with the total area of 1,154,221km^2

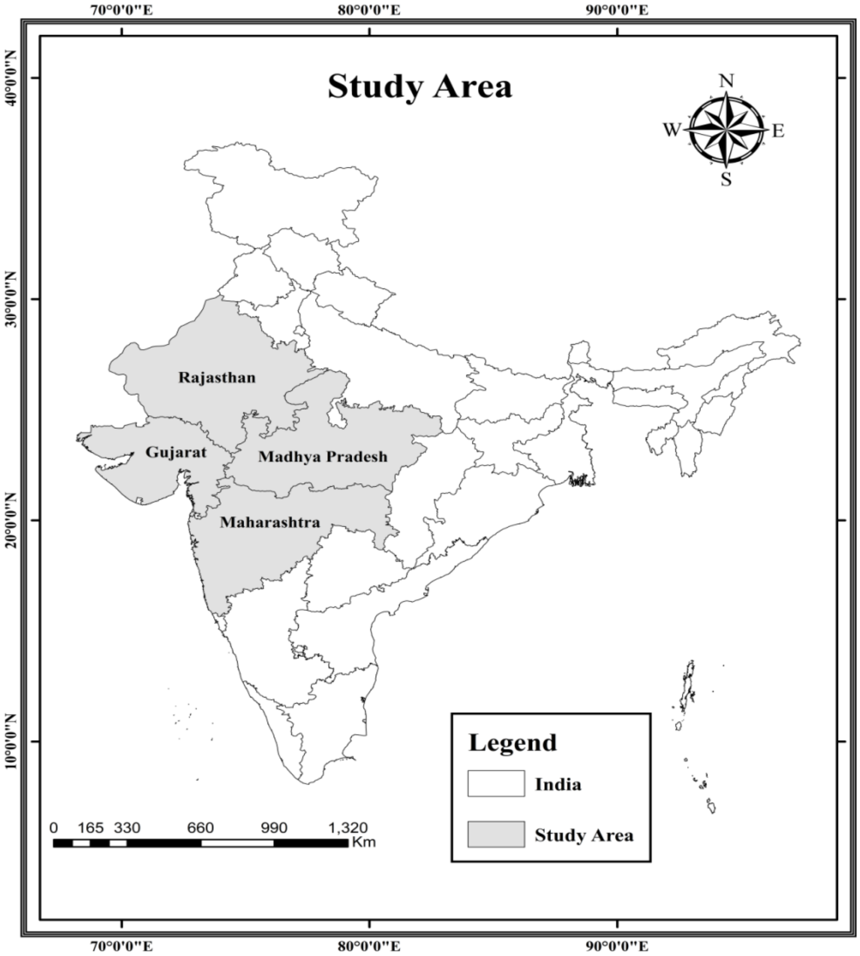

Figure2.1 – Study area

2.1.1 Rajasthan

The cultivated area is 17.4 million ha, constituting almost half of the total area of the state. Over 70% area is rainfed with average precipitation of 575mm. The soils are coarse and poor in fertility and the cropping intensity is 125%. Major crops of this state are pearl millet, maize, chickpea, mustard, Custer bean and spices. This state lies between latitudes 23°30' &30°32'N and longitudes 69°30' &78°17'E with the total area of 342,239km^2.

2.1.2 Gujarat

The state characterized by hot semi-arid conditions has 49% of the total geographical area as cultivated lands (9.6 million ha). The irrigated area is only 32% of the total cultivated area. The cropping intensity is low at 118%. The total food grains production of the state is 5.26 million tones. The major crops are groundnut, cotton, wheat, pearl millet, maize, sorghum, rice, castor, gram and mustard. This state lies between latitudes 20°10' &24°70'N and longitudes 68°40' &74°40'E with total area of 196,024km^2.

2.1.3 Madhya Pradesh

Madhya Pradesh is primarily Kharif crops growing state. Kharif crops occupy about 54.25% whereas Rabi crops occupy about 45.75% area out of the total cropped area in the state. Major Crops in Madhya Pradesh are Paddy, Wheat, Maize, Jowar, Gram, Tur, Urad, Moong, Soya bean, Cotton, Sugarcane, Potato, Onion, Garlic, Papaya, Banana and Mango. This state lies between latitudes 21°15' & 26°88'N and longitudes 74°03' & 82°9'E with total Area of 308,245km^2.

2.1.4 Maharashtra

The cultivated area (17.43 million ha) is about 80% of the total geographical area and the irrigated area is about 17% (2.94 million ha). With large dependence on rainfall, the cropping intensity is around 127%. The major crops of the state are Mangoes, Grapes, Bananas, Oranges, Wheat, Rice, Sorghum, Pearl millet, Pulses, Groundnut, Cotton, Sugarcane, Turmeric and Tobacco. This state lies between the latitudes 15°55' &22°N and longitudes 72°50' &80°9’E with total area of 307,713km^2.

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.

6. 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 General

This Chapter deals with the Satellite data, Ground data, software's used and methodology carried out for this project.

4.2 Data Used:

- **MOD13Q1** (MODIS Terra Vegetation Indices 16-Day Level3 Global 250 m)
- **DEM** (Digital Elevation Model)
- **Historical Rice-Fallow Maps**
- **Vector Data (India Shapefile)**
- **Ground Data**

4.2.1 MODIS Data:

MODIS (Moderate Resolution Imaging Spectroradiometer) is a main tool on board Terra (initially referred to as EOS AM-1) and Aqua (initially referred to as EOS PM-1) satellites. Terra's orbit around the Earth is scheduled 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. MODIS captures data in 36 spectral bands at different spatial resolutions (2 bands (250m), 5 bands (500m) and 29 bands (1km)). In total the instrument captures the entire earth for every 1-2 days with ranging wavelength o.4μm to 14.4μm which makes it possible to get cloud free data when available immediately after rainy or cloudy day. These data will enhance our knowledge of global dynamics and processes taking place on land, in the lower atmosphere and in the oceans. MODIS plays a crucial role in developing validated, global, interactive Earth system models capable of predicting global change correctly enough to help policymakers make sound environmental protection choices.

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) and 6.1 mbps (orbital average)
- Quantization: 12 bits
- Spatial Resolution: 250 m (bands 1 to 2), 500 m (bands 3 to 7), 1000 m (bands 8 to 36)
- Design Life: 6 years

MOD13Q1 **(MODIS Terra Vegetation Indices 16-Day Level3 Global 250 m)** was used for the study. This data was provided for every 16 days with 250m spatial resolution as L3 product in Sinusoidal Projection. MOD13Q1 has 2 primary vegetation layers. The first one is NDVI (Normalized Difference Vegetation Index) and the other is EVI (Enhanced Vegetation Index (EVI). The algorithm chooses the best available pixel value from all 16 day period acquisitions using the criteria of low view angle, Highest EVI/NDVI value and low clouds. The data will be in HDF format. The HDF file will have MODIS reflectance bands red (1), near-infrared (2), Blue (3), mid-infrared (7) and four observation layers along with vegetation and the two quality layers. Rajasthan, Gujarat, Madhya Pradesh, Maharashtra in total covers five tiles (i.e., h24v5, h24v6, h25v6, h24v7, h25v7)

Spatial Resolution: 250m

Temporal Resolution: 16 days

Coordinate System: Sinusoidal

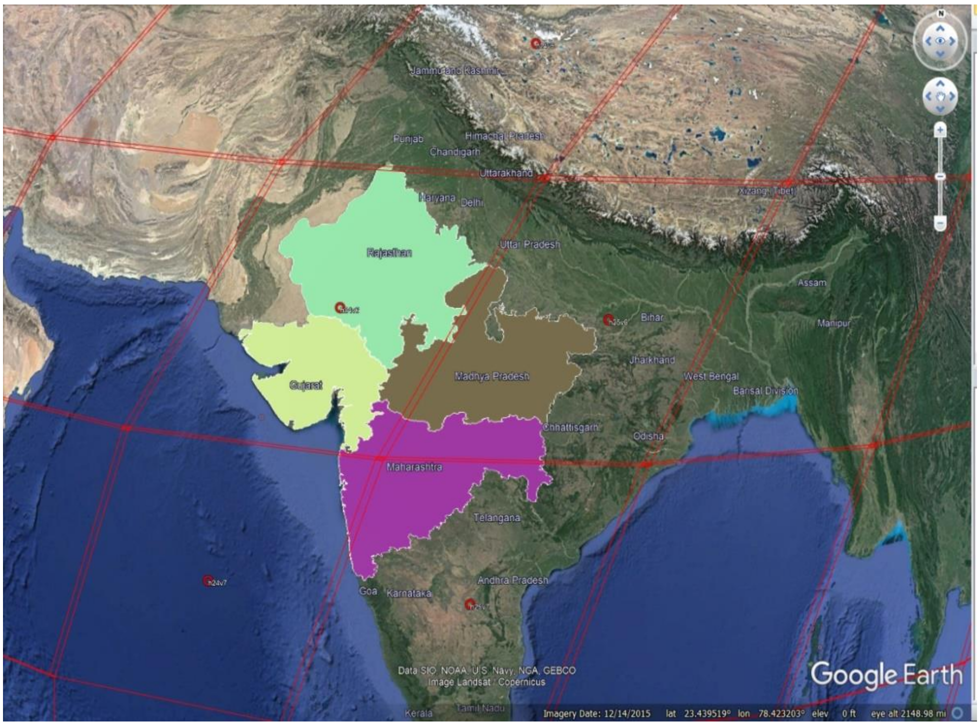

Figure4.1 – MODIS Tiles covering Study Area

4.2.2 DEM:

The DEM (Digital Elevation Model) used for classification was SRTM(Shuttle Radar Topography Mission) DEM of 30m spatial resolution, which was used as one of the layer while classification to prepare agriculture and non-agriculture mask.

4.2.3 Historical Rice-Fallow Maps:

Historical Rice-Fallow maps of 2000 and 2010 years are taken from ICRISAT RS&GIS Team. These maps have 11 classes of which seven classes are considered as rice classes. These maps are further used for mapping the change detection for 2000-2015 and 2010-2015.

4.2.4 Vector Data (India Shape file):

The Vector data used for classification and preprocessing is Indian States shape file. The study area is extracted from this Indian Shape file.

4.2.5 Ground Data:

The ground data was collected by ICRISAT -RS/GIS TEAM from 328 sample sites. Ground survey information samples were based on local expert knowledge, distinct LULC type, and preliminary land-use classifications. For each location following information was recorded:

- Existing crop type
- Soil type
- GPS Coordinates
- Crop calendar
- Crop intensity(single, double and triple crops)
- Cropping pattern(previous/present including season wise) Irrigation techniques/watering methods

These ground points are further used for class identification, validation and accuracy assessment.

Figure4.2 Ground data Field images

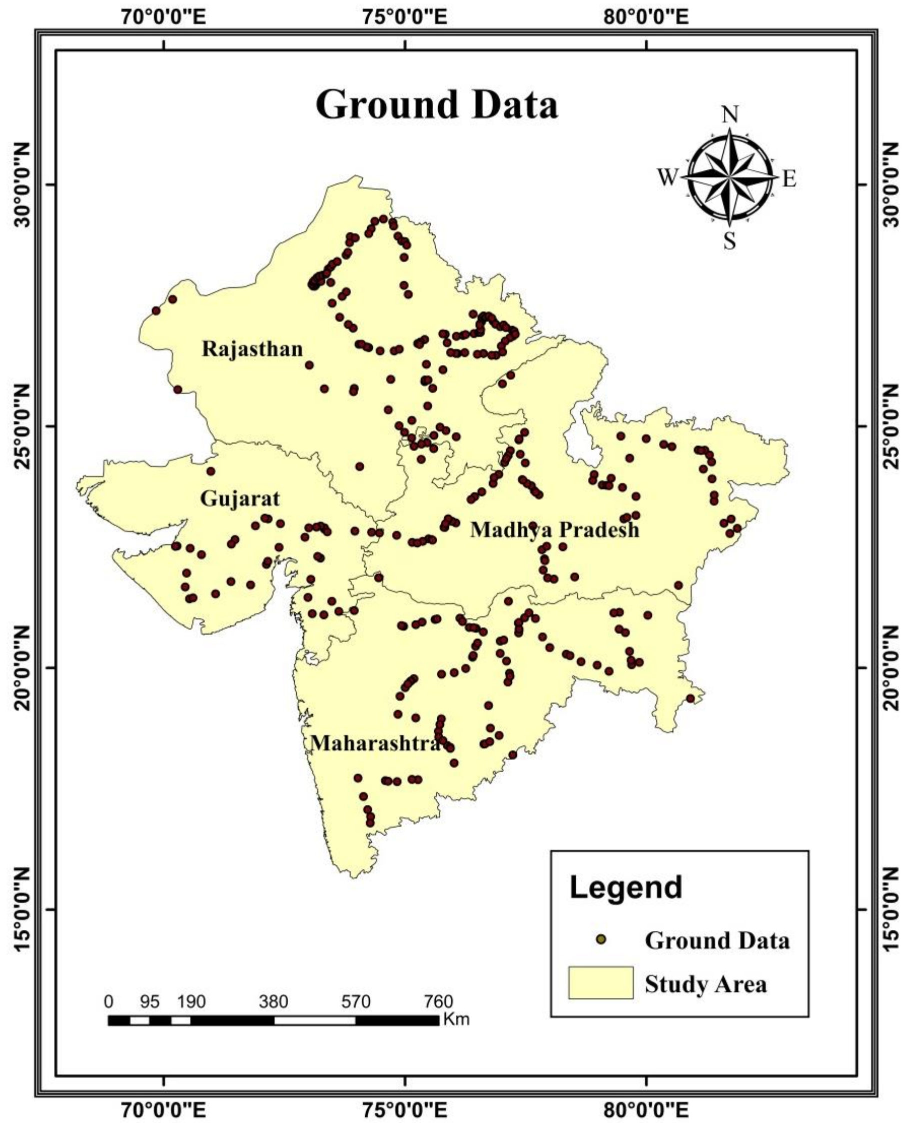

Figure4.3 Field plot data point distributions in the study area.

4.3 Software used:

- MRT (Modis Reprojection Tool)
- ERDAS ER Mapper
- ERDAS IMAGINE 2014
- ArcGIS 10.4
- Google Earth Pro
- MS Office

- MRT(MODIS Reprojection Tool, Version 4.1) is 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). WE have used this tool for Data Conversion.

- ER Mapper involves in advanced image processing and compression capabilities. We have used ER Mapper for preparation of Mega File Datasets which will be further used for classification purpose.

- ERDAS Imagine is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications. 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, mosaicking of imagery, stereo and automatic feature extraction of map data from imagery.

4.4 Methodology:

The present study used MOD13Q1 temporal data to identify the rice cropping areas. The 16 days composites are taken to make a time series dataset for a crop year or a calendar year. With these datasets we can identify start of the season, peak of the season and end of the season for crop growing locations using temporal profiles. Using the NDVI values we can also identify the crop type based on certain peak thresholds for that crop. In this project we applied Spectral Matching Technique which is found to be ideal in mapping rice areas (Gumma et al., (2011)). Mapping spatial distribution of rice fallows using MODIS 250 m 16-day time series and ground survey data using spectral matching techniques is a significant latest advancement in the use of this technique. Figure3.4 shows the methodology carried out for this study.

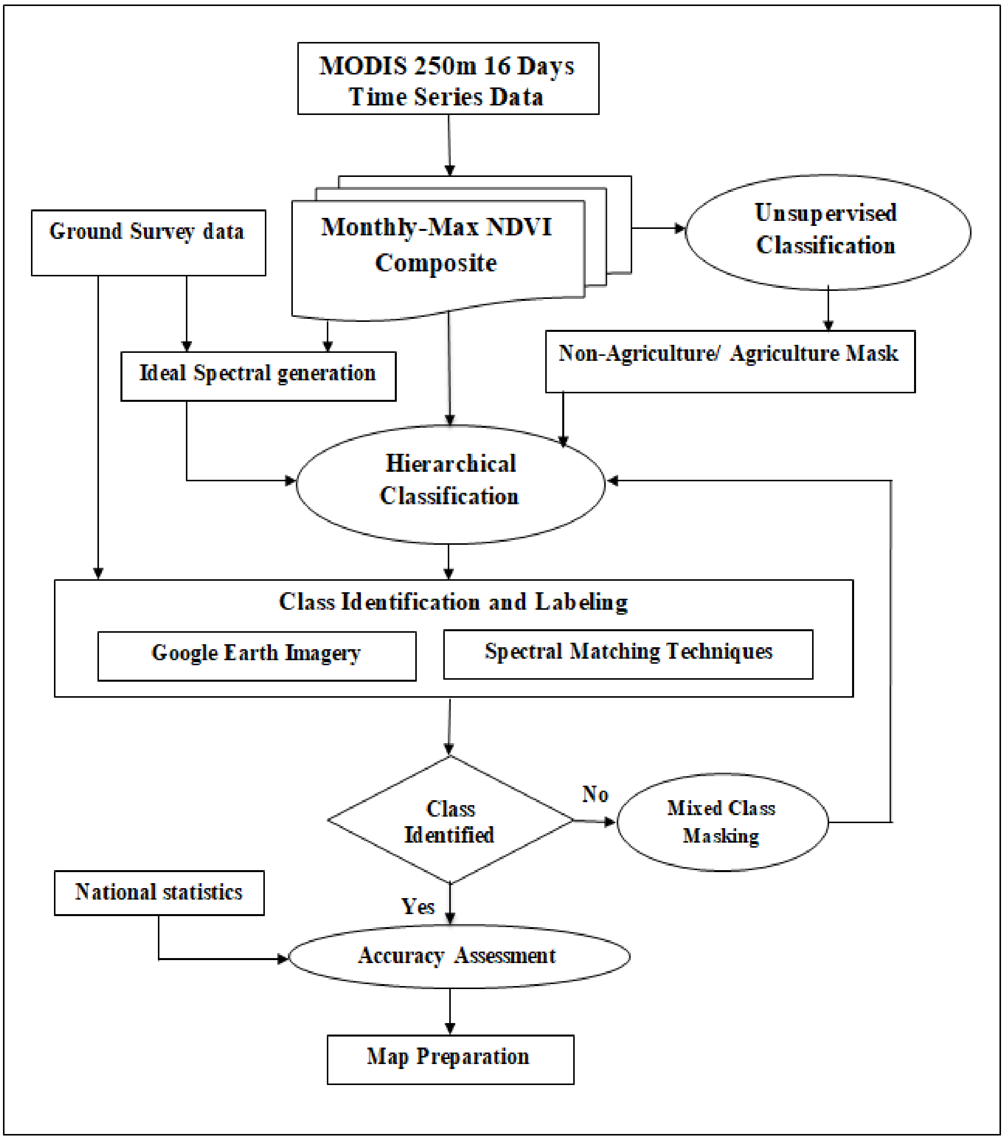

Figure4.4 Flow chart showing methodology

4.4.1 Preparation of Datasets:

- **Downloading the data:** The modis data required is downloaded from USGS EROS data center (https://e4ftl01.cr.usgs.gov/MOLT/) in the form of HDF files.
- **Format Conversion and Reprojection:** MRT (MODIS Reprojection Tool) was used for Data Conversion and Reprojection. The downloaded files of MODIS are in .hdf format and it will be converted into .tif files in this tool. Process In MRTool is as follow:

- Adding .hdf files: Add the Downloaded modis .hdf files by clicking Open Input File. We have selected a single day images at a time. Five tiles are covering the entire study area (i.e., h24v5, h24v6, h25v6, h24v7, h25v7). Once the .hdf files are loaded, the source information is displayed in the Input File Info, Available/Selected bands, Spatial Subset and Coordinates.
- Band Selection: By default, all available bands are selected and appear in the Selected Bands. We need only **NDVI** bands. Click on all the unwanted bands and deselect them
- 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
- Resampling**:** Selected the Resampling Type as "Nearest neighbor".
- Reprojection: 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.
- Executing the conversion: Click on the run button to start the conversion process.

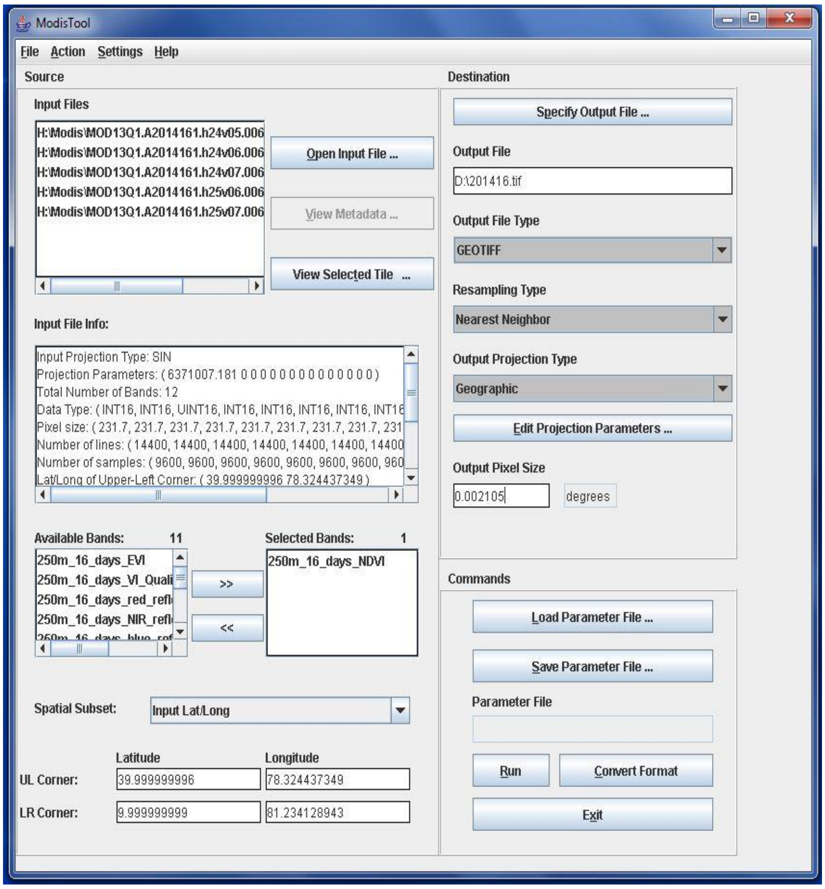

Figure4.5.a MRT Application Interface

After processing, the status window appears as "Finished Processing". Similar procedure is done for all the tiles of the Julian dates for the given year. Figure4.5.(a, b) shows the MRT Application interface.

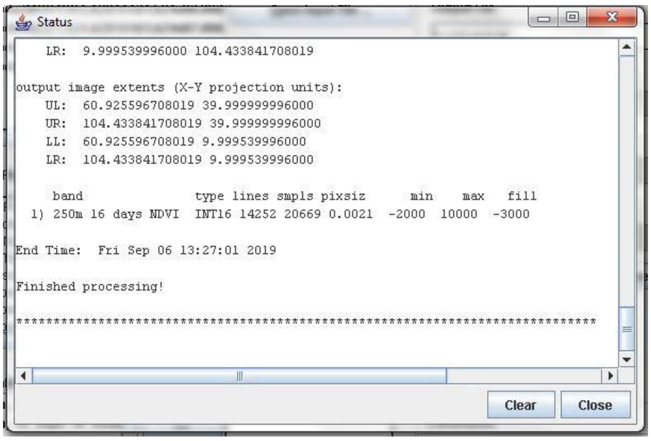

Figure4.5.b MRT Application Interface

4.4.2 Mega Datasets Preparation:

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 limitations for size or dimension of a mega-file.

A time series of MODIS 16-day composite reflectance images of 250m resolution was obtained from June, 2014 to May, 2015 (MOD13Q1 data product).The 16-day composite images in the MOD13Q1 dataset are free of cost and pre-calibrated. The large scale size and daily overpass rate of MODIS make it attractive for crop mapping for 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. The 16-day composite images were downloaded for the year 2014-2015. There were one or two composites per month. The monthly MVCs were stacked into a 12-band NDVI MVC mega-file image. This process is done in ERDAS ER Mapper (Figure4.6).

- Stacking of all the bands: All the required bands for the NDVI Mega-file are added and stacked together to form a single file.

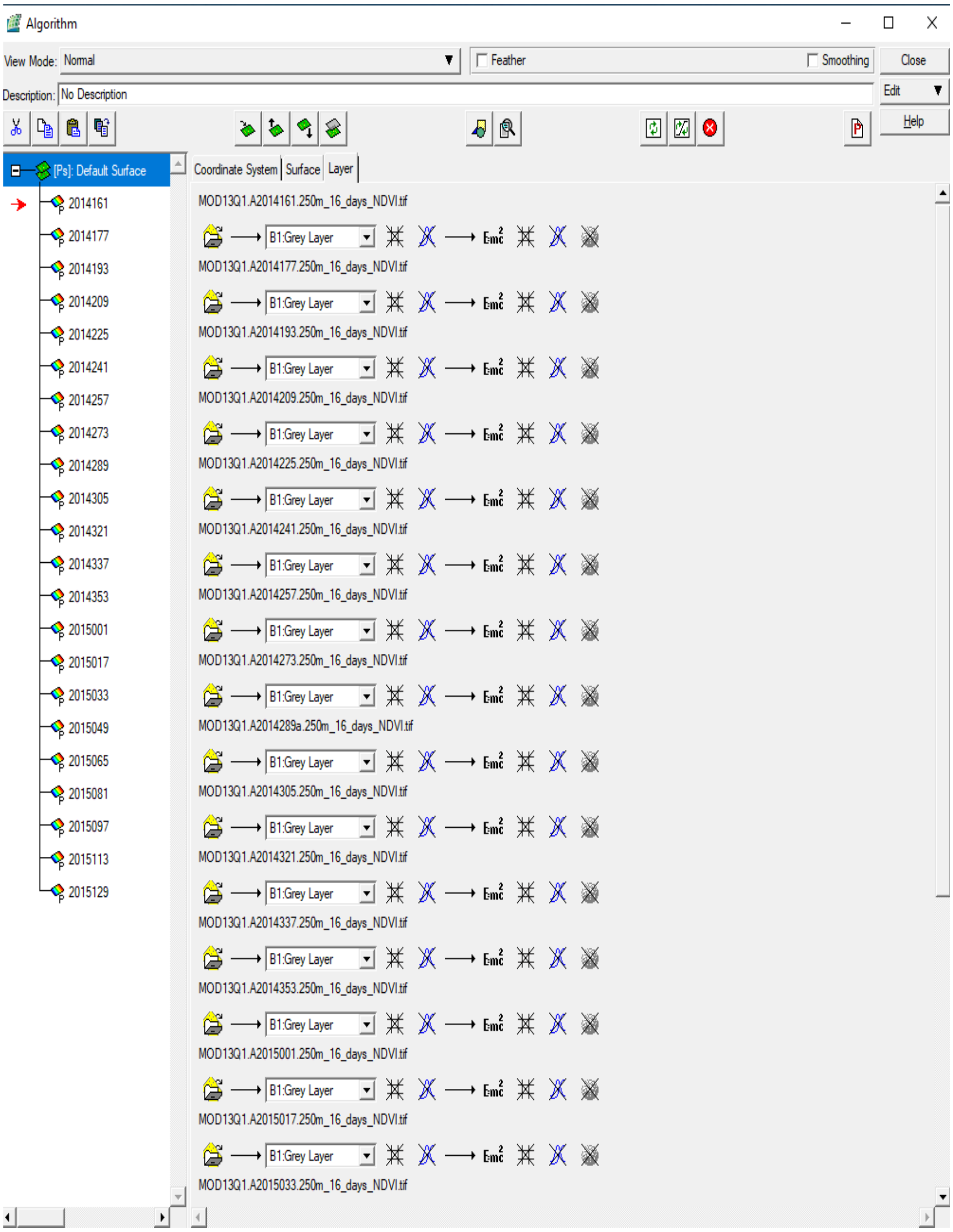

Figure4.6. Stacking of Time series data

- NDVI Maximum Value Composite (MVC): 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. 16day MODIS NDVI spectral images are composited to get monthly maximum value composites

$$NDVI\ MV_{Ci} = Max\ (i1, i2, \ldots)$$

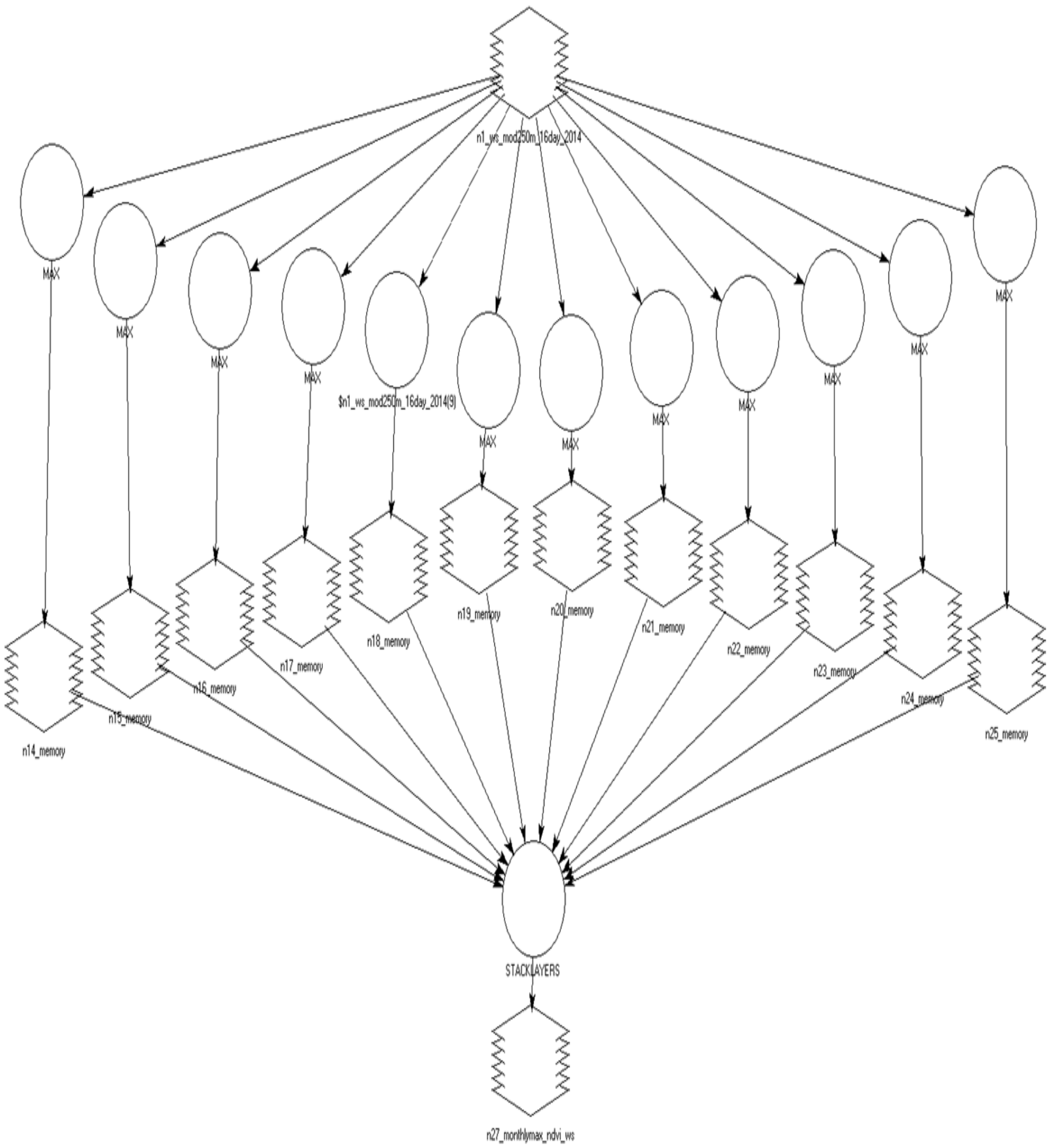

Figure4.7. Model for NDVI max value composite

Where MVC_i is Monthly maximum value composite of i^{th} month (e.g.: "i" is Jan-Dec). i1, i2, i3, i4,. 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. Figure3.7 represents the model for NDVI max value composite and Figure 4.8 represents the mega file data cube.

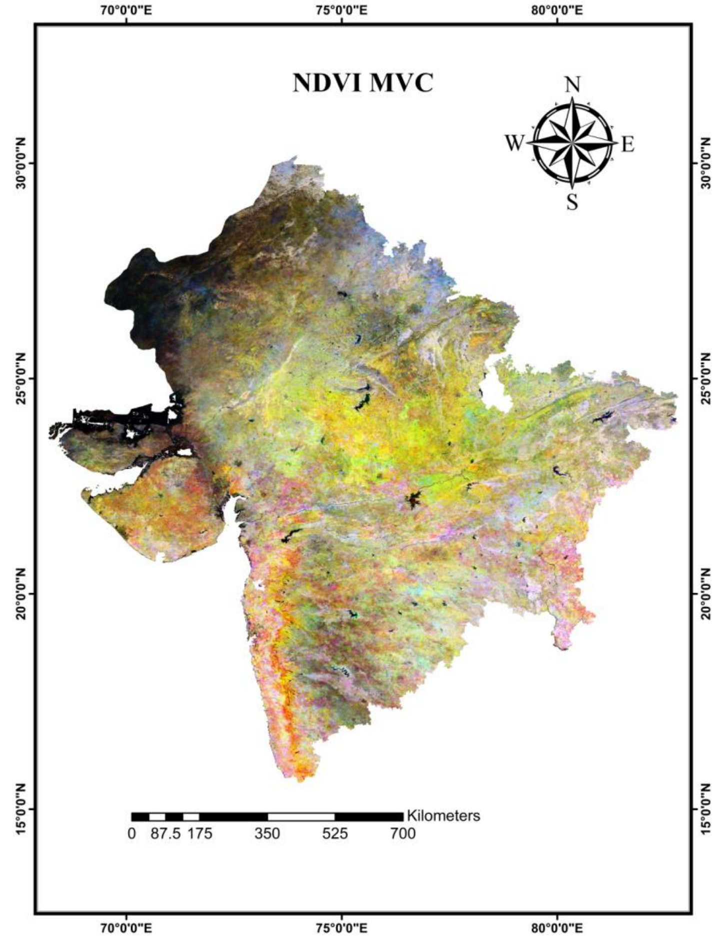

Figure4.8. NDVI Mega File Data Cube

4.4.3 Slope Map Generation:

SRTM 30m DEM was downloaded from USGS Earth Explorer for the study area. The 30m SRTM covers total of 138 tiles for the study area.

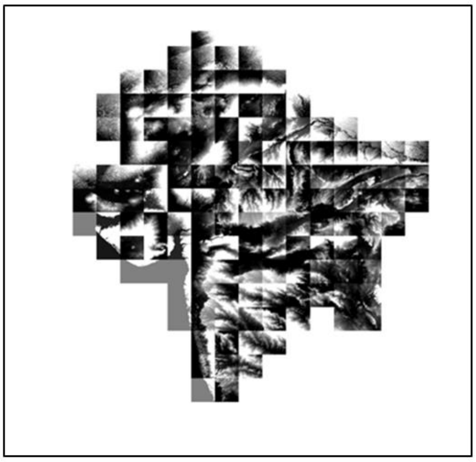

Figure4.9. SRTM 30m DEM Tiles for study area

These tiles are further mosaicked and slope map was generated from this mosaicked image. This slope map was further used in classification.

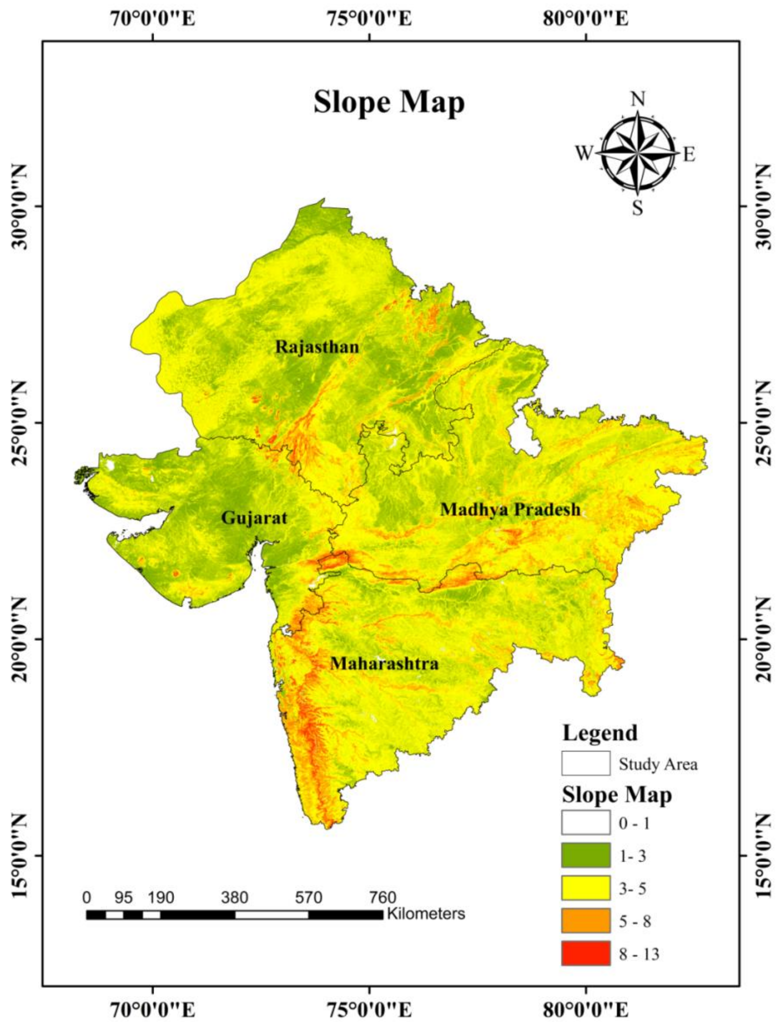

Figure4.10. Slope map

4.4.4 Agricultural Mask File Generation:

4.4.4.1 Unsupervised Classification:

After the generation of mega files, the slope map is layer stacked along with it. And the 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, 60 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 and spectral matching techniques. In unsupervised classification, based on natural groupings of the spectral properties of the pixels, without the user mentioning how to classify any portion of the image the software classifies 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 60 iterations and convergence threshold of 0.99. In all 60 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 60 classes obtained on time series composite from the unsupervised classification were merged using rigorous class identification and labeling using protocols. From these Classes we generated an Agricultural and Non-Agricultural mask which was further used for generating the rice maps.

4.4.4.2 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 labelling 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

4.4.4.3 Class Identification and Labelling process:

The class identification and labelling 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 labelling, 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

4.5 Rice Map Generation:

4.5.1 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. 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 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 are based on annual average NDVI values and timing of the onset of greenness

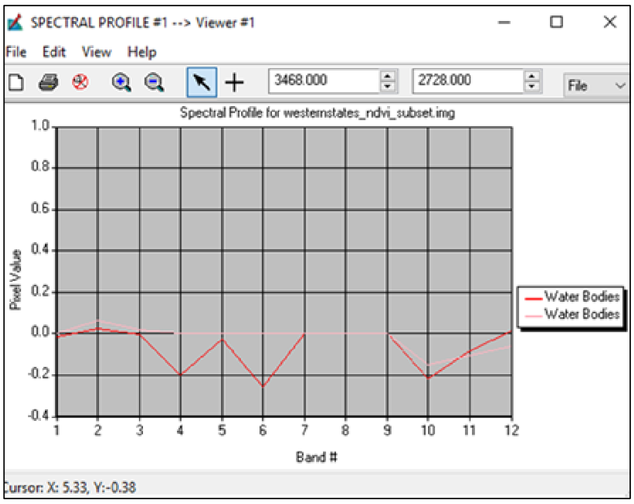

Figure4.11.a, Spectral Signatures for Water Bodies

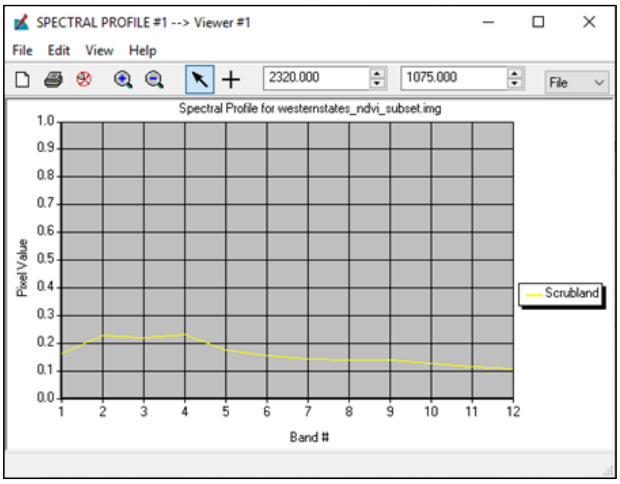

Figure4.11b. Spectral Signatures for Scrubland

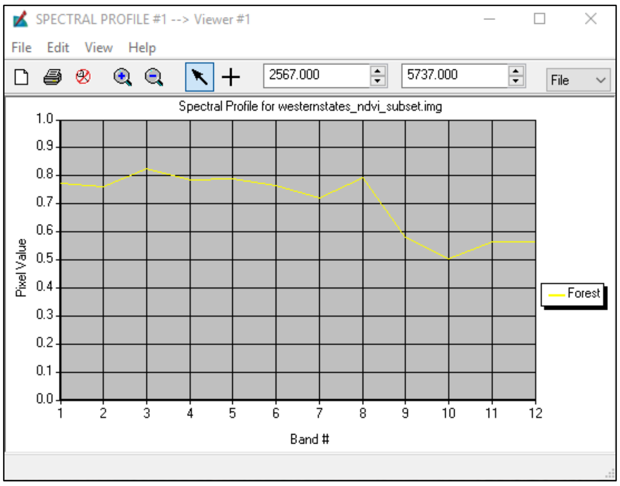

Figure4.11.c. Spectral Signatures for Forest

4.5.2 Hierarchical Classification:

The stacked MODIS NDVIMVC have been masked the agricultural areas using agricultural mask file (explained in section 4.4.4). Agricultural masked NDVI MVC, Ideal spectra signatures and ground data sample points, have been used to generate a NDVI thresholds of different cropping seasons at different crop phenological stages for mapping rice fallows. If the applied conditions are satisfied for each month, the pixel values are classified as Class 1. Finally, the satisfied conditions in all the months are summed up to generate six classes. Where, 1 to 5 classes are labelled as 'Non-Rice' and sixth class is labelled as 'Kharif Rice'. The Non-Rice class is recoded as Class 0 and Kharif Rice is recoded as Class 1. Kharif season hierarchical classification method is as follows (Figure4.12, Figure4.13)

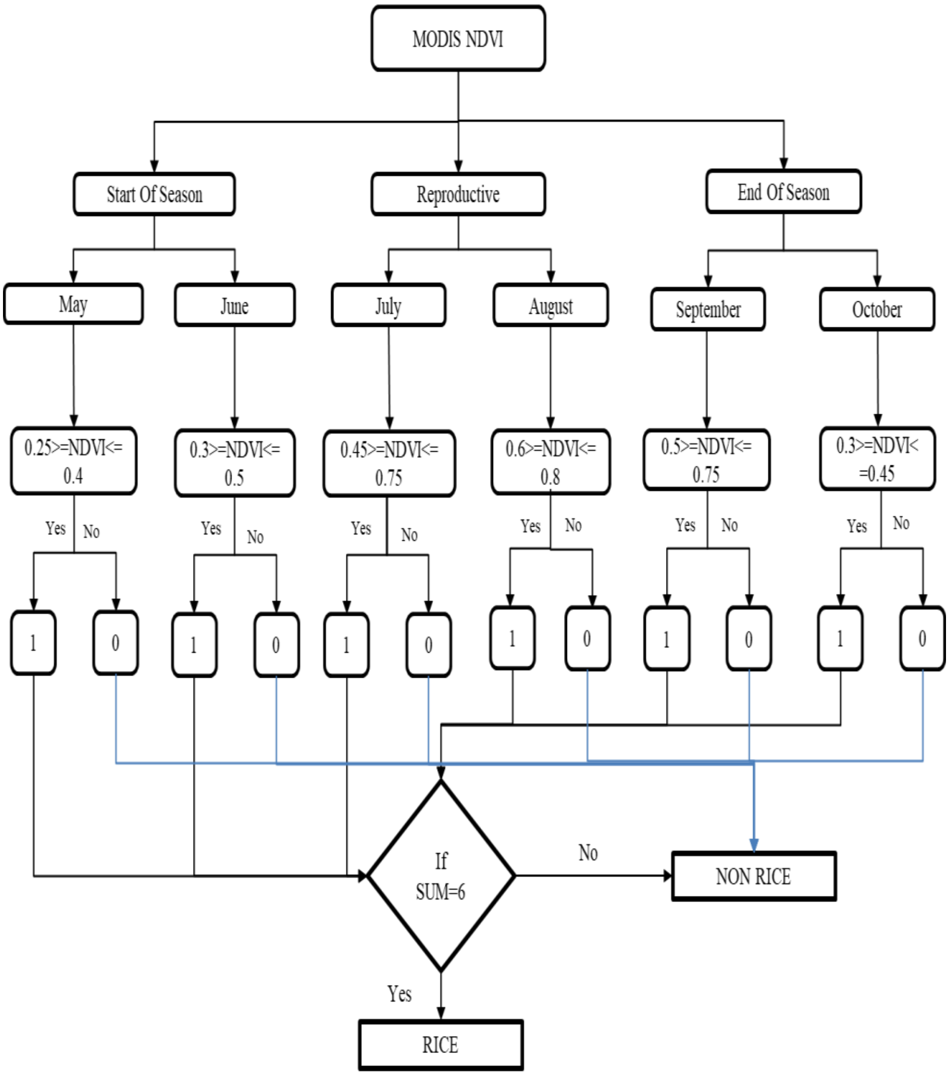

Figure4.12. Hierarchical Classification for Kharif Season

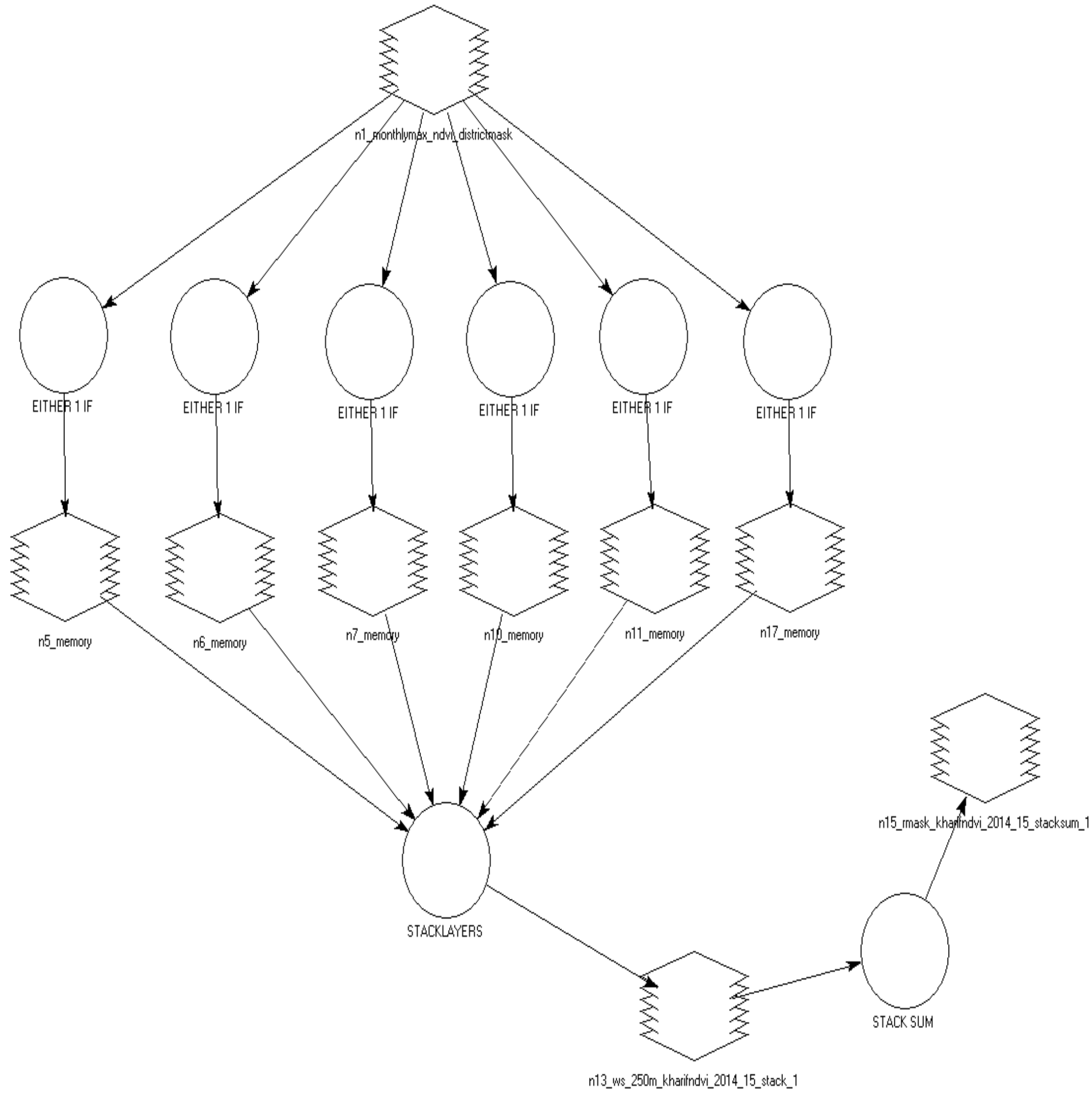

Figure4.13. Classification Model for Kharif Season

Similar hierarchical classification method is performed for Rabi season to generate Rabi rice mapping. Following (Figure4.14) represents the classification algorithm followed for Rabi season. Here, the classes 1-5 are recoded as Class 0 ('Non-Rice) and sixth class is recoded as Class 2 ('Rabi-Rice').

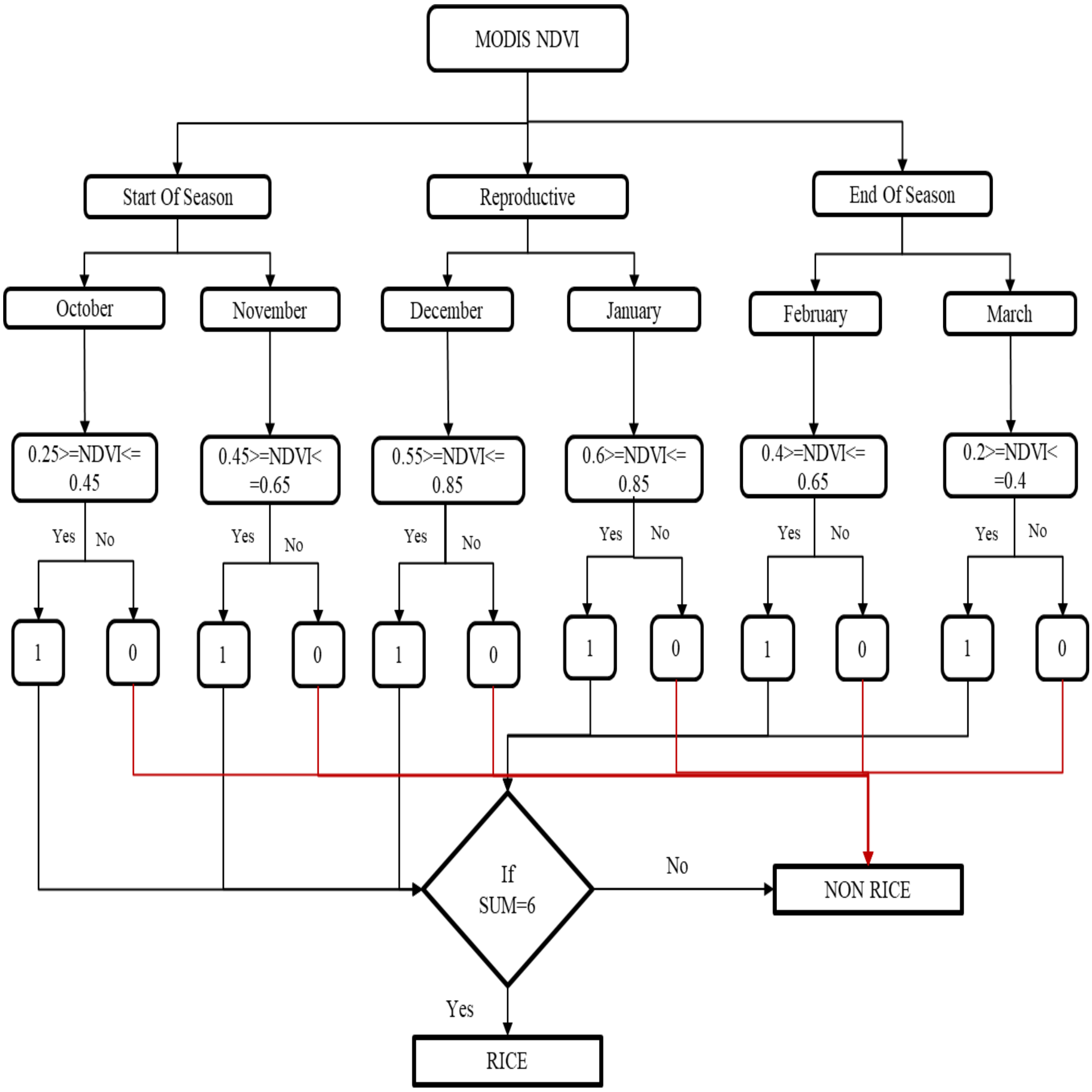

Figure4.14. Hierarchical Classification for Rabi Season

The generated outputs of Kharif Rice (Figure5.1) and Rabi Rice (Figure5.2) are merged together, to identify single and double rice crops. The Class 0 is labelled as 'Non-Rice'; Class 1 as 'Kharif rice'; Class 2 as 'Rabi-Rice'; and Class 3 as' Double crop 'Kharif-Rabi Rice' (common pixels from both maps indicates the presence of rice both in kharif and rabi seasons). The model is shown in the following (Figure4.15) and the spectral signature for double crop rice is shown in (Figure4.16)

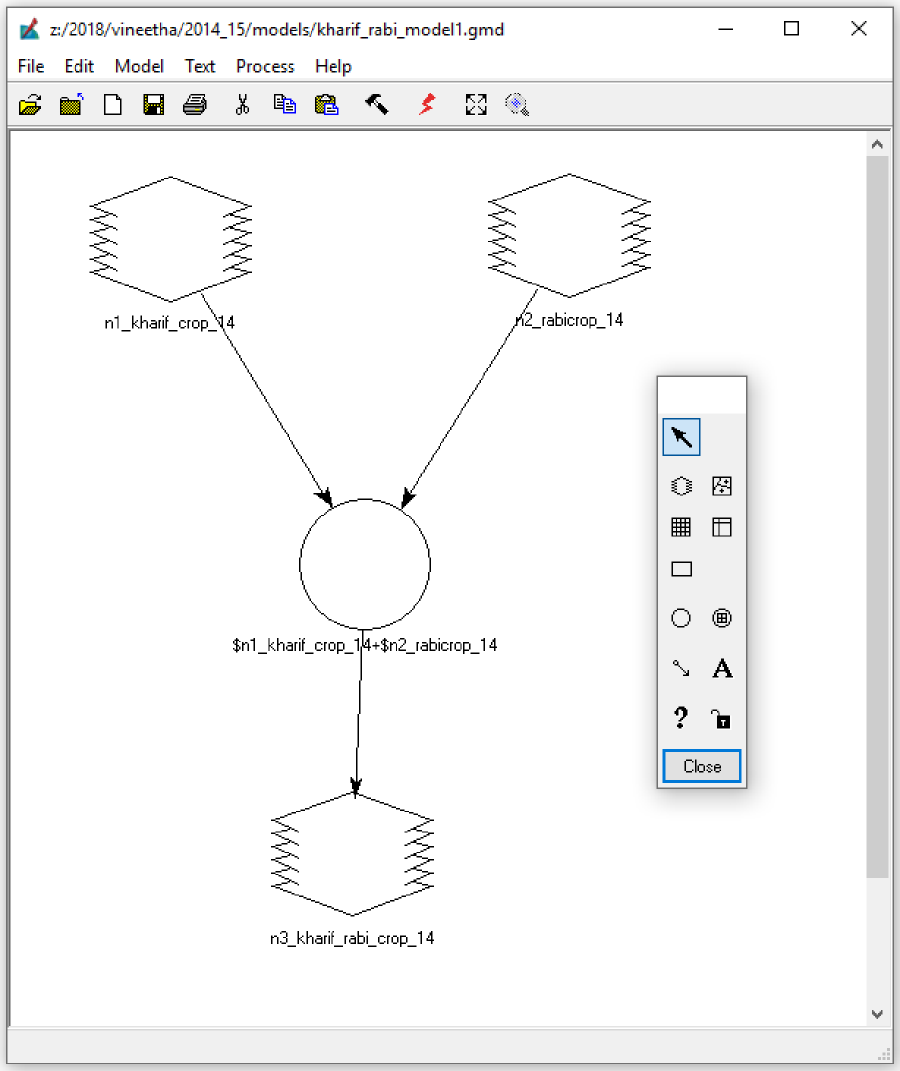

Figure4.15. Model for Double Crop

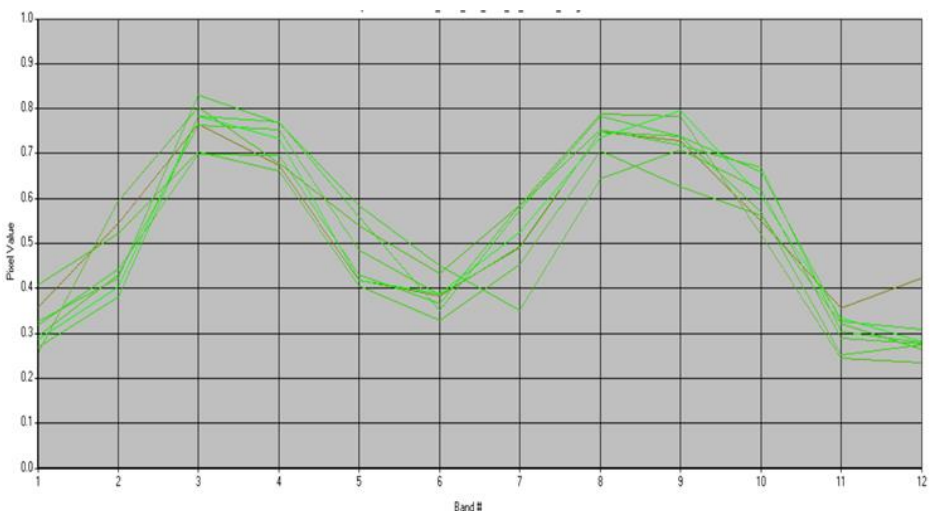

Figure4.16. Spectral signatures for Double Crop Rice

A similar Hierarchical Classification is performed for the NDVI values of Non-Rice class (Class 0), to generate Rabi fallows. The Class 6 is labelled as Rabi-Fallows and recoded as Class4 and rest as Class 0 and the Rabi-Fallow class has the spectral signatures as (Figure4.17) This Map is further merged with the previous three classes to identify Rice-fallows. The resultant map has seven classes in total. Class1 is labelled as ‘DC (Double crop)-Rice in Kharif_Non Rice in Rabi’; Class2 as ‘DC-Non Rice in Kharif_Rice in Rabi’; Class 3 as ‘DC-Rice in kharif_Rice in Rabi’ Class 5 as ‘SC-Rice in Kharif_Fallow in Rabi’; Class 4 is the class with Rabi fallows (Non-Rice Fallows), Class 6, Class 7 have zero pixels as there won’t be the common pixels for fourth, second and third classes. Since we are considering only Rice Fallows Class 4, Class 6, Class 7 are recoded as Class 0.

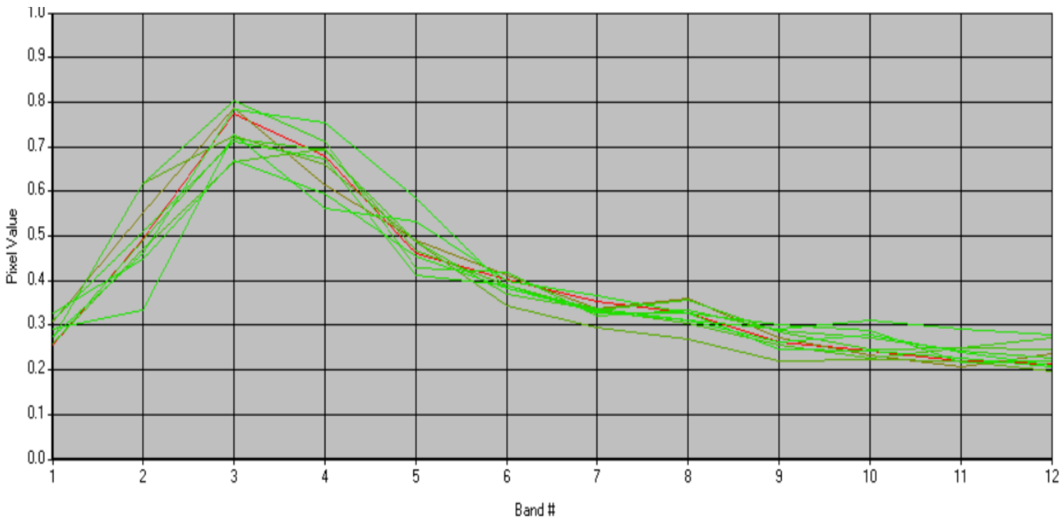

Figure4.17. Spectral signatures for Rice-Fallow

4.6 Change Detection:

Change detection analysis, describe and quantify differences between images of the same scene at different times. Historical Rice-Fallow maps of 2000 and 2010 years are taken from ICRISAT RS&GIS Team. These maps have 11 classes of which seven classes are considered as rice and rice fallow classes. These maps are used along with the resultant map to identify and map the change detection for 2000-2015 and 2010-2015 for the Western and central part of India.

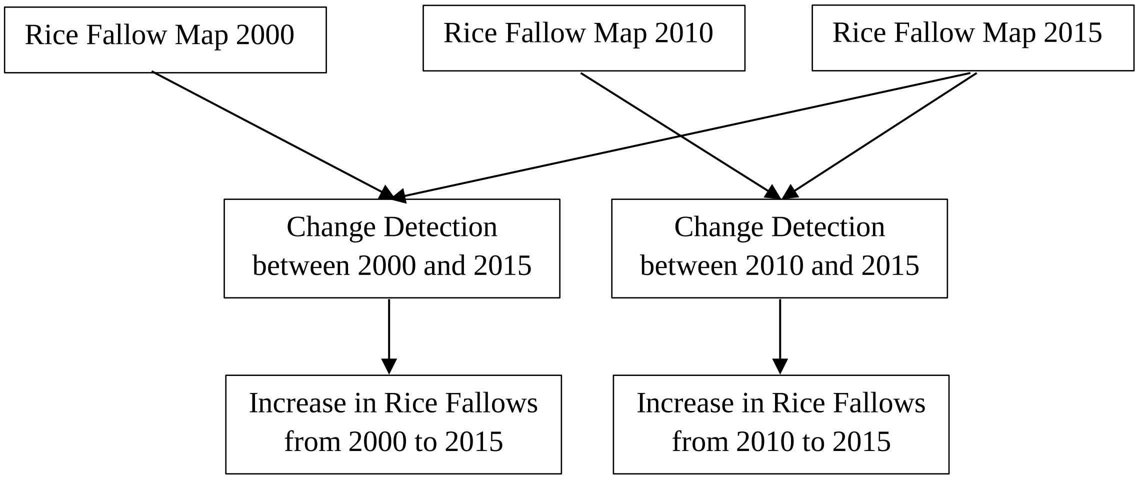

Figure4.18. Methodology for Change Detection

4.7 Validation:

Validations of this all maps are done by comparing the mapped area with the national statistics available and the graphs are plotted.

CHAPTER 5

RESULTS AND CONCLUSIONS

5.1 Results

The results are divided into two sections i.e.

1. Rice fallow maps at each state level (Gujarat, Rajasthan, Madhya Pradesh and Maharashtra)

2. Intensification of rice fallow areas in two time periods i.e., during 2000-2015 and 2010-2015.

5.1.1 Mapping of Rice fallows:

The spatial mapping of rice fallow acreage during kharif and rabi seasons are explained as follows**.** Figure5.1 represents the spatial distribution of Rice areas in Kharif season. The classified map shows, 3729725 ha of rice area during kharif season whereas 1029729 ha area in Rabi season represented in Figure5.2. Maximum area of rice is grown in kharif season, as rice mainly depends on monsoon rainfall in kharif and irrigation sources in Rabi season. The classified rice maps of two seasons are further merged to identify the double cropping Rice areas (i.e., the areas having rice in both Kharif and Rabi seasons), DC rice in Kharif and non-rice in Rabi seasons (2027650), and DC non-rice in Kharif and rice in Rabi seasons (629674). The identified Double crop rice area is 400055.00ha shown in (Figure5.3). In similar way Rice Fallow area is also mapped as explained (in section 4.5.4) and the rice-fallow maps are represented in (Figure5.4). The area coved with rice in kharif and fallow in Rabi is 1302020.

Figure5.5 represents the final rice fallow map has four major classes in which first Class is named as Dc_Rice in Kharif_Non Rice in Rabi; Second Class as DC_ Non Rice in Kharif_Rice in Rabi; Third Class as DC_ Rice in Kharif_ Rice in Rabi and fourth Class as (Single Crop) SC_Rice in Kharif_Fallow in Rabi; and other all values as Unclassified. And the figures5.5a, 5.5b, 4.5c, and 5.5d represent the same maps at state level (Gujarat, Madhya Pradesh, Maharashtra, and Rajasthan).

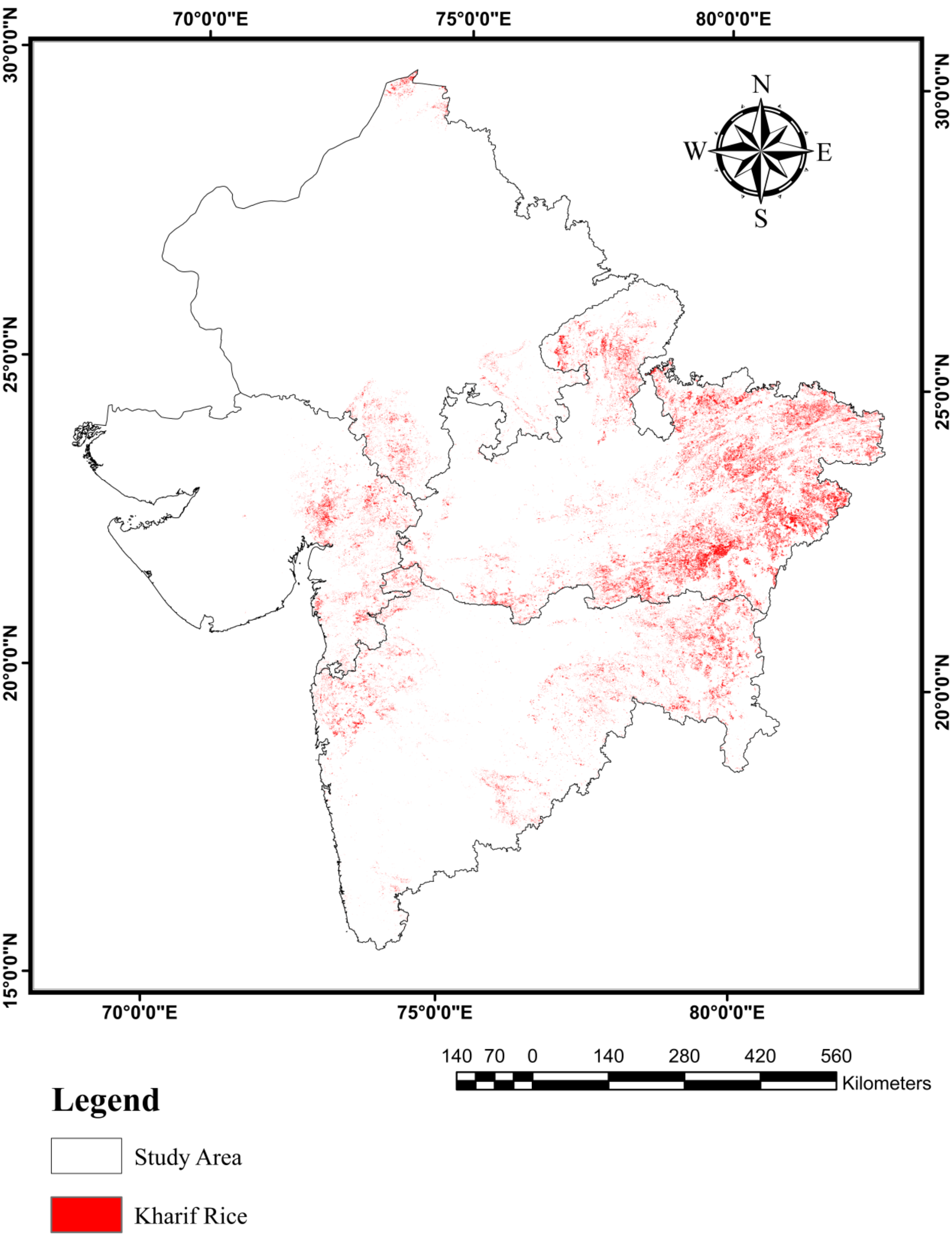

Figure5.1. Rice areas In Kharif season

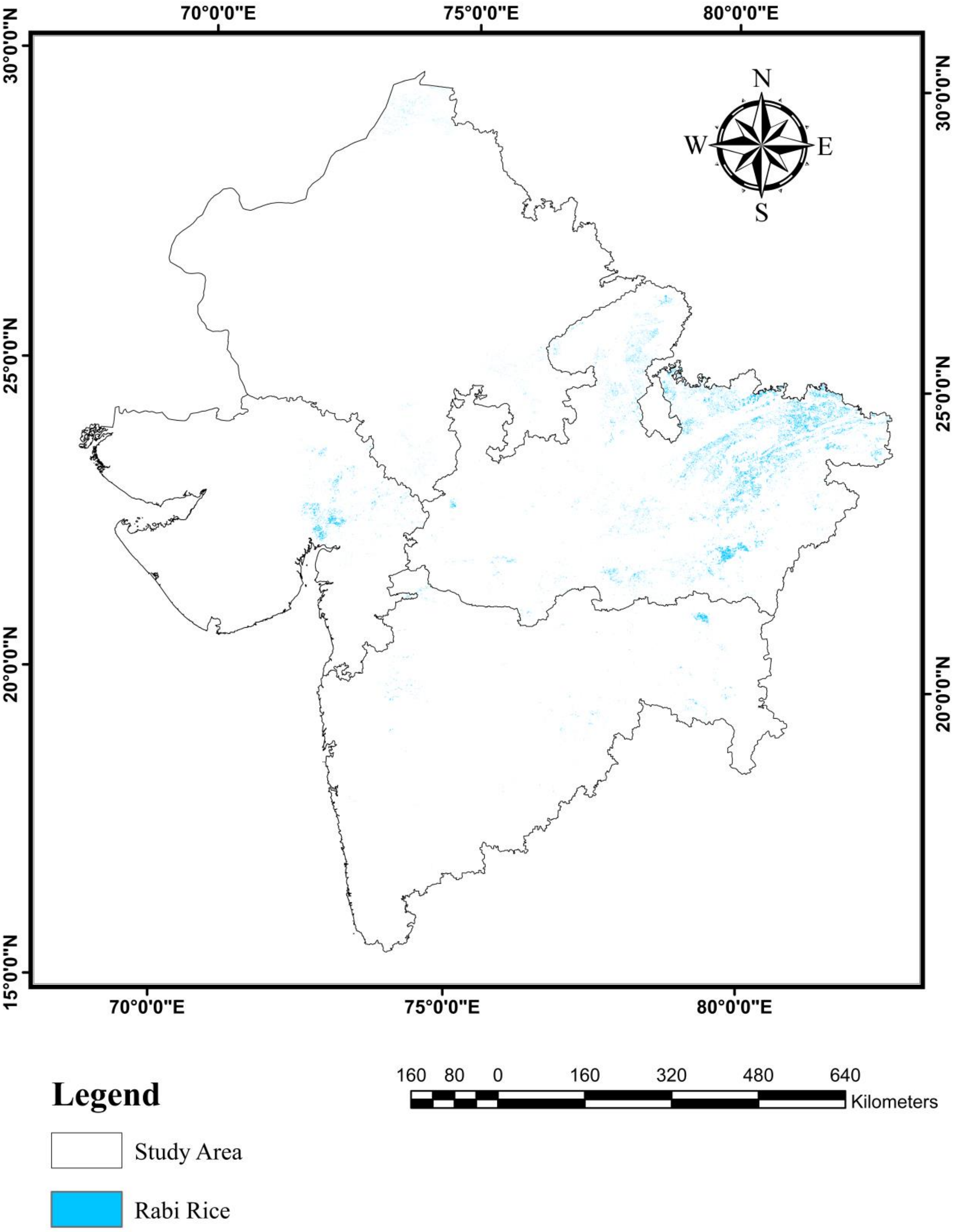

Figure5.2. Rice areas In Rabi season

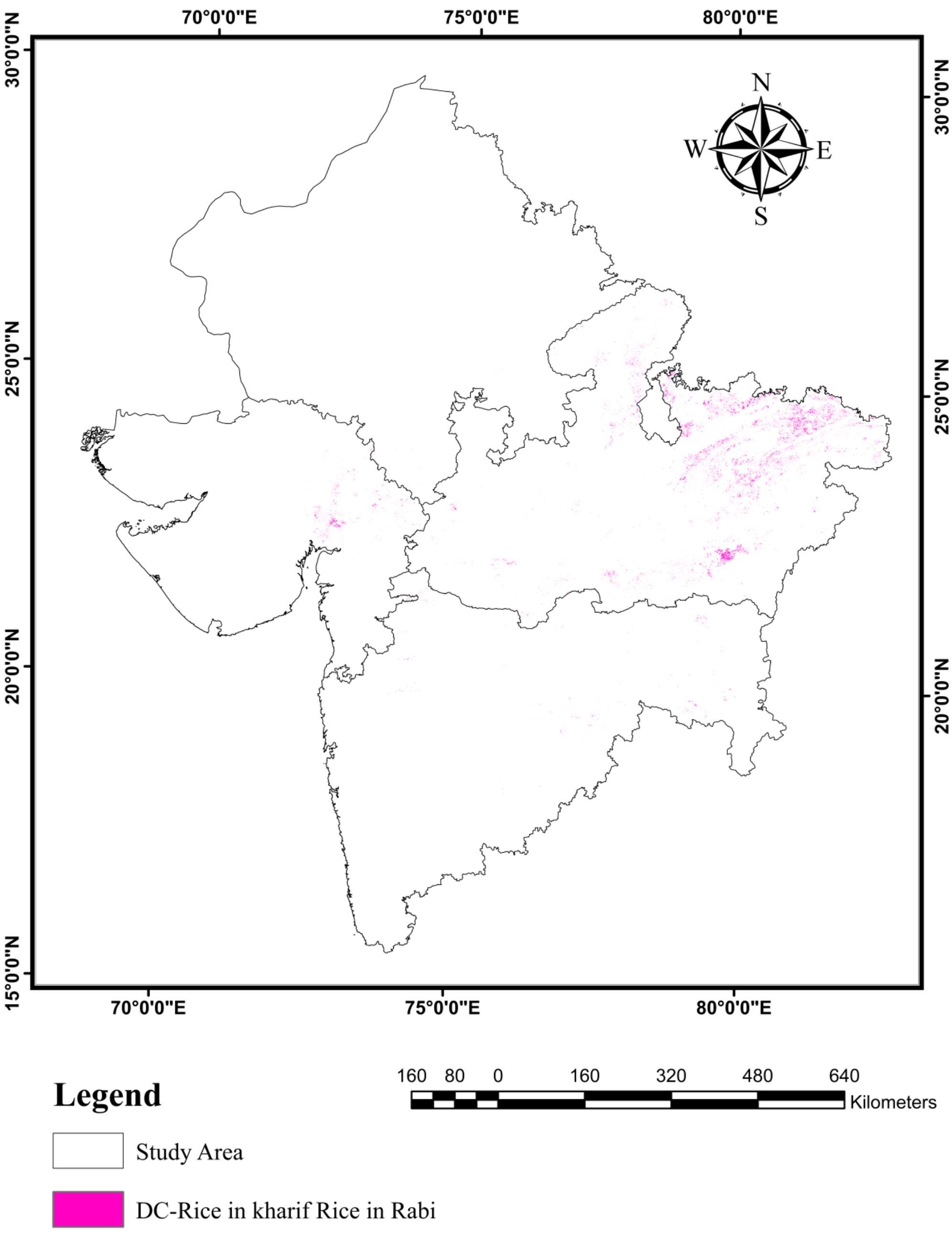

Figure5.3. Rice areas In Kharif and Rabi Seasons

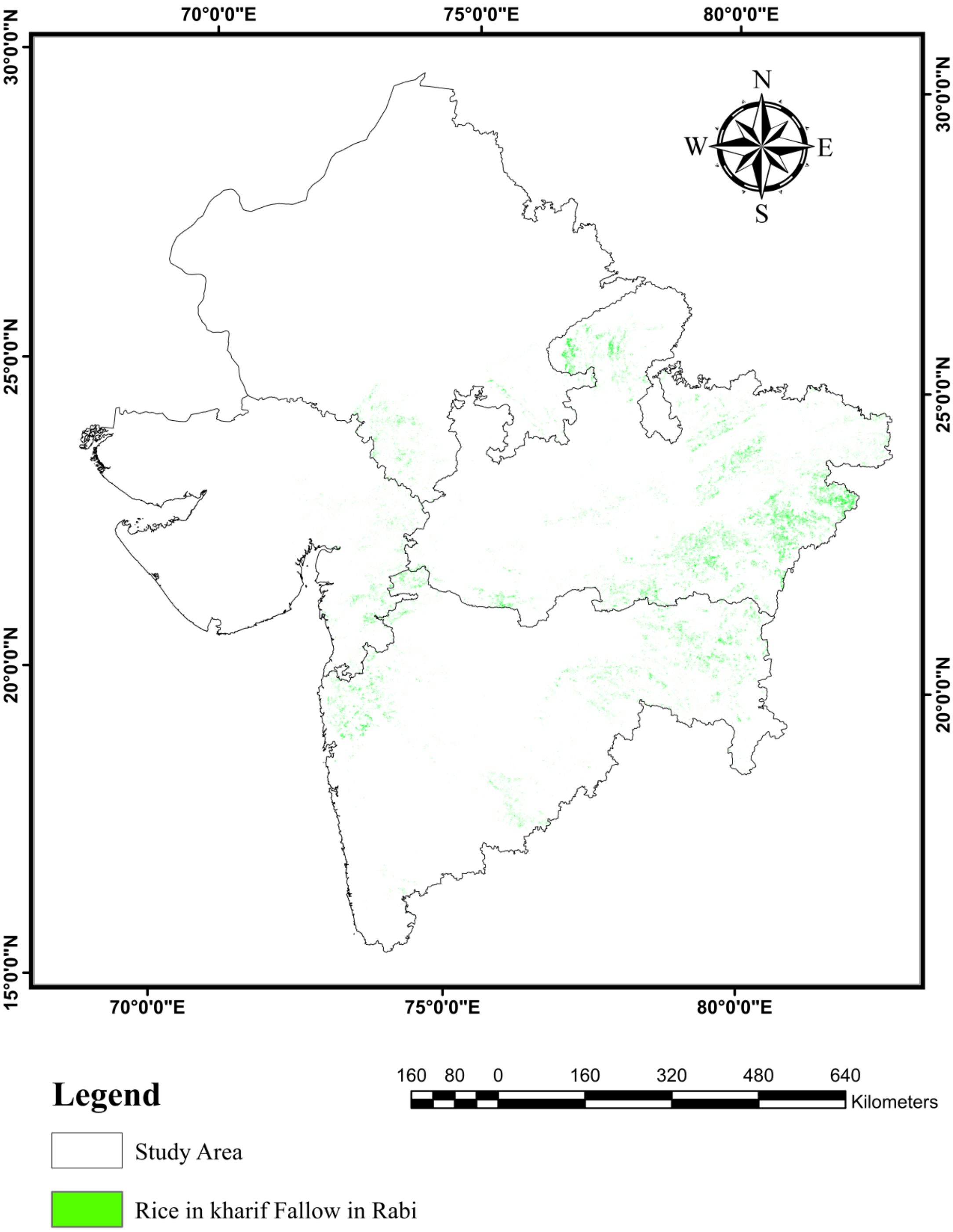

Figure5.4. Rice in Kharif and Fallow in Rabi Seasons

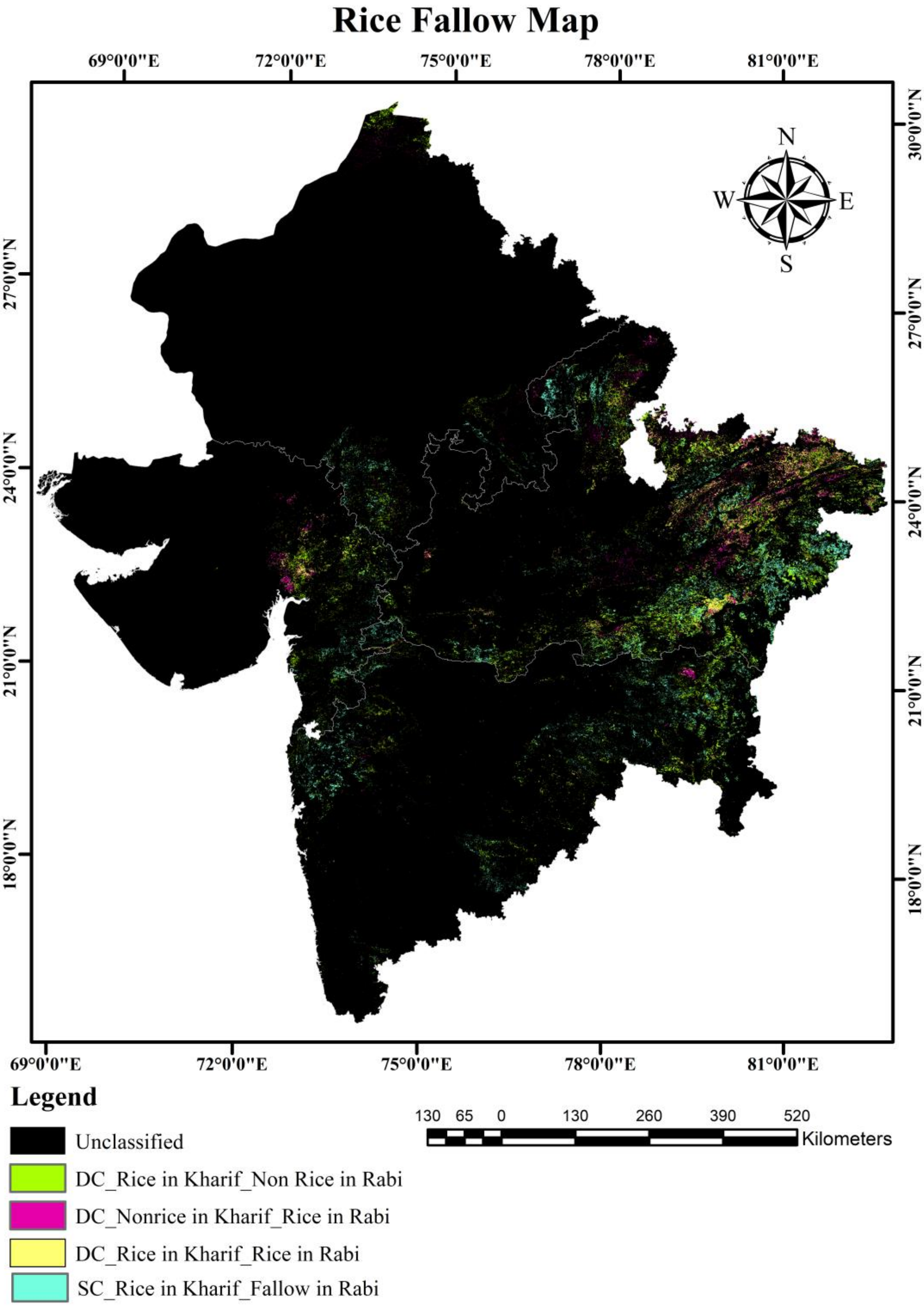

Figure5.5.Classified Map for Study Area

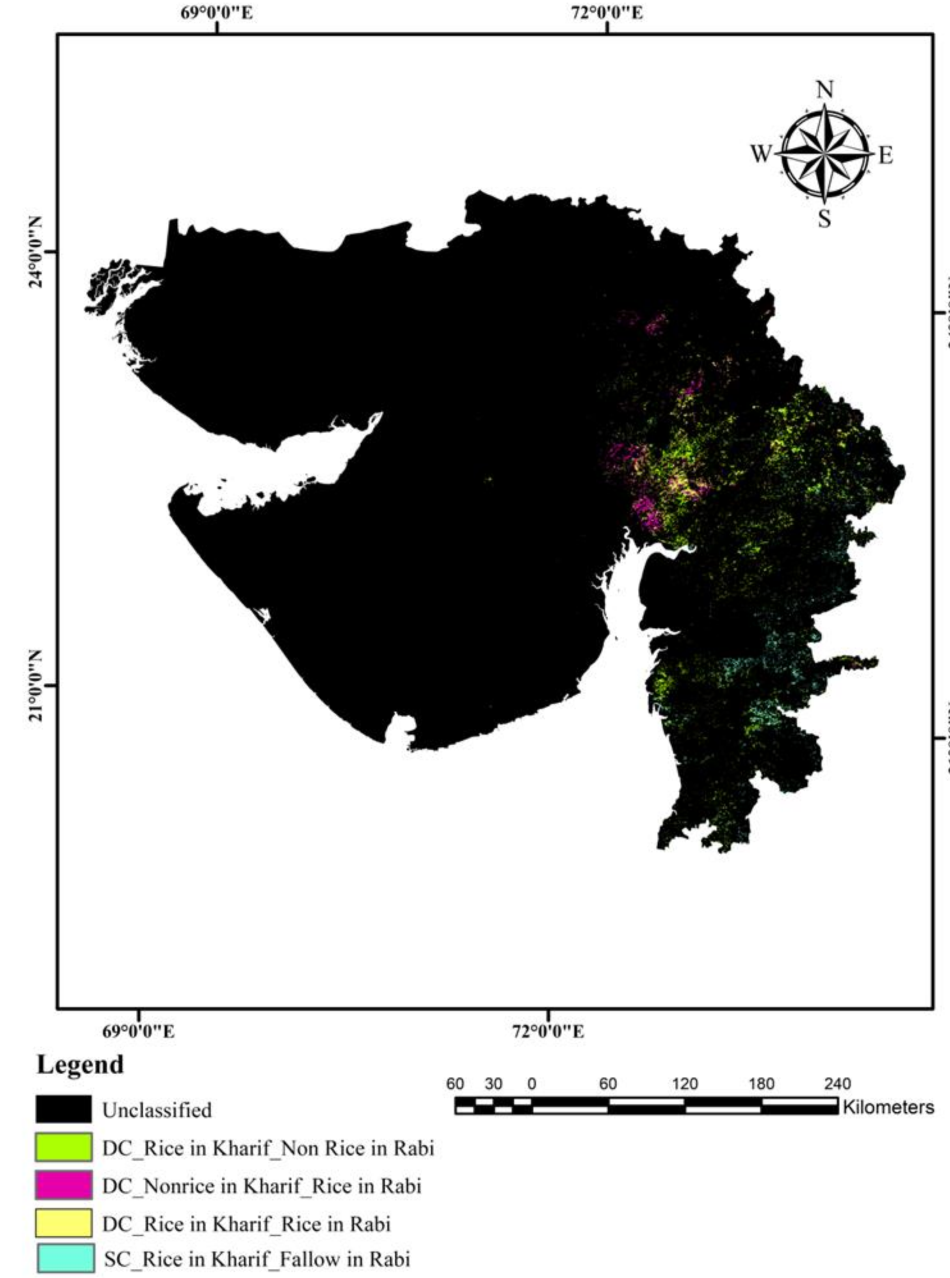

Figure5.5.a. Classified Map for Gujarat

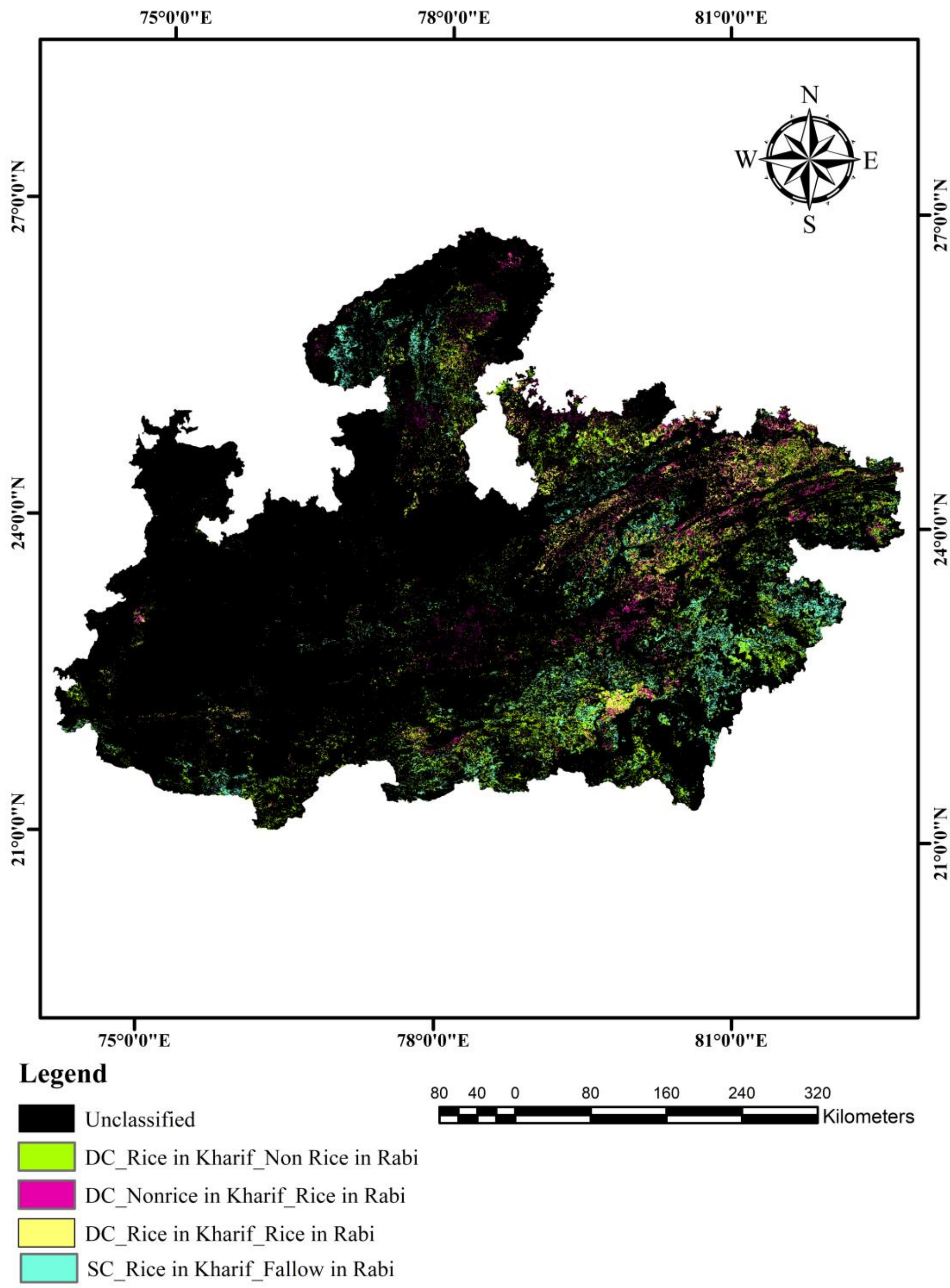

Figure5.5.b. Classified Map for Madhya Pradesh

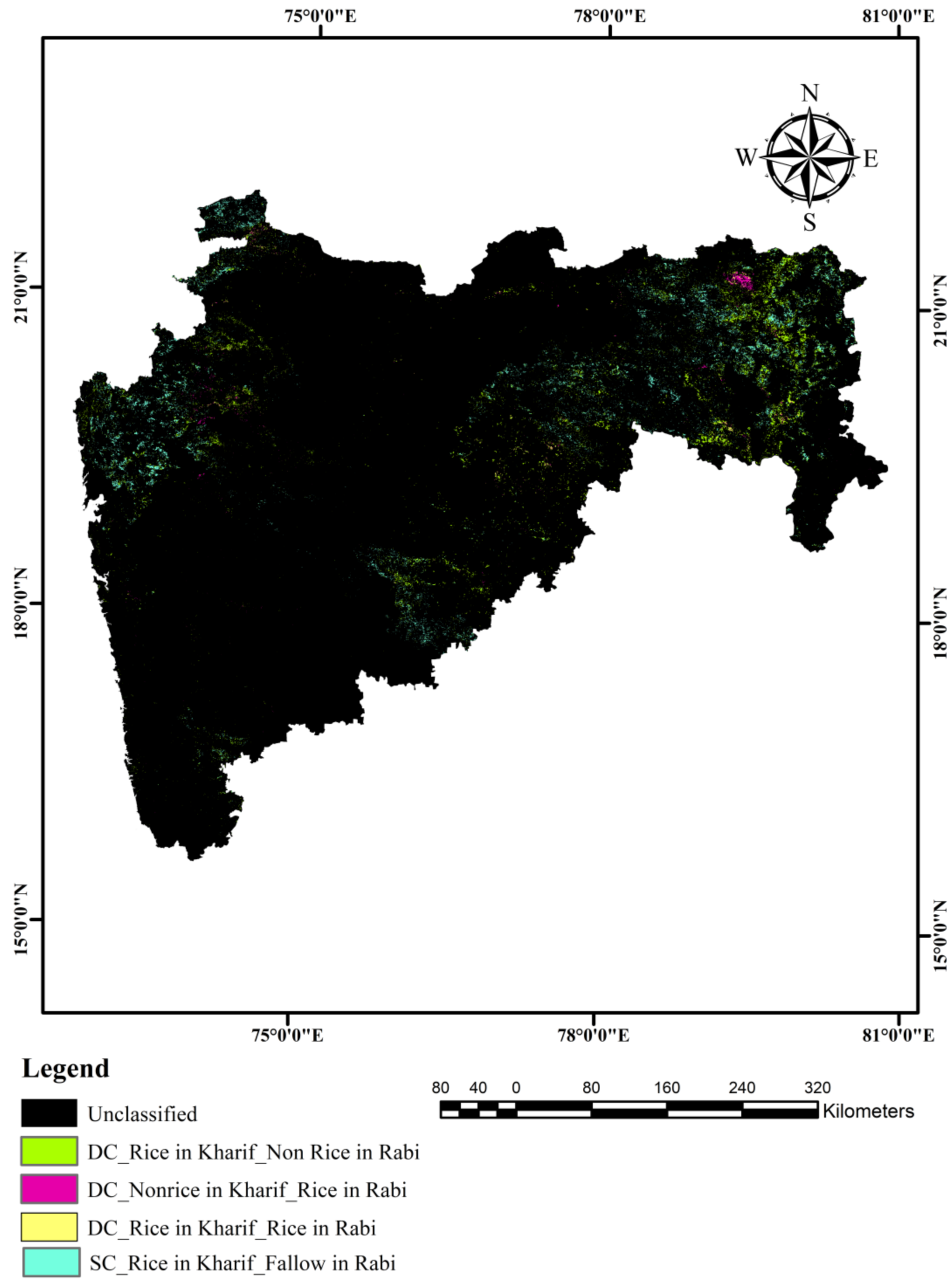

Figure5.5.c. Classified Map for Maharashtra

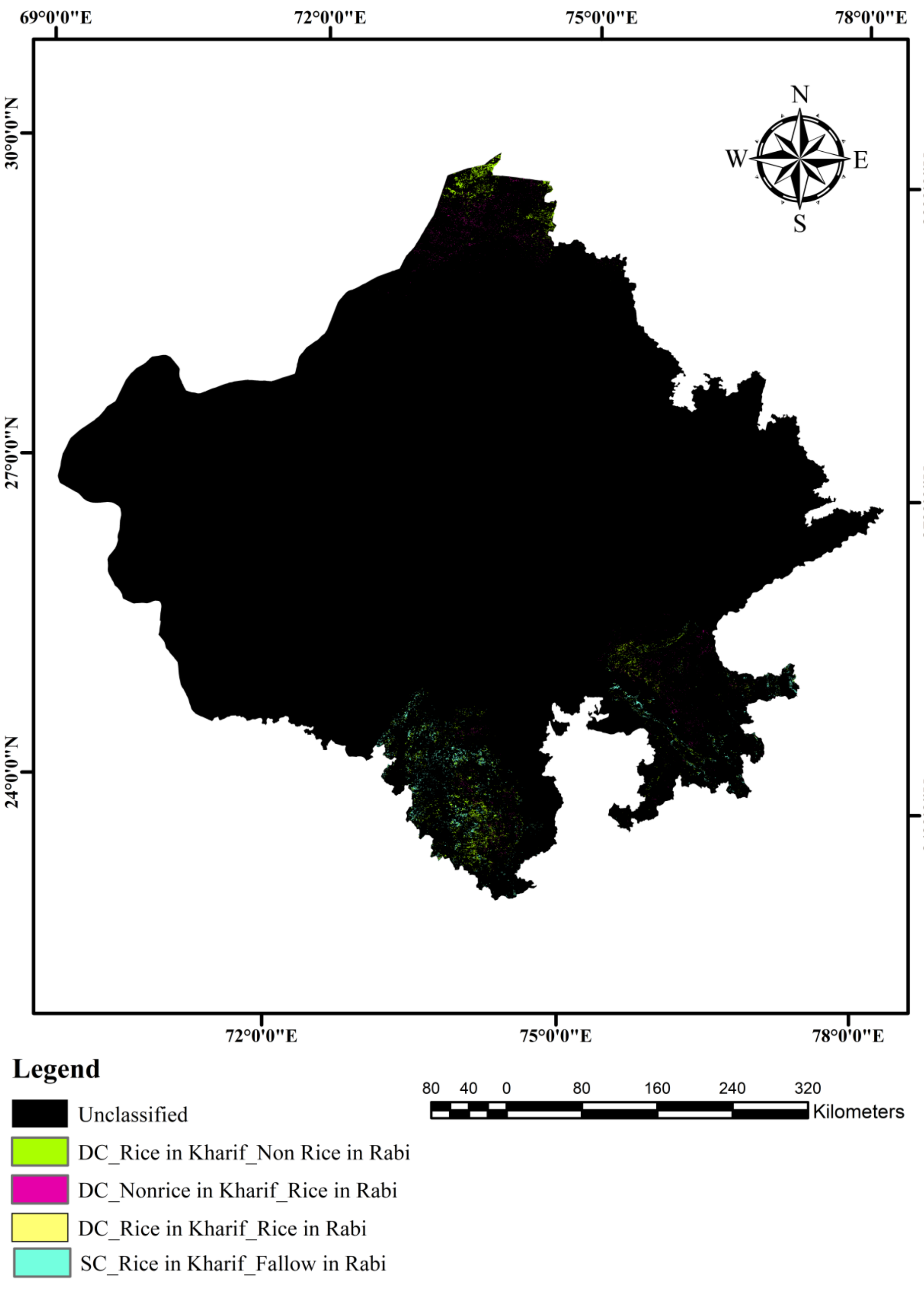

Figure5.5.d. Classified Map for Rajasthan

Table 1 represents the validation of classified mapped area with the national statistical area. As per the classified map area the state Rajasthan has occupied with 196452 ha, Maharashtra with 709566 ha, Madhya Pradesh with 2219857 and Gujarat has occupied with 287761 area of Rice in Kharif season. Overall in the study area, the state Madhya Pradesh has maximum area covered with rice followed by Maharashtra, Rajasthan and Gujarat. Similar with the national statistical values and slight variations with the classified map area values.

Figure5.6 represents the pattern of rice area of classified map and National statistics in four states of study area. The x-axis represents states and Y axis represents the area in hectares. The classified map follows the similar pattern with the national statistical rice areas and has a significant correlation R^2 value (0.7179) which is shown in figure5.7. Thus this concludes that the method followed for the classification of rice fallow mapping is valid. Each point denotes a district in a study area.

Table 5.1. Validation with National Statistics Rice

States	Classified Rice Area(Hectares)	National Statistics Rice Area(Hectares)
Rajasthan	196452	159680
Maharashtra	709566	1013900
Madhya Pradesh	2219857	1799000
Gujarat	287761	627065

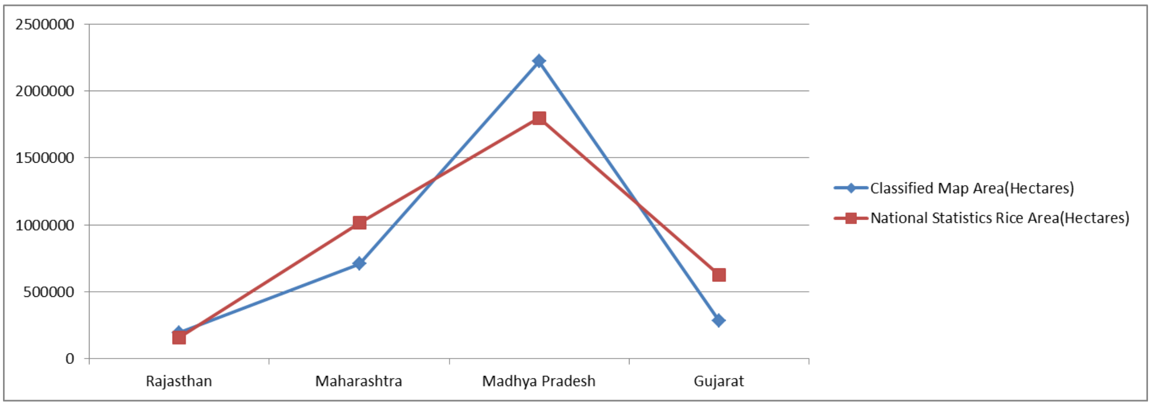

Figure5.6. Graph representing validation with National Statistics Rice

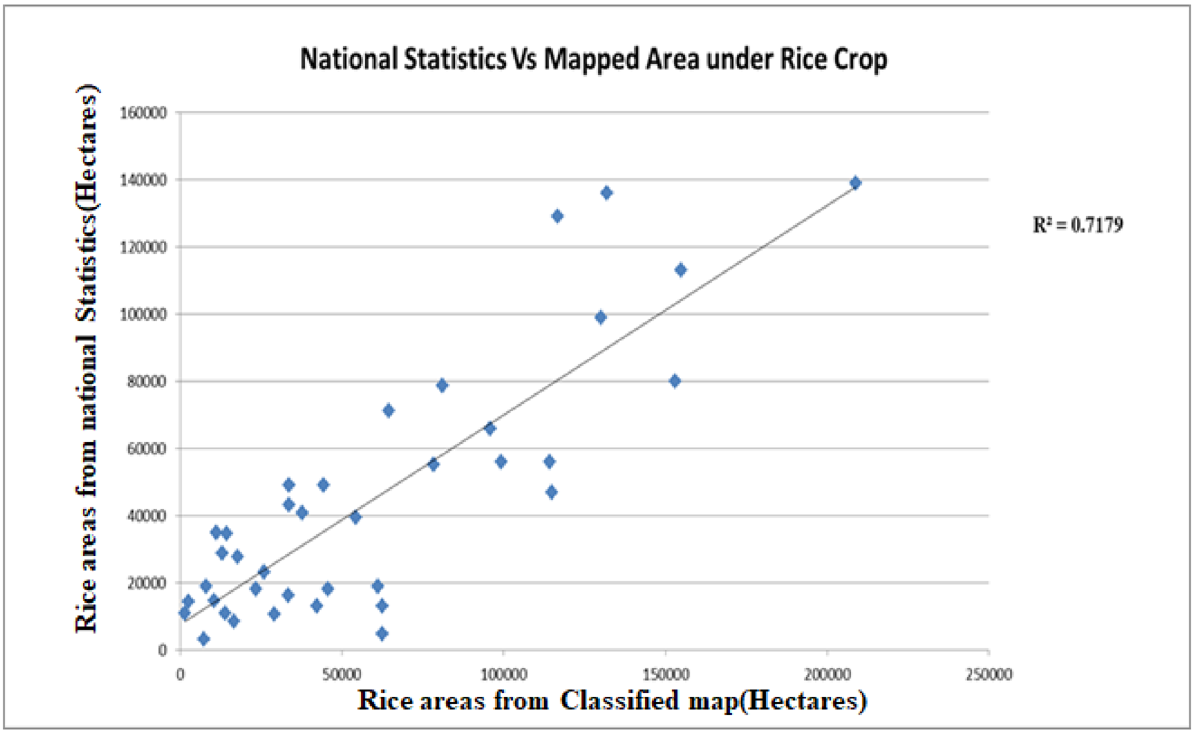

Figure5.7. Correlation between National statistics and Mapped rice area at District level

5.1.2 Intensification of Rice Fallow Areas

Figure5.8 represents the increase in rice fallow areas during 2000 to 2015. It shows that the area increases by 867147 ha from the year 2000 to 2015. Whereas, during 2010 to 2015 the area increased by 900731 ha is represented in the Figure5.9

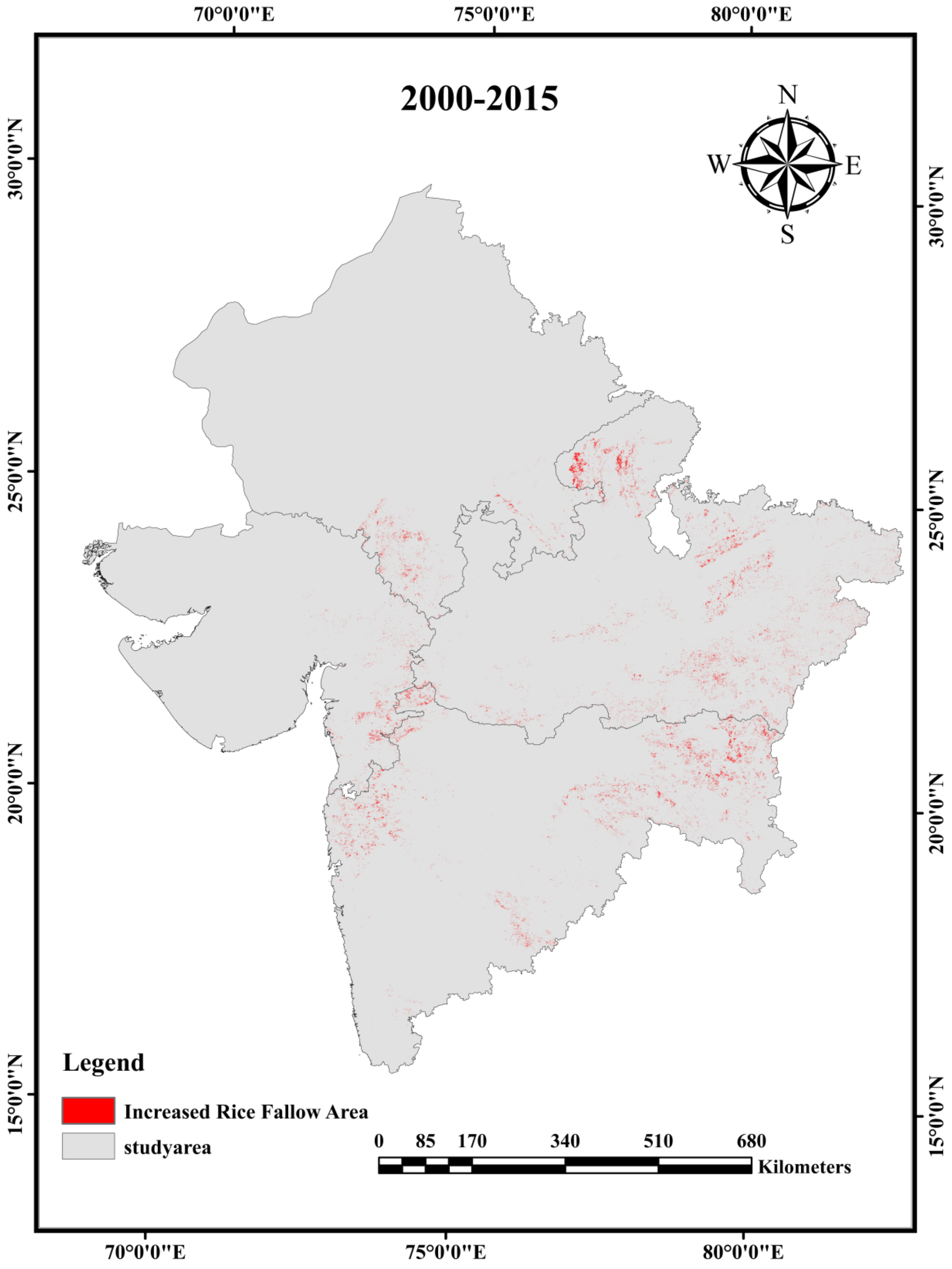

Figure5.8. Increased Rice-fallow Area from 2000 to 2015

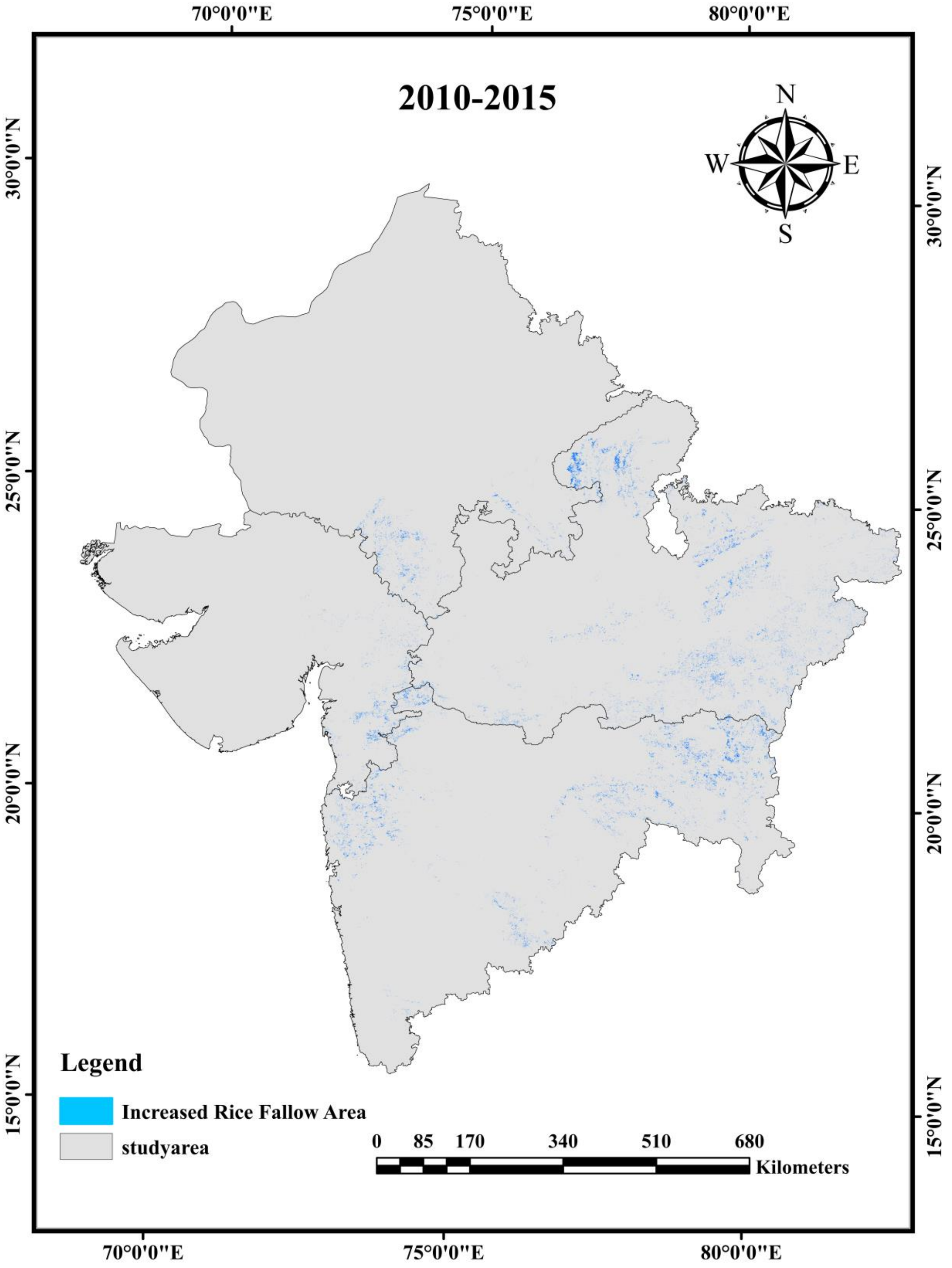

Figure5.9. Increased Rice-fallow Area from 2010 to 2015

5.2 Conclusions

- Separation of rice growing areas from other land use land cover classes is based on Ideal Temporal Signatures
- Rice cropping pattern and the fallows areas were mapped fairly accurately for large areas using MODIS data.
- The classified map showed good correlation with National Statistics(R^2=0.72)

CHAPTER 6

LIMITATIONS AND SCOPE FOR FURTHER STUDY

6.1 Limitations

- Due to the coarse resolution imagery, we are unable to identify the small fragmented fields.
- Since MODIS data is optical data, it cannot penetrate through clouds. Hence getting cloud free images during monsoon is difficult, so we used maximum value composite of available data.

6.2 Scope for further study

- To overcome the limitations the mapping can be done using Higher resolution Satellite data (Sentinel-1, Sentinel-2).
- SAR data can be used for Kharif season mapping, as it can penetrate through clouds giving better data for crop identification in Monsoons.
- Also need to focus on identifying different crops using advantages of different satellite images.

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