MONITORING OF COTTON CROPLANDS IN ODISHA USING GEOSPATIAL TOOLS

Project work submitted to

Centurion University of Technology and Management, Paralakhemundi, Odisha

For the award of degree of

Bachelor of Science
In
Agriculture

By

PRAGADA TANUJA (Reg.No.130806agr222)

GUDLA VARUN (Reg.No.130806agr137)

M.S.SWAMINATHAN SCHOOL OF AGRICULTURE
CENTURION UNIVERSITY OF TECHNOLOGY AND MANAGEMENT
PARALAKHEMUNDI
DIST: GAJAPATI – 761211
ODISHA, INDIA

May, 2017

MONITORING OF COTTON CROPLANDS IN ODISHA USING GEOSPATIAL TOOLS

Report Submitted to

Centurion University of Technology and Management, Paralakhemundi

By

Pragada Tanuja

Gudla Varun

International Crops Research Institute for the Semi – Arid Tropics

Patancheru, 502 324

Telangana State, India

icrisat@cgiar.org

May 2017

DECLARATION

We, **Pragada Tanuja** and **Gudla Varun** hereby declare that the report entitled upon **"Monitoring of Cotton croplands in Odisha using Geospatial tools"** is an authenticated work carried out by us 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 our study as a part of curriculum in **Bachelor of Science in Agriculture**.

Date:

Place: HYDERABAD

Pragada Tanuja

Gudla Varun

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to several people, without whom this dissertation would not have been completed.

We express our heartfelt gratitude and indebtedness to **Dr. G. Murali Krishna** (Scientist, RS & GIS, ICRISAT) for his extensive help in helping us with the basics, methodologies and suggestions. We extend sincere thanks for his inspiring guidance, constant interest, suggestions, and encouragement throughout the course of these investigations. We were grateful to the **Learning Systems Unit (LSU)** at ICRISAT, for providing us an opportunity to join an institute of international repute and excellence in research.

We owe our heartiest thanks to **Mr. Irshad A Mohammed** (Lead Scientific Officer, ICRISAT), **Mr. Suryadeb Chakraborthy** (Senior Scientific Officer, ICRISAT) and **Mr. Ismail Rafi** (DBA, ICRISAT) for their suggestions and support to carry out this work successfully. We would also like to express our sincere gratitude to **Dr. Anthony M Whitbread** (Research Program Director, Innovation Systems for Dryland Agriculture).

We sincerely acknowledge to International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for providing the infrastructure and the datasets. Working for ICRISAT gave us an opportunity to work on this project that lead to B.Sc. Agriculture dissertation.

Perhaps our greatest good fortune has been to have friends like **P. Pranay** and **N. Keerthi** who met us at the time of preparation of our study and helped us with this work. We express our gratitude to all whose names have not been mentioned individually but have helped us directly or indirectly in this work.

ABSTRACT

Title	**: Monitoring of cotton croplands in Odisha using Geospatial tools**
Name	**: Pragada Tanuja and Gudla Varun**
Institute	**: Centurion University of Technology and Management, Paralakhemundi, Odisha, India**
Supervisor	**: Gumma Murali Krishna**
Submitted	**: 01st May, 2017**

Agriculture is the backbone of our Indian economy and the crucial sector for ensuring food security. 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. For proper planning and efficient utilization of the land and water, it is necessary to understand the crop period, necessary types of crops to be cultivated in the suitable areas and hydrological cycle. The reliable prediction of crop and hydrological parameters 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. As the part of the technology, Geospatial tools play a vital role in the field of agriculture.

In the present study, MRT2011 (MODIS Reprojection Tool, Version 4.1), 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). This software was applied to districts of Odisha (Rayagada, Kalahandi and Balangir) and extracted the NDVI (Normalized Difference Vegetative Index). This helps in identification of Crop area and other vegetative indices. Then the classification of LULC (Land use/land cover) is done using the ERDAS Imagine2014 (ver.14.00).

To study the diversification of crops, we need to collect the data and analysis has been done taking into consideration of major crop of the study area like Rice. Our study mainly focuses on how Cotton replaces Rice in some parts of study area (i.e., from 2002-2014 is 29000ha to 135000ha) due to lack of irrigation facilities and unproductive soils with low yields. By taking the data of 2013-14 and carried out the classification using above software. This result shows the amount of area affected to crop diversification.

(Keywords: Remote Sensing, GIS, MODIS Reprojection Tool, ERDAS Imagine, Land use/Land cover, NDVI)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Description
AGIS	Agricultural Geographic Information System
AOI	Area of Index
AVHRR	Advanced Very High Resolution Radiometer
AWiFS	Advance Wide Field Sensor
Bt	*Bacillus thuringensis*
CAB	Cotton Advisory Board
CCD	Charge Coupled Devices
CCI	Cotton Corporation of India
EDS	Euclidean Distance Similarity
EMS	Electro Magnetic Spectrum
ERDAS	Earth Resources Data Analysis Systems
FLD	Front Line Demonstration
GIS	Geographic Information System
Hdf	Hierarchical data format
HDF-EOS	Hierarchical data format – Earth Observing System
HRG	Hemispherical Resonator Gyroscope Sensor
HRS	High Resolution Stereoscopic
HRVIR	High Resolution Visible and Infrared Sensor
ICDP	Intensive Cotton Development Programme
KBK	Kalahandi Balangir Koraput region
LISS	Linear Imaging Self Scanning
LSWI	Land Surface Water Index
LULC	Land use/ Land cover

MFI	Mega File Image
MFDC	Mega File Data Cube
MIC	Micronaire
MIR	Mid Infrared
MODIS	Moderate Resolution Imaging Spectroradiometer
MRT	Modis Reprojection Tool
MSAS	Modified Spectral Angle Similarity
MSP	Minimum Support Price
MSS	Multispectral scanner
MVC	Maximum Value Composite
NDVI	Normalized Difference Vegetative Index
NFSM	National Food Security Mission
NIR	Near Infrared
OLI	Operational Land Imager
RGB	Red Green Blue
SCS	Spectral Correlation Similarity
SMT	Spectral Matching Techniques
SNR	Signal to Noise Ratio
SSV	Spectral Similarity Value
SWIR	Shortwave Infrared
Tif	Tagged Image Format
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
USGS	United States Geological Survey
VIS	Visible

VMI	Value Monitoring Interface
WGS84	World Geodetic System 84
WRS	Worldwide Reference System

CHAPTER 1

INTRODUCTION

Agriculture is the backbone of Indian economy and the crucial sector for ensuring food security. 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 drought assessment & 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.

In Odisha, Rice is the principal food crop occupying about 44.55 lakh ha annually (41.24 lakh ha in Kharif season + 3.31 lakh ha. in Rabi season). The entire Rabi area is irrigated & covered by high yield Paddy where as 36% of Kharif Paddy area is covered under irrigation. The rice production reached the record level of 76.55 lakh tones during 2007-08 and at present is 69.16 lakh tones (during 2008). The yield rate of rice is 1.6 tonnes/ha as against national average of 2.2 tonnes/ha. Due to lower production in the yields, farmers are diverting to income generating crops. The unproductive areas of rice are diversifying into commercial crops like Cotton, Jatropha and Oilseeds etc.

Presently, the commercial mode of agriculture has been rapidly spreading in which farmers will easily benefitted by good amount of money. But the right path of cultivation will be achieved by better cultivation practices, suitable soil and climatic conditions for the crops. Major commercial crops are Cotton, Sugarcane, Tobacco, Jute and Oilseeds etc. which are growing in larger areas. Proper planning prior cultivation should be taken which can be obtained by taking the help of geospatial tools.

Presently, the major commercial crop in Odisha is cotton. In this study, we have discussed about the scenario of cotton and its expansion towards unproductive rice fields. Though the contribution of Odisha towards India’s total cotton production is barely 0.5%, the cotton produced in the state is of exportable quality.

1.1 Role of Remote Sensing in the field of Agriculture:

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 crop land. 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 a rather sparse temporal resolution.

Applications of remote sensing techniques:

1. Agriculture.
2. Forestry.
3. Water resources.
4. Detection of water pollution.
5. Geology and mineral sources.
6. Mapping of land use / land cover.
7. Monitoring of environmental hazards.
8. Weather and climatic related applications.
9. Engineering applications.
10. Human induced geological hazards.

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.

Problems of remote 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.

1.2 Role of GIS in the field of agriculture:

The use of remote sensing technology involves large amount of spatial data management and requires an efficient system to handle such data. Hence Geographic Information System makes it possible to store, analyze and retrieve data for large and complex problems.

What is GIS?

Geographical Information System (GIS) is a computer based system designed tool applied to geographical data for integration, collection, storing, retrieving, transforming and displaying spatial data for solving complex planning and management problems. This tool focuses on proper integration of user and machine for providing spatial information to support operations, management, analysis and decision making.

Uses of GIS in Agriculture:

Droughts, floods, group of insects and poor farming techniques have affected the agricultural community for centuries. Improvements have been made to insure the safety and gain of crops worldwide and yet these factors and many more continue to make or break individuals and communities affected by them.

Geographic Information Systems are incredibly helpful in being able to map and project current and future fluctuations in precipitation, temperature, crop output, and more. By mapping work together to create more effective and efficient farming techniques; this could increase food production in parts of the world that are struggling to produce enough for the people around them. GIS can analyze soil data combined with historical farming practices to determine what the best crops to plant, are where they should go, and how to maintain soil nutrition levels to best benefit the plants.

Agricultural Geographic Information Systems **(AGIS)** can map not only topography and crop health, but help solve wider economic issues in municipalities and urban centers that may stem from rural farming practices. The future implications of AGIS are great and immense in scope. With the penetration of technology in the global culture today it is possible that in a few years GIS could be available to rural farmers in the developing world to better help them grow crops, feed their families, and produce enough food to ship to neighboring areas. Farmers in severe-weather prone areas (like flood plains or drought zones) would be able to predict what this weather could do to crops, could move fields to better geographic locations, and know how to irrigate based on local water resources and weather patterns. The world food crisis could be alleviated using GIS.

1.3 Software Used:

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). This software was applied to districts of Odisha (Rayagada, Kalahandi and Balangir) and extracted the NDVI (Normalized Difference Vegetative Index). This helps in identification of Crop area and other vegetative indices. **Arc GIS** (Ver.10.2.2) used for creating the shape file (.shp). Then the classification of LULC (Land use/land cover) is done using the **ERDAS** Imagine2014 (ver.14.00).

1.4 Sensors:

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, afocal (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

Primary Use	**Band**	**Bandwidth**[1]	**Spectral Radiance**[2]	**Required SNR**[3]
Land/Cloud/Aerosols Boundaries	1	620 – 670nm	21.8	128
	2	841 – 876nm	24.7	201

Table 1 : MODIS Bands for 250m

1 Bands 1 to 2 are in nm.

2 Spectral radiance values are (W/m^2 -µm-sr).

3 SNR = Signal-to-noise ratio

Source: https://modis.gsfc.nasa.gov/about/specifications.php

1.5 Rationale of the study:

The three districts of **ODISHA** namely **RAYAGADA, KALAHANDI** and **BALANGIR** have selected for our study purpose are mainly Rainfed. Our study mainly focuses on how cotton replaces rice in some parts of study area (i.e., from 2002-2014 is 29000ha to 135000ha). A work was formulated to study the changes in the crop pattern within the districts using remote sensing data.

The Specific objectives of the present study are:

- Case study on the Crop Diversification in the concerned districts
- Extraction of land use/ land cover information of the study area using Remote Sensing and GIS
- Showing the Diversified area using Geo Spatial Tools

CHAPTER 2

STUDY AREA

The area which we have selected for the project in Odisha districts namely **Balangir**, **Kalahandi** and **Rayagada**. These are the major cotton growing areas. We have studied the scenario of cotton in Odisha as it's a new entrant into the commercial agriculture and rapidly progressing in the suitable conditions of the state. The study shows how the cotton areas in Odisha increased from the early 90's to till now with the help of Geospatial tools i.e. Remote sensing and GIS. The tools will help for planning or further spreading of the cotton areas in the state. Here we explained about the successful cotton growth in Odisha and the type of farming.

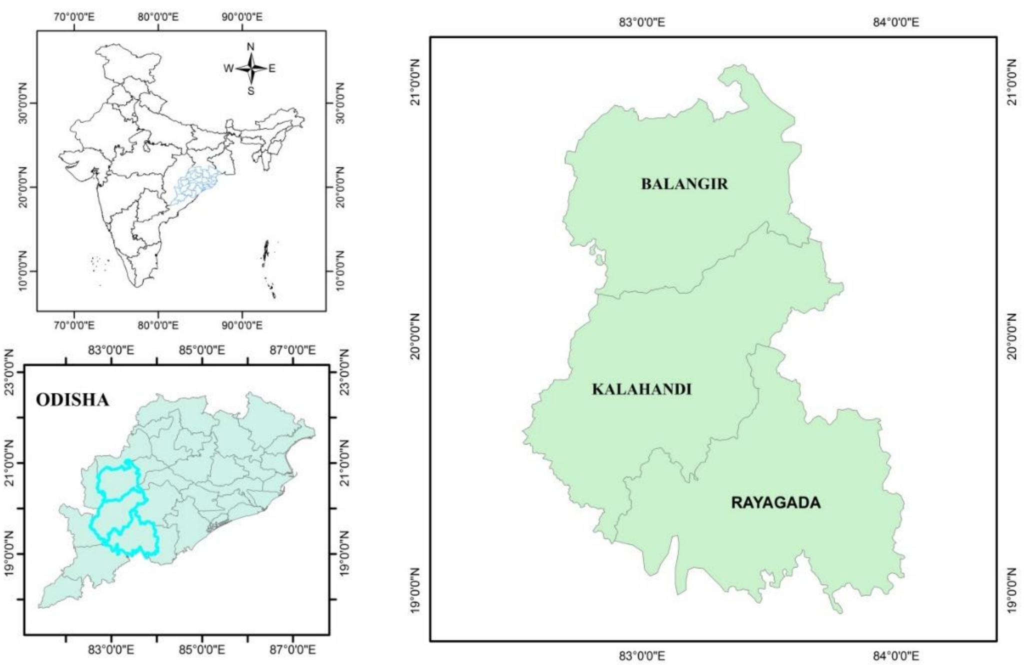


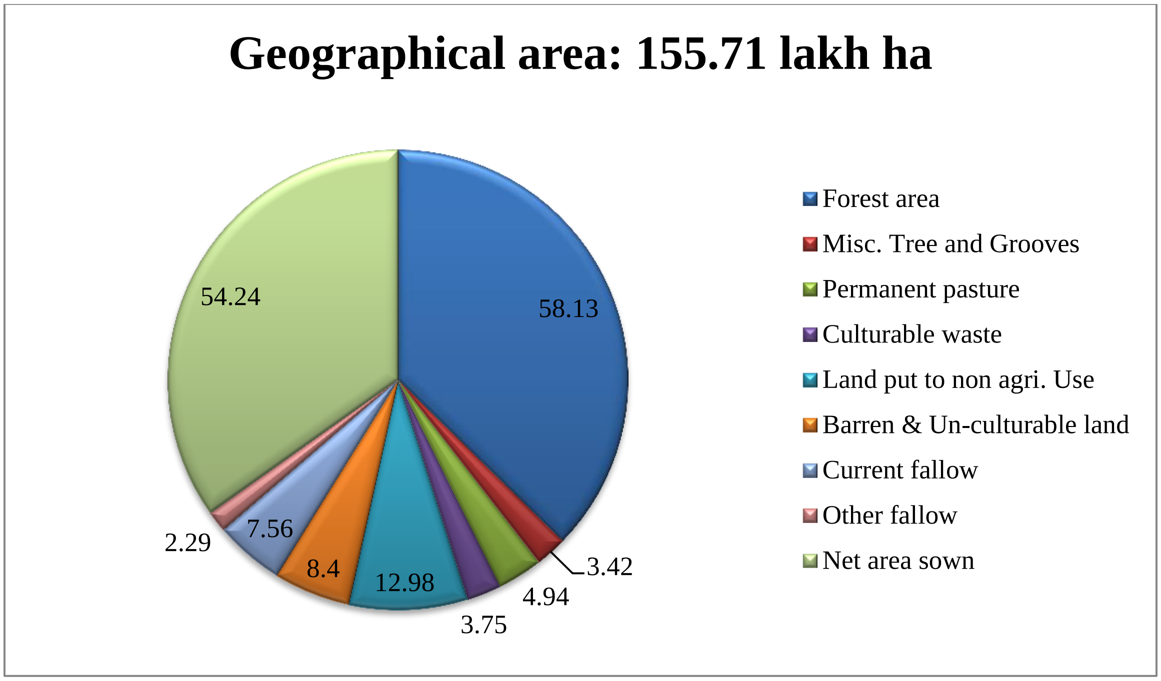
Figure 1: Major Cotton growing districts of Odisha

2.1 Status of Cotton area, production and yield:

Over the years, country has achieved significant quantitative increase in cotton production. Till 1970s, country used to import massive quantities of cotton in the range of 8.00 to 9.00 lakh bales per annum. However, after Government launched special schemes like intensive cotton production programmes through successive five-year plans, that cotton production received the necessary impetus through increase in area and sowing of Hybrid varieties around mid-70s. Since then country has become self-sufficient in cotton production barring few years in the late 90s and early 20s when large quantities of cotton had to be imported due to lower crop production and increasing cotton requirements of the domestic textile industry.

Since launch of **"Technology Mission on Cotton"** by Government of India in February 2000 significant achievements have been made in increasing yield and production through development of high yielding varieties, appropriate transfer of technology, better farm management practices, increased area under cultivation of Bt cotton hybrids etc. All these developments have resulted into a turnaround in cotton production in the country since last 6/7 years. The yield per hectare which was stagnant at about 300 kg/ha for so many years, jumped to 472 kgs in the year 2005-06 and now it reached to the level of 504 kgs to 566 kgs per hectare. Though this per hectare yield is still lower against the world average of about 705 Kgs to 805 kgs per hectare, country is expected to make more strides in cotton production in the years to come. The fundamental changes that taking place in the realm of cotton cultivation in the country, are having the potential to take the current productivity level near to the world average soon.

2.2 Overview of Odisha



Source: Status of Agriculture in Odisha 2014-15

Figure 2: Overview of Odisha

2.3 Scenario of Cotton in Odisha:

Odisha has one of the richest traditions of handloom and handicrafts in the country, which goes back to the time of antiquity. Apart from that, handloom and handicrafts products of Odisha are appreciated all over the country and outside because of exquisite designs, natural motifs and superb color combination. The state is purely depending on handloom in the textile sector and

Cotton is the major raw product of this sector. In Odisha, Cotton cultivation is an up-coming activity. Many of the western belt farmers mainly from Rayagada, Balangir, Kalahandi, Nabarangpur, and Nuapara districts are cultivating this cash crop because of suitable soil and climate conditions. Sea Island cotton is becoming familiar in the Ballipal region of Balasore district.

An average of 3.5 lakh bales of Cotton is cultivating in the state, of which approximately 2 lakh bales are ginned and pressed in the state. The traders and spinners of other states procure the remaining cotton. The area of cotton cultivation has been increasing tremendously. But the problem of selling the cotton in right price to the right person/agent/ organization is the difficult task to the common farmers. The production process starts with the farmer. Once the cotton is yielded, small farmers are not able to sell it in right price as always there is challenge for them to bring the small amount of cotton to the market from such a remote area by any means of transportation. This also will be costlier than their final selling price of their product. Even though the government agency is working in that area for the purchase of cotton but it is not helpful to them. They are compelling to sell to the private agent in low price to avoid the price fluctuation and for getting early price realization of their product for the domestic expenditure in the day to day life. It leads to major losses but our point is that the farmers should sell to the Government for their beneficial reasons.

We have studied how the traditional and major crops are diversified with commercial crop pattern in the three main districts, which we have seen commercial with contract type of farming is going on. Major commercial crop here is Cotton which changed the lives of the farmers in these districts due to its ultimate value in the Indian market.

Cotton is majorly growing in these agro climatic zones North-Eastern Ghats (Ganjam (Part), Gajapati, Rayagada, Kandhamal, Boudh), Eastern Ghats Highland (Nabarangpur (Part), Koraput (Part)), Western Undulating Lands (Kalahandi, Nuapada), Western Central Table Lands (Bargarh, Subarnapur, Balangir).

2.4 Suitability of Cotton in Odisha

Cotton, being known as “White Gold”, is an important fibre crop of the agro-supply chain system. World cotton production currently stands at approximately 23 million tons, grown in 90 countries, by an estimated 30 million farmers.

Climatic requirements:

Cotton is primarily grown in dry tropical and subtropical climates at temperatures between 11^0C and 25^0C. It is a warm climate crop threatened by heat or freezing temperatures (below 5^0C or above 25^0C), although its resistance varies from specie to specie. Excessive exposure to dryness or moisture at certain stages of the plant development (lasting five to seven months) may be detrimental.

The climatic factors also a play a major role while observing in Geospatial tools. The cloud should be clear for the perfect imagery. We have used the MODIS data, as the product will be obtained with cloud free in the monsoon season.

In Odisha cotton is having good familiar conditions with undulating topography and subtropical climate.

2.5 The Timelines of Non-Bt cotton and Bt- cotton in Odisha: (*Bacillus thuringenesis*)

2.5.1 Period of Non-Bt:

The farmers used to cultivate non-Bt varieties i.e. Hybrids or Desi varieties since 1990's. It continues until Bt enters, the major reasons it has been replaced due to heavy pest damage to the crops. The varieties used in Odisha are *MCU- 5, Sabitha, Bunny, Sri Tulsi* and *Dharani*. The yield rate of the cotton varies from region to region, crop to crop and also is based on the type of seed used. Farmers at few fertile regions of Rayagada had said they used to get more than 20 quintals seed cotton per acre. *MCU- 5* is cultivated more in Rayagada and Nabarangpur districts, whereas the other varieties are cultivated in all other cotton cultivated districts. Among all the varieties, share of *Sabitha* variety in cotton farming is higher in the ending periods of Non-Bt cotton compared with *MCU-5*, as it is a high yielding variety, during the same period is lower. But *MCU-5* is having good staple length compared with *Sabitha* and *Bunny* variety.

The diversification of major crops like rice and millets to cotton as a commercial crop, had taken up by the farmers from Andhra Pradesh. Mainly the farmers concentrated in the concerned study areas especially Rayagada district. The input for cultivating cotton used to bring from their native places and taking here the lands for lease. They have taught the cultivation of cotton to the Odisha farmers, by that time the results of the yield and money of the cotton leads to spreading into other areas. Nearly thousands of families have been migrated from Andhra Pradesh and started cultivation here. In this way, the birth of cotton in Odisha has been took place. Major factors for cultivating here are suitable climate and topography, availability of labor is more, less land rent. This causes by spreading to other districts in the past 25 years.

As the non-Bt varieties are prone to more pest damage, the field and environment in these conditions are fresh and the farmers made more money. But after 10 years the pest i.e. the bollworms had started damaging in these areas which causes huge losses for some farmers. Most of them returned to their homes in the periods of 1999-2002 due to lesser yields.

M.VENKATESWARULU

The farmer hailed from Guntur, Andhra Pradesh to Odisha in 1995 for the cultivation of cotton. He settled at Bikrampur block, Gunupur, Rayagada district. Presently he is cultivating cotton in 20 acres and red gram in 10 acres.

He migrated to this place because of Black cottony soils, humid climate, less labor cost, less land rent, no bollworm attack as it's a new place for the cultivation, High land topography which is more suitable for cotton growth and high availability of labor.

Before 2002 it was Non- Bt, which the farmers used to cultivate and had shown better yields but after that the bollworm infestation started, farmers entered drastic losses in the period of the 1999-2002.

Now he is getting more profits by introduction of Bt cotton in India after 2002 which fills colors in their life. It increases their yield despite of high seed cost. But after certain period the release of new strain in Bt that is Bollgard 2 is susceptible to the tobacco caterpillars that leads in reducing yield. Now the farmer is in full sorrow because the whitefly attack has been increased dramatically which leads to the crop damage by Leaf curl virus. For that they are increasing pesticide sprays every year, it results in decreasing yield as it become more resistant with the certain group of insecticides. Farmers are asking for the control against this and they are rethinking about non-Bt seeds as they are happy when some good insecticides which kill bollworm instantly and in return providing better yields. But this new technology leads to increase in the whitefly attack.

So that's why farmer has been started red gram cultivation which is having good market by reducing cotton cultivation in the year 2016.

Presently this year he sprayed the pesticides number of times and got good yield for cotton as this year had good rains. He sells his cotton to Cotton Corporation of India (CCI) every year. If he needs money urgently, he will sell some to the local private agents.

2.5.2 Period of Bt:

The golden phase started for the farmers after the year 2002 when Governement of India has approved Bt, a genetically modified crop for the cultivation. It has been released by Monsanto as BOLLGARD. This type of cotton has been the first biotech crop technology approved for commercialization in India in 2002. More than 6 million farmers adopted the technology on their farms.

In 2003 Monsanto introduced a second-generation trait product in cotton with Bollgard® II insect-protected cotton in 2003. The product provides farmers with the same benefits as the original Bollgard product, as well as expanded protection against other cotton pests. In 2006 Monsanto becomes the first agriculture company to introduce a stacked second-generation product, launching Bollgard II with Roundup Ready Flex cotton. The product provides farmers with the same benefits as Bollgard II, as well as the flexits Roundup Ready Flex technology.

Due to the success of Bollgard in India, in 2006 Bollgard® II – a double-gene technology-was approved by the Genetic Engineering Approval Committee, the Indian regulatory body for biotech crops. Mahyco-Monsanto Biotech (MMB) - a 50:50 joint venture between Mahyco and Monsanto Holdings Pvt. Ltd. sub-licensed the Bollgard II and Bollgard technologies to more than 30 Indian seed companies. Each Indian seed company has introduced the Bollgard technology into their own germplasm. Indian farmers now have a choice of over 300 Bt cotton hybrid seeds. Bollgard is used by more than 6 million Indian farmers.

It has been a great choice for the farmers in that period after 2002 as they are happier for better results. It gave them double yield and money. But after a good of period time the new technology had also faced its new flaws.

The Odisha government has become more concerned as the crops are diversified more by introducing Bt cotton in many areas. After it introduction number of districts is grown in a rapid time. Some farmers are benefitting and others not, the government had initiated a ban but the benefiting farmers did not care for the rules. Despite being discouraged by the Odisha government as a matter of policy, is being grown in many areas of Rayagada, Balangir and Kalahandi districts. Environmentalists have been protesting this genetically modified variety of cotton, as 93 goats died at a village in Balangir district allegedly after feeding on the leaves of cotton plants. However, government officials, who claim not to be encouraging the cultivation, remain blissfully oblivious to the fact that hundreds of farmers in Balangir and its adjoining districts grow Bt cotton with seeds procured from agents based in Andhra Pradesh. Sources said that attitude of the officials suited the Bt cotton promoters in Andhra Pradesh. Agents from across the border flood the rural areas of Balangir, Kalahandi and Rayagada with Bt cotton seeds providing even monetary support to the growers in certain cases.

We have seen that cotton was being grown in an area of around 20,000 hectares in Balangir district, 18,290 hectares in Kalahandi and 12,410 in Rayagada. Koraput, Nuapada, Sonepur, Ganjam, Gajapati, Boudh, Phulbani, Bargarh were among the other cotton-growing districts of the state. However, officials have no idea about the scale and size of Bt cotton cultivation because, having taken a policy decision not to encourage it, they have never made an attempt to assess how it has invaded districts close to the Andhra Pradesh border. Some of the district agriculture officials confessed to have found evidence of Bt cotton cultivation during raids but said they could do little to stop farmers from purchasing the seeds from agents from other states. The farmers of Rayagada district, who have been growing Bt varieties, argue that the seeds are easy to get and the crop is generally free from pests and insects. In contrast, the non-Bt crop involves a lot of expenditure on pesticides. Environmentalists, however, describe this as a blinkered view of the situation. “They are saying what they have been asked to say by the agents from Andhra Pradesh. The truth is that Bt crop is dangerous to health because it causes severe itching among human beings and can be fatal in the case of cattle, adding that as long as the government does not intervene to stop its cultivation, the crop would continue to pose a threat to humans and animals.

But the companies have guaranteed that there will be no side effects for the human and animals. They have said it is due to over application of pesticides can be fatal for the grazing animals. It has been proved that it did not release any toxic proteins in the soil, doesn’t cause to effect to microbial growth.

BT cotton advantages:

- Increases yield of cotton due to effective control of three types of bollworms, viz. American, Spotted and Pink bollworms.
- Insects belonged to Lepidoptera (Bollworms) are sensitive to crystalline endotoxin protein produced by Bt gene which in turn protects cotton from bollworms.
- Reduction in insecticide use in the cultivation of Bt cotton in which bollworms are major pests.
- Potential reduction in the cost of cultivation (depending on seed cost versus insecticide costs).
- Reduction in environmental pollution using insecticides.
- Bt cotton exhibit genetic resistance or inbuilt resistance which is a permanent type of resistance and not affected by environmental factors. Thus, protects crop from bollworms.
- Bt cotton is ecofriendly and does not have adverse effect on parasites, predators, beneficial insecticides and organisms present in soil.
- It promotes multiplication of parasites and predators which help in controlling the bollworms by feeding on larvae and eggs of bollworm.
- No health hazards due to rare use of insecticides (particularly who is engaged in spraying of insecticides).

BT cotton disadvantages:

- High cost of Bt cotton seeds as compared to non Bt cotton seeds.
- Less vigor if hybrid seeds are used for next year
- Heavy usage of fertilizers.
- Effectiveness up to 120 days, after that the toxin producing efficiency of the Bt gene drastically reduces.
- Ineffective against sucking pests like jassids, aphids, whitefly etc.

2.6 Major Cotton growing districts in Odisha:

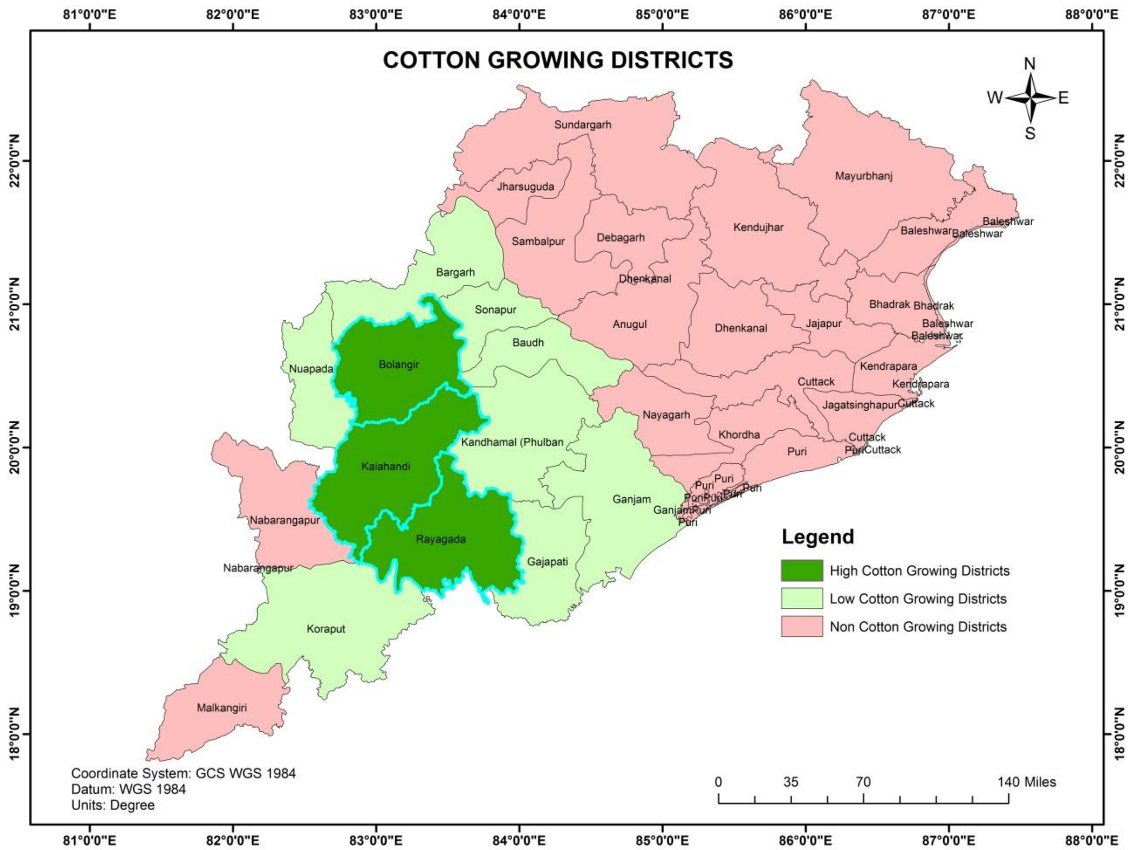


Figure 3 : Major Cotton growing districts in Odisha

Cotton is a major commercial crop in KBK districts in the kharif season. KBK (Kalahandi Balangir Koraput Region) in Odisha has been regarded as the most backward region by the planning commission. It includes eight districts mainly **Kalahandi,** Nabarangpur, Nuapada, **Koraput**, Rayagada, Malkangiri, **Balangir** and Sonepur. Recently three more districts have been included Ganjam, Nayagarh and Jajpur.

In the above figure the dark green colored are the major growing districts in area i.e our study area **Balangir, Kalahandi, Rayagada** and the light green colored are the less growing districts i.e. Koraput, Ganjam, Gajapati, Kandhamal, Baudh, Sonepur, Bargarh, Nuapada.

The major crops grown in the study area are Rice, Maize, Finger millet, Green gram Red gram, Black gram and Horse gram etc. Rice cultivation dominates the cropping pattern to such an extent that achievements made in terms of diversification sometimes become overshadowed due to the small weightage of crops diversified into. Diversification towards commercial crops has taken place in the form of cotton, groundnut and sugarcane. From our study cotton emerges as a crop with high value per unit but its production is limited to mainly the KBK region and the districts with major cotton cultivating area are Balangir, Kalahandi and Rayagada.

One of the most positive changes seen is the diversification of new area brought under cultivation towards cotton. Some of the farmers' area under cultivation has gone up from a mere 3 hectares to about 40 hectares. This change is most prominent in Balangir, Kalahandi and Rayagada.

District Wise Major Key Indicators of Odisha during 2013-14

Area in '000hect.

Districts	**Rainfall (in mm)**		**Geographical area**	**Cultivated area**	**Net area sown**	**Gross cropped area**	**Kharif cropped area**	**Rabi cropped area**
	Normal	**2013**						
Balangir	1289.8	1422.9	657.00	346.00	292.00	353.88	471.78	117.90
Kalahandi	1330.5	1855.6	792.00	378.00	335.00	381.26	598.31	217.05
Rayagada	1285.9	1485.8	707.00	193.00	160.00	194.99	249.02	54.03

Table 2: District Wise Major Key Indicators of Odisha during 2013-14

Source: Odisha Agriculture Statistics 2013-14.

2.6.1 Balangir:

Geographical Situation:

Balangir district is bounded by Sonepur and Boudh in the east, Nuapada in the west, Kalahandi in the south and Bargarh is in the north. It lies between $20^{0}11^{1}40^{11}$ – $21^{0}5^{1}08^{11}$ North Latitude and $82^{0}41^{1}15^{11}$ – $83^{0}40^{1}22^{11}$ East Latitude.

Balangir is located under Western Central Table Land Agro climatic Zone characterized by hot and sub humid climate. Basing on the physiographic and irrigation availability Balangir District has been divided in to four Agro– ecological situations (AES) and characterized by a hot dry summer and highly erratic rainfall distribution of south–west monsoon rains i.e.

1. Plain land irrigated
2. Undulating plain drought prone
3. Undulating sub- mountainous tract rainfed

Basic Information:

Geographical area- 657000ha

Cultivated area- 345475ha

- High- 189325
- Medium- 70155
- Low- 85995

Soil type: the district has Red and Yellow, Red and Black, Black, Laterite and Brown forest soil.

Normal and Actual rainfall:

Normal and Actual rainfall is 1289.8 mm. The district receives rainfall from the South-west monsoon during June to August. The coldest month of the district is December whereas the hottest month of the district is May.

Temperature: The mean maximum and minimum temperature of Balangir district is 34.9^0C and 21.0^0C with mean morning humidity 67% and evening humidity 57 %. Sometimes in summer season the maximum temperature rises to above 50^0C.

Condition of cotton in the district

The main crops grown in Balangir are Rice, Black gram, Chickpea, Horse gram, Green gram, Groundnut and Cotton. Now a days Wheat and sugarcane are also improving. The area under rice has declined by about 8 percent in the case of profit earning farmers and 17 percent in the case of non-profit earners. There has been a substantial change in the area under cultivation. Also, area under rice has declined giving scope for crops like vegetables (other vegetables have increased in area from 2690 hectares to 17000 hectares), green gram, sesame and cotton. This decrease has resulted due to diversification from paddy towards cotton. There has been a nearly 17-fold increase in the area under cotton. Increase in area in conjunction with increase in yield rate has led to a nearly 2567% increase in output. The yield rate post adoption in the case of cotton is higher in the case of profitable farmers as compared to non-beneficiaries. In Balangir 90.5% of the households sell cotton at their farm gates and only 9.5% sell cotton at markets. Kantabanjhi, Jogimunda, Patnagarh, Belpara and Khaprakhol are the major cotton growing areas.

2.6.2 Kalahandi:

Geographic location:

Kalahandi district occupies the South-Western portion of Odisha and is situated between $19^0 08^1$N and $20^0 25^1$N Latitude and $82^0 32^1$ E and $83^0 47^1$ E Longitude.

It is bounded in the North by Raipur (Chhattisgarh), Balangir and Nuapada district. In the west by Raipur and Nabarangpur districts in the south Rayagada district and the east by Rayagada and Kandhamal districts. The total geographical area of the district spreads over 7920 sq.kms, comprising of 2 Sub-division which includes 13 blocks & 2238 villages with a breakup of rural & urban areas covering 7678 and 815 sq.kms, respectively. Area wise, the district ranks 7th in Odisha.

Basic Information:

Geographical Area: 792000 hectares.

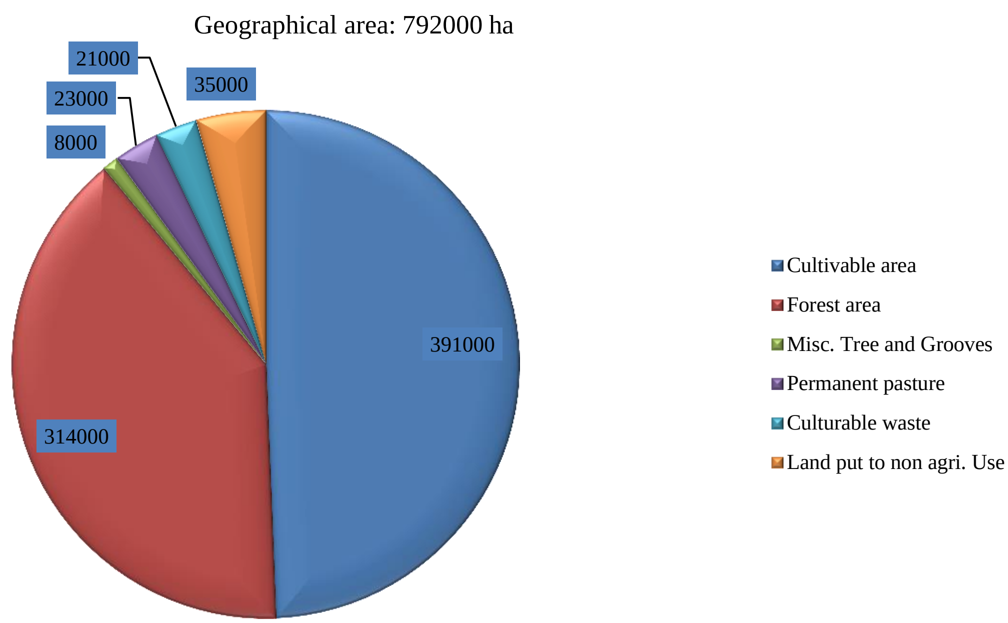


Figure 4: Geographical Area – Kalahandi

Soil type:

The district has two distinct physiographic regions the plain lands and the hilly tracts. The Soil condition of the district can be broadly classified as under.

Sl.No.	Type of soil	Percent
1.	Red soil (Red laterite)	31.63%
2.	Black clay (Heavy)	13.90%
3.	Clay and Sandy loam	54.47%

Table 3: Soil type – Kalahandi

Rainfall & Climate:

The average annual rainfall of the district is 1330.5 mm. The monsoon starts in late June & generally lasts up to September. The rainfall is much erratic in the plain area punctuated by long dry spells. The climate of Kalahandi is like that of central Indian type where summer season is prolonged & severe with a brief spell of winter, which is main cause of drought, bring a normal feature of the district. May is the hottest month of the year where the maximum temperature reaches about 45^0 Celsius (113 Fahrenheit). December is the coolest month where the mean of daily minimum temperature is recorded at 11^0celsius (52 Fahrenheit).

Condition of cotton in the district:

The major crops growing in the district are Rice, Wheat, Cotton, Pulses and Vegetables and the cropping intensity has reached 167%. In Kalahandi, there has been a substantial increase in the area under cultivation and a slight decrease in area under rice. The increase in cultivated area has given scope for diversifying primarily into vegetables and cotton besides small increments in other crops.

Kalahandi is marked by more than a 1081% increase in area under cotton in the case of profitable farmers and 266% in the case of non-profitable farmers. In actual terms the increase of about 24 hectares in the case of beneficiaries has been due to a 12-hectare decline in the area under paddy along with additional area cultivated being diverted towards cotton. But the sprayers use is more for cotton cultivation but in this district surprisingly lowest i.e. 37% compared with Sonepur district i.e. 73%, despite being a major diversified crop. But the production and area is higher in Kalahandi district. In the sale of cotton in Kalahandi the situation is completely in contrast with Balangir. In Kalahandi, almost entire production (98%) of the cotton is sold at nearby mandis and only 2% is sold at farm gates.

Since two decades, cotton cultivation in the non-irrigated black cotton soil has come up immensely from 5000 ha in 1996 to 46152 ha. in 2015. The major Cotton growing blocks in Kalahandi district are Bhawanipatna, Kesinga, Golamunda, Narla, M.Rampur and Lanjigarh. Besides the support of green revolution in the Indravati Aycut area of Indravati project in Jaipatna, Kalampur, Junagarh, Dharamgarh blocks of the district the impact have also been felt in non-irrigated blocks of the district. This saw progress in the field of Paddy, Cotton, Maize, pulses and oil seeds and the district is in the green revolution phase. Now Kalahandi is the 2nd highest Rice and Maize growing and the highest Cotton growing districts of the state. Special centrally sponsored scheme of national food security mission to increase production and productivity of Rice, Pulses & Cotton in a sustainable manner,)

Source: SAMIKSHYA (Directorate of Economics & Statistics Journal of Socio-Economic Issues, Vol.10; June-2016)

2.6.3 Rayagada District:

Geographic location:

Rayagada district is located between $19^{0}0^{1}$and $19^{0}58^{1}$ north latitude and $82^{0}5^{1}$ and $84^{0}2^{1}$ east longitude in the southern part of Orissa. It is bounded by Gajapati district in the east, Koraput and Kalahandi districts in the west, Kalahandi and Phulbani districts in the north and Koraput and Srikakulam (Andhra Pradesh) districts in the south. As per 2001 census the district having 7073 sq. kms of geographical area occupies the 8th rank in the state. The district of Rayagada is constituted by five towns including two census towns and 2,667 villages spread over 11 C.D blocks.

Basic information:

Geographical area- 758745ha

Cultivated area- 193504ha

- High- 128962ha
- Medium- 42705ha
- Low- 21837ha

Climate: Rayagada district comes under North Eastern Ghats Zone characterized by hot, moist and sub-humid climate and classified as tropical. The summers here have a good deal of rainfall, while the winters have very little. The average annual temperature in Rayagada is 26.5 °C. The average annual rainfall is 1312 mm.

Soils: It consists of Brown forest, lateritic, Red alluvial, Black and mixed Red Soil groups.

Condition of cotton in the district:

The major crops growing in the district are Rice, Wheat, Finger millets, Green gram, Black gram, Groundnut, Sweet potato, Maize and Cotton. Rayagada district is the main place of birth for cotton in Odisha. As the farmers from Andhra Pradesh had moved here at this district in the places named Gunupur, Muniguda and Padampur. They started cultivation of cotton since two decades by taking lands on lease. Most of the farmers are contract based and largely growing cotton in these areas. The major growing blocks are Gunupur, Muniguda and Rayagada.

In Odisha state, Rayagada district cotton stands for best in quality and production. Most of the produced cotton exported to Gujarat and Andhra Pradesh through private traders. Some of the farmers are using CCI for selling the cotton. Here the soil and climate are mostly favorable for the cotton growers. The area is increasing rapidly from 16970 ha. in 2006-07 to 26700 ha. in 2013-14.

2.7 Area, Yield and Production of Cotton (Kharif) in 2013-14 for the study area

A=Area in '000ha. Y=Yield in Kg. /ha. P=Production in '000bales

DISTRICT	AREA	YIELD	PRODUCTION
Balangir	39.76	435	101.74
Kalahandi	43.06	333	84.35
Rayagada	26.71	499	78.40

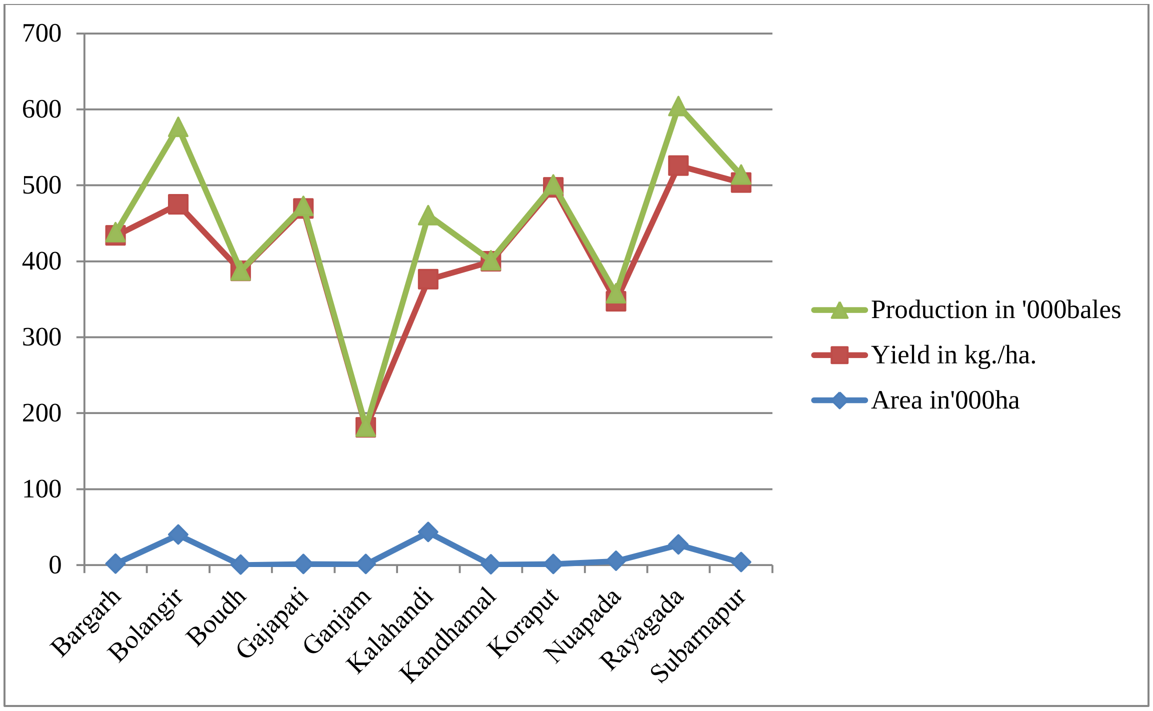
Source: Odisha Agriculture Statistics 2013-14.

Table 4: Area, Yield and Production of Cotton (Kharif) in 2013-14 for the study area

The Production of Cotton has declined from 336 thousand bales in 2012-13 to 299 thousand bales in 2013-14.

In the below figure, we can clearly observe that Balangir, Kalahandi and Rayagada districts are with more area and production of cotton. In other districts, cultivation of cotton has becoming more familiar in recent years.

District Wise Area, Yield and Production



Source: Odisha Agriculture Statistics 2014-15

Figure 5: District Wise Area, Yield and Production

2.8 Statistics of 2013-14 for the Classification of Study Area

- **Crop wise irrigated area during Rabi 2013-14**

Area in '000 ha.

Districts	Rice	Wheat	Maize	Total pulses	Total oilseeds
Balangir	3.86	0.52	0.66	3.55	7.59
Kalahandi	39.51	2.47	1.18	5.29	10.85
Rayagada	4.04	0.13	2.02	2.56	3.74

Table 5:Crop wise irrigated area during Rabi 2013-14

- **District Wise Area Covered Under Mixed Cropping During 2013**

(Area in ha.)

Name of the district	Red gram + Cotton + Jowar	Cowpea + Cotton
Balangir	-	2362
Kalahandi	71	-
Kandhamal	77	-
Rayagada	1100	-
Gajapati	3180	-
Ganjam	360	-
Bargarh	-	800

Source: Odisha Agriculture Statistics 2013-14.

Table 6: District Wise Area Covered Under Mixed Cropping During 2013

2.9 Cotton: Marketing and Value Addition

Though the contribution of Odisha towards India's total cotton production is barely 0.5%, the cotton produced in the state is of exportable quality. In the study area, the districts are involved in various types of marketing.

The marketing of cotton is undertaken mainly through three types of agencies

1. Corporations and Cooperatives

2. Private Traders

3. Contract Farming

In Odisha, the buying and selling of cotton is regulated by the Regulated Market Committees established as per Orissa Agriculture produce and Market Act 1956. Five market yards have been established under five RMCs equipped with godowns, auction, halls, farmers rest sheds, farmer information centers and grading laboratories. The procurement centers for cotton include:

- Kesinga and Utkela under Kesinga RMC, Karalada under Bhawanipatna RMC which will come under Kalahandi district.
- Gunupur, Muniguda and Rayagada under Rayagada RMC.
- In Balangir District cotton procurement centers include Kantabanjhi and Jogimunda under Kantabanjhi RMC.

The firms buying this cotton include Eco Farm (India) Pvt., Kesinga, Bioorganic farm, natural organic, Amita group, Kamadhenu Ginning mill, V.V. Cottons, Boirays, Ambika Agro industries, Jaydurga Ginning mill, Natural organic Pratima Agro Industry, and Cotton Corporation of India. From these 92% of the cotton is procured by Private traders and 5% by the CCI.

The advantages of the RMCs are proper weighing of cotton, help in grading, payment of proper price due to auction in the form of cash or cheque, storage space and knowledge about rates at different markets.

The area under cotton was increased dramatically in the three districts from 2006-07 to 2013-14. Major change is seen in Balangir and Kalahandi districts because of availability of more black soils.

(Area in ha.)

Districts	**2006-07**	**2013-14**
Balangir	19600	39800
Kalahandi	16040	43100
Rayagada	16970	26700

Table 7: Area under cotton

2.9.1 Contract farming scenario in study area

The farmers of these areas have also entered the arena of contract farming over the years. The inclination of the farmers towards instant cash and assured market has attracted them for contract farming. This has resulted in more and more farmers entering the process and utilizing their land for contract farming instead of traditional farming practices. The widespread practice of contract farming for jatropha, cotton, maize, rubber, lemongrass and groundnut is indicating that Odisha is also in favor of contract farming.

Advantages and disadvantages of Contract Farming:

The vertical coordination involved in contract farming has both advantages and disadvantages to both the contractual parties, i.e. the farmer and the company. The advantages of such a system is often more pronounced for a state like Odisha where agriculture is predominant and small farmers are large in number because contract companies provide with necessary inputs and extension services. It is however not free from problems. The benefits that farmers and the companies can accrue along with the constraints they face in entering contract.

Advantages

- Inputs and production service provided to the farmers
- New technologies and new skills made available to the farmers
- Linking with new market to the small farmers

Disadvantages

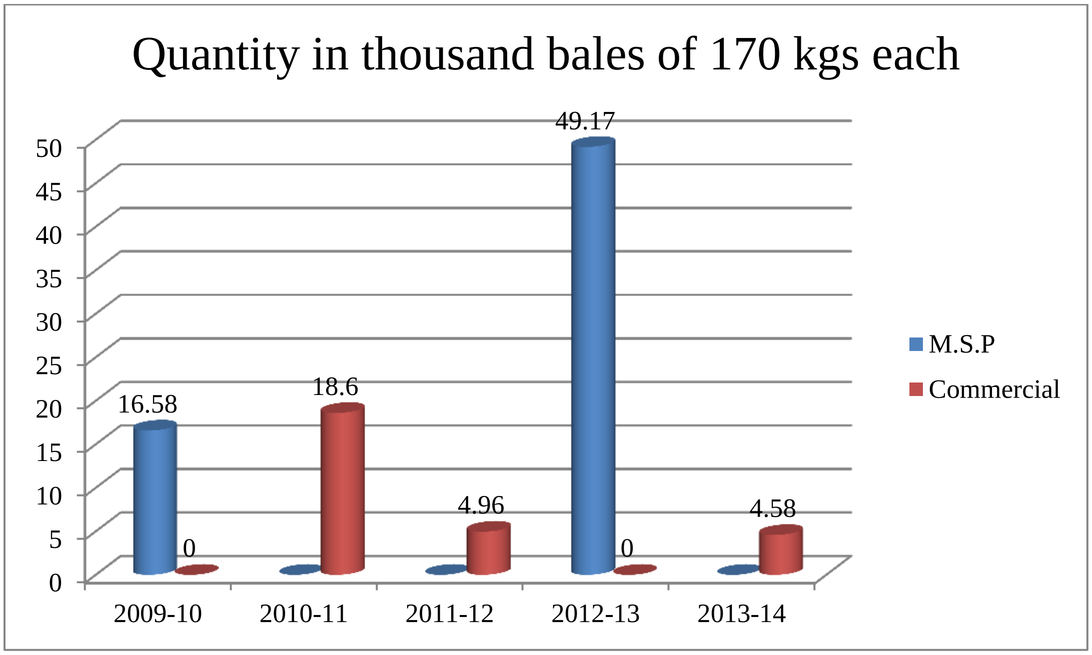
- Manipulation of quotas by the contractors.
- Sponsoring companies may be unreliable or exploit a monopoly position.

- The staff of sponsoring organization may be corrupt, particularly in the allocation of quotas.
- Farmers may become indebted because of production problems and excessive advances.
- Gradation is made by the company.

For a farmer, the advantage largely lies with the fact that he gets access to inputs and extension services which otherwise would not been easily available to him. One of the most attractive benefits for the farmer is linkage which he gets with credit, since farmers use the contract agreement as collateral to arrange the credit with a commercial bank in order to fund inputs. Farmers do not have to search for and negotiate with local and international buyers since project sponsors usually organize transport for their crops normally from their farm gate. But at the same time, a farmer while entering into contract of growing new crops should be ready to bear the production risk of the quality and market prices in some cases, risk of handling advanced technology which he usually is not acquainted with, manipulation of quotas by the companies in case the market is not favorable, and risk of indebtedness with the production problems.

2.10 Odisha state cotton purchases by Cotton Corporation of India from 2009-10 to 2013-14

It clearly shows that the whole cotton sold is major for private traders and less for CCI i.e. M.S.P. The contract farming rate is higher and it leads to more exporting and goes to the hands of private people.



Source: Cotton Corporation of India Ltd., Navi Mumbai.

Figure 6: Quantity in thousand bales of 170 kgs each

- **District Wise Procurement of Seed Cotton by different farms during 2013-14**

Quantity in Qtl.

District	CCI	Private	Total
Balangir	-	324852	324852
Kalahandi	-	445509.62	445509.62
Rayagada	22703.54	407217.96	429921.5

Source: Odisha Agriculture Statistics 2013-14.

Table 8: District Wise Procurement of Seed Cotton by different farms during 2013-14

It clearly shows above the major producers of study area i.e. Balangir and Kalahandi are selling to the Private rather than CCI. Only Rayagada district farmers are benefiting by selling their produce to the CCI.

The ultimate decision is lies within the farmers as they are losing huge amount of money by selling to private traders.

PURNA CHANDRA RAO

Purna Chandra Rao, an old man of 75 years and a farmer by profession, lives with his wife in Bikrampur village of Gunpur block. He originally hails from ***Varshing*** *village of* ***Chaluamba*** *Panchayat of* ***Guntur*** *district (Andhra Pradesh). He migrated to* ***Odisha*** *in 1995. He was cultivating cotton and chilly in his native place. He faced loss there and came to Odisha in search of land that suited cotton cultivation. He found the land in Gunupur block and shifted with his family. Now after 15 years he is known as one of the successful farmers and a big producer of cotton in Gunupur. He is the first man who started cotton cultivation in Gunpur. He did not leave his field in Andhra Pradesh but leased it out to local people. Now his son is cultivating the field there.*

When he came to Odisha, lease rate of land was comparatively cheap. He took 30 acres of land on lease @ Rs.500 per acre and started cotton cultivation from which he earned huge profit. Then slowly he expanded his cotton cultivation. In the year 2006, he took 70 acres of land on lease for three years, 35 acres in Reguda and other 35 acres in Vikrampur. But he incurred a drastic loss in Reguda as the land was not suitable for the cultivation. He directly sells the produce to Cotton Corporation of India (CCI), and never depends on the contractor or middleman. The CCI, Odisha has fixed the rate of cotton at Rs.3000.00/- per quintal. He has not signed any contractual agreement with them as he has hope on them as an old seller.

Now he is old and unable to carry out such a huge job. He has reduced the operation to 8 acres.

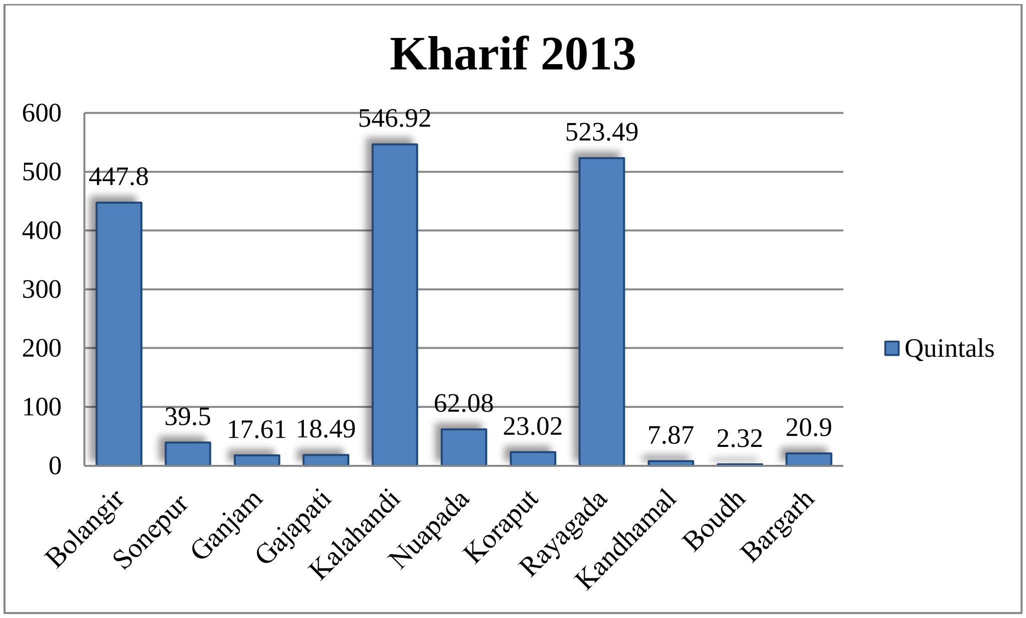
Apart from this he is now busy in maintaining a farm house where he has planted lemon in 3 acres, teak in 4 acres and other fruit plants like papaya, coconut, guava, mango etc. along with many kinds of flowers too. The land in which farm house is made belongs to another person, who is living in Hyderabad. He is maintaining the land properly from which he gets much satisfaction. He said that whenever he will face drastic loss again in Odisha, the possibility of which is very low, he will go back to his state.

2.11 Missions on improving cotton in Odisha:

- **National Food Security Mission (**NFSM)**:** Commercial crops (Cotton, Jute and Sugarcane)

Commercial crop is being implemented under which it has been envisaged to promote fiber crops like Jute & Cotton. The present aim is to raise the area under cotton to above 134000 ha. by substituting the crop in high land where non-remunerative non-paddy & paddy crops are grown. Steps are being taken to make available quality hybrid & high yielding seeds to cotton growers in the state. Besides, technical assistance for raising the crop is being rendered through the extension personnel of the department.

- **District wise seed distribution during Kharif 2013**
  For the development of cotton, Government of Odisha supplied seeds for the Kharif season.



Source: Odisha Agriculture Statistics 2013-14.

Figure 7: Kharif 2013 Production District wise

- **Intensive Cotton Development Programme (ICDP)**

Mini-Mission-II of Technology Mission on Cotton:
The Intensive Cotton Development Programme (ICDP) is now implemented as a Mini Mission - II under the Technology Mission on cotton and one of the major commercial crops. Cotton is predominately grown in the KBK districts in the Kharif season and one of the major commercial crops. Cotton cultivation has been increasing in Balangir, Kalahandi and Rayagada districts. During 2013-14, emphasis was given on area expansion, use of quality/ hybrid seeds, farmers training and intensification of IPM practices etc.

During 2013-14, 100 Farmers Field Schools (FFS) and 412 Front Line Demonstrations (FLDs) were taken up to train & demonstrate the farmers on use of latest production technology. Besides, to popularize the use of pheromone traps on cotton crop for control of pests, ₹0.90 lakh has been utilized to cover 299 hectares during 2013-14. To educate the cotton farmer's 86 awareness campaign programmes for fiber quality management and 150 farmers' trainings were organized with an expenditure of ₹16.10 lakh. During 2013-14, 28 sprinkler sets were supplied to the famers with a subsidy amount of ₹4.20 lakh.

One of the most positive changes seen is the diversification of new area brought under cultivation towards cotton.

- In Balangir, the average price of cotton is marginally higher at the mandis (₹3,700/q) as compared to price at farm gate (₹ 3,600/q).
- In Kalahandi, the average price of cotton is marginally higher at mandis (₹ 3,650/q) as compared to price for the private traders (₹3,500/q)
- In Rayagada, the average price of cotton is marginally higher at ginning mills and CCI (₹4,000/q) as compared to price at farm gate (₹3,800/q).

- **MSP of Cotton from 2011-12 to 2013-14**

₹/Qtls.

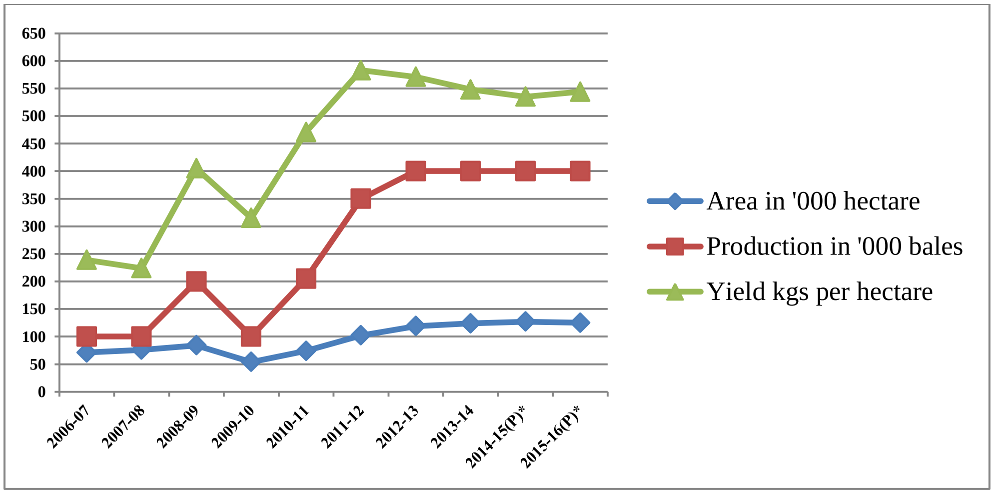
VARIETY	2011-12	2012-13	2013-14
Medium staple	2800	3600	3700
Long staple	3300	3900	4000

Source: Odisha Agriculture Statistics 2013-14

Table 9: MSP of Cotton from 2011-12 to 2013-14

2.12 Odisha Data from 2006-07 to 2015-16

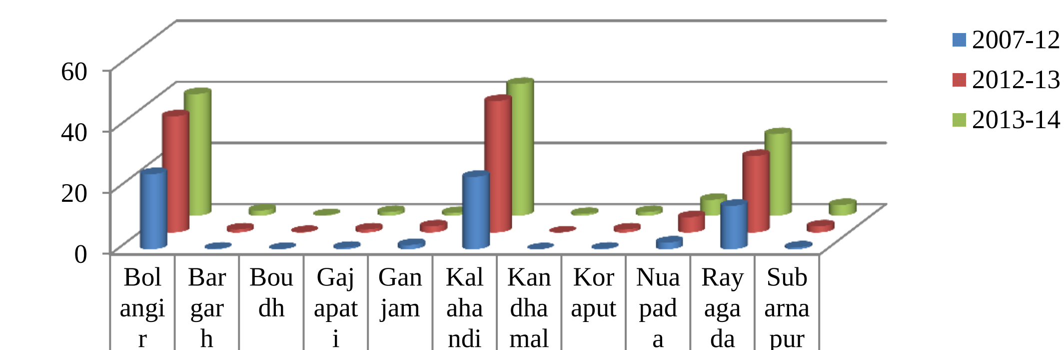
- Due to diversification into cotton and other commercial crops from rice and other millets, the farmers are getting more benefited. The year wise change or shifting into other crops leads to more variation in the pattern. From the below figure, we can observe the changes of cotton in Odisha in Area, Yield and Production



Source: Cotton Advisory Board; P-Provisional; *As per CAB meeting dated 2-2-2016 *Inclusive of State-wise loose cotton production

Figure 8: Odisha Data from 2006-07 to 2015-16 Odisha Data from 2006-07 to 2015-16

- From the three timelines mentioned below in the figure we observed a gradual increase of area in the cotton growing districts of Odisha. The study area has shown majority of all the districts.



	Bolangir	Bargarh	Boudh	Gajapati	Ganjam	Kalahandi	Kandhamal	Koraput	Nuapada	Rayagada	Subarnapur
2007-12	24.6	0.2	0.1	0.5	1.4	23.7	0	0.2	2.2	14.2	0.6
2012-13	38	1	0.16	1	2	43	0	1	5	25	2
2013-14	39.8	1.7	0.18	1.2	0.9	43.1	0.6	1.2	5.2	26.7	3.5

Zero denotes either nil or negligible

Figure 9: Increase of Area in the Cotton Growing Districts of Odisha.

Source: Odisha Agriculture Statistics (2007-08 to 2013-14), Directorate of Agriculture and Food Production, Govt. of Odisha.

- We have also observed the statistics of Rice areas which shows unproductive yields and diversified to Cotton and other high value crops.

District	Percentage change					
	(1997-98 to 2001-02)			(2001-02 to 2005-06)		
	Area	Yield	Prod	Area	Yield	Prod
Balangir	**-5.39**	23.74	17.05	10.04	**-12.57**	**-3.77**
Sonepur	-0.15	3.52	3.38	2.52	13.75	16.63
Kalahandi	13.57	**-0.22**	13.30	10.11	**-21.37**	**-13.40**
Nuapada	5.17	33.69	40.56	-3.24	-22.82	-25.30
Koraput	27.61	25.82	60.49	-2.26	9.69	7.23
Malkangiri	15.32	48.70	71.44	-3.10	25.74	23.02
Nabarangpur	11.07	12.59	25.05	1.63	-3.39	-1.80
Rayagada	8.98	20.73	31.52	**-22.65**	**-5.88**	**-27.17**
KBK	8.37	14.73	24.36	2.42	-5.26	-3.02

Table 10: Percentage Change in Area, Yield and Production of Rice in KBK Districts

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials used

3.1.1 Remote sensing data

1. MODIS (250 m resolution) time series NDVI multi-spectral data (2010-11, 2013-14 and 2016-17)

3.1.2 Software used for the study:

1. Land use/Land cover Mapping
    - ERDAS Imagine 10.4
    - Google Earth Pro
2. Geospatial Analysis and data conversion
    - ArcGIS 10.2.2
    - MODIS Re-projection Tool (MR Tool)
3. Analysis and Report writing
    - Adobe reader, Microsoft Excel, Word and PowerPoint

3.2 Land use database

Land use /Land cover for the crop years of Odisha state are prepared using MODIS Time-Series Mega files of Normalized Difference Vegetation Index (NDVI) are downloaded from the USGS Earth explorer website.

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 (Red) that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light (Red) and less near-infrared light. **NDVI = (NIR — RED) / (NIR + RED)** where NIR is ‘Near infrared’. 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 give 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.

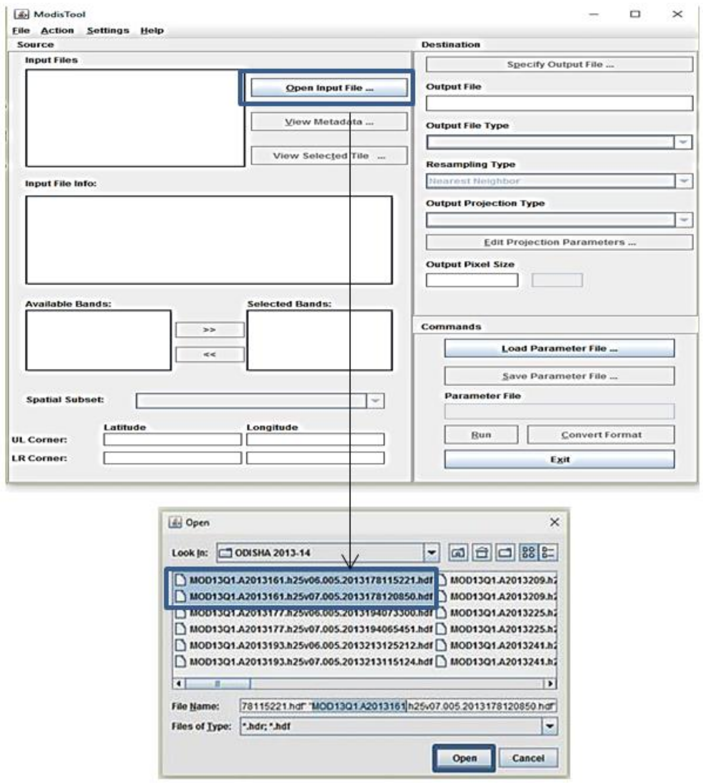
We have taken the path and row of **h25 v06** and **h25 v07** for the study area purpose.

The downloaded files of MODIS are in .hdf format and it will be converted into .tif files in the conversion tool named MODIS reprojection tool.

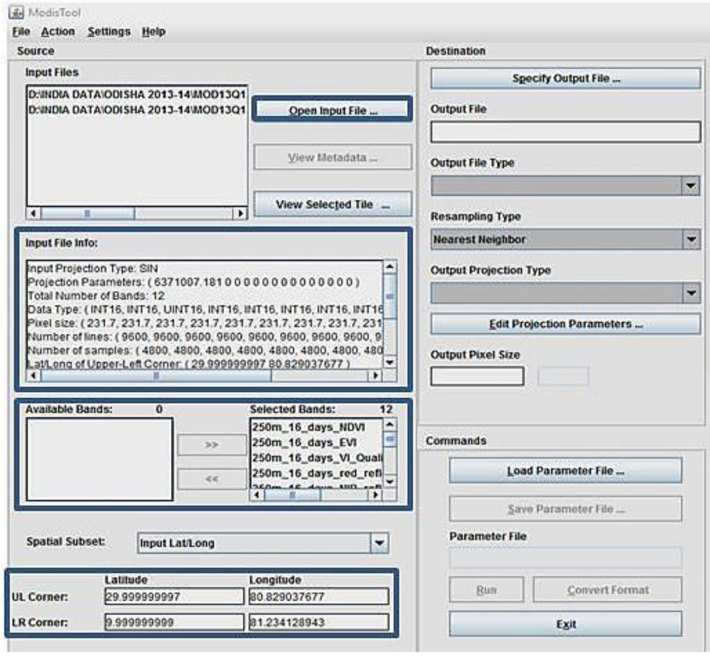
3.3 Process of MR Tool

1. Open the MR Tool file.

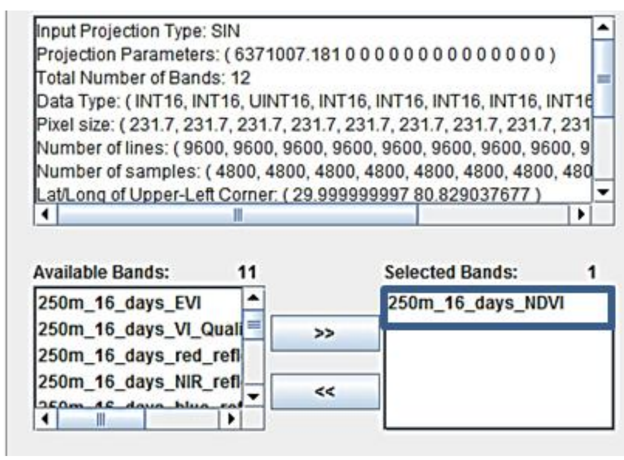
2. **Add .hdf files:** Insert the data of downloaded modis .hdf files i.e. which is stored in ODISHA 2013-14 folder by clicking **Open Input File**. We have to select the single day images at a time. Two tiles are covered the entire Odisha area, so we selected 2 .hdf files of the same date.



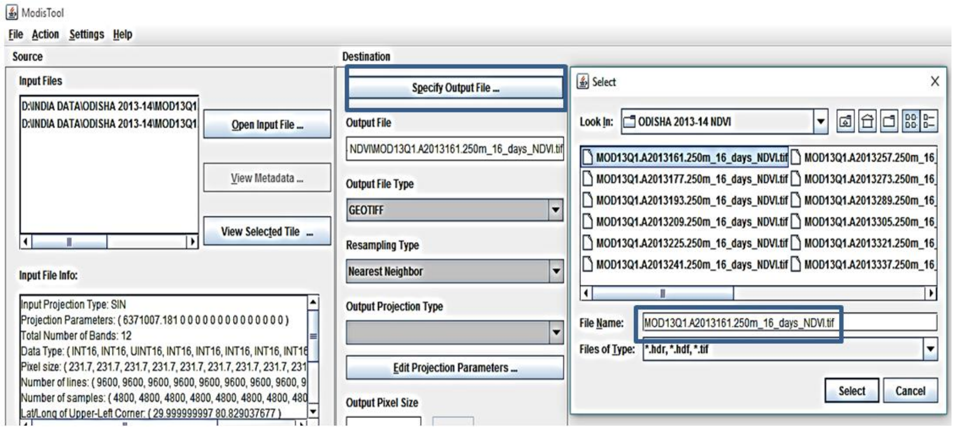
Once the .hdf files are loaded, the source information is displayed in the Input File Info, Available/Selected bands, Spatial Subset and Coordinates.



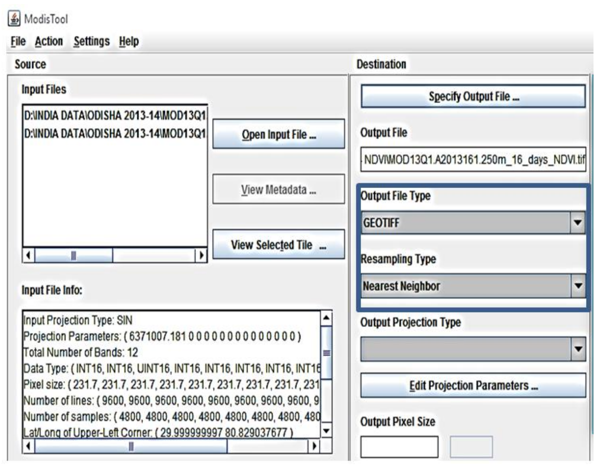
3. **Band selection:** By default, all available bands are selected and appear in the box to the right (Selected Bands). We need only **NDVI** band. To separate certain bands from processing, click on the unwanted bands and use the “**<<**” button to deselect them (below figure). This will move it to 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.



4. **Output file:** Specify the output file by naming it and created a destination folder for the files. Provided an output name like the input file name i.e. “MOD13Q1.A2013161” which should be saved in .tiff format we have followed the same consistency.

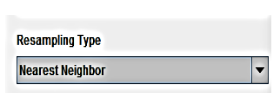


It is very important to include the file extension as part of the file name. The file extension indicates the file format of the output image. If we add **".hdf"** it will give **HDF-EOS**, **".tif"** will give **GeoTIFF** and **".hdr"** will give **raw binary**.

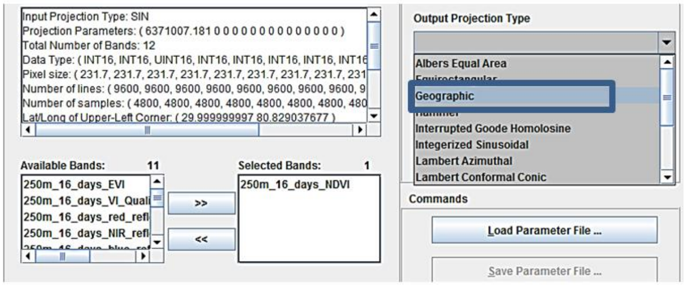


In Output File Type, we have selected GEOTIFF which is a standard image format in image processing software.

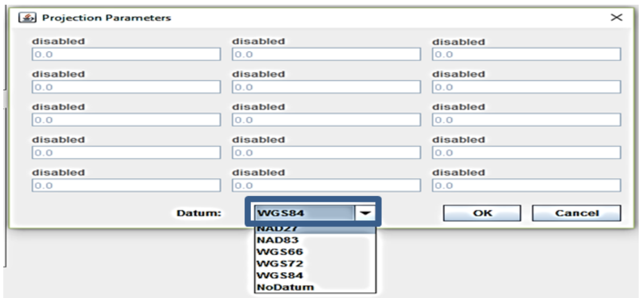
5. **Resampling:** Selected the Resampling Type as "**Nearest neighbour".**



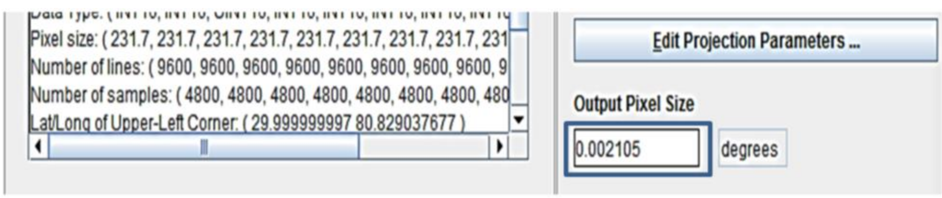
6. **Reprojecting:** It transforms the sinusoidal equal area projection of the input .hdf into the geographic coordinate system.
   - The **Output Projection Type** is selected from the list as **Geographic**



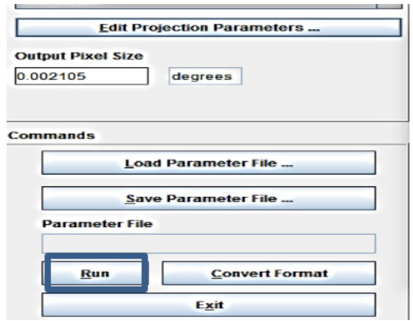
For the parameters we have to open Edit projection parameters and select **WGS 84** as datum.



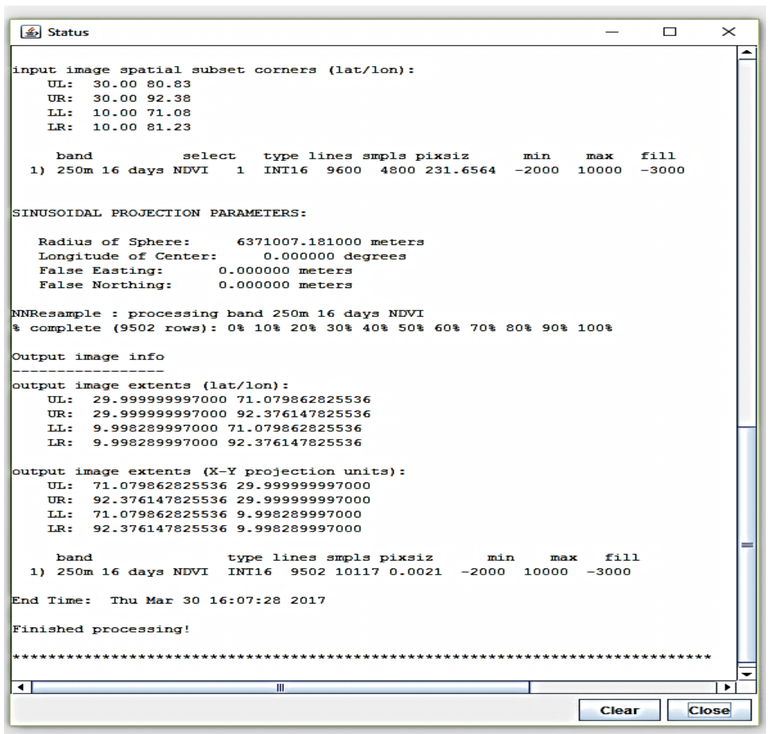
7. **Output Pixel Size: 0.002105 degrees.** it should be defined as our outpt image will be in geographic coordinates, the pixel resolution is measured in degrees. MOD13Q1 is 250m resolution, this is equivalent to 0.002105 degrees at the equator.



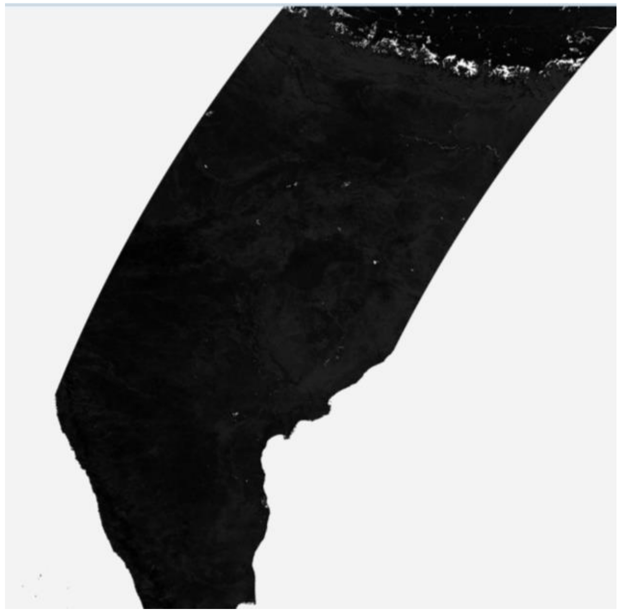
8. **Executing the conversion:** Clicked RUN button to stop the conversion process.



After processing, the status window appears as **“Finished processing”.**



9. End product .tiff file which will be shown as below of two tiles. Like the below process, it should be done for all the tiles of julian dates for the given year.



10. Mega-file data cube composition

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 10June, 2013 to 25May, 2014 (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 2013 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 2013 to May 2014 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.**

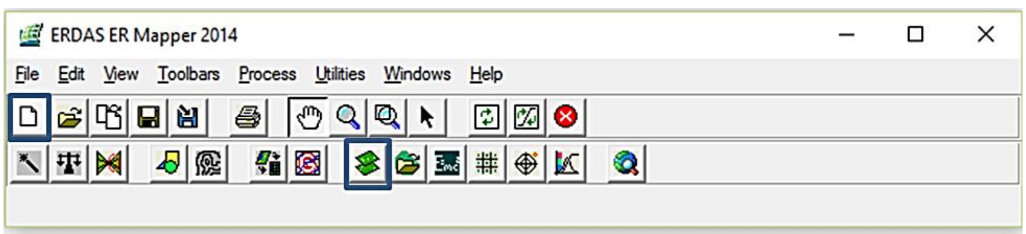
- ER Mapper involves in advanced image processing and compression capabilities.
- ERDAS Imagine is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications. Imagine is aimed mainly at geospatial raster data processing and allows users to prepare, display and enhance digital images

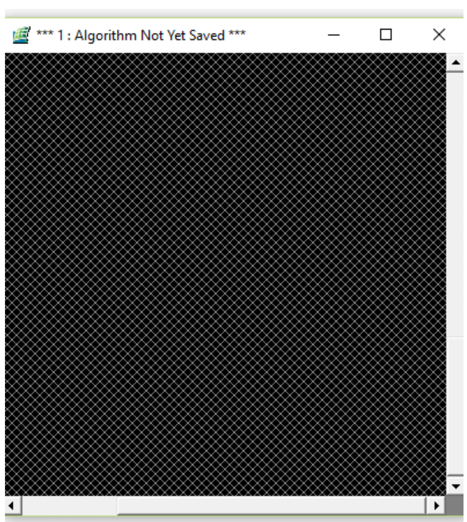
for mapping use in geographic information system (GIS) and computer-aided design (CAD) software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions. By manipulating imagery data values and positions, it is possible to 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, mosaicking of imagery, stereo and automatic feature extraction of map data from imagery.

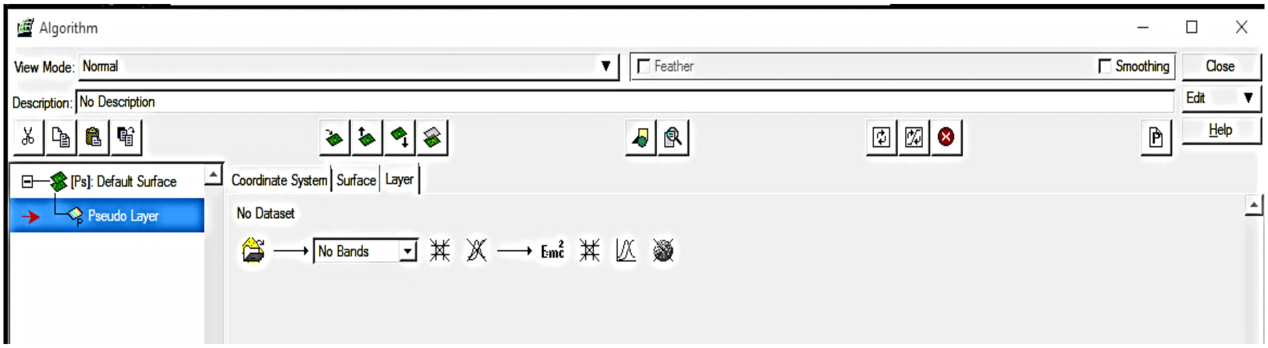
3.4 Process of Erdas ER Mapper for creation of Maximum Value Composite files

3.4.1. Preparation of NDVI time series composite

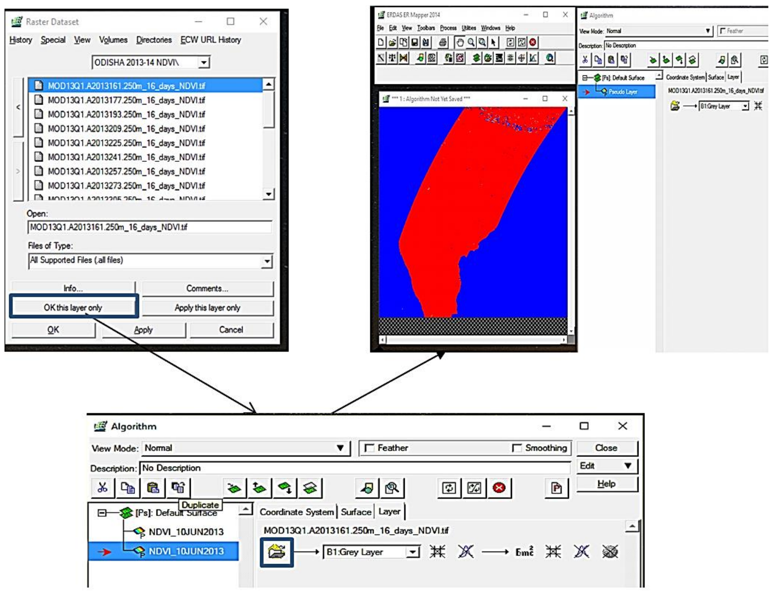
1. Open Erdas ER mapper and click 'New' file and then click 'Edit Algorithm' icon.



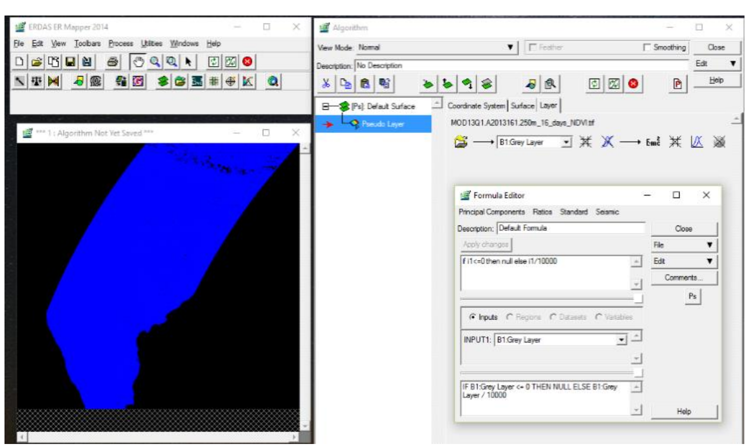


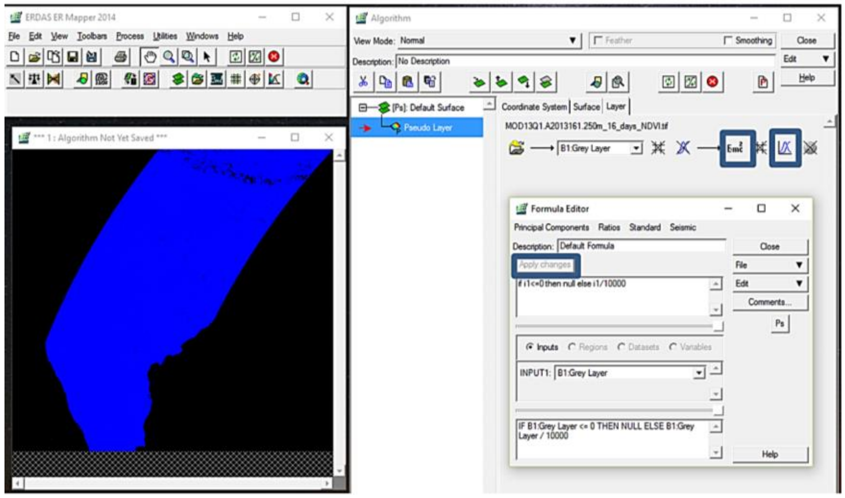


2. Added a **Raster Dataset** named **"MOD13Q1.A2013161.250m_16_days_NDVI.tif"** in 

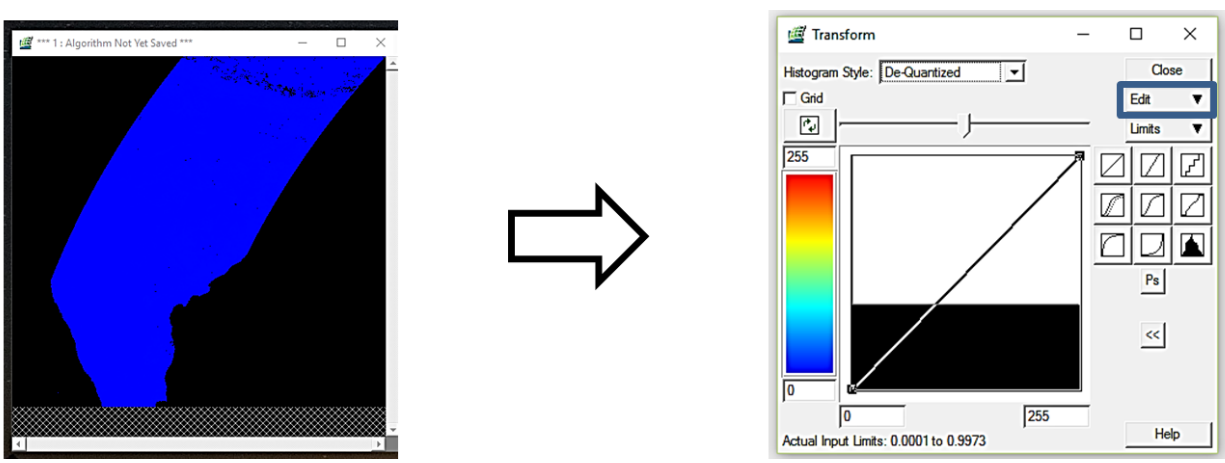


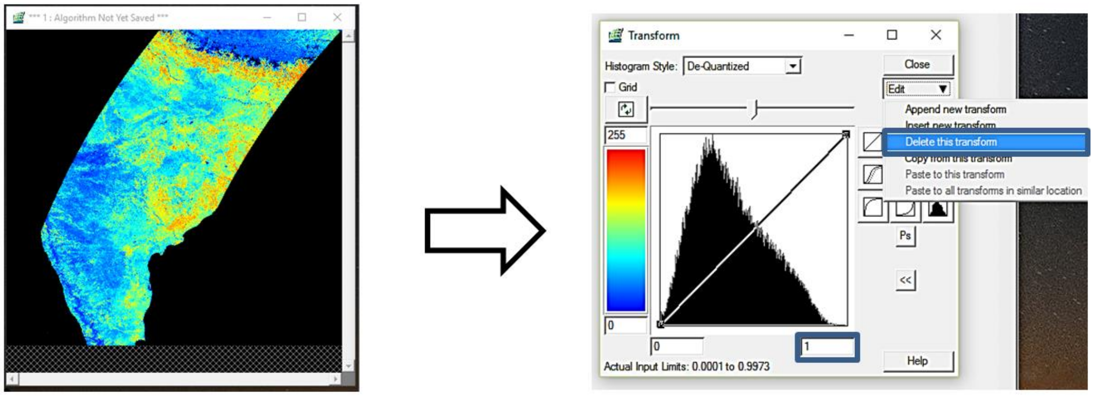
3. After this open "Formula Editor"  and entered **"if i1<=0 then null else i1/10000".** Click 'Apply changes' then the colour of the map changes from Red to Blue.

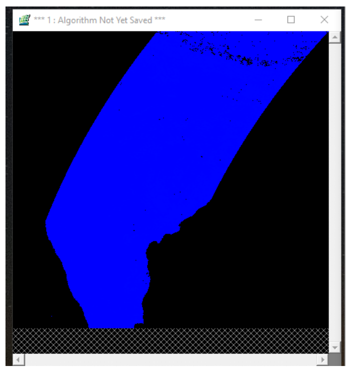




4. Open Transformation limits and assign input limits as 0 and 1 and go for transformation and click edit transform limits icon and then the window in the below opens, click on the Edit pull down menu and click **delete this transform** (this is done to retain the real values)

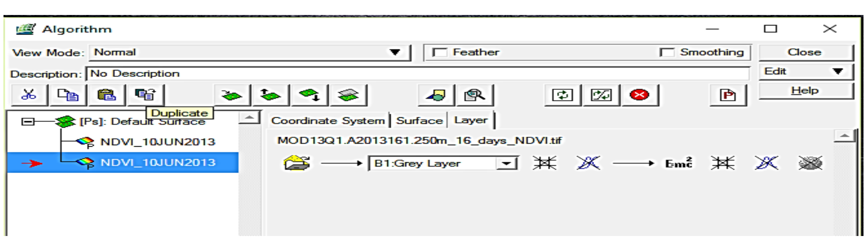


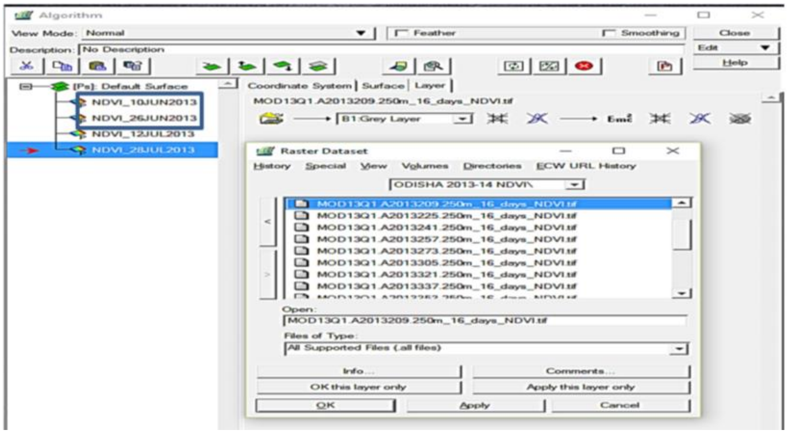




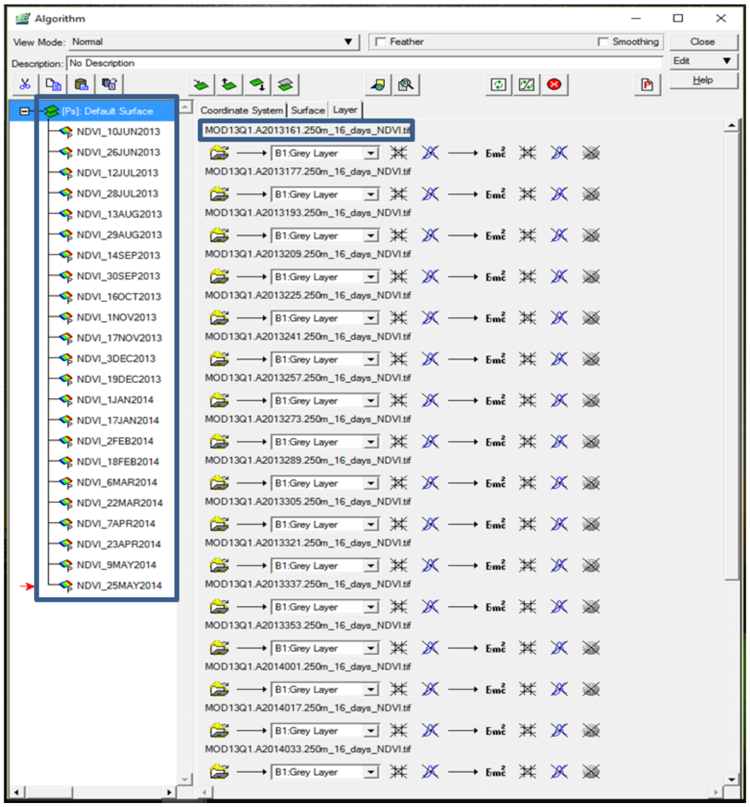
Important note: the two steps mentioned above are critical in the process of creating a megafile hence always double check at this point to make sure that steps have been accurately executed.

5. Using the duplicate icon shown in below make one more duplicate of the same.
Then rename the layer as NDVI_10JUN2013 to NDVI_26JUN2013.





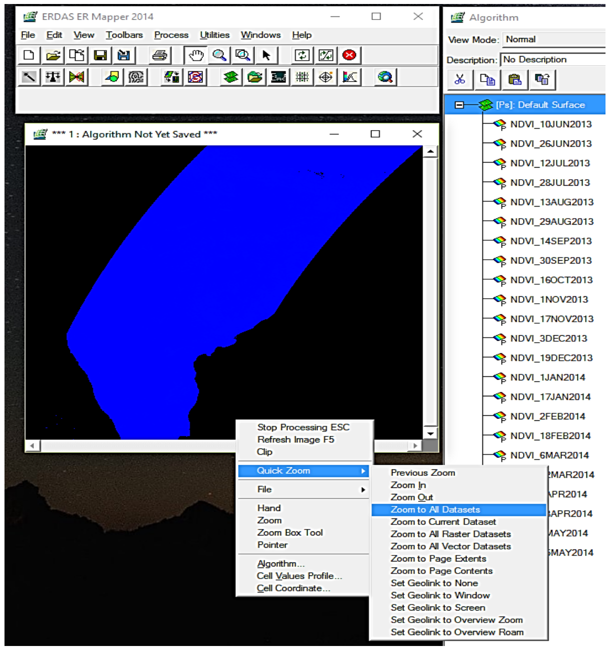
Same procedure repeats and link corresponding layers…. Finally, 16 day NDVI images are shown in below.

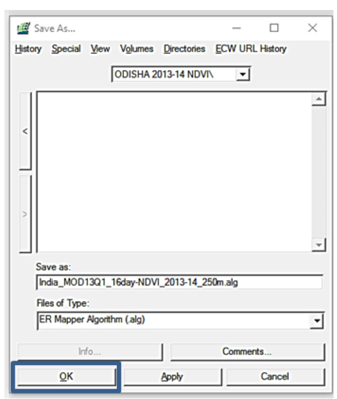


NOTE:

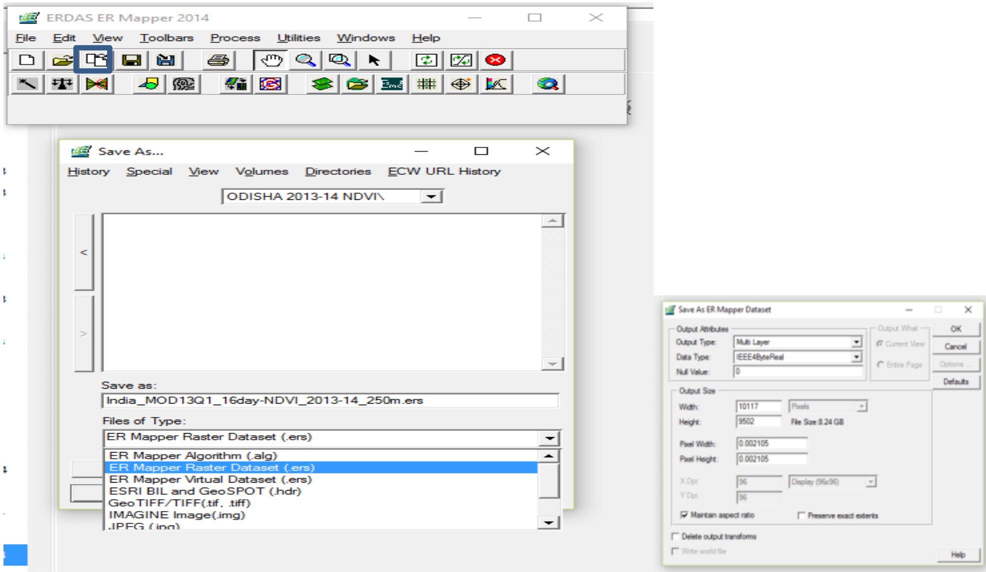
- In the figure shown above, make sure that the right data is loaded into the appropriate layer.
- Keep saving the algorithm file after completing every 3 or 4 Julian dates.

6. Then right click to **Quick Zoom-> Zoom to all Datasets** and save the file as .alg as shown below "India_MOD13Q1_16day-NDVI_2013-14_250m.alg" then click OK.

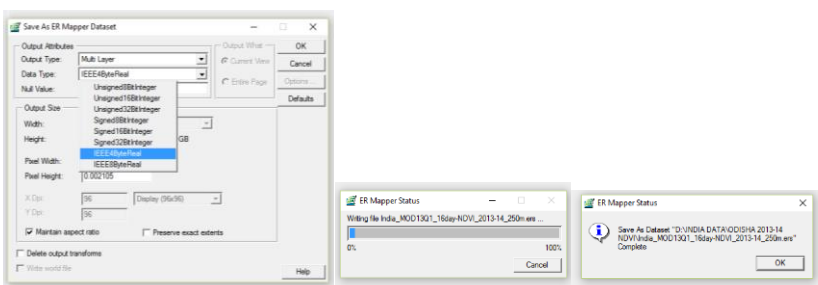




7. Continue the above procedure for rest of the dates. Make sure that all the dates and bands are properly filled into the spaces provided. Check at least twice before saving the file in the ERS format. Save the algorithm file in .ers format

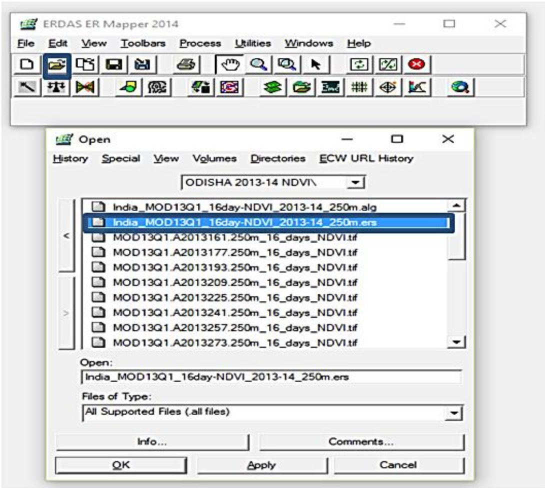


From the Data Type pull down menu, select the proper data type to save (in this case IEEE4ByteReal) and click OK. This ends the session for creating a Mega file (Time series data) for MODIS NDVI Data.

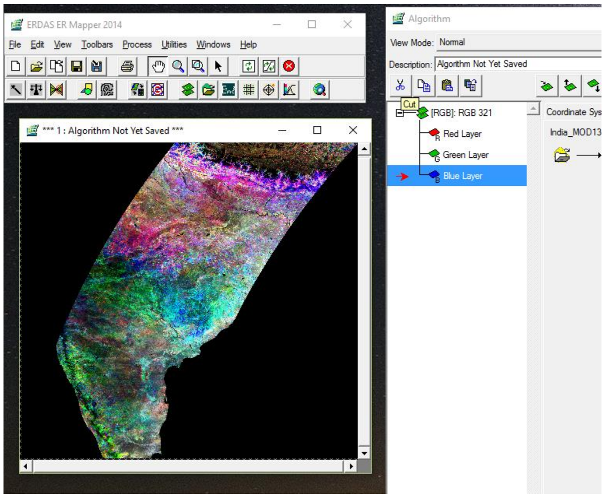


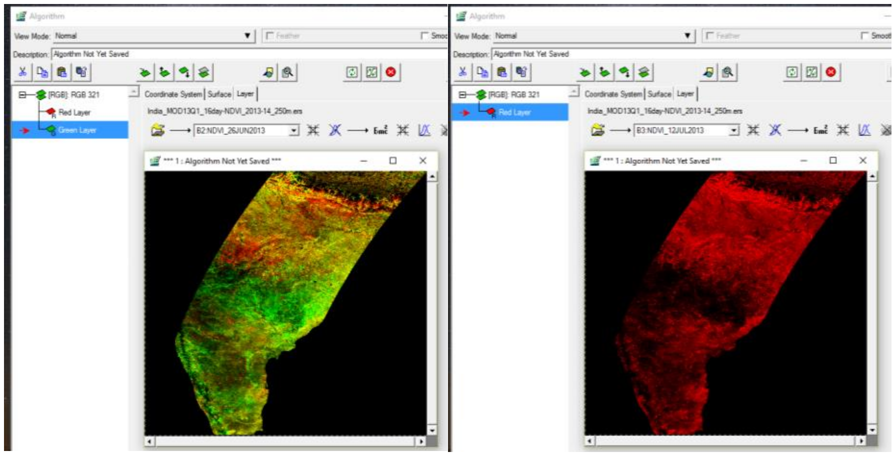
3.4.2 Preparation of Megafile for NDVI-Maximum Value Composite (MVC)

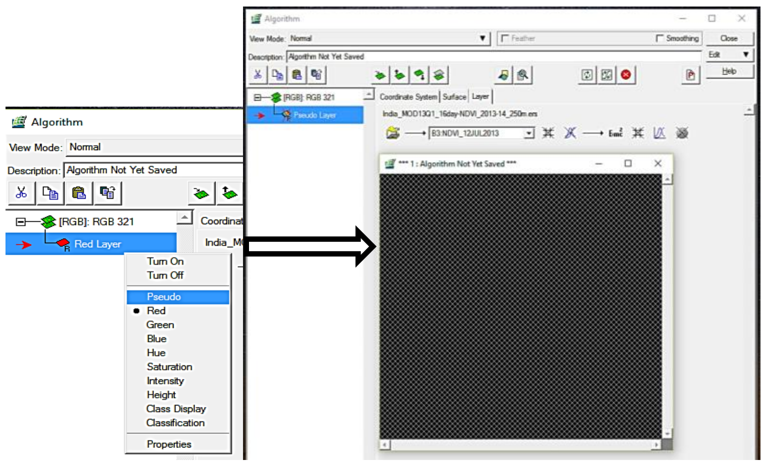
1. Open the NDVI file i.e. "India_MOD13Q1_16day-NDVI_2013-14_250m.ers" NDVI megafile.

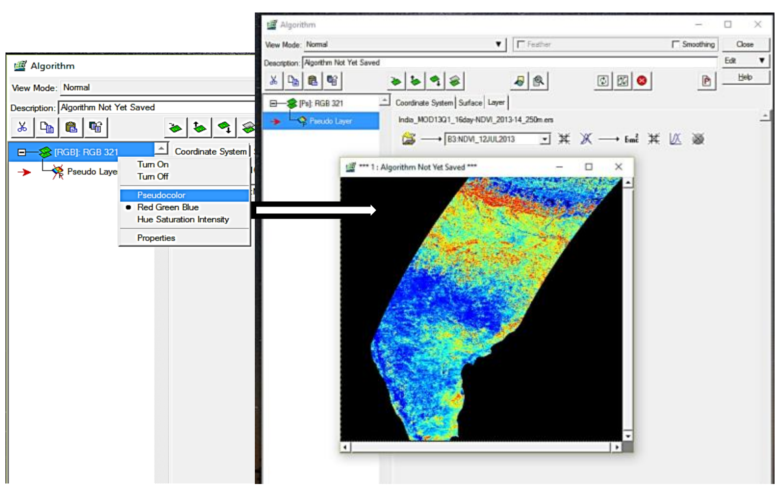


2. Once the NDVI file is opened, click on the Edit Algorithm icon and change the RGB color combination to Pseudo. Cut the Green and Blue layers, change the Red layer into Pseudo color.

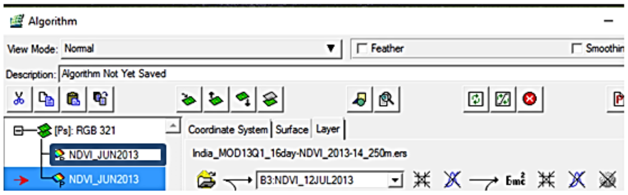



Algorithm
View Mode: Normal
Description: Algorithm Not Yet Saved
[RGB]: RGB 321
Red Layer
Green Layer
Coordinate System | Surface | Layer
India_MOD13Q1_16day-NDVI_2013-14_250m.ers
B2:NDVI_26JUN2013
B3:NDVI_12JUL2013
*** 1 : Algorithm Not Yet Saved ***

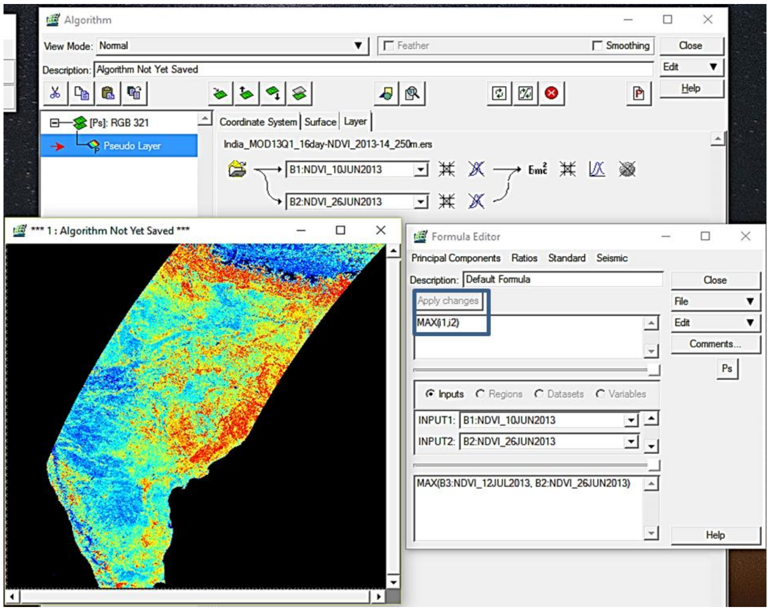

Algorithm
View Mode: Normal
Description: Algorithm Not Yet Saved
[RGB]: RGB 321
Red Layer
Turn On
Turn Off
Pseudo
Red
Green
Blue
Hue
Saturation
Intensity
Height
Class Display
Classification
Properties
Pseudo Layer
India_MOD13Q1_16day-NDVI_2013-14_250m.ers
B3:NDVI_12JUL2013
*** 1 : Algorithm Not Yet Saved ***


Algorithm
View Mode: Normal
Description: Algorithm Not Yet Saved
[RGB]: RGB 321
Pseudo Layer
Turn On
Turn Off
Pseudocolor
Red Green Blue
Hue Saturation Intensity
Properties
[Ps]: RGB 321
India_MOD13Q1_16day-NDVI_2013-14_250m.ers
B3:NDVI_12JUL2013
*** 1 : Algorithm Not Yet Saved ***

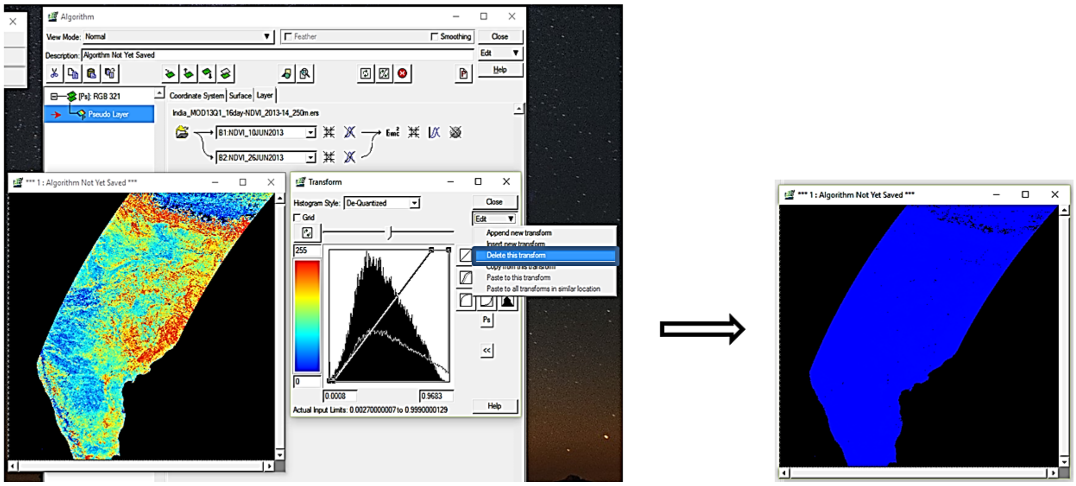
3. Rename the pseudo layer as "NDVI_JUN2013".



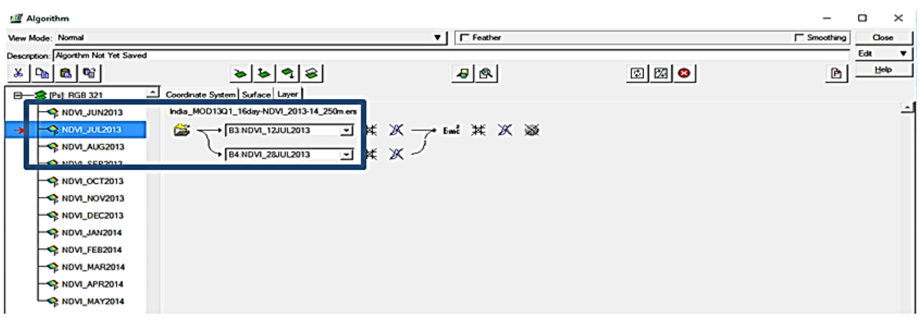
4. Click on the Edit formula and type the formula "MAX(i1,i2)" depending on the number of images acquired in that particular month.



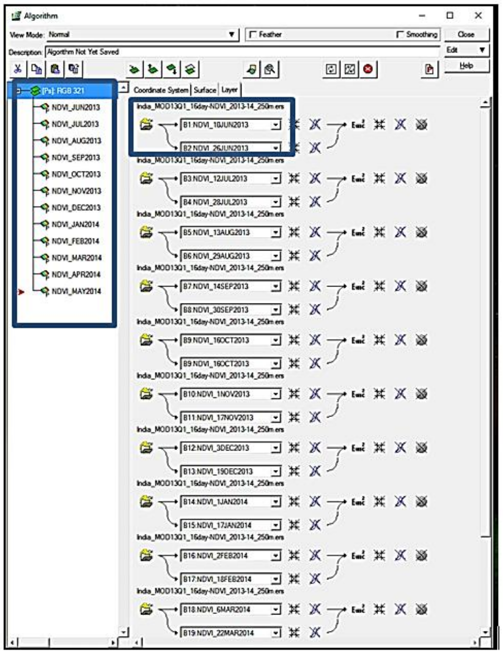
5. Click on the Edit Transformation Limits icon and click on Edit pull down menu and click delete this transform and click Close.



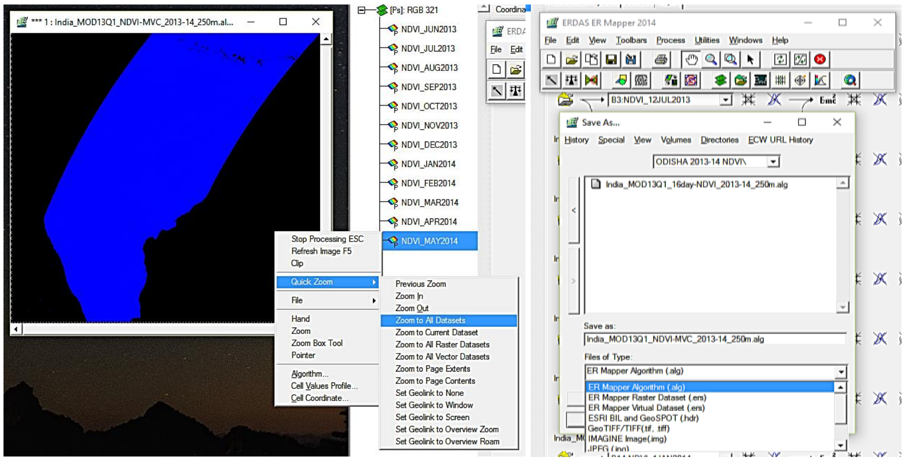
6. Duplicate the first layer, i.e. NDVI_JUN2013 and rename the duplicated layer as NDVI_JUL2013, which is the Maximum Value Composite for the month of July. The formula same as Jun (MAX (i1, i2)), where i1 and i2 are the NDVI layers for the dates 12th, 28th of July 2013. The output layer. i.e. NDVI_JUL2013 represents the Maximum NDVI value for each pixel amongst the selected 2 NDVI layers for that particular month (i.e. JULY).



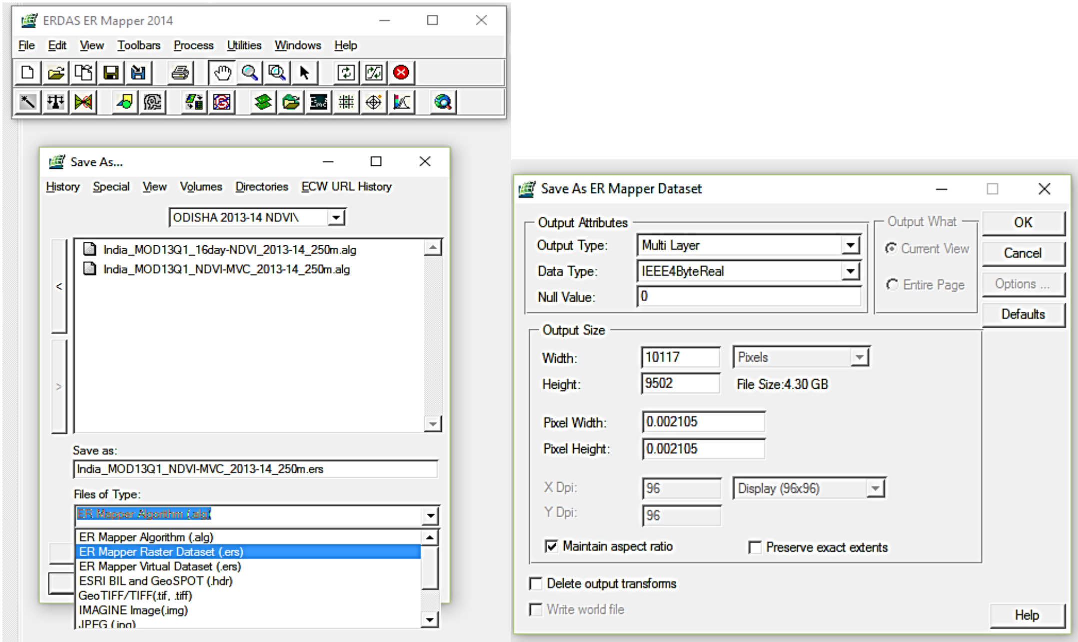
7. Repeat the same procedure for the rest of the months, taking note on the number of acquisitions for the particular month that we are processing and keep changing the formula accordingly.

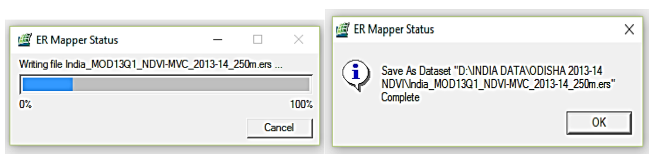


8. Then right click to Quick Zoom-> Zoom to all Datasets and save the file as .alg as shown below “India_MOD13Q1_NDVI-MVC_2013-14_250m.alg” then click OK.

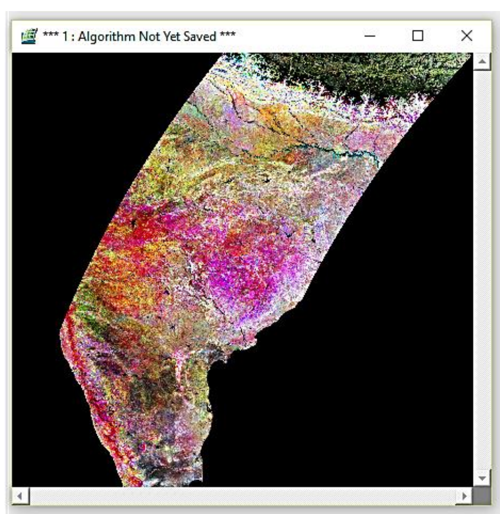


9. After computing the MVC for all the months, save the algorithm file as “India_MOD13Q1_NDVI-MVC_2013-14_250m.ers”. while saving, save as data type as IEEE4ByteReal and click OK.





10. This ends the session for creating the Megafile for Maximum Value Composite. Resultant NDVI-MVC of June 2013- May 2014 has shown below.

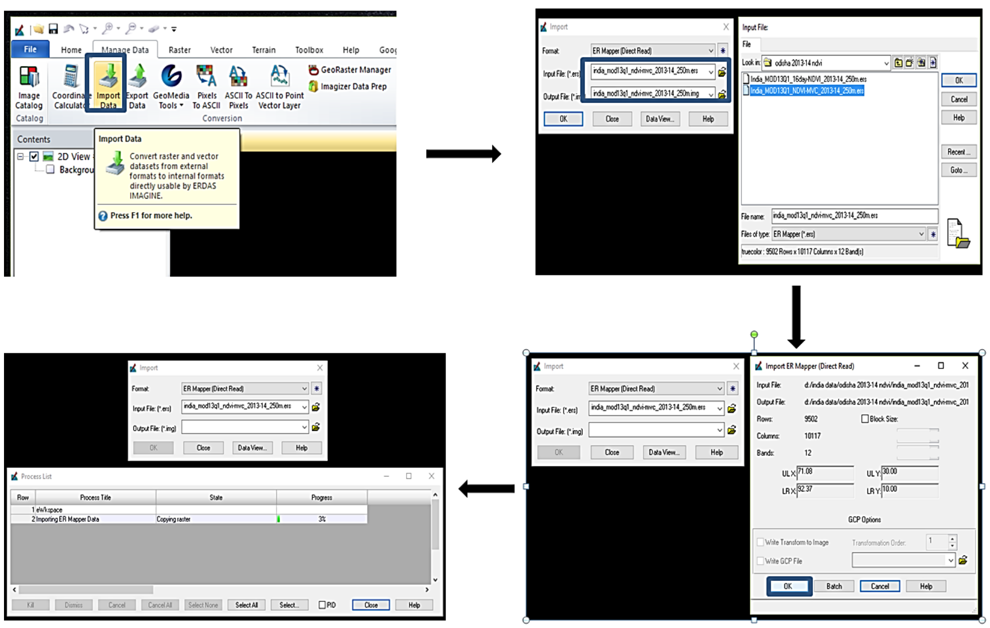


3.5 Process of Erdas imagine

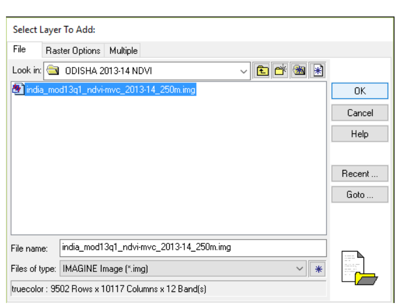
This process used for image conversion and clasification purposes.

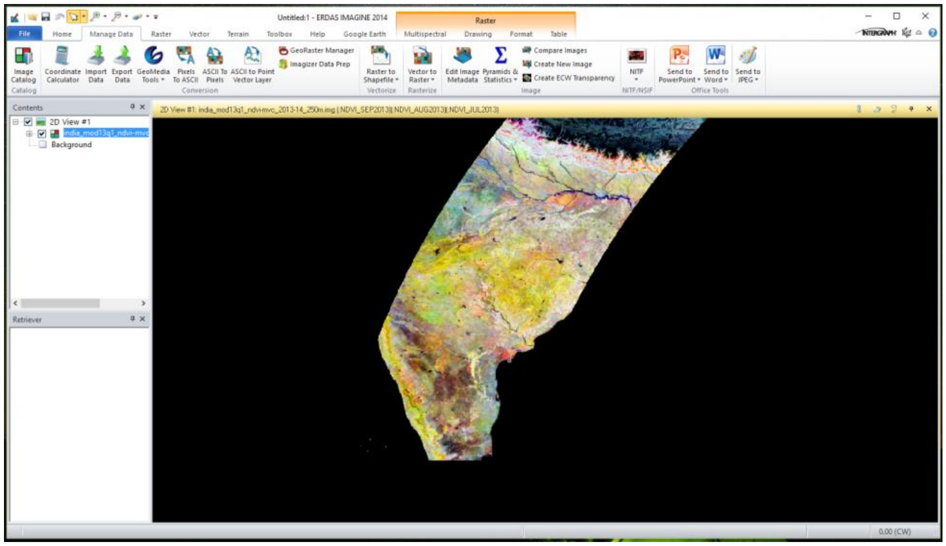
3.5.1 Creation of Image file

1. After the completion of process in Erdas ER Mapper, the .ers file should be converted to .img file as a main part for classification.
   Open Import data-> Change the format into ER Mapper(Direct Read)-> Load the saved MVC .ers file i.e. **“India_MOD13Q1_NDVI-MVC_2013-14_250m.ers”** in Input and the output is should be with an extension of .img and click OK.

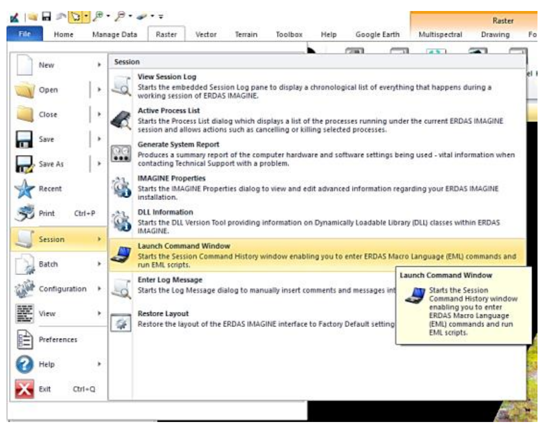


2. After conversion into .img file open the saved file in the Erdas imagine.

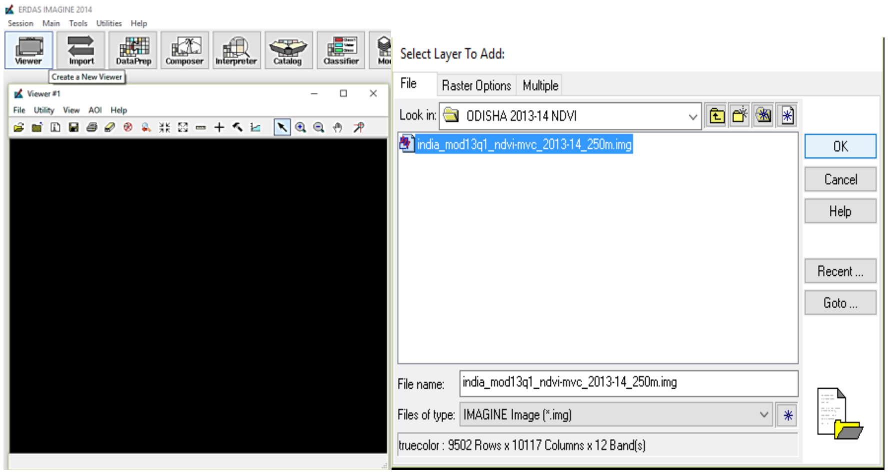


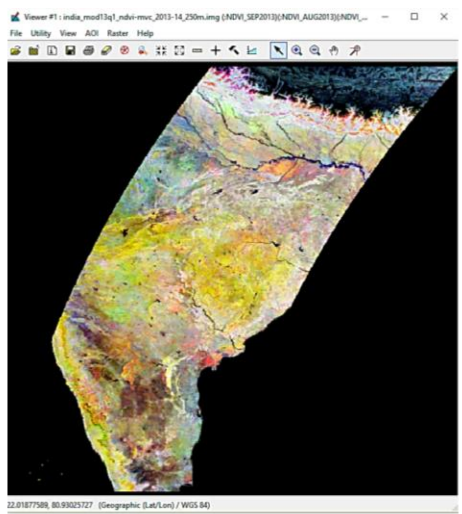


3. After loading of the image file the required data of my case study has to be subset in the India image.
   Launch Command Window and enter Imagine.

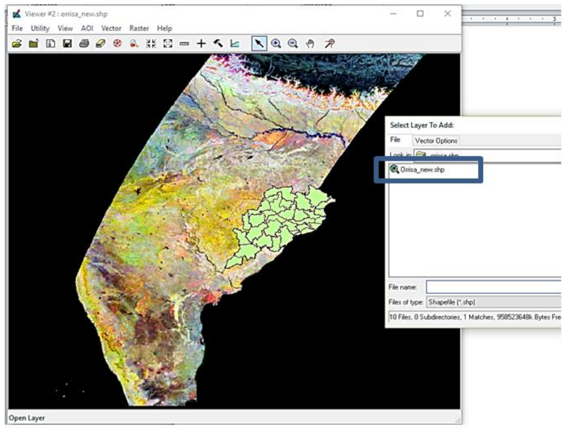


4. Open Viewer and load the image file.

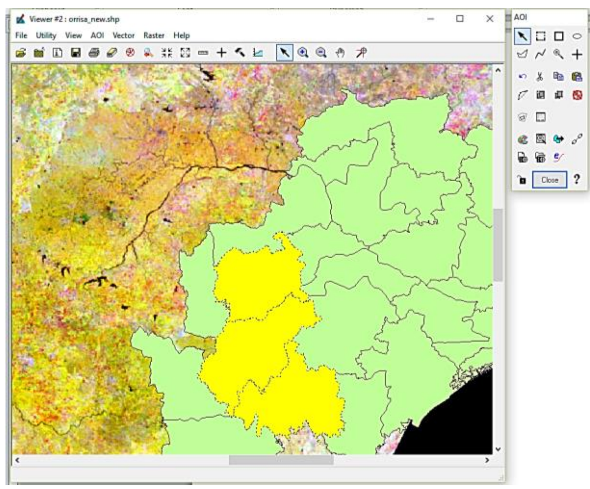




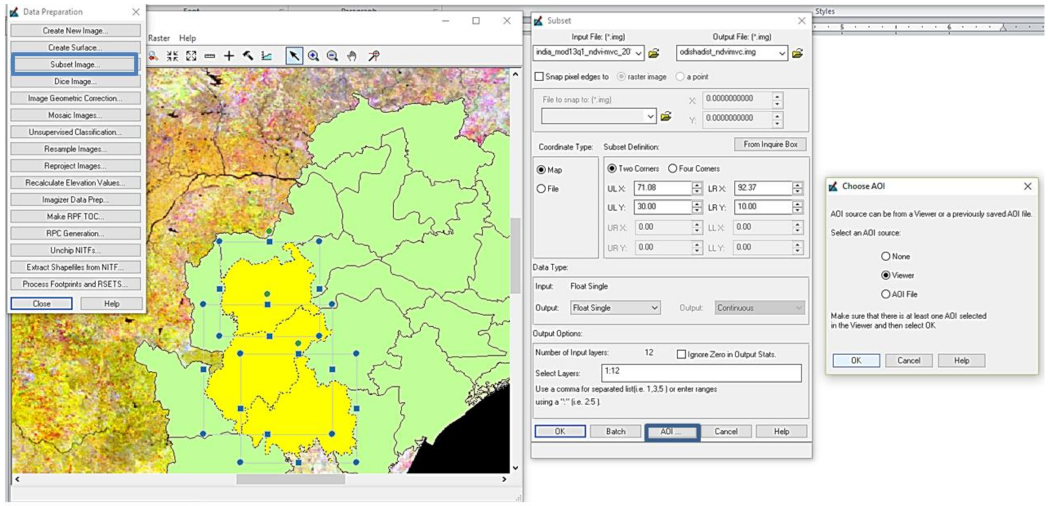
5. Load the Odisha shape file on the image file.

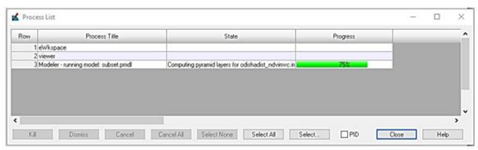


6. Mark the AOI (Area of Interest) on the selected districts i.e. Balangir, Kalahandi and Rayagada districts from the Odisha state shape file.

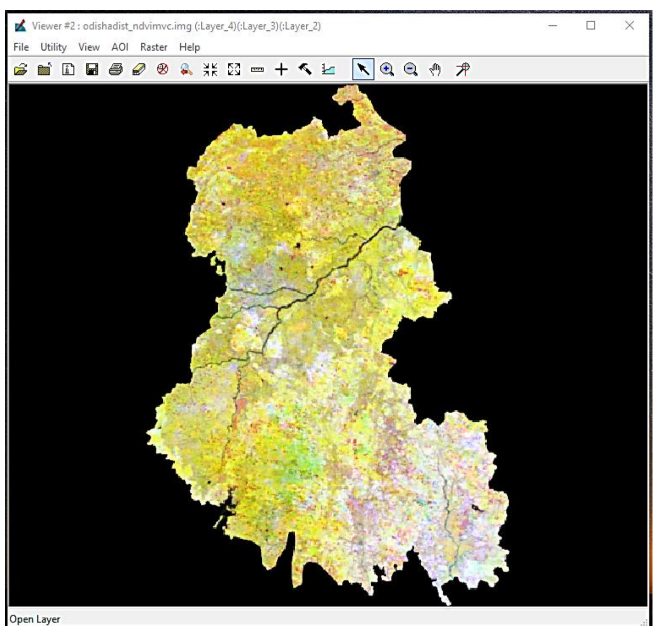


7. After marking AOI, click Data Preparation->Subset Image->Load the image file in Input->For the output file named as "**odishadist_ndvimvc.img**"->Select the AOI marked on the districts and click option AOI in Subset window-> Click Viewer-> Click OK.





8. It leads to dissection of required districts of study area and further it follows the next steps towards classification.



3.6 Mapping of Land use / Land cover

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, 40 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 Rice, Cotton, Waterbodies, Forests and Shrub lands and the similar classes are merged.

Land Use 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 like 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 several 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 2010TM) followed by progressive generalization, was used on 12-band NDVI MFDC constituted for the crop years 2013-14. The classification was set at a maximum of 40 iterations and convergence threshold of 0.99. In all 40 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 40 classes obtained on time series composite from the unsupervised classification were merged using rigorous class identification and labeling using protocols.

3.6.1 Ground truth collection:

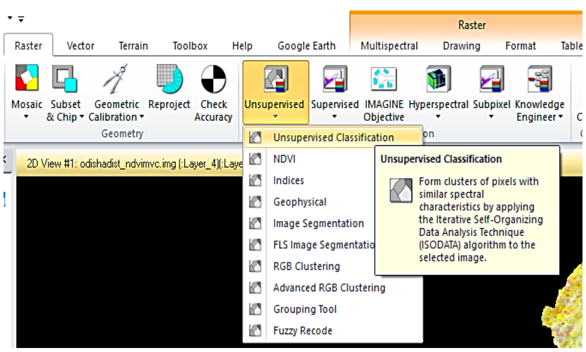
We have collected some ground truth points in the district of Rayagada for Cotton

Crop	Latitude	Longitude
Cotton	19° 5'12.43"N	83°47'30.73"E
Cotton	19° 5'37.22"N	83°47'48.01"E
Cotton	19° 5'43.30"N	83°47'57.59"E
Cotton	19° 6'6.34"N	83°48'12.78"E
Cotton	19° 7'59.20"N	83°45'41.20"E

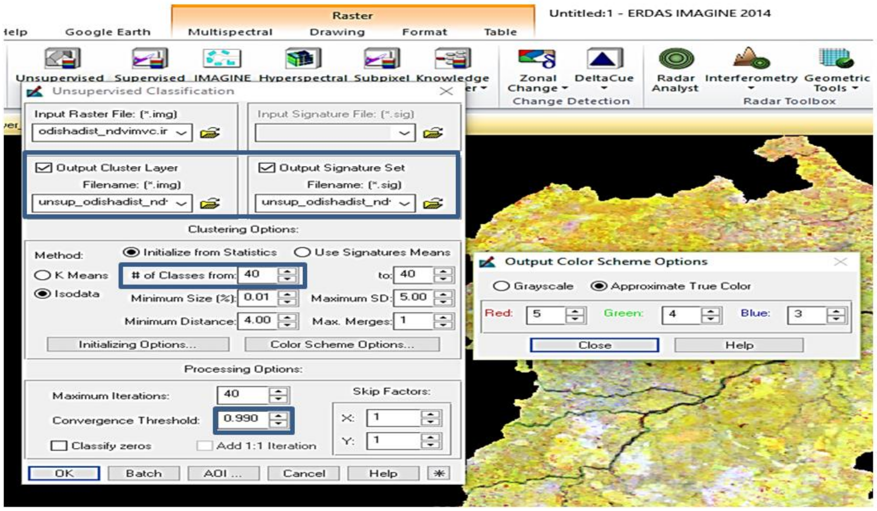
Table 11: Ground truth points

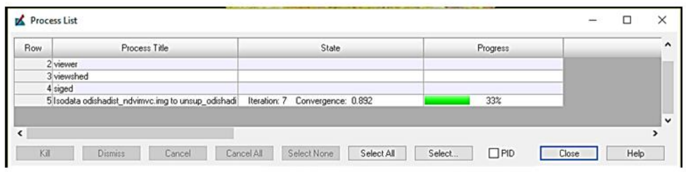
3.6.2 Process of Unsupervised classification

1. Click Raster->Unsupervised classification

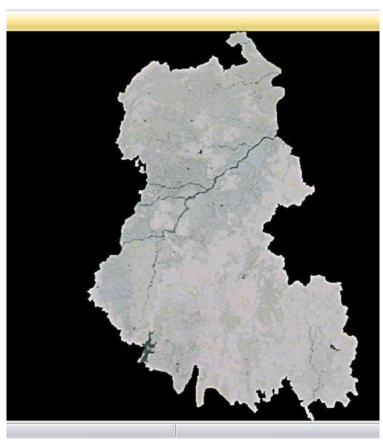


Input Raster File i.e. the saved odishadist_ndvimvc.img-> Name the output cluster layer as unsup_odishadist_ndvimvc.img-> Name the output signature set as unsup_odishadist_ndvimvc.sig-> Click **Isodata** and give Classes from 40 to 40-> Change color scheme options from Red 4 Green 3 Blue 2 to Red 5 Green 4 Blue 3-> Put Maximum iterations to 40 and Convergence threshold to 0.990-> Click OK.

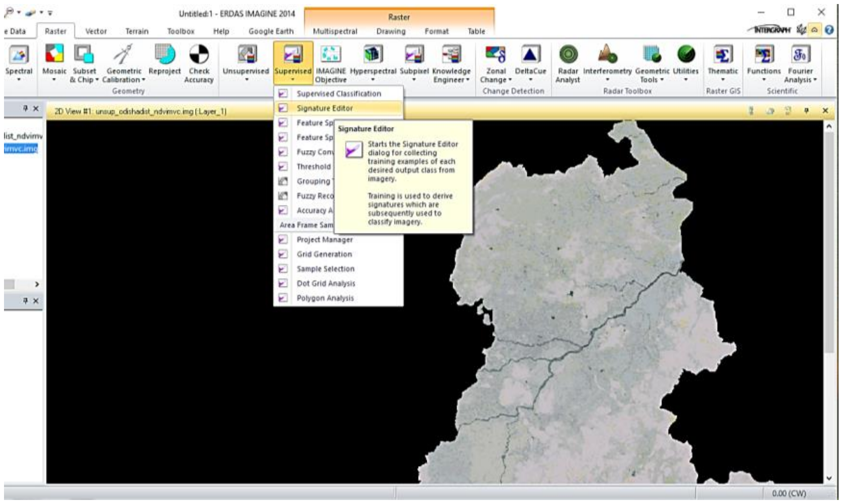


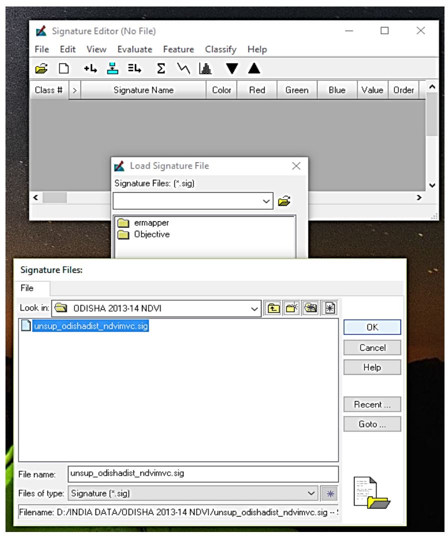


2. Product of this conversion gives the unsupervised image and signature file for the process of classification.

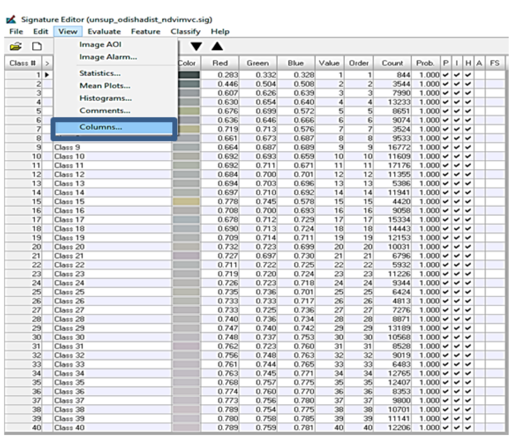


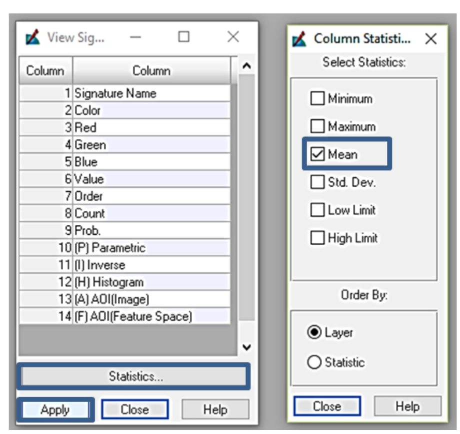
3. Click Raster-> Supervised-> Signature Editor-> Load the saved signature file i.e. unsup_odishadist_ndvimvc.sig





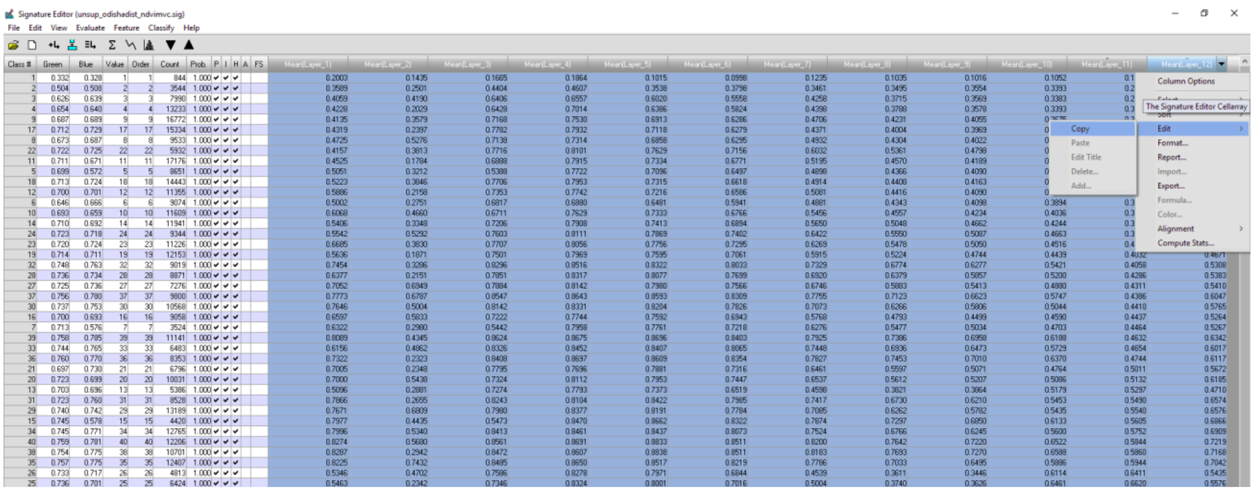
4. Click view in the signature editor-> Columns-> Statistics-> Choose Mean-> Click Apply

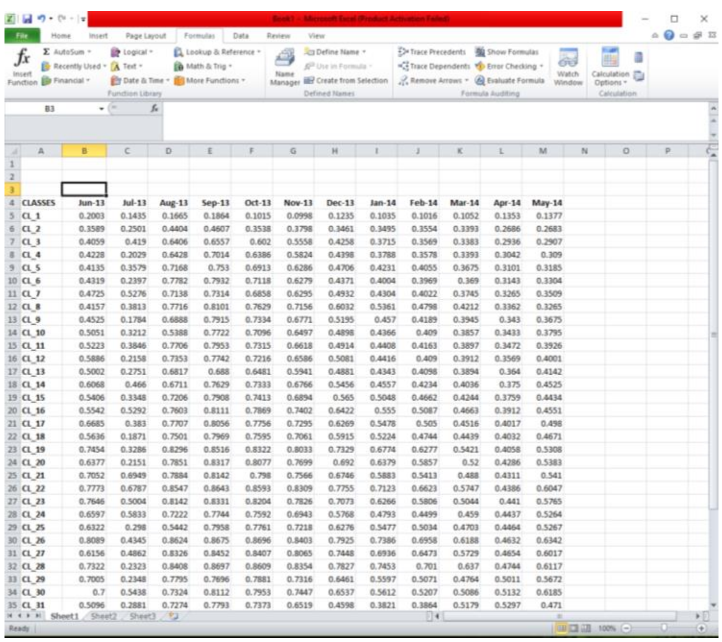




5. After applying we can observe the mean values of 12 months i.e. June-2013 to May-2014.

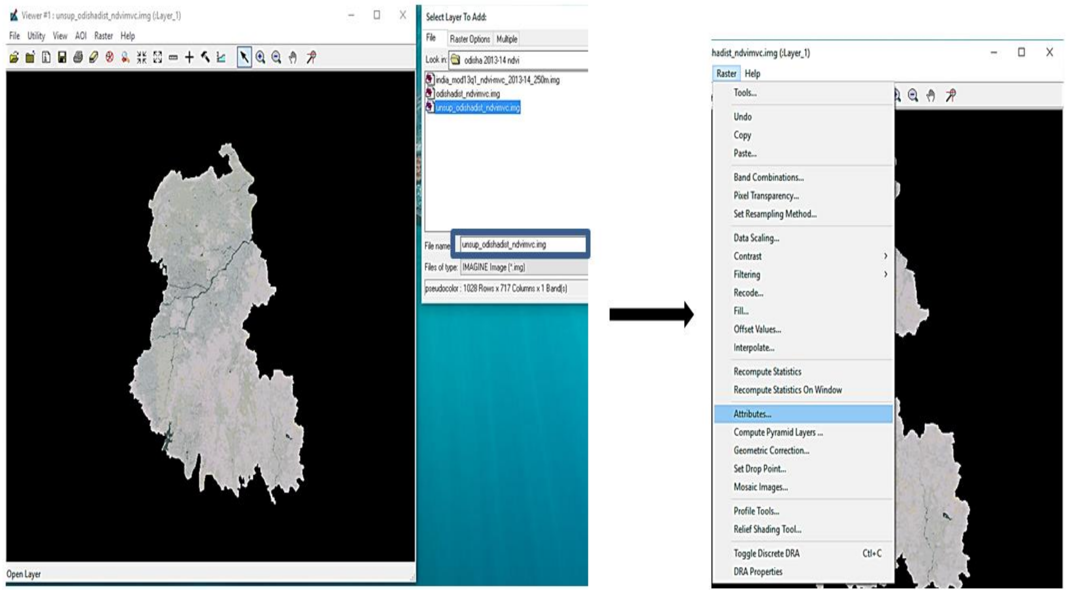
Select the all mean values-> Click Edit-> Copy-> Paste in Microsoft Excel sheet for further processing.



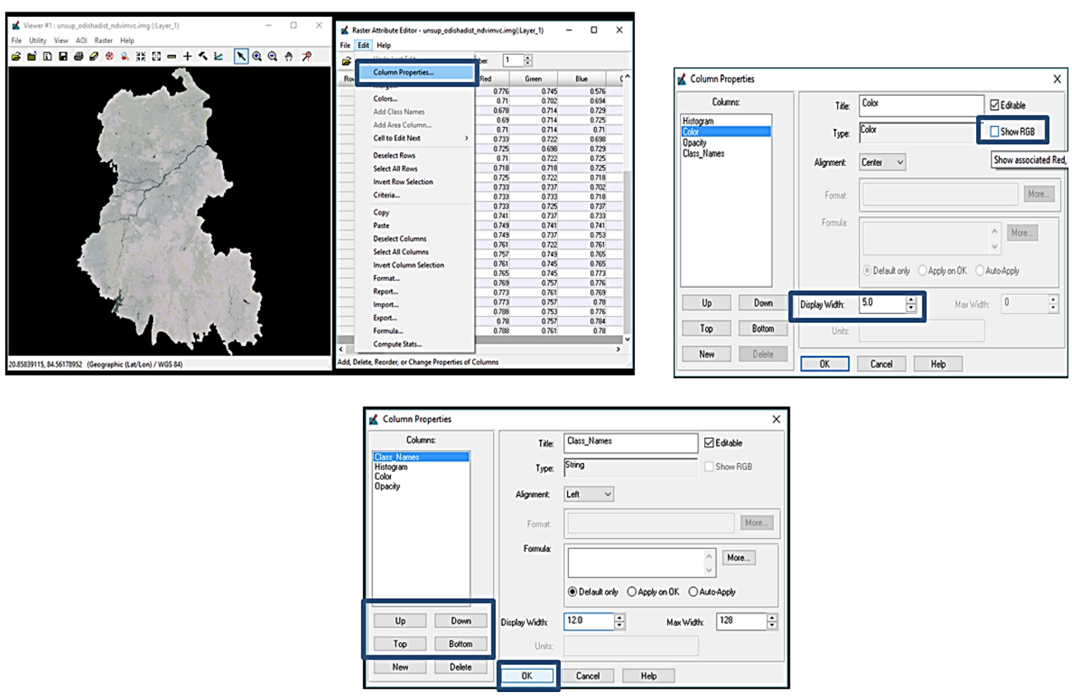


6. Open Viewer and load the unsupervised image i.e. “unsup_odishadist_ndvimvc.img”

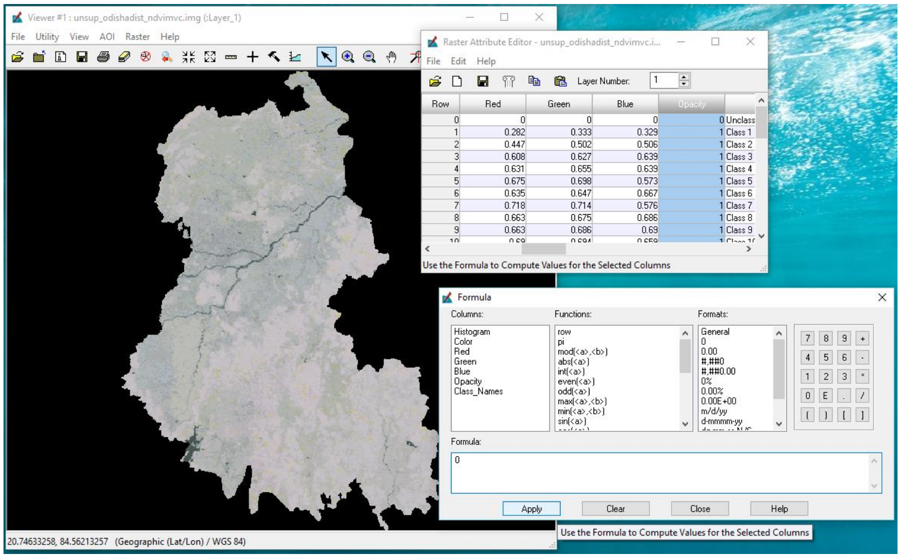
Click Raster in Viewer pane -> Select Attributes.



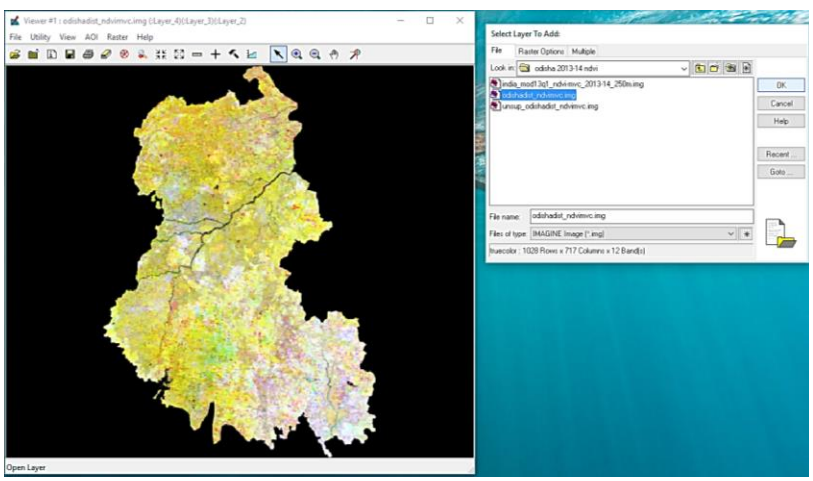
7. After opening Attributes-> Select Column properties-> Columns->Color(Uncheck RGB)-> We can adjust Display width for our convinience and can arrange the categories by using ‘Up-Down-Top-Bottom’-> Click OK.



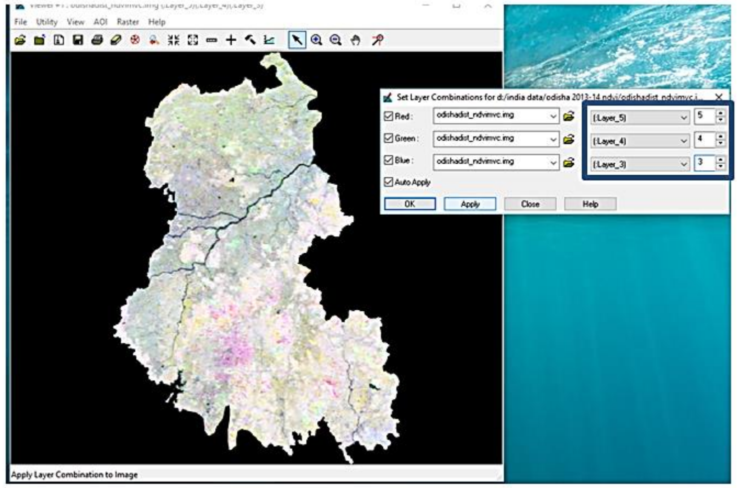
8. Make the Opacity as ‘0’ by using formula and click Apply.



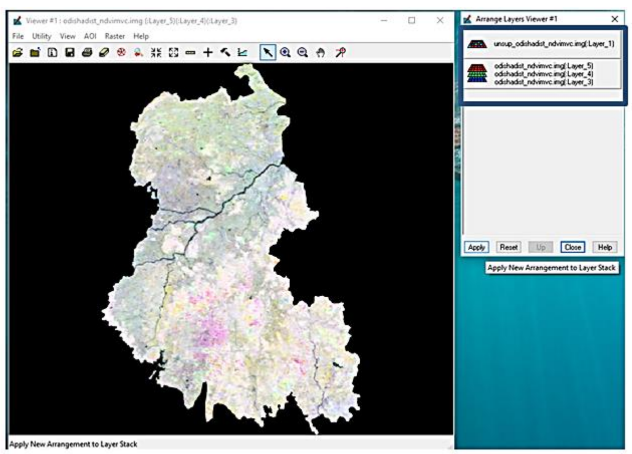
9. Added the maximum value composite layer (odishadist_ndvimvc.img) on the unsupervised layer.



10. For this layer, we have to change the band combinations from Red 4 Green 3 Blue 2 to Red 5 Green 4 Blue 3 and it changed accordingly to it-> Click OK



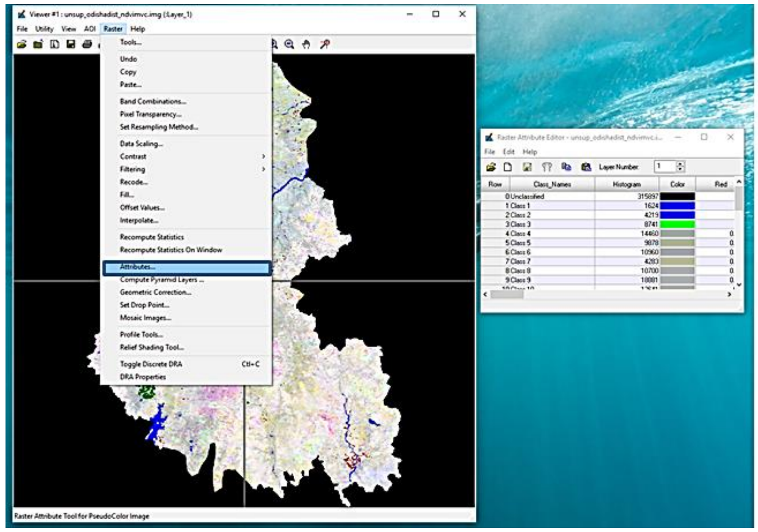
11. Open View and make sure that the unsupervised layer should on the top of ndvi mvc layer-> Click Apply.



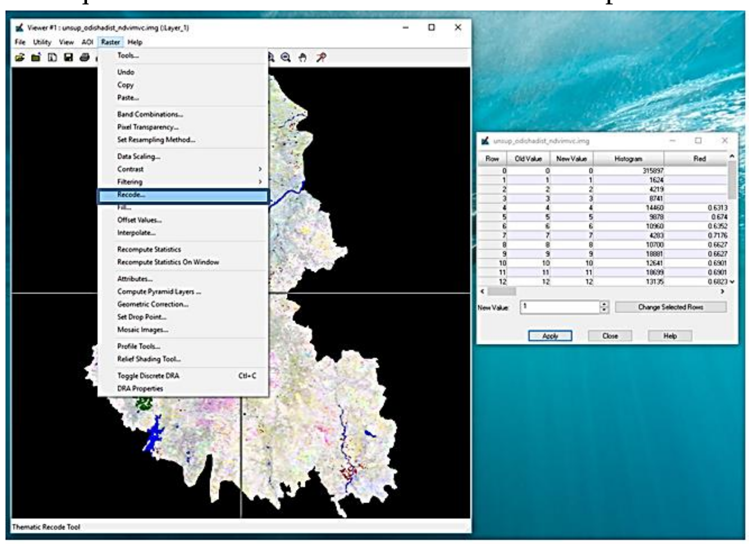
12. After adjusting layers related for the classification, they should be saved accordingly after every edit of the classes.

The process includes the following steps.

i. For recoding the desired area from one class to other we must select Raster-> Attributes-> Observe which class has been pointed on our desired area.

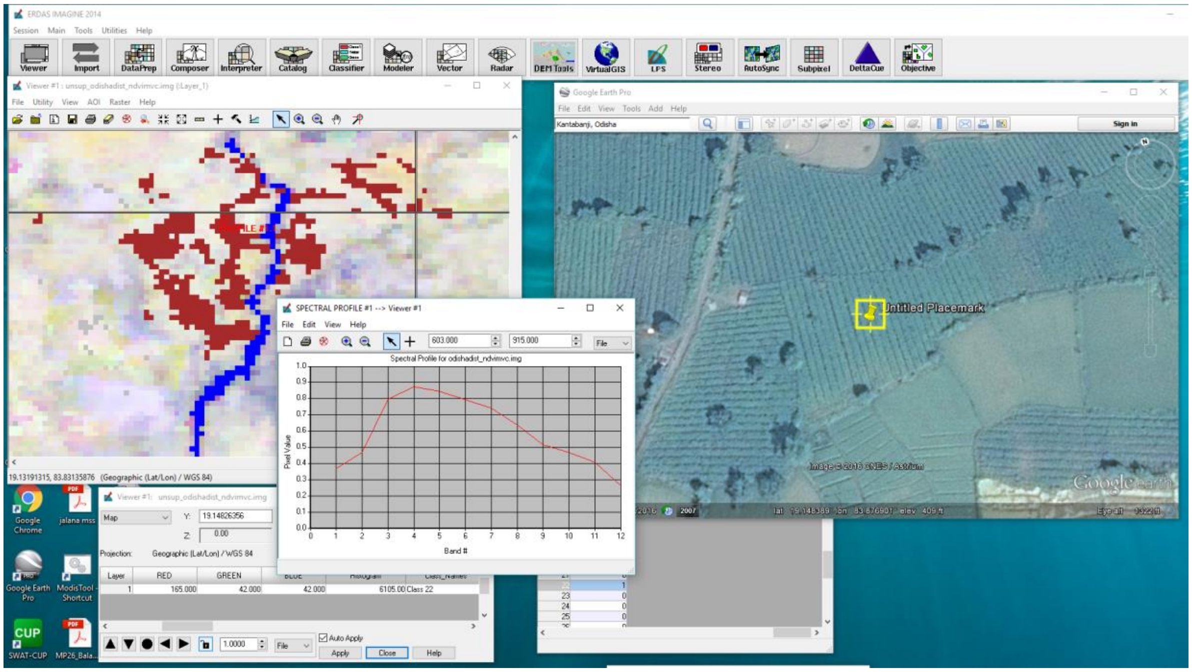


ii. After observing the required class, we must select Raster-> Recode-> Select the required class-> Enter the new value in the place of old value.

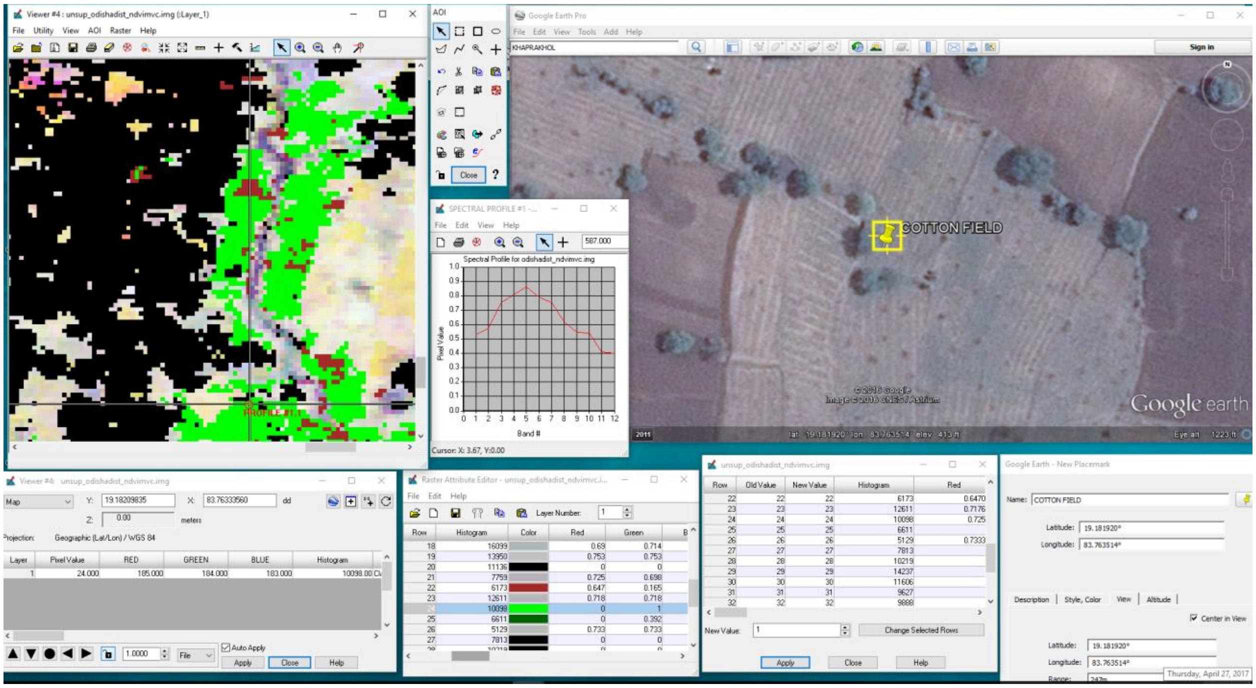


The following classes are identified during the process of classification.

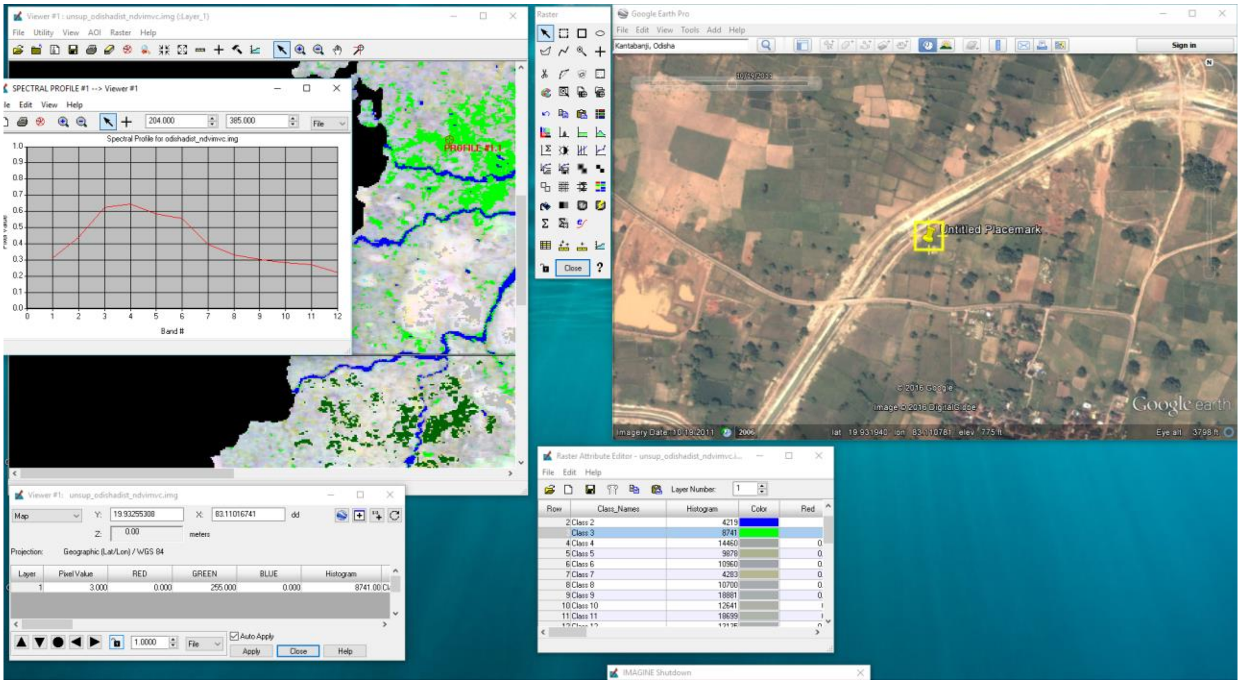
Cotton crop lands at Kalahandi district.



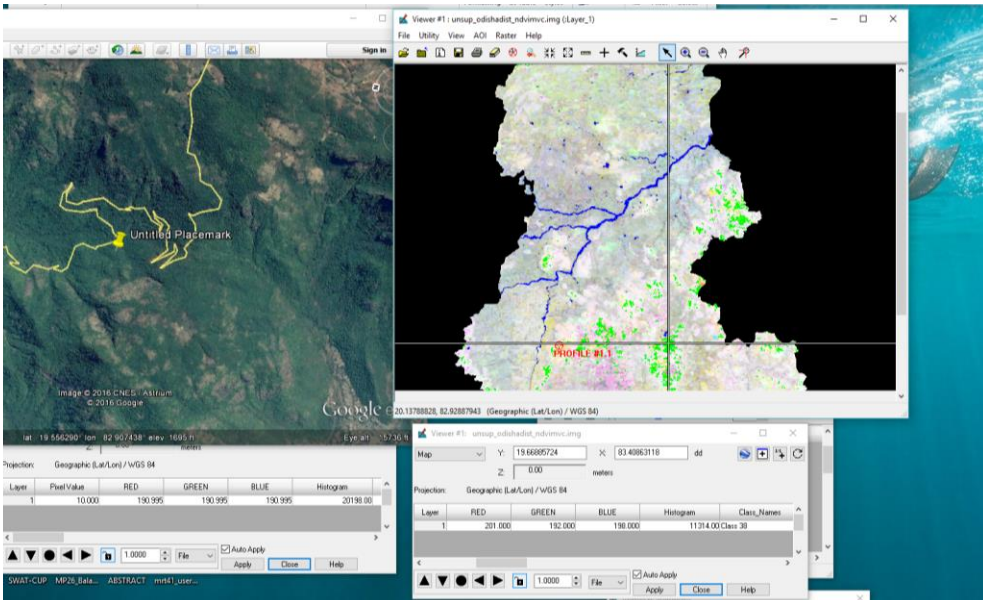
Cotton fields at Rayagada district.



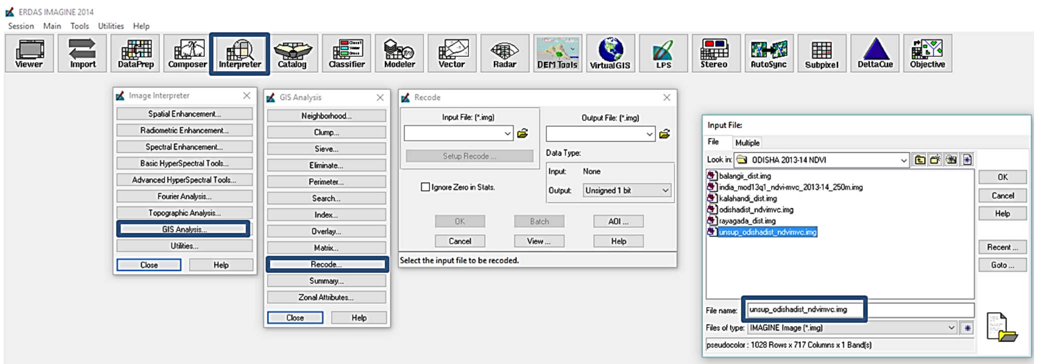
Rice fields at Balangir district.

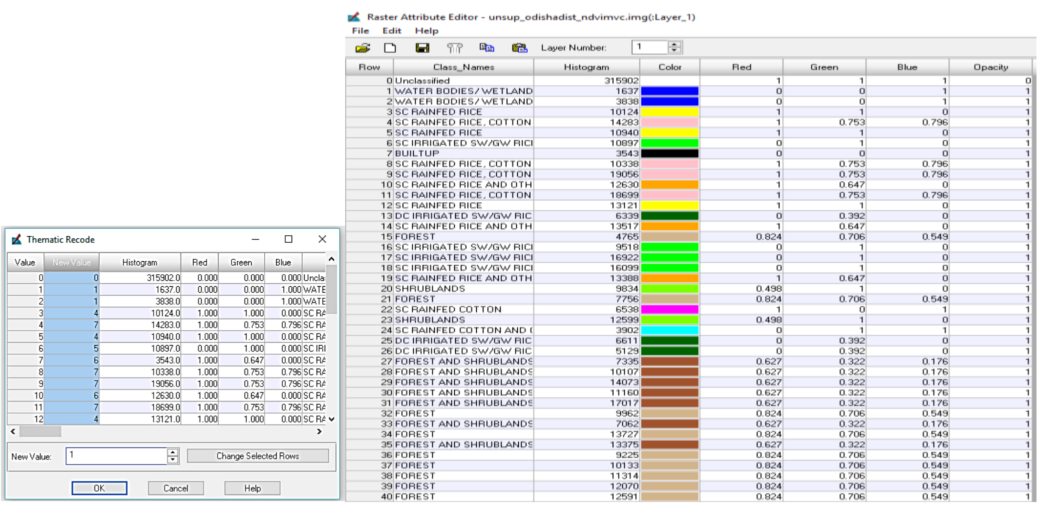


Forest area observation



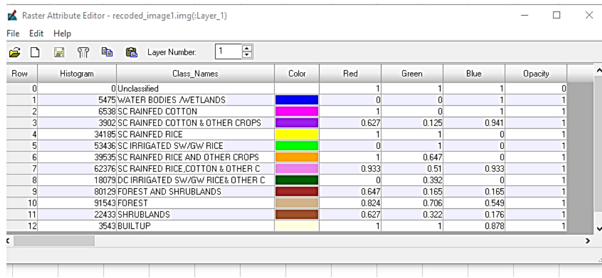
iii. After checking of all the 40 classes, we have to combine all the repeated class names into one single class and give unique color to differentiate the classes. This process is called Recoding. For that we must select Image Interpreter-> GIS Analysis-> Recode. In the input file we have placed "**unsup_odishadist_ndvimvc.img**" and given output as "**recoded_image.img**". During recoding enter the new value for each class.

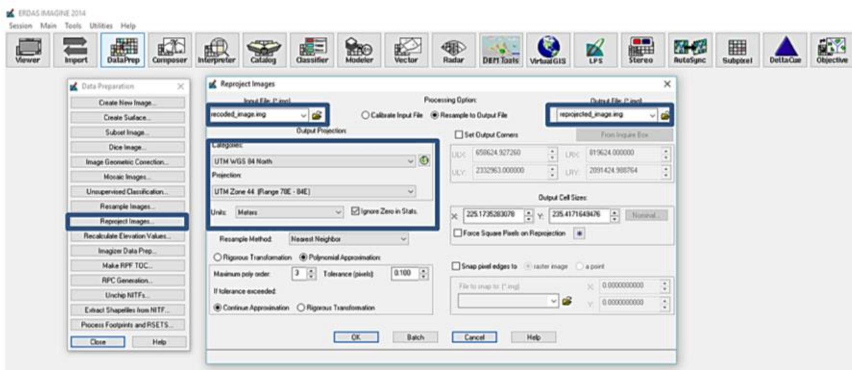




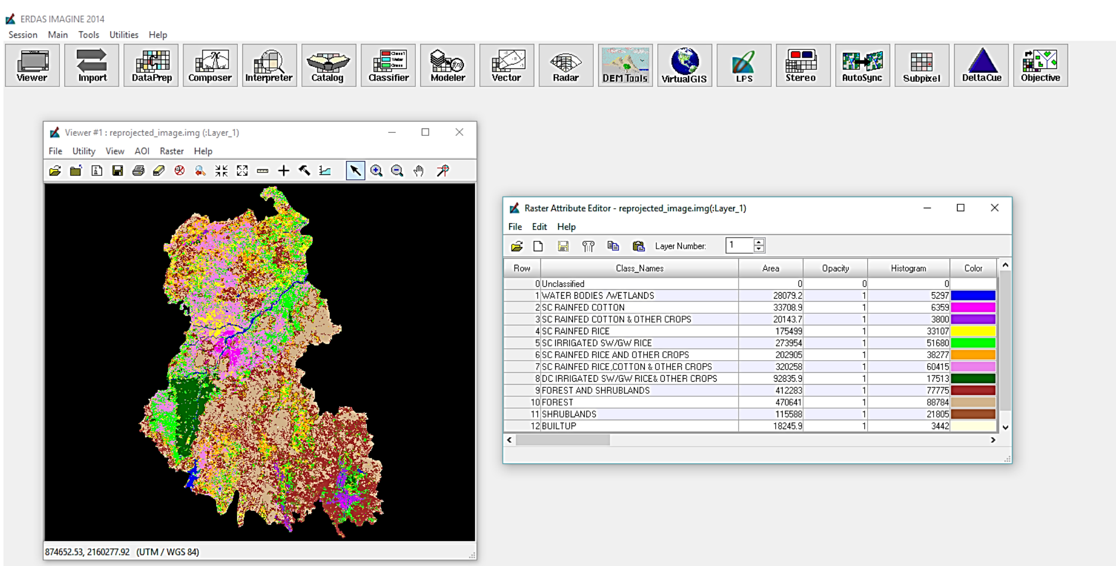
iv. The 40 classes are recoded into 12 classes, and the image should be reprojected to know the area of respective classes. For that we must select Data Preparation-> Reproject Images -> Input file: **recoded_image.img**-> Output file: reprojected_image.img-> In

Categories select UTM WGS 84 North-> In Projection select UTM Zone 44 (Range 78E – 84E)-> Ignore Zero in Stats.-> Press OK.





v. After the process of reprojection open the reprojeted image file in the viewer and select attributes. In the attributes table, add Area column beside the class name and we can observe the area in hectares.

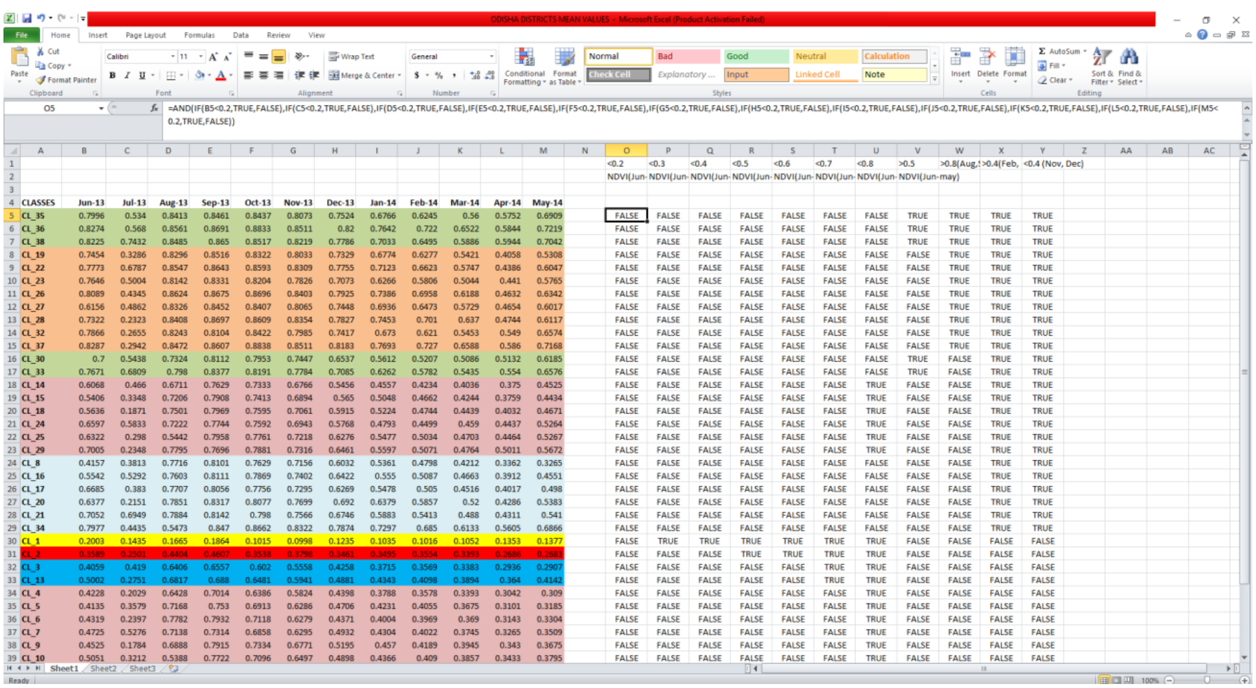


3.7 Spectral Matching Techniques (SMT):

Crop type mapping of data is performed using **spectral matching techniques** (P. G. Thenkabail 2007). It will match the class spectra derived from classification with an ideal spectra-derived MODIS MFDC based on precise knowledge of land use from specific locations.

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, P. S. Thenkabail 2005 and V. Dheeravath 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 (P. G. Thenkabail 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 (P. G. Thenkabail 2007). We have used **Spectral similarity value (SSV)** for our study.

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. SMTs, the class temporal profiles (NDVI curves) are matched with ideal temporal profile (quantitatively based on temporal profile similarity values) to group and identify classes.



=AND(IF(B5<0.2,TRUE,FALSE),IF(C5<0.2,TRUE,FALSE),IF(D5<0.2,TRUE,FALSE),IF(E5<0.2,TRUE,FALSE),IF(F5<0.2,TRUE,FALSE),IF(G5<0.2,TRUE,FALSE),IF(H5<0.2,TRUE,FALSE),IF(I5<0.2,TRUE,FALSE),IF(J5<0.2,TRUE,FALSE),IF(K5<0.2,TRUE,FALSE),IF(L5<0.2,TRUE,FALSE),IF(M5<0.2,TRUE,FALSE))

CLASSES	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14
CL_35	0.7996	0.534	0.8413	0.8461	0.8437	0.8073	0.7524	0.6766	0.6245	0.56	0.5752	0.6909
CL_36	0.8274	0.568	0.8561	0.8691	0.8833	0.8511	0.82	0.7642	0.722	0.6522	0.5844	0.7219
CL_38	0.8225	0.7432	0.8485	0.865	0.8517	0.8219	0.7786	0.7033	0.6495	0.5886	0.5944	0.7042
CL_19	0.7454	0.3286	0.8296	0.8516	0.8322	0.8033	0.7329	0.6774	0.6277	0.5421	0.4058	0.5308
CL_22	0.7773	0.6787	0.8547	0.8643	0.8593	0.8309	0.7755	0.7123	0.6623	0.5747	0.4386	0.6047
CL_23	0.7646	0.5004	0.8142	0.8331	0.8204	0.7826	0.7073	0.6266	0.5806	0.5044	0.441	0.5765
CL_26	0.8089	0.4345	0.8624	0.8675	0.8696	0.8403	0.7925	0.7386	0.6958	0.6188	0.4632	0.6342
CL_27	0.6156	0.4862	0.8326	0.8452	0.8407	0.8065	0.7448	0.6936	0.6473	0.5729	0.4654	0.6017
CL_28	0.7322	0.2323	0.8408	0.8697	0.8609	0.8354	0.7827	0.7453	0.701	0.637	0.4744	0.6117
CL_32	0.7866	0.2655	0.8243	0.8104	0.8422	0.7985	0.7417	0.673	0.621	0.5453	0.549	0.6574
CL_37	0.8287	0.2942	0.8472	0.8607	0.8838	0.8511	0.8183	0.7693	0.727	0.6588	0.586	0.7168
CL_30	0.7	0.5438	0.7324	0.8112	0.7953	0.7447	0.6537	0.5612	0.5207	0.5086	0.5132	0.6185
CL_33	0.7671	0.6809	0.798	0.8377	0.8191	0.7784	0.7085	0.6262	0.5782	0.5435	0.554	0.6576
CL_14	0.6068	0.466	0.6711	0.7629	0.7333	0.6766	0.5456	0.4557	0.4234	0.4036	0.375	0.4525
CL_15	0.5406	0.3348	0.7206	0.7908	0.7413	0.6894	0.565	0.5048	0.4662	0.4244	0.3759	0.4434
CL_18	0.5636	0.1871	0.7501	0.7969	0.7595	0.7061	0.5915	0.5224	0.4744	0.4439	0.4032	0.4671
CL_24	0.6597	0.5833	0.7222	0.7744	0.7592	0.6943	0.5768	0.4793	0.4499	0.459	0.4437	0.5264
CL_25	0.6322	0.298	0.5442	0.7958	0.7761	0.7218	0.6276	0.5477	0.5034	0.4703	0.4464	0.5267
CL_29	0.7005	0.2348	0.7795	0.7696	0.7881	0.7316	0.6461	0.5597	0.5071	0.4764	0.5011	0.5672
CL_8	0.4157	0.3813	0.7716	0.8101	0.7629	0.7156	0.6032	0.5361	0.4798	0.4212	0.3362	0.3265
CL_16	0.5542	0.5292	0.7603	0.8111	0.7869	0.7402	0.6422	0.555	0.5087	0.4663	0.3912	0.4551
CL_17	0.6685	0.383	0.7707	0.8056	0.7756	0.7295	0.6269	0.5478	0.505	0.4516	0.4017	0.498
CL_20	0.6377	0.2151	0.7851	0.8317	0.8077	0.7699	0.692	0.6379	0.5857	0.52	0.4286	0.5383
CL_21	0.7052	0.6949	0.7884	0.8142	0.798	0.7566	0.6746	0.5883	0.5413	0.488	0.4311	0.541
CL_34	0.7977	0.4435	0.5473	0.847	0.8662	0.8322	0.7874	0.7297	0.685	0.6133	0.5605	0.6866
CL_1	0.2003	0.1435	0.1665	0.1864	0.1015	0.0998	0.1235	0.1035	0.1016	0.1052	0.1353	0.1377
CL_2	0.3589	0.2501	0.4404	0.4607	0.3538	0.3798	0.3461	0.3495	0.3554	0.3393	0.2686	0.2683
CL_3	0.4059	0.419	0.6406	0.6557	0.602	0.5558	0.4258	0.3715	0.3569	0.3383	0.2936	0.2907
CL_13	0.5002	0.2751	0.6817	0.688	0.6481	0.5941	0.4881	0.4343	0.4098	0.3894	0.364	0.4142
CL_4	0.4228	0.2029	0.6428	0.7014	0.6386	0.5824	0.4398	0.3788	0.3578	0.3393	0.3042	0.309
CL_5	0.4135	0.3579	0.7168	0.753	0.6913	0.6286	0.4706	0.4231	0.4055	0.3675	0.3101	0.3185
CL_6	0.4319	0.2397	0.7782	0.7932	0.7118	0.6279	0.4371	0.4004	0.3969	0.369	0.3143	0.3304
CL_7	0.4725	0.5276	0.7138	0.7314	0.6858	0.6295	0.4932	0.4304	0.4022	0.3745	0.3265	0.3509
CL_9	0.4525	0.1784	0.6888	0.7915	0.7334	0.6771	0.5195	0.457	0.4189	0.3945	0.343	0.3675
CL_10	0.5051	0.3212	0.5388	0.7722	0.7096	0.6497	0.4898	0.4366	0.409	0.3857	0.3433	0.3795

CLASSES	<0.2 NDVI(Jun-	<0.3 NDVI(Jun-	<0.4 NDVI(Jun-	<0.5 NDVI(Jun-	<0.6 NDVI(Jun-	<0.7 NDVI(Jun-	<0.8 NDVI(Jun-	>0.5 NDVI(Jun-may)	>0.8(Aug,!	>0.4(Feb,	<0.4 (Nov, Dec)
CL_35	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
CL_36	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
CL_38	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
CL_19	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_22	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_23	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_26	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_27	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_28	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_32	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_37	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
CL_30	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE
CL_33	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE
CL_14	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
CL_15	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
CL_18	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
CL_24	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
CL_25	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
CL_29	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
CL_8	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE
CL_16	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE
CL_17	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE
CL_20	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE
CL_21	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE
CL_34	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE
CL_1	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_2	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_3	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_13	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_4	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_5	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_6	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_7	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_9	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
CL_10	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE

The ideal NDVI curves for different classes of land use

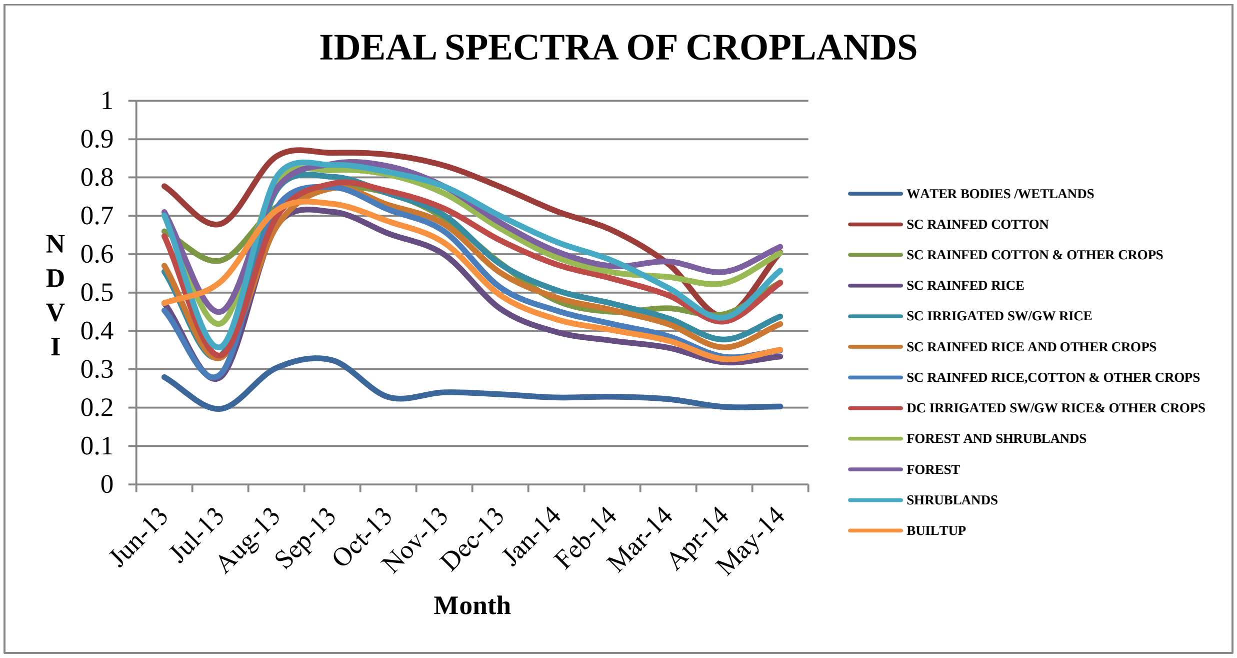


Figure 10: Ideal NDVI curves

RESULTS AND DISCUSSIONS

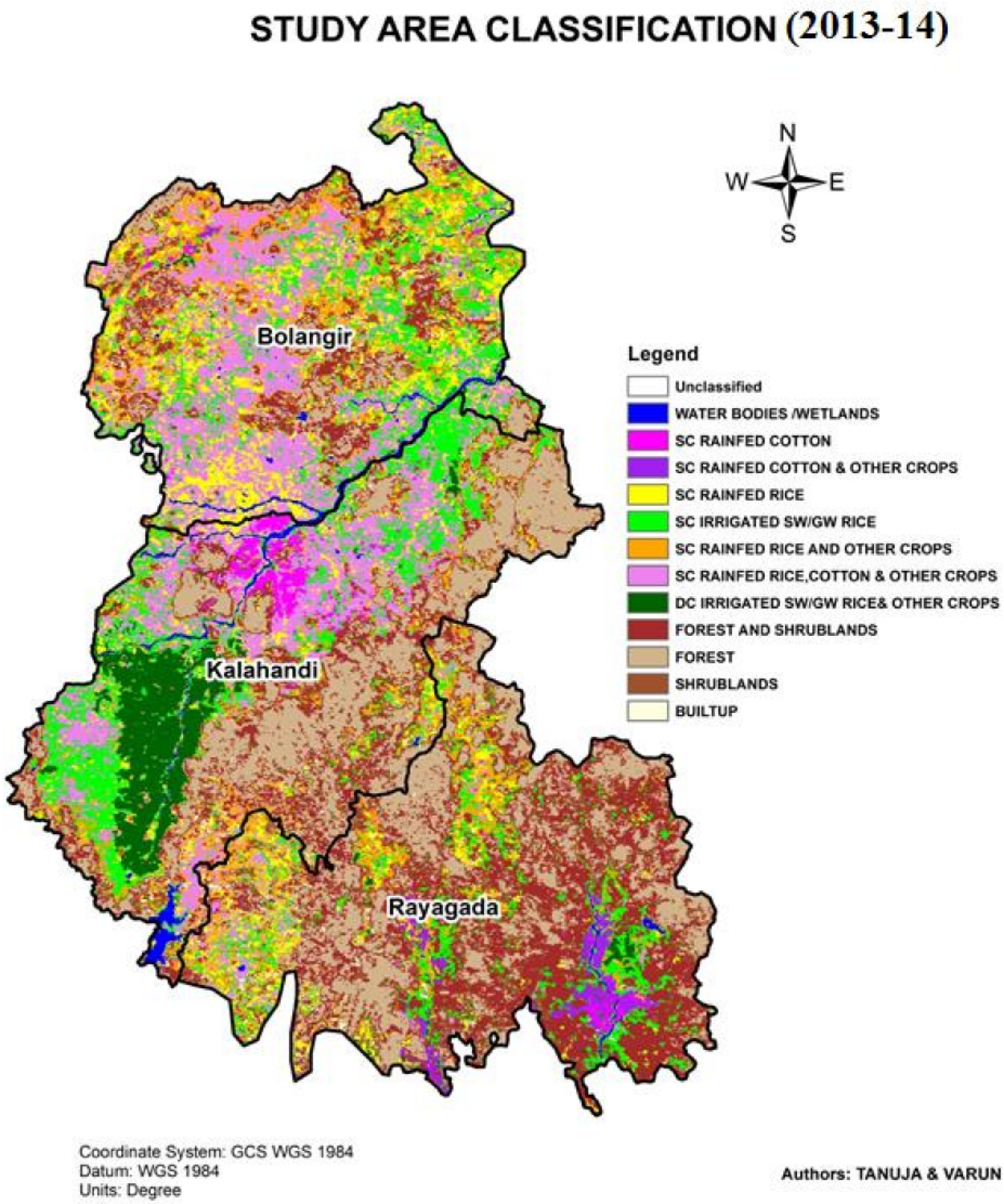


Figure 11: Study Area Classification

- The results include the classification and the amount of land under classification.

CLASSES	AREA (Hectares)
Unclassified	0
WATER BODIES /WETLANDS	28079.2
SC RAINFED COTTON	33708.9
SC RAINFED COTTON & OTHER CROPS	20143.7
SC RAINFED RICE	175499
SC IRRIGATED SW/GW RICE	273954
SC RAINFED RICE AND OTHER CROPS	202905
SC RAINFED RICE,COTTON & OTHER CROPS	320258
DC IRRIGATED SW/GW RICE& OTHER CROPS	92835.9
FOREST AND SHRUBLANDS	412283
FOREST	470641
SHRUBLANDS	115588
BUILTUP	18245.9
TOTAL	**2164141.6**

SC- SINGLE CROP; DC- DOUBLE CROP; SW- SURFACE WATER; GW- GROUND WATER

Table 12: Amount of land under classification

- During the process of classification, we have observed some croplands in the two classes namely Forests and Shrublands, Shrublands because of MODIS 250m imagery.
- Due to large pixel area, we have considered the major part of the class and placed in respective class.
- We have observed the major patches of cotton cropland in Rayagada and Kalahandi districts in certain classes. But in Balangir district the cotton crops are mixed with rice areas so we identified that particular classes and regrouped into SC Rainfed Rice, Cotton and other crops.

CONCLUSIONS

Monitoring of cotton croplands in Odisha using geospatial tools is done. Based on the results obtained from the classification, the following conclusions are drawn:

- Most of the cotton croplands are growing in the areas of black soil and near to the river basins.
- From the increased cotton area in 2013-14 kharif, obtained from LULC analysis, it had been concluded that there has been a development in cotton production.
- We have observed good quality and yield of cotton is growing in Rayagada district due to favorable conditions for cotton and the marketing channel was well shaped.
- Kalahandi region is the center of the study area and major growers of cotton. This district is facing problems in marketing and processing. So, government should focus on both by establishing CCI yard and Cotton processing industry.
- We have studied the development of cotton cultivation before and after the introduction of Bt varieties.
- The percentage increase of cotton crop land from 2006-07 to 2013-14 as follows.
  Balangir- 100%
  Kalahandi- 168%
  Rayagada- 157%
- There is a slight increase in the cotton growing lands in the remaining districts every year.
- Implementations of the government programmes are more important in adopting the new cropping systems. Instead of having agricultural diversification as a programme, it should be a part of agricultural planning.

  The overall study had a positive impact on the farmers of these districts from a static rice oriented cropping system to high diversified income generating cotton cropping system. Increase in subsidies and more financial support to the small-scale farmers will help them to show interest in high income generating crop like cotton.

REFERENCES

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

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. 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.

10. Gumma, M.K., Thenkabail, P.S., Velpuri, N.M., 2009b. Vegetation Phenology to Partition ground water from surface water irrigated areas using MODIS 250m time series data for the Krishna river basin (India). International Association of Hydrological Sciences IAHS PUBL. 330, 2009.

11. V. Dheeravath, P.S. Thenkabail , G. Chandrakantha , P. Noojipady , G.P.O. Reddy , C.M. Biradar , M.K. Gumma , M. Velpuri. "Irrigated areas of India derived using MODIS 500 m time series for the years 2001–2003." *ISPRS Journal of Photogrammetry and Remote Sensing*, 2009.

12. Thenkabail, P.S., Schull, M., and Turral, H. "Ganges and Indus River Basin land use/land cover (LULC) and irrigated area mapping using continuous streams of MODIS data." *Remote Sensing of Environment.* 2005: 95, 3, 317-41.

13. GIS becomes indispensable for mapping agriculture. GCN. Patrick Marshall. October 18, 2013. http://gcn.com/Articles/2013/10/18/USDA-GIS.aspx?Page=1

14. NuGIS: A nutrient use Geographic Information System for the U.S. Fixen, Paul E.; Williams, Ryan; Rund, Quentin B. International Plant Nutrition Institute. 2007. http://www.ipni.net/nugis

15. Diversifying Agriculture: The New Mantra, Yojana, January 2001 by Arabinda Ghosh

16. ‘Trade Liberalization & Indian Agriculture-Cropping Pattern Changes and Efficiency Gains in Semi-Arid Tropics’, Oxford University Press by Ashok Gulati and Tim Kelley (1999)

17. Marketing of Agricultural Produce in Orissa by B. Bhuyan

18. Agricultural Diversification, Migration and Poverty Reduction in Orissa: in Interpretative Analysis by Dr. Damodar Tripathy and Julie Tripathy

19. Orissa Agricultural Statistics, 1995-96 to 2005-06 by Government of Odisha

20. Agronica, Directorate of Agriculture and Food production by Government of Orissa

21. www.ori.nic/diorissa/market.htm website (kbk)

22. Contract Farming in Odisha: Prospects and Constraints by Regional Centre for Development Cooperation (RCDC), Bhubaneswar (www.rcdcindia.org, www.banajata.org)

23. National Remote Sensing Centre, Indian Space Research Organisation (Scenario of Remote sensing in agriculture).

24. Odisha Agriculture Statistics by Directorate of Agriculture and Food Production (2010-11, 2013-14)

25. ICAR- Central Institute for Cotton Research (Statistical data).

26. Contract Farming in India: An Introduction by Ashok Gulati, P.K. Joshi, Maurice Landes

27. Soil of Orissa and Its Management by *Dr. G.C. Sahu.Antaryami Mishra*

28. Light demand for cotton Kalahandi by Orissa Post

29. http://www.monsanto.com/global/in/products/pages/bollgard-bollgard-2.aspx -

30. Inequality and GM Crops: A Case-Study of Bt Cotton in India by Stephen Morse, Richard Bennett, and Yousouf Ismael *University of Reading, United Kingdom*

31. The Marketing Strategy of Economic Development in Kalahandi by Dr. Digambara Patra

32. Supply chain management of cotton in Odisha: Small and medium farmer's concern by Narendra N. Dalei, Anshuman Gupta, Paradip Dash