Satellite Based Agriculture Information System: An Efficient Application of ICT

Principal Investigator
DR. DHARMENDRA SINGH
DR. AJIT SINGHVI INSTITUTE CHAIR PROFESSOR
HEAD, DEPT. OF COMPUTER SCIENCE AND ENGINEERING
PROFESSOR, DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE-247667, UTTARAKHAND (INDIA)
E-MAIL: DHARMFEC@IITR.AC.IN
MOB.: +91-9897060088

Team Members: Mr. Ankush, Mr. Deepak, (Ph.D Candidates)

Contents

1 Overview:

The applications of satellite imagery are very diverse and most of the image sensors are designed for specific purposes, therefore, for some applications they are incomplete while for some they are either redundant or complementary. For example, the information contained in multispectral datasets provides a valuable basis for environmental studies while the low spatial resolution characteristics of these datasets reduce their performance in many applications. Data Fusion (DF) is a formal framework in which the means and tools for the alliance of data originating from different sources are summarized. It aims at obtaining information of enhanced quality where the exact definition of the term "quality" depends upon the application of fused datasets. The satellite instruments provide a huge number of diverse datasets and therefore it is important to use these datasets properly so that their application avenue can be extended.

Nowadays scientists are paying special attention on Moderate Resolution Imaging Spectroradiometer (MODIS) because it has temporal as well as spectral capabilities. Therefore, in this project, our main concern is geared towards enhancing the use of MODIS image which is limited by the spatial resolution of acquired images. Consequently, fusion of high-resolution satellite image may enhance MODIS capability. Recent advances in nonlinear signal processing provide extremely interesting tools for performing fusion at different spatial/spectral resolutions. Due to the nature of satellite imagery, it could be denoted that diverse physical properties of targets are measured by different sensors from different points of view. For instance, MODIS sensors provide images with lower spatial resolution, but they have the advantages of higher temporal resolution. In such circumstances, multi-sensor image fusion to get benefits from all available datasets, is supposed to be an effective paradigm for increasing the usability of satellite imagery for agricultural resource monitoring.

To provide this valuable information to various users from planner to farmer, satellite data may play a major role. Another important challenge is to have a cost-effective solution, so end users like farmers can use this information with minimum cost. Nowadays, various satellite data like optical, microwave, infrared, hyperspectral etc. are available, but the important aspect is the cost of the data and its usage in agricultural monitoring. Useful information on key parameters like crop area, crop types, crop health, soil moisture etc., required for developing an agricultural monitoring system, can be obtained accurately and timely with minimum cost by using data fusion techniques. Therefore, present project proposes to develop methods for fusing the information of various satellite data in order to monitor crop area, crop type, crop health condition and soil moisture. Additionally, it also monitors the effect of meteorological condition on agricultural system. Another objective is to develop such an ICT based method through which end users like farmers and planners both can get timely information for pre-harvesting and post harvesting scenarios.

2 Context and Background:

India's agriculture is statistically the widest economic sector, which forms the basis of largest employment source and a major section of the overall social expansion. Timely monitoring of key crop parameters would be of great help to the farmers in proper agriculture/crop monitoring and improving agricultural productivity. Following are the list of customers, who will be interested in the agriculture related information,

- Government agencies
- Insurance companies
- End users i.e., Farmers

So far, in India these customers depend on physical inspection-based data for monitoring. Insurance companies in government schemes like Pradhan Mantri Fasal Bima Yojana (PMFBY) and private companies like Mahindra Tech Agribusiness operate on two main parameters,

- Area approach - defined areas for each notified crop for widespread calamities
- On individual basis - for localized calamities such as hailstorms, landslides, cyclones and floods

In Area approach, they work only in their defined area where they have service for human inspection and notified crops for which they have past years' statistics.

Following are the key factors that drive growth in the agriculture sector:

- ***Enhancement of Food Productivity:***

The enhancement in food productivity has direct impact on industry growth, as many industries solely focus on agriculture. Selection and usage of good breeds of crop having high yield potential, combined with resistance to diseases is very important. Proper land use has become the central component in understanding the interactions of human activities with the environment, which significantly contributes to the growth of the industry.

- ***Food Management:***

Improved management of agricultural resources has become a key factor in the growth of the industry because increasing population needs increase in agricultural production.

As there is a definite need for improved management of food or agricultural resources, it is important to obtain reliable data regarding location of these resources. Digital practices can play a significant role in the improvement of the present system of generating and acquiring agricultural maps and resource data more accurately.

3 Problem and Challenges:

The demand for agricultural products is increasing day by day due to growing population and therefore agriculture sector is facing new and emerging challenges to meet the demand. For this purpose, accurate and timely information of agricultural field is very much required, which can be used to evolve strategies for sustainable management of agricultural resources. Nowadays, satellite data, computer evolution and communication technology offer great scope for efficient planning and monitoring of agricultural resources. Although the use of satellite data is of profound importance to agricultural applications, the lack of relevant data processing skills has adversely impacted its usage. To address this challenge, *Satellite Based Agriculture Information System (SBAIS)* has been developed. SBAIS is the India's first satellite data based online information system for agriculture/crop monitoring at district and tehsil level. Agriculture information system helps in regular monitoring, keeping track of statistics and in analyzing the historic data of crops which is available along with crop images and statistics.

Monitoring of agricultural system using satellite data generally depends upon actual information of cultivated area, crop type, crop condition; region wise knowledge of agricultural system and effect of meteorological conditions on the development of various algorithms. Regular field visits need to be carried out in synchronization with the satellite movement for proper analysis of the obtained satellite data. Another important challenge is cost-effectiveness of the solution, so that the end users like farmers can also use this information with minimum cost.

4 Objective:

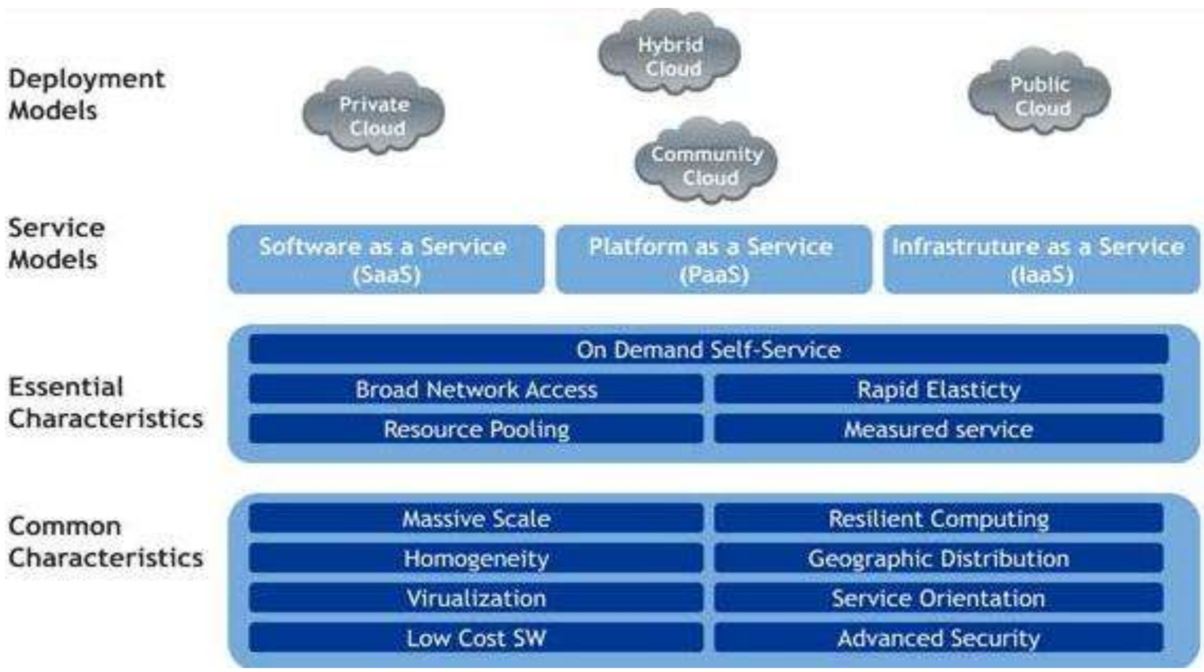
To increase agricultural productivity, advance agriculture practices need to be implemented which can be accomplished by proper agriculture/crop monitoring. For this purpose, *Satellite Based Agriculture Information System (SBAIS)* has been developed. SBAIS is India's first satellite data based online information system for agriculture/crop monitoring at district and tehsil level in Uttarakhand state. The system is based on the analysis of multi-temporal satellite data and composed of mainly two modules namely "Classification" and "Crop Monitoring". In classification module, the location of greenness/vegetation can be identified, and the agricultural area is segregated from other land cover classes. Through this module, in addition to the agricultural region identification, the change in area of greenness from the previous year till the selected year can also be estimated which helps in identifying variations in the vegetation of an area within a time period. The Crop Monitoring module is based on Normalized Difference Vegetation Index (NDVI) which is a measure of plant/crop's "greenness" on the basis of photosynthetic process or chlorophyll content in the plant and hence it helps in identifying the crop health. For crop health monitoring, two options are available, one is Julian date wise and another is year wise. In Julian date wise option, the season wise effect on the crop health can be monitored and the alterations occurring in crop health in a specific time period can be observed. Through year wise option, along with vegetative state (healthy/normal/weak) estimation for all the respective years, the year wise fluctuations between the selected years in the physical conditions of a vegetation can also be identified.

5 Solution:

For improving the agriculture productivity, by timely monitoring various crop parameters and changes in various land cover classes, *Satellite Based Agriculture Information System (SBAIS)* has been developed. The whole methodology is implemented in cloud with two computing facilities, an application server for preprocessing data with a web server for user interface and one storage facility for maintaining database. The implementation of application server and web server is carried out as given in Fig. 5.1:

Figure 5.1 SBAIS working model

Service Delivery through Cloud Computing Environment



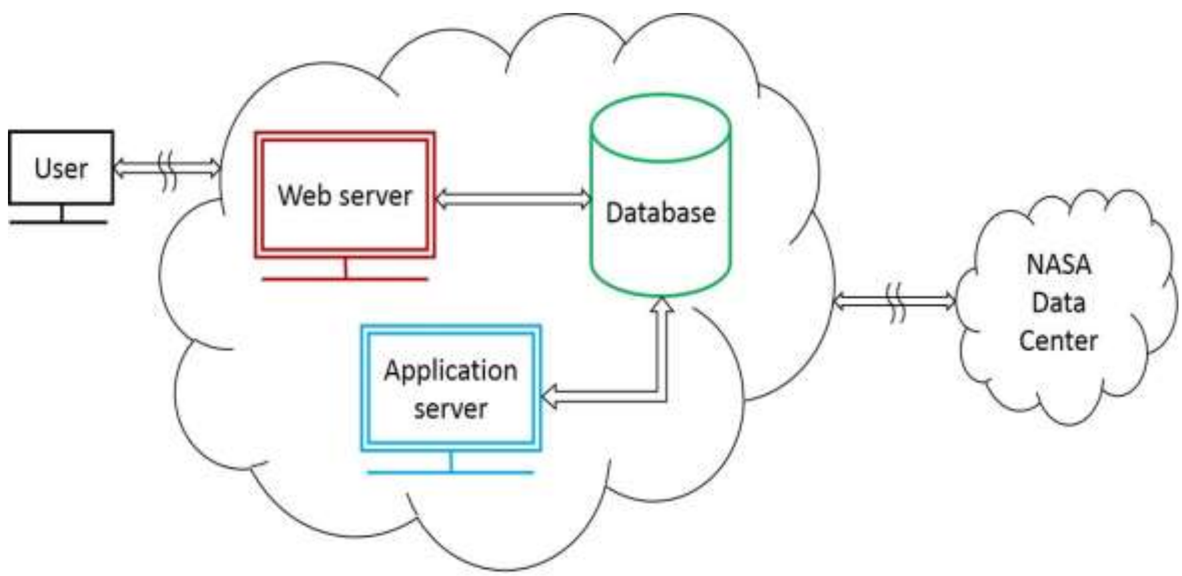


Fig. 5.2: Cloud based structure for implementation

5.1 Features available in SBAIS:

5.1.1 Crop Monitoring

In this module there are few sub features based on Normalized Difference Vegetation Index (NDVI). NDVI is computed from the reflections obtained from wavelengths of red and near infrared portion of the spectrum. Due to photosynthetic activity that occurs in plant, it absorbs most of the visible portion of the spectrum but reflects about 40% in near IR spectrum. The computed NDVI can take a value between -1 to +1, and plants usually have positive value of NDVI. Higher the value of NDVI, denser the plants or healthier the plants are. All the sub modules are developed for district wise and tehsil wise monitoring.

5.1.1.1 Normalized Difference Vegetation Index (NDVI) map

NDVI map is generated by computing NDVI for the selected data and region and then applying color map depending upon the obtained values. The figure below shows the NDVI map of Haridwar district of Uttarakhand state, for the date of selected year and previous year. This helps user to get an idea about changing density of vegetation in the selectedarea.

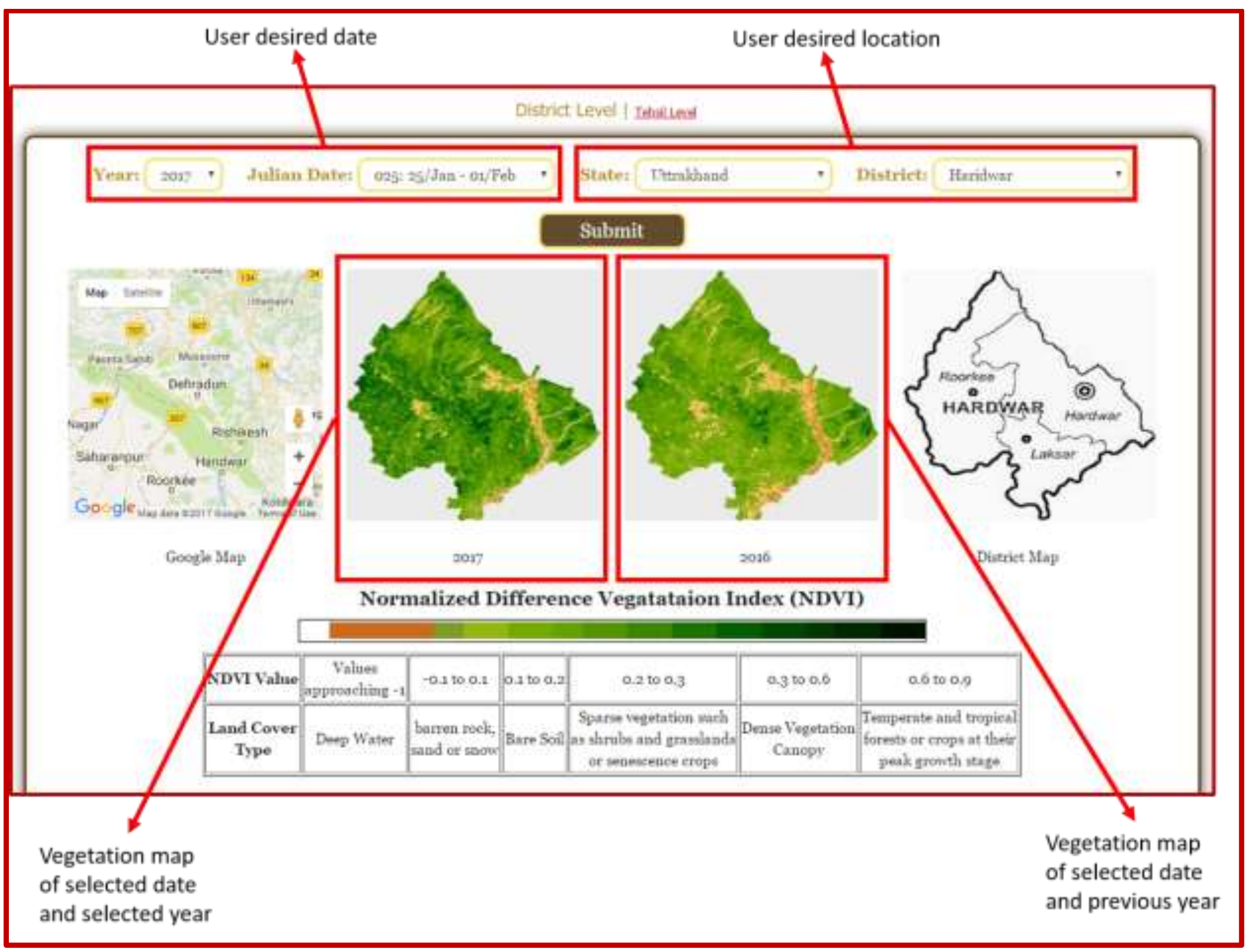


Figure 5.3 Vegetation map in comparison with the previous year

5.1.1.2 NDVI Profile

NDVI profile is generated by plotting average NDVI values of the selected region over a time period. Average NDVI values of different locations are precomputed and stored, which are then later used to generate NDVI profile. For a selected location, the NDVI profile can be viewed in three different time scales such as Year wise in Fig. (a), Julian date wise in Fig. (b) and Cyclic profile Fig. (c) of Fig. 5.4 (Different vegetation profiles based on the selection of user). This information helps user to gain knowledge about vegetation trends of different periods and to identify crop cycles in any particular region.

Fig. (a)

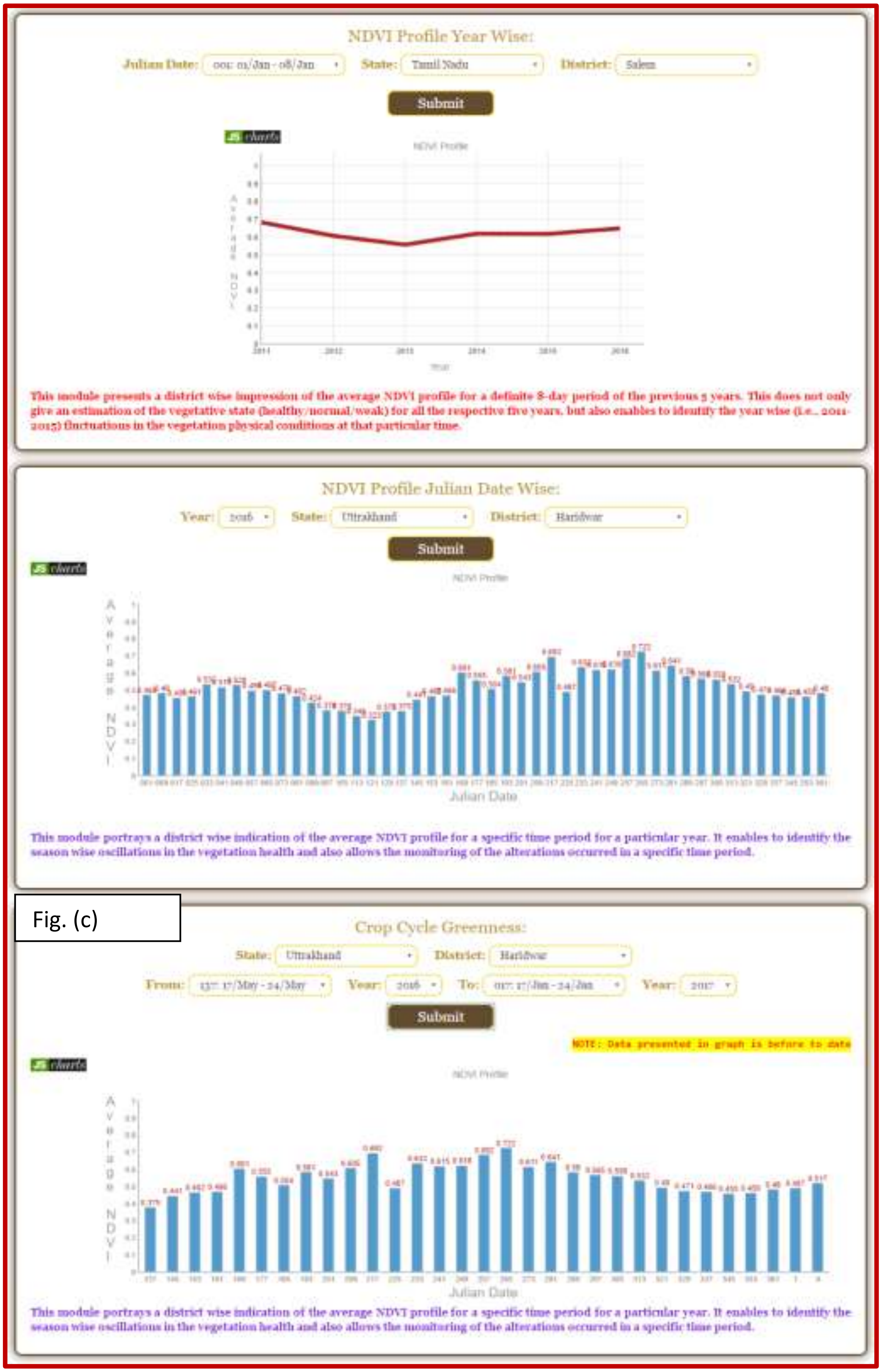


Fig. (c)

Figure 5.4 Different vegetation profiles based on the selection of user

5.1.2 Classification and Change Detection:

5.1.2.1 Classification

A knowledge-based decision tree classifier is used to classify the satellite data. Since we are interested only with vegetation, other classes are grouped into one class and is represented with red, while vegetation is represented with green as shown in figure 5.5 (a). Similar to the NDVI map, classified map of selected region is displayed for the selected date of current and previous year.

5.1.2.2 Change Detection

In this module, change detection algorithm is implemented to identify the changes in vegetation. Both positive and negative changes in vegetation are identified from the two different classified images of the consecutive years. Shown in figure 5.5 (b), the change map of Haridwar district with green color is showing no change in vegetation, blue is showing positive change and red is showing negative change.

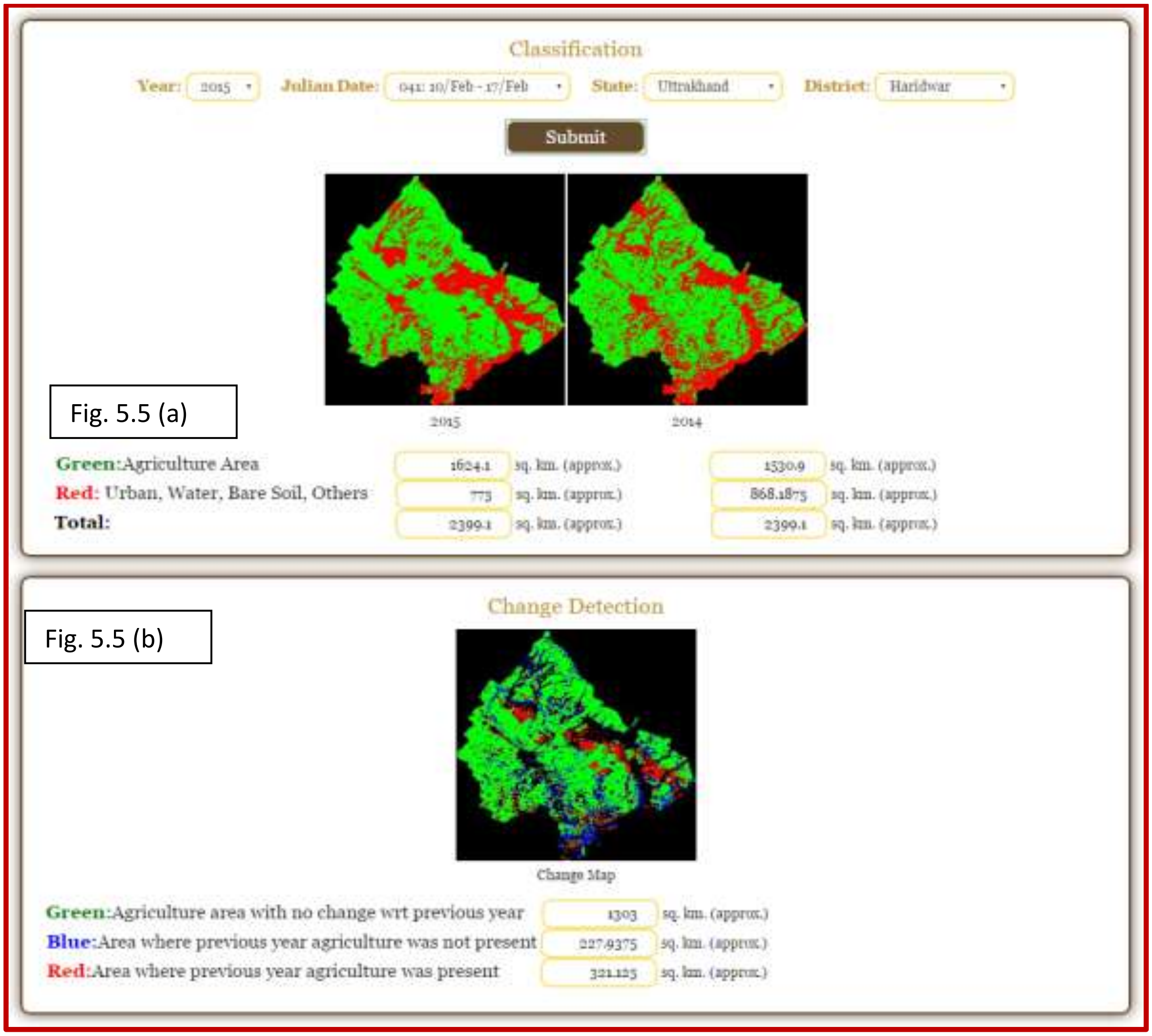


Figure 5.5 Classification map of the selected date vis-à-vis previous year on same date. This map reflects the changes (Green: agriculture area with no change, Blue: increase in agriculture area compared to previous year, Red: decrease in agriculture area compared to previous year)

5.1.3 Drought Monitoring:

This module uses satellite data to estimate drought condition of a selected area. It uses Vegetation Condition Index (VCI) derived from satellite data to determine the drought condition. This data is very useful for insurance agencies to get the information on the crop insured areas. It can also be useful for policy makers to make the irrigation facility available to the desired locations. Moreover, with the availability of past 10 years of data, prominent drought affected areas can be marked and required remedial measures can be taken, such as building irrigation channels, educating farmers to cultivate crops which required less water etc. which is shown in Fig. 5.6

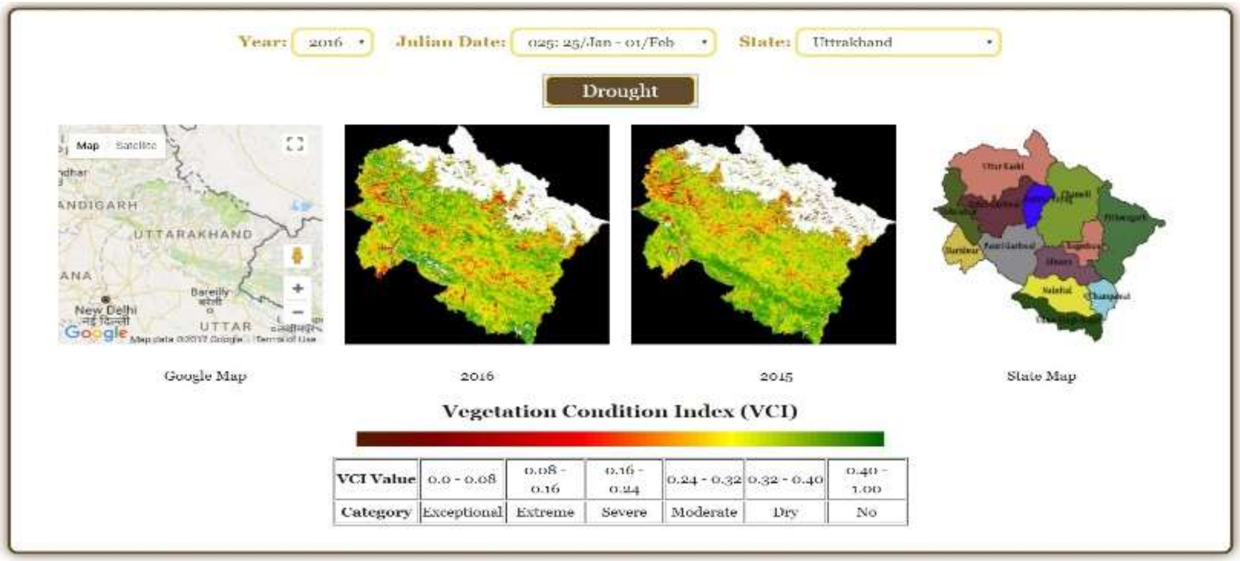


Figure 5.6 Drought map of the selected date with comparison to previous year same date

6 Difference between Satellite Based AIS (SBAIS) and Conventional Agriculture Monitoring and Cost Analysis:

Sr. No.	**SBAIS**	**Conventional Agriculture Monitoring**	**Cost Saving through SBAIS**
1.	Low cost and less manpower	High cost and high manpower	Approximately 60% cost will be saved
2.	Data can be managed efficiently	Can't be managed as efficiently	Will be available at a very low cost
3.	Transparency	Possibility of errors	NA
4.	Highly accurate in crop health monitoring up to village level, Fasal Bima, Decision making etc	Possibility of errors and very expensive	Approximately 60% cost will be saved
5.	Spatial query about the area for last 5 years	Not possible	Will be available at a very low cost
6.	Data integration and Overlay from different sources can be managed with less time and cost	Expensive and time consuming	Approximately 60% cost will be saved
7.	Graphical and map	Not possible, expensive	Will be available at a

	output and display is possible and cheap		very low cost
8.	Search by computer/ Web Based/ Mobile App based Information	Manual check	More Efficient
9.	Facility to provide automatic SMS alarm and message regarding crop health and other land use information	Not possible or very expensive with possibility of errors	Will be available at a very low cost, with approximately 80% cost saving

7 Comparison of traditional system of Agri support vis-a-vis newer technologies:

Monitoring of agricultural system generally depends upon actual information of cultivated area, crop type, crop condition, region wise knowledge of agricultural system and effect on meteorological conditions. Generally, for this information, people depend upon ground survey methods, information from various agriculture centers etc. Nowadays, people are trying to use M2M technique or sensor-based technique to monitor the agriculture system. But all these techniques have following limitations/problems and difficulties:

- Very cumbersome, time consuming and difficult to monitor large areas
- In M2M based technique, it is difficult to manage different sensors for a long time
- In sensor based, managing and monitoring the sensors is not very easy
- All these methods are quite expensive

So, satellite-based monitoring is alternate way to monitor the agriculture areas on large scale and in a very cost-effective manner. IOT devices can also be used as alternate to make this pervasive to improve productivity and yield.

8 Benefits of Satellite Based Agriculture Information System Mapping for State / Country:

- Agriculture information system with satellite data as input (no Human interface)
- To retrieve real-time information of crops like health etc. at district and village level
- To provide information to end user through cloud service and to make it cost effective and hassle free
- Web based and SMS based service

9 Way Forward:

The developed satellite-based agriculture information system is helping the agriculture sector in the following ways:

- The project can be adopted by other states as well for crop monitoring which will enable them to build a streamlined and advanced crop information system. Such a model will enable them to study requirements for crop growth which depends upon the geographical factors like climate, rain patterns, soil condition etc.
- It enables the common man to get one stop information regarding crop health and land cover by web service or mobile
- The information system also helps in identifying the problems in crop health at district level which enables the production of healthy and better-quality crops
- Effective and efficient display of crop health in last five years in any particular area as well as monitoring of the whole crop growth cycle
- It is enabled to send automatic SMS to the district authorities for taking proper measures in problematic areas which results in swift action and consequently crops suffers less damage
- It provides relevant information regarding crop health related statistics online to the end user because of which end users are kept updated with the crop health

- It helps the Government to take proper measure for giving Fasal Bima and other facilities to farmers
- It has easy user interface for everyone using mobile app for wide acceptability
- It improves decision making by using gathered information
- Agriculture field monitoring is conducted for soil moisture and soil type mapping
- It is equipped to assist agriculture planner to take proper decision and to provide proper help like fertilizer, water etc.
- It further aims to support the planning, monitoring and evaluation of agriculture product, including human resource management, planning, and resource allocation
- It also supports the development and implementation of policies, allocation and use of resources to promote, protect and restore the agriculture product for special needs groups, especially farmers
- It provides land cover change information by which planners can take proper decision for fruitful use of land
- It accepts satellite data as input in the for a selected area daily
- The system can rescaled or otherwise manipulated to get the land cover/agriculture data for different purposes
- A satellite database will be developed for last 5 years/10 years and database manager will be deployed
- It also includes query and analysis programs so that answers to simple queries can be retrieved as required by users like crop health in last 5 years of that particular area, in any particular time etc.

10 Teaching Notes:

Learning objectives:

- To be able to appreciate the utility of satellite images to determine and retrieve useful information for improvement of agriculture monitoring system for improved agriculture production and management
- To be able to identify problems faced by insurance agency in handling and evaluating claims regarding any calamities

Suggested questions and Analysis:

- What are satellite images and what are their properties?
- What is the key information that can be retrieved from satellite data regarding agriculture field and its management?

Group discussion:

- What are the advantages and disadvantages of using satellite-based monitoring over manual check for agriculture monitoring and insurance agencies?
- What additional modules can be added in the system to make it more useful for the users?

Role-play activity:

- Make groups of 5-6 people
- Groups should discuss the issues with the manual monitoring of crops and advantages as well as shortcomings of satellite-based monitoring

Summary:

Key lessons learnt (15 minutes). Each participant shall write down a summary in not more than 500 words highlighting key learning from the case.

11 Abbreviations

Abbreviations	Full Form
AIS	Agriculture Information System
ICT	Information and Communication Technology
IOT	Internet of Things
M2M	Machine to Machine
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
PMFBY	Pradhan Mantri Fasal Bima Yojana
SBAIS	Satellite Based Agriculture Information System
VCI	Vegetation Condition Index