A PRELIMENERY REPORT ON

MAPPING CROP FIELDS BY APPLYING MACHINE LEARNING ALGORITHMS TO MULTI-TEMPORAL SENTINEL-2 DATA

SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE
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FOR THE AWARD OF THE DEGREE

OF

BACHELOR OF ENGINEERING (COMPUTER ENGINEERING)

SUBMITTED BY

GAURAV PANDITA	**71715715G**
JADHAV TEJAS MAHESH	**71715771H**
PAWAN MANTRI	**71715882K**

DEPARTMENT OF COMPUTER ENGINEERING

STES'S SINHGAD INSTITUTE OF TECHNOLOGY

KUSGAON BK, LONAVLA, 410401

SAVITRIBAI PHULE PUNE UNIVERSITY

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CERTIFICATE

This is to certify that the project report entitles

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Submitted by

GAURAV PANDITA	**71715715G**
JADHAV TEJAS MAHESH	**71715771H**
PAWAN MANTRI	**71715882K**

is a bonafide student of this institute and the work has been carried out by him/her under the supervision of **Prof. Manisha Galphade** and it is approved for the partial fulfillment of the requirement of Savitribai Phule Pune University, for the award of the degree of **Bachelor of Engineering (Computer Engineering)**.

Prof. Manisha Galphade
Guide
Department of Computer Engineering

Dr. S. D. Babar
H.O.D
Department of Computer Engineering

Dr. M.S. Gaikwad
Principal
Sinhgad Institute of Technology, Lonavala

External Examiner
Savitribai Phule Pune University

Place : Lonavala
Date :

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GAURAV PANDITA	71715715G
JADHAV TEJAS MAHESH	71715771H
PAWAN MANTRI	71715882K

(BE Computer Engineering)

ABSTRACT

Currently, management in agricultural sector is an area of active development and implementation of methods that apply remotely sensed data to solve production tasks. One of such tasks is the crop identification by using satellite images. This project proposes a crop identification method based on the algorithm for calculating estimates using satellites images. The classification features are the set of time series values, built by the sequence of satellite images. The scope of this project utilizes Sentinel-2 data derived normalized difference vegetation index (NDVI) data to map the spatial distribution of crop fields. Classification And Regression Tree Machine learning algorithms are used in order to map crop fields.

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LIST OF ABBREVIATIONS

ABBREVIATION	ILLUSTRATION
SAR	Synthetic Aperture Radar
NDVI	Normalized Difference Vegetation Index
RF	Random Forest
CART	Classification and Regression Tree
GEE	Google Earth Engine
ML	Machine Learning

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Chapter 1

INTRODUCTION

1.1 Overview

Rice is a staple food resource for more than half of the world population. It plays an important role in the global economy, food security, and water use. In 2017, rice was classified by the FAO (Food and Agriculture Organization of the United Nations) as the second most produced cereal in the world. Moreover, according to the International Food Policy Research Institute, the demand for rice is increasing by 1.8% per year. Thus, obtaining information on the rice's location and distribution is of great importance for food security and water use.

Currently, management in agricultural sector is an area of active development and implementation of methods that apply remotely sensed data to solve production tasks. One of such tasks is the crop identification by using satellite images. This project proposes a crop identification method based on the algorithm for calculating estimates using satellites images. The classification features are the set of time series values, built by the sequence of satellite images. The scope of this project utilizes Sentinel-1A Synthetic Aperture Radar (SAR) data and Landsat-derived normalized difference vegetation index (NDVI) data to map the spatial distribution of paddy rice fields. Support vector machine (SVM) and random forest (RF) machine learning classification algorithms are used in order to map paddy rice fields.

The objective of this study is to use high-spatial-resolution Sentinel-1 and Landsat multitemporal imagery to detect rice-based cropping patterns in the major rice growing areas, including identifying the best polarization to differentiate different rice cropping patterns and comparing the performance of rule-based and decision tree classifiers in classifying different cropping patterns.

1.2 Motivation

Rice is a staple food resource for more than half of the world population. It plays an important role in the global economy, food security, and water use. Although existing policies encourage domestic production with the goal of promoting self-sufficiency but overestimation of domestic rice production by government, lack of adequate transportation links between rice-producing and consuming regions, and over-fertilisation in turn, causes high levels of soil or water contamination and subsequent decline in crop yield.

Thus, obtaining information on the rice's location and distribution is of great importance for food security and water use.

1.3 Problem Definition And Objective

To facilitate greater understanding of agriculture land used for rice/wheat farming using data from sentinel 1A satellite. Sentinel-2 Synthetic Aperture Radar (SAR) data present an opportunity for acquiring crop information without restrictions, at a spatial resolution appropriate for individual crop fields and a temporal resolution sufficient to capture the growth profiles of different crop species. Utilizing multi-temporal Sentinel-2 Synthetic Aperture Radar (SAR) data derived normalized difference vegetation index (NDVI) data to map the spatial distribution of crops. By applying classification and regression tree (CART), support vector machine (SVM) and random forest (RF) machine learning classification algorithms mapping of crop fields is done.

1.4 Project Scope And Limitations

Scope :

- Estimation of domestic rice/wheat production.
- Control of crop lands used.
- Verification of information provided by farmers about crops seeded on fields.
- Mapping land usage in areas with no information from the farmers about crops seeded on fields.
- To facilitate greater understanding of agriculture land use for rice/wheat farming and the corresponding links to economics and food security.

Limitations :

- Requires internet connection
- Presence of cloud cover in images can be challenging.

1.5 Methodologies of Problem Solving

Method 1 : Google Earth Engine driven approach.

- Accessing the Image from Google Earth Engine.
- Calculation of RED & NIR bands were used to calculate NDVI matrix.
- Applying ML algorithm to NDVI Image
  - Support Vector Machine Classification
  - Random Forest Classification
  - Classification and Regression Trees (CART) Classification.
- Output - a Satellite Image Mapped with the crop on it.

Method 2: ARC GIS driven approach.

- Selecting the area of interest.
- Downloading satellite image of the desired place.
- Loading the image into ARC GIS.
- Pre-processing (cleaning) the satellite image.
- Generating the NDVI image.
- Applying ML algorithm to NDVI image.
- Output - a Satellite Image Mapped with the crop on it.

Chapter 2

LITERATURE SURVEY

1. Mapping paddy rice fields by applying machine learning algorithms to multi-temporal Sentinel-2 and Landsat data
Authors Alex O. Onojeghuo, George A. Blackburn, Qunming Wang, Peter M. Atkinson , Daniel Kindred, Yuxin Miao

Description: This study has demonstrated that the combination of multi-temporal SAR and NDVI images acquired within the rice growing season can effectively delineate paddy rice fields from surrounding land cover classes. A variety of multi-temporal Sentinel-2 SAR polarizations (VH and VV) fused with Landsat-derived NDVI time series data were used to map paddy rice fields across parts of northeast China with two machine learning algorithms (SVM and RF).
The classified outputs generated with both classifiers showed a significant increase in the overall classification accuracies when NDVI data were introduced to the classification process. The results showed that the optimal approach with the best overall and paddy rice classification accuracy was the VH polarization SAR data combined with NDVI time series (i.e. dataset 2 = VH + NDVI) classified using the RF algorithm.

2. Detecting Rice Cropping Patterns with Sentinel-1 Multi-temporal Imagery.
AUTHORS: Kaun Chai

Description: In the study, we used time series of co (VV) and cross (VH) polarized backscatter as well as the band ratio(VV/VH) to find most discriminatory information for separating rice from other crops and fallow land in two consecutive patterns, considering the significant difference between that VH was the best single single polarization to classify stage
and its sensitivity to rice crop growth. Further studies could explore multi-polarizations to improve the performance of the classifiers, such as introducing VV-polarized signatures at flooding/crop establishment stage.

3. Crops Identification by using Satellite Images and Algorithm for Calculating Estimates.
Authors: N.S. Vorobiova

Description: The paper proposes a method of crop identification based on the algorithm for calculating estimates. The advantages of the proposed algorithm: the usage of time series with gaps, accounting of the geographical position of the field. As seen from the results of classification, ACE method gives the total probability of correct classification (Q = 0.72) higher than the classifier by Mahalanobis Distance (0.64). However, the value 0.72 is not satisfactory, and improvement of the quality of the classification is required. A detailed study of the testing sample showed that some of the data are unreliable: incorrect crops for some fields are given as well as the division of crops into classes was carried out non optimally. Therefore, the direction of future research is to study the issue of division crops into groups, so that the best classification quality is achieved at the highest possible splitting crops into classes

4. Mapping Paddy Rice Using Sentinel-1 SAR Time Series in Camargue, France

Authors: Hassan Bazzi , Nicolas Baghdadi , Mohammad El Hajj , Mehrez Zribi , Dinh Ho Tong Minh , Emile Ndikumana , Dominique Courault and Hatem Belhouchette

Description: In this paper, a simple yet powerful tool for mapping the rice area over the Camargue region of France using a Sentinel-1 SAR data time series was introduced.

The SAR backscattering time series of 11 agricultural crop types in the area were first analyzed during the period between May 2017 and September 2017. The analysis of the SAR temporal behavior revealed that rice crops are clearly described by Gaussian profile of the “VV/VH” time series, an increasing linear profile of the “VH” time series, and a high fluctuation in the VV/VH signal when compared to other crop types. To classify rice areas using this description, the position of the maximum, standard deviation, and correlation coefficient of the Gaussian fitting curve of VV/VH, the variance of the VV/VH signal, and the slope of the linear fitting of the VH signal were extracted for each plot during the period between May 2017 and September 2017. The derived metrics were then introduced into a decisional tree and a random forest classifier to classify the rice areas. The results show a significant accuracy when comparing the classified rice map to the national data. A very high overall accuracy was obtained using both the decisional tree (96.3%) and RF classifier (96.6%). Finally, the accuracy of the estimated rice area reaches 97.3% when comparing the rice classified area to the declared rice area for the year 2017.

CHAPTER 3

SOFTWARE REQUIREMENT AND SPECIFICATION

3.1 Assumptions and Dependencies

The software requirement specification of our project will have the entire necessary requirement which will be a baseline of our project. The software requirement specification will incorporate functional and nonfunctional requirements, system architecture, data flow diagrams, UML diagrams, experimental setup requirements and performance metrics.

- Purpose and Scope of Document :-

A software requirements specification (SRS) is a document that is created when a detailed description of all aspects of the software to be built must be specified before the project is to commence. It is important to note that a formal SRS is not always written. In fact, there are many instances in which effort expended on a SRS might be better spent in other software engineering activities.

- Overview of responsibilities of Developer

1. To have understanding of the problem statement.

2. To know what are the hardware and software requirements of proposed system.

3. To have understanding of proposed system.

4. To do planning various activities with the help of planner.

5. Designing, programming, testing etc.

- Purpose

The main purpose of this project is to obtain information on the rice/wheat location and distribution is of great importance for food security and water use.

- Objectives

1. We formulate the problem of secure data transmission in sensor networks, and identify the challenges specific to this context.
2. To provide security against malicious cloud hackers
3. To reduce complexity of existing system
4. We design efficient techniques for data decoding and verification at the base station.
5. We perform a detailed security analysis and performance evaluation of the proposed technique

- System Specifications

1. Hardware : Intel core
2. Speed : 3.60 GHz
3. RAM : 4 GB
4. Hard Disk : 30 GB
5. Key Board : Standard Windows Keyboard
6. Mouse : Two or Three Button Mouse
7. Monitor : 15 VGA Display

- Software Specifications

1. Operating System : Windows 10 / Linux / Mac
2. Browser : Any web browser.

3.2 Functional Requirements

- User Login
- User Authentication
- Location coordinates
- NDVI matrix/image generation.
- Graphical output generation and display.

3.3 External Interface Requirements

3.3.1 User Interface

- Login Page – Where the user would be able to login.
- Registration Page – New users can register here.
- GEE Platform – User can interact with the application.

3.4 Non-Functional Requirements

3.4.1 Performance Requirement-

- The performance of the functions and every module must be well.
- The overall performance of the software will enable the users to work efficiently.
- Performance of encryption of data should be fast.
- Performance of the providing virtual environment should be fast.

3.4.2 Safety Requirement-

The application is designed in modules where errors can be detected and fixed easily. This makes it easier to install and update new functionality if required.

3.4.3 Security Requirement-

All data will be managed by the user and so the security of the system remains intact.

3.4.4 Software Quality Attributes-

Our software has many quality attribute that are given below: -

• **Adaptability**: This software is adaptable by all users.

• **Availability**: This software is freely available to all users. The availability of the software is easy for everyone.

• **Maintainability**: After the deployment of the project if any error occurs then it can be easily maintained by the software developer.

• **Testability**: The software will be tested considering all the aspects.

• **Reliability**: The performance of the software is better which will increase the reliability of the Software.

• **Integrity**: Integrity refers to the extent to which access to software or data by unauthorized persons can be controlled.

• **Security**: Users are authenticated using many security phases so reliable security is provided.

• **User Friendliness**: Since, the software is a GUI application; the output generated is much user friendly in its behavior.

3.5 System Requirement

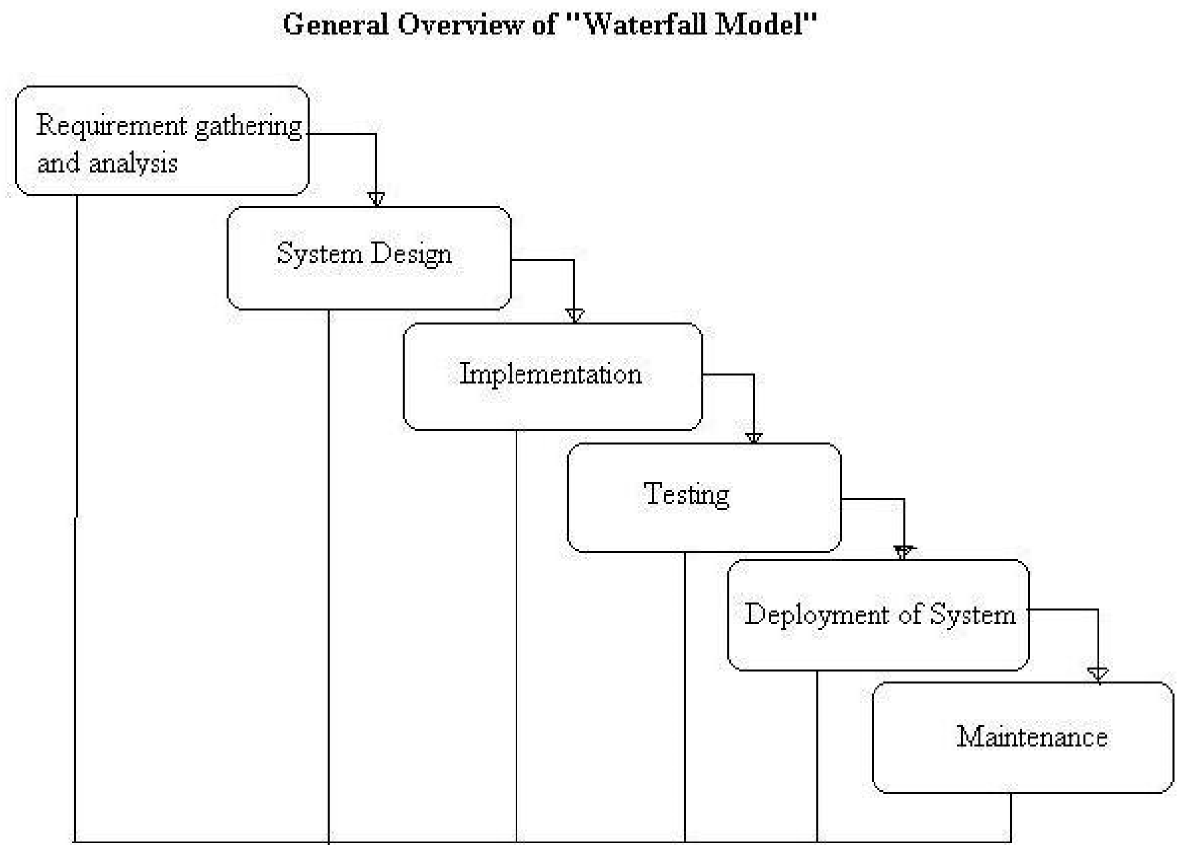
3.5.1 Software Requirement

Operating system	:	Windows / Linux / Mac.
Coding Language	:	JavaScript
Web Browser	:	Any web browser.

3.5.2 Hardware Requirement

System	:	Intel I3 Processor and above.
Hard Disk	:	30 GB.
Monitor	:	15 VGA Color.
Ram	:	8 GB.

3.6 Analysis Models: SDLC Model To Be Applied



SYSTEM IMPLEMENTION PLAN: -

1. Requirement gathering and analysis:

In this step of waterfall, we identify what are various requirements are need for our project such are software tools and hardware required, sources of input, and interfaces.

2. System Design:

In this system design phase, we design the system which is easily understood for end user i.e. user friendly. We design some UML diagrams and data flow diagram to understand the system flow and system module and sequence of execution.

3. Implementation:

In implementation phase of our project we have implemented various module required of successfully getting expected outcome at the different module levels.

With inputs from system design, the system is first developed in small programs called units, which are integrated in the next phase. Each unit is developed and tested for its functionality which is referred to as Unit Testing.

4. Testing:

The different test cases are performed to test whether the project module are giving expected outcome in assumed time. All the units developed in the implementation phase are integrated into a system after testing of each unit. Post integration the entire system is tested for any faults and failures. Here we test the accuracy of the different classifiers with different sets of input data provided.

5. Deployment of System:

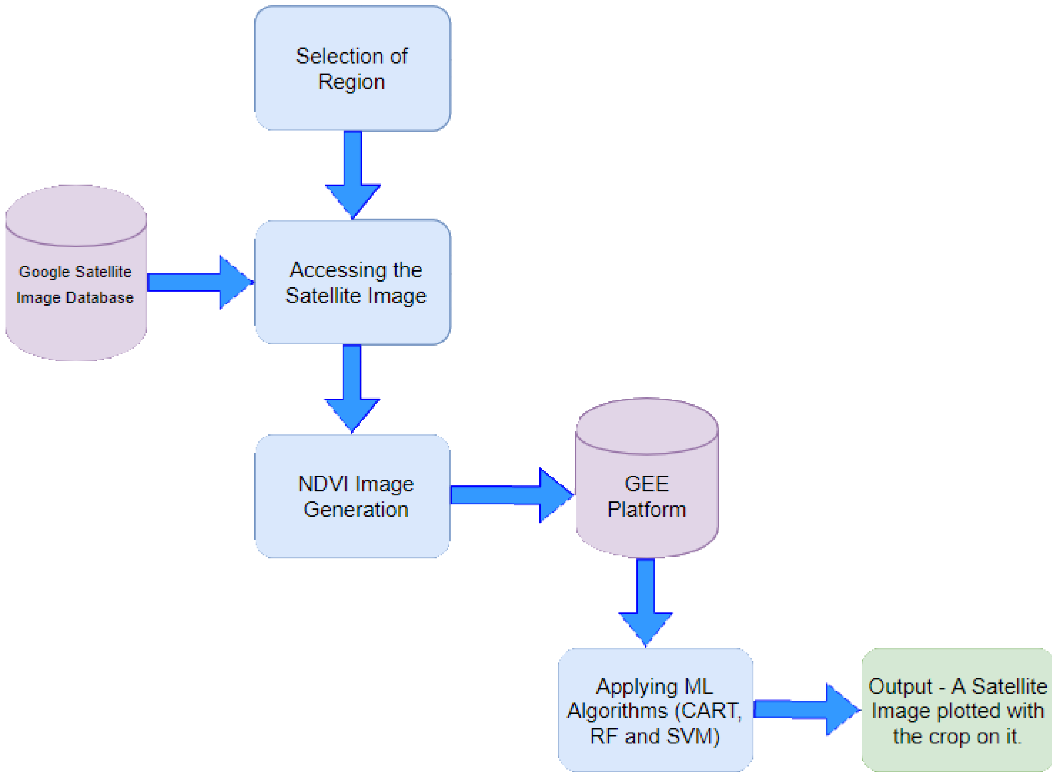
Once the functional and nonfunctional testing is done, the product is deployed in the customer environment or released into the market.

6. Maintenance:

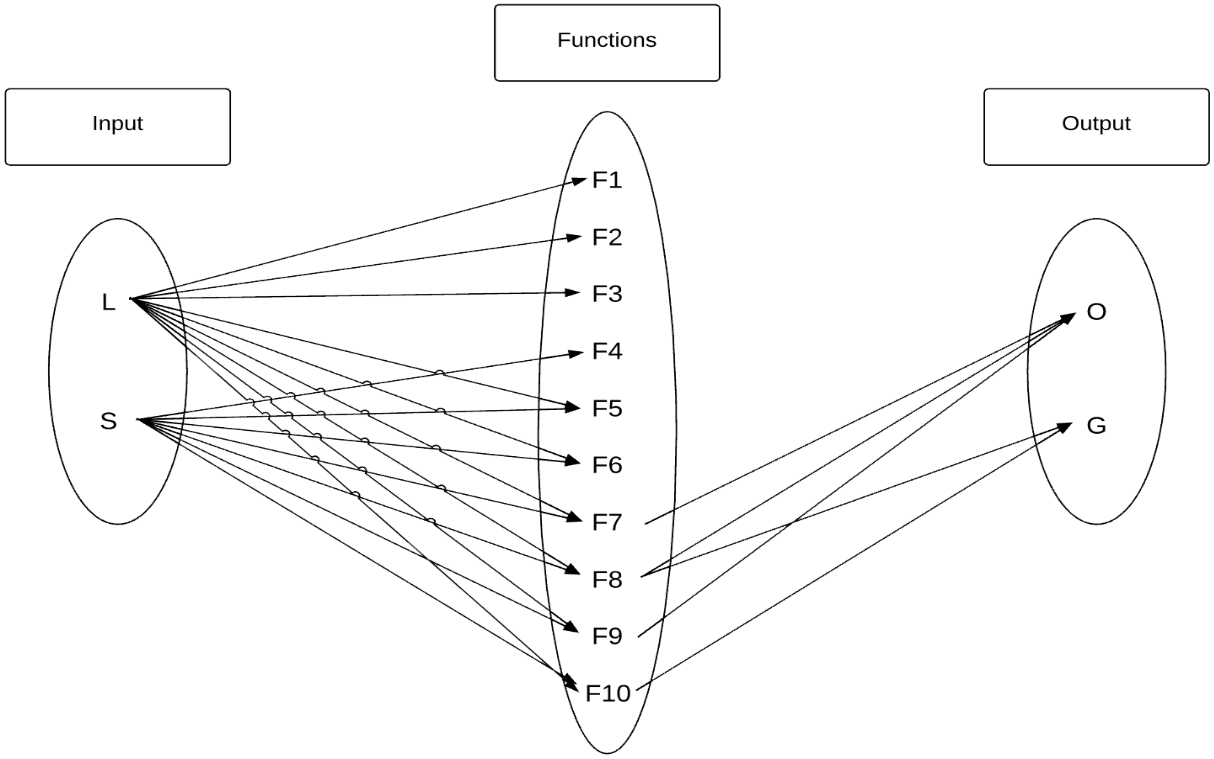
There are some issues which come up in the client environment. To fix those issues patches are released. Also to enhance the product some better versions are released. Maintenance is done to deliver these changes in the customer environment. All these phases are cascaded to each other in which progress is seen as flowing steadily downwards like a waterfall through the phases. The next phase is started only after the defined set of goals are achieved for previous phase and it is signed off, so the name "Waterfall Model". In this model phases do not overlap.

CHAPTER 4
SYSTEM DESIGN

4.1 System Architecture



4.2 Mathematical Model



- Set Theory Analysis:
  - let M be the machine learning framework as the final set
  - M =
  - identify the inputs as I
  - I = L , S
  - L = L1, L2, L3, L4 where L is set of Landsat Images.
  - S = S1, S2, S3, S4 where S is the set of sentinel-2 data set.
- Identify the outputs as P
  - P = O , G
- = O1, O2 where O is Set of optimal images
  - G = G1, G2 where G is Set of Graphical image representation
- Identify the functions as F
  - M =
  - F = F1() ,F2(),F3(),F4(),F5(),F6(),F7(),F8(),F9(),F10()
  - F1(l) :: Calculation of average backscatter value
  - F2(L) ::Generating NDVI image
  - F3(L) :: Landsat image preprocessing
  - F4(S) :: Sentinel-2 image preprocessing
  - F5(L,S) :: Combining Output of F3 and F4
  - F6(L,S) :: Applying SVM Classification Algorithm
  - F7(L,S) :: Applying RF Algorithm
  - F8(L,S) :: Comparison of result generated by SVM and RF Algorithm
  - F9(L,S) :: Optimal Image selection
  - F10(L,S) :: Graphical result generation

4.3 Data Flow Diagram

A data-flow diagram (DFD) is a way of representing a flow of a data of a process or a system (usually an information system). The DFD also provides information about the outputs and inputs of each entity and the process itself. A data-flow diagram has no control flow, there are no decision rules and no loops.

4.3.1 Level 0 Data Flow Diagram

A Level 0 Data Flow diagram (DFD), also known as a context diagram, shows a data system as a whole and emphasizes the way it interacts with external entities.

FLOW OF EVENTS:

- It only shows the interaction between user and GEE.
- User has to only enter the coordinates and select the type of ML classifier and crop.
- The application will give you the output in crop classified image.

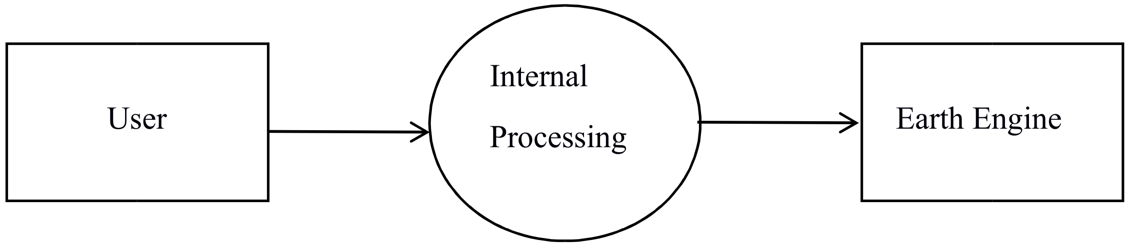


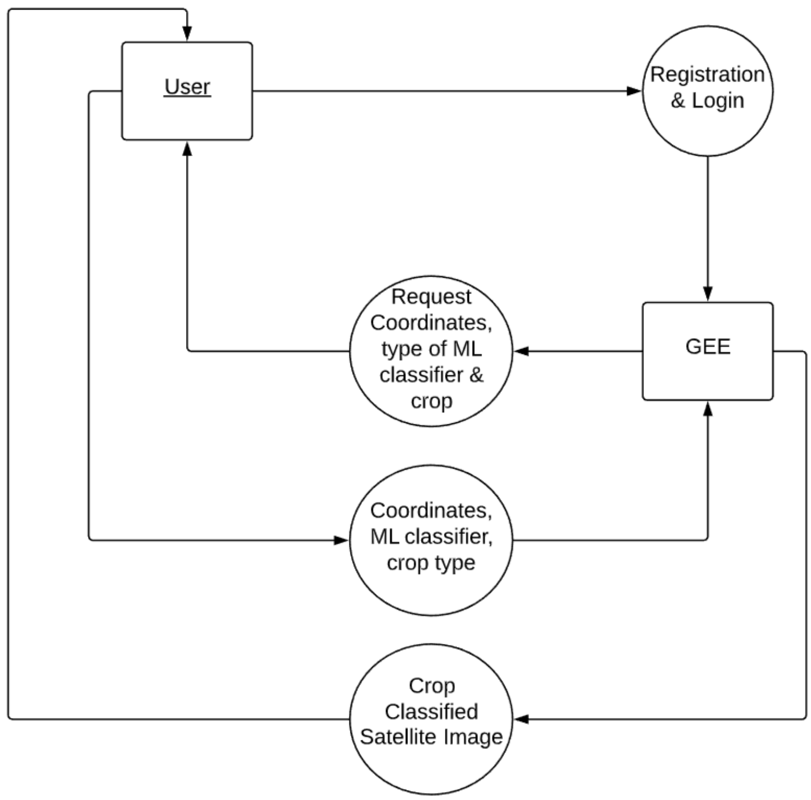
FIGURE LEVEL 0

4.3.2 Level 1 Data Flow

A level 1 data flow diagram (DFD) is more detailed than a level 0 DFD but not as detailed as a level 2 DFD. It breaks down the main processes into sub processes that can then be analyzed and improved on a more intimate level.
FLOW OF EVENT:

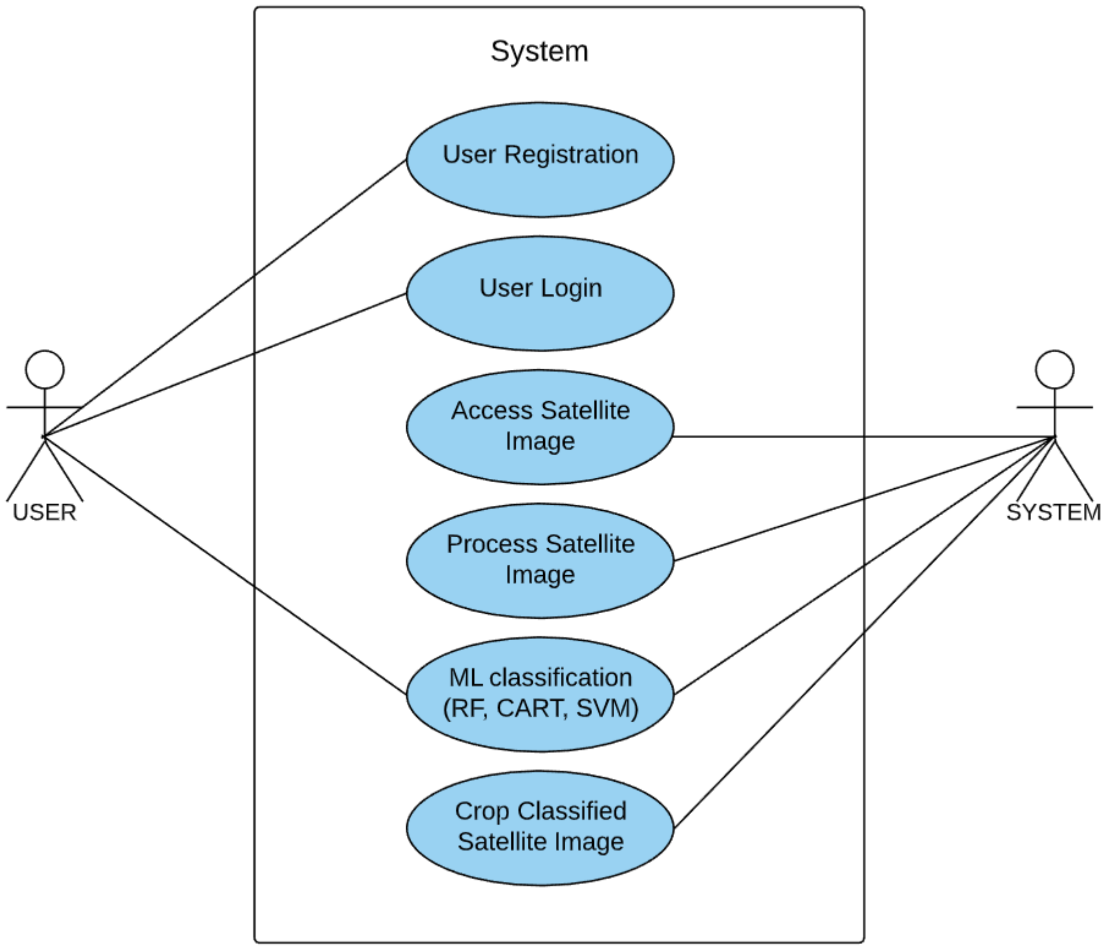
1. Below diagram show the Data Flow Level 1 diagram.
2. As the data flow model consist of external entity which are shown by User and GEE.
3. The processing between the external is shown by circle.
4. When the user registers and login the processing between them happen such as it uses post method to check the credentials of user and if correct gives access to the application.

5. Now application is able to extract the data from the user by requesting to user and receive the data.
6. At last, application gives the output in classified crop image format along with statistical representation.



4.5 UML Diagram

USECASE DIAGRAM :-



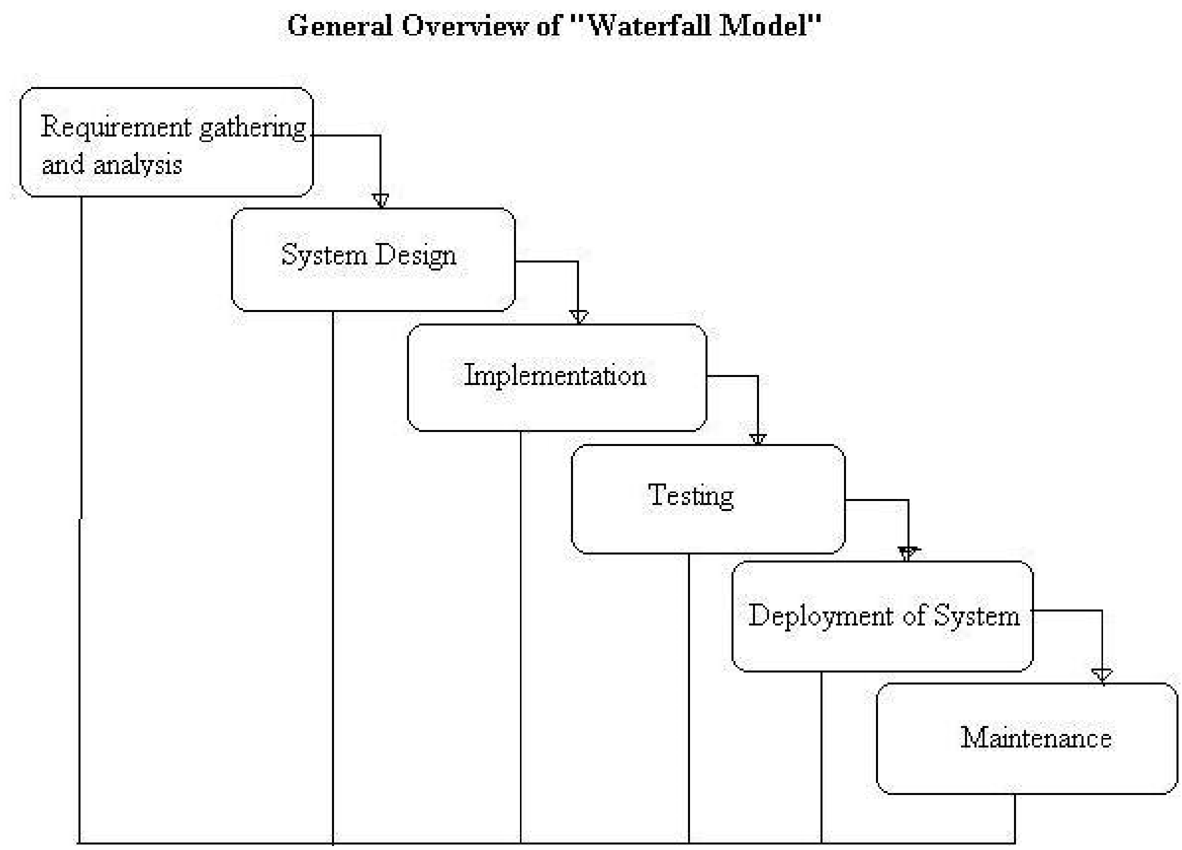
FLOW OF EVENTS:

- **Step 1:** User registers and logins.
- **Step 2:** User recognizes area of interest and gets the corresponding coordinates.
- **Step 3:** User enters the start and end date for satellite image collection.
- **Step 4:** Then user selects the ML classifier to be applied.
- **Step 5:** Selects the crop to be classified.
- **Step 6:** User gets the satellite image mapped with the crop on it.

Chapter 5

PROJECT PLAN

5.1 Project Estimates



Waterfall is the most popular version of the systems development life cycle for software engineering and IT projects. It proceeds through a sequential, single direction process that flows like a waterfall.

- Requirements: This application should classify crop fields with acceptable accuracy.
- Design: The design phase is best broken into logical design and physical design sub phases. The logical design sub phase is when possible solutions are brainstormed and theorized. We analyze different models and obtained structured output.
- Implementation: After designing the model we implemented our design in Google Earth Engine.
- Verification: We verified our project by using satellite images from google earth.
- Maintenance: We implemented suggestions provided by our guide and included support for various bugs.

5.1.1 Project Resources

The internet

Google Developer Docs

Text Books regarding earth explorer

5.1.2 Risk Management w.r.t. NP Hard analysis

Risk Analysis and Management is a key project management practice to ensure that the least number of surprises occur while your project is underway. While we can never predict the future with certainty, we can apply a simple and streamlined risk management process to predict the uncertainties in the projects and minimize the occurrence or impact of these uncertainties. This improves the chance of successful project completion and reduces the consequences of those risks.

Project team members at various levels identify and handle risks in different flavors. However, this will be ineffective without a structured risk management framework, as this leads to:

- Incomplete impact evaluation, leading to loss of Knowledge of the overall impact on the project objectives, like scope, time, cost, and quality.

Identification of secondary or new risks arising from the already identified risks

- Lack of transparency and a communication gap within and outside the team

Thus, it is very important for any project organization to set up an effective risk management framework. Instituting such a practice as a project team culture ensures:
Conscious and focused risk identification and management
Project progress as desired, with the least amount of deviations or surprise, and in line with project and organizational objectives
Early and effective communication of project issues to organization and project stakeholders

- An effective team building tool, as team buy-in and acceptance is assured

5.2 Risk Identification

Risk identification is the process of determining risks that could potentially prevent the program, enterprise, or investment from achieving its objectives. It includes documenting and communicating the concern.
Project management: Risk Assessment and Management Plan

5.2.1 Risk List

Type	List	Impart Analysis	Indicator
Direct Risk	Project structure/ Requirement	There is great risk in meeting the user requirement for the project. Since the success of project depends on the what user gives the coordinate if the user input is correct then only model is able to meet the requirements of user	High
Indirect Risk	Choosing the right technology:	Choosing the wrong technology for the project can be a nightmare to implement and maintain	High
Indirect Risk	Familiarity with technology or Application Area	If we don't know the technology, then it is difficult to learn the new technology	High
Indirect Risk	Having right tools	Using right algorithm and tools is necessary because of these tools project may not be able to work	Low
	Schedule	The system is a big problem ,as the system should go live at the end of the semester.	High

TABLE 5.1: RISK LIST

5.2.2 Problem resolution plan

The probability on the indicator occurrence of each possible project risks have been analyzed in terms of low, medium, high risk, where low risk applies for unlikely that the type of risk will occurs during the life of the software, medium risk represents for the risk where there is 50% Chance that the risk will occur and high risk is for a risk that will be a great deal of chance that will occur. Each risk that receive the high score will have a corresponding plan to manage and control of that risk.

Here is the breakdown of how we are going to attack each risk.

Type	List	Management strategies: how to cope
Direct risk	Project structure/ Requirement	Flexible architecture. analyzing before adding new requirements if it is very important to change the architecture
Indirect risk	Choosing the right technology	Careful research and consideration of possible technology, during design stage.
Indirect risk	Schedule and having	Follow the project plan and use the right
	the right tools	software modeling process to complete project on time
Direct risk	Insufficient testing	Use through testing plan to satisfy requirement measurement

TABLE 5.2: RESOLUTION PLAN

5.3 Project Schedule

5.3.1 Project task set

Major Tasks in the Project stages are:

- Task 1: Requirements collection for the project
- Task 2: Draft of preliminary project.
- Task 3: Research and relevant reading
- Task 4: Project proposal and review
- Task 5: Gather data on the basis of research and review
- Task 6: User requirements
- Task 7: Design
- Task 8: Validate and reviewing

5.4 Team Organization

Proper project team organization is one of the key constraints to project success. If the project has no productive and well-organized team, there's an increased probability that this project will be failed at the very beginning because initially the team is unable to do the project in the right manner. Without right organization of teamwork, people who form the team will fail with performing a number of specific roles and carrying out a variety of group/individual responsibilities.

5.4.1 Team structure

Our group consisted of three members Tejas, Gaurav and Pawan. Various roles were assigned which consisted of collection of data in the form of research papers and technologies associated with it, implementation of code, testing of outcomes, test the solution to validate requirements documentation.

5.4.2 Management reporting and communication

A group of people turns into a team when every person of the group is capable of meeting the following conditions:

- Understanding the work to be done within the endeavor
- Planning for completing the assigned activities
- Performing tasks within the budget, timeline, and quality expectations
- Reporting on issues, changes, risks, and quality concerns to the leader
- Communicating status of tasks
- Being a person who can jointly work with others

CHAPTER 6

PROJECT IMPLEMENTATION

6.1 Overview of project module

The implementation phase involves putting the project plan into action. The implementation phase is where we and our project team actually do the project work to produce the deliverables. The implementation phase keeps the project plan on track with careful monitoring and control processes to ensure final deliverable meets the acceptance criteria.

6.2 Tools and Technologies Used

Different types of tools and technologies were used which consisted of amazon web services, echoism to test the skill any time anywhere, Alexa skill set to type and test your skill trough browser.

6.3 Algorithm Used

- **Step 1:** Accessing the Image from Google Earth Engine.
- **Step 2:** Calculation of RED & NIR bands were used to calculate NDVI matrix.
- **Step 3:** Applying ML algorithm to NDVI Image
    - Support Vector Machine Classification
    - Random Forest Classification
    - Classification and Regression Trees (CART) Classification.
- **Step 4:** Output - a Satellite Image Mapped with the crop on it.

CHAPTER 7
SOFTWARE TESTING

7.1 Type of Testing

- **Login Testing**

For Login testing, we devised two cases:

1. Trying to Login with Authentic Credentials

    We tested this aspect by trying to login using the registered credentials. This test case was quite successful. The application granted the access to the authorized/ registered user.

2. Trying to Login with unauthorized user

    We tested this aspect by trying to login using un-registered/unauthorized credentials. The test suite gave 100% satisfactory results, as no un-registered user was granted the access.

- **Registration Testing**

For Registration testing, we again devised two cases:

1. First Registration:

    We tested this suite by registering in the application for the first time. The test gave positive results. Every new user was successfully able to register. And the updates were accordingly reflected back in the database.

2. No user can register with existing usernames:

    We added an element in the application such that no user can register with the existing name. Again, the system gave positive response in this test suite. As no user was able to register with the existing user name.

- **GUI Testing**

For this testing, we went for unravelling every aspects of GUI. The buttons, the input boxes etc. Every element on the GUI responded correctly with its designated response and functions allocated to the buttons and input boxes respectively.

- **Co-ordinate Testing**

For Co-ordinate Testing, we designed a single test case. In which, the co-coordinative results given by the application were check against a standard scale of co-ordinates. The system gave accurate result.

- **Image Testing**

For Image Testing, we designed a simple test in which we assessed, whether the system with the responding with the correct map image for the given input coordinate. The application flawlessly passed the test.

CHAPTER 8

RESULTS

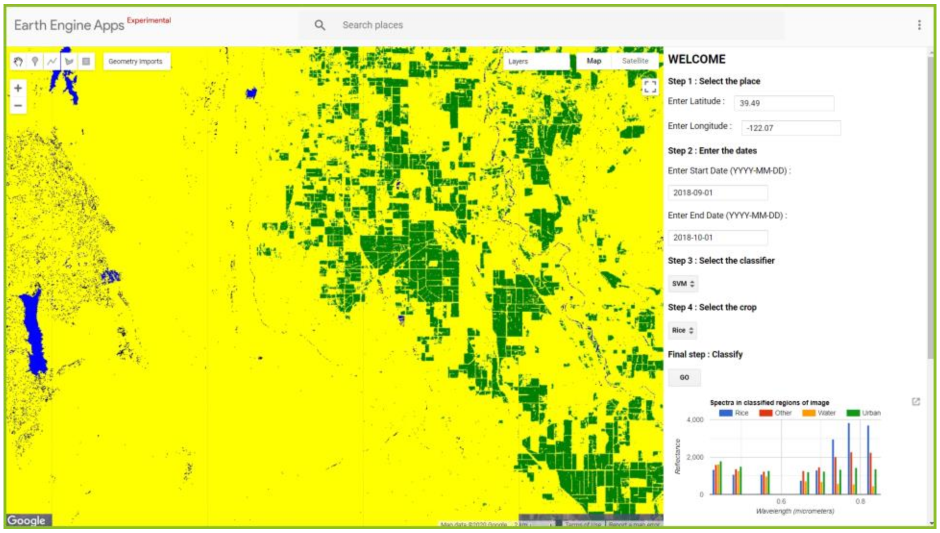


Fig 8.1 - Rice Crop Classification Using SVM

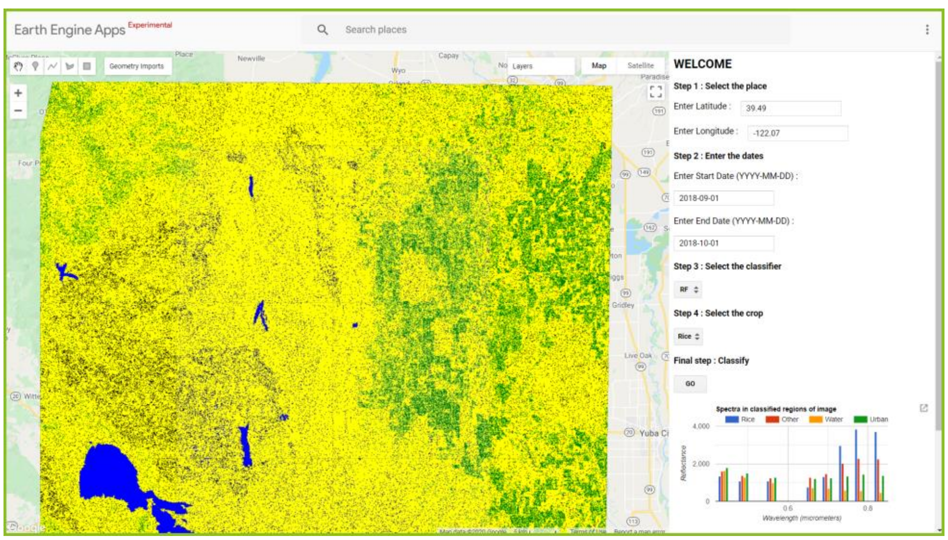


Fig 8.2 - Rice Crop Classification Using RF

Fig 8.3 - Rice Crop Classification Using CART

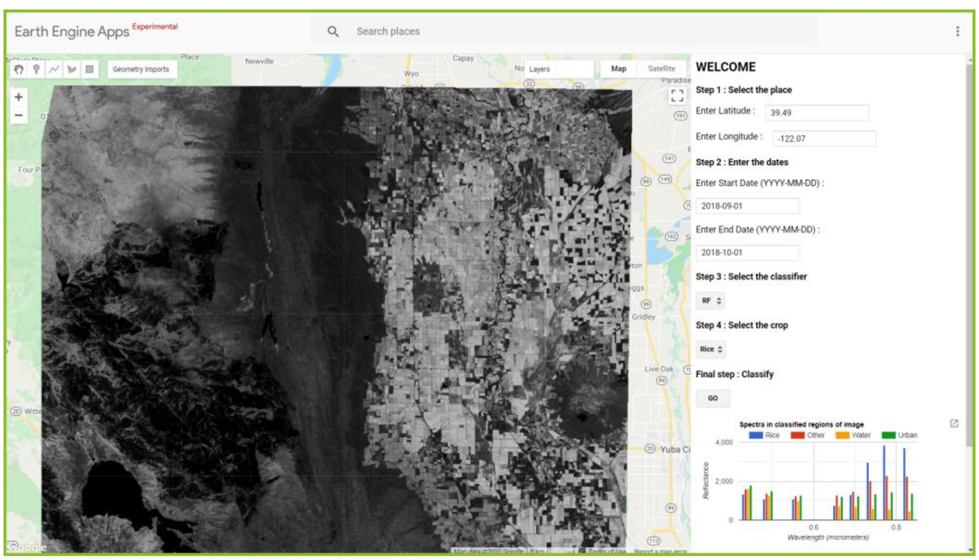


Fig 8.4 - NDVI Image

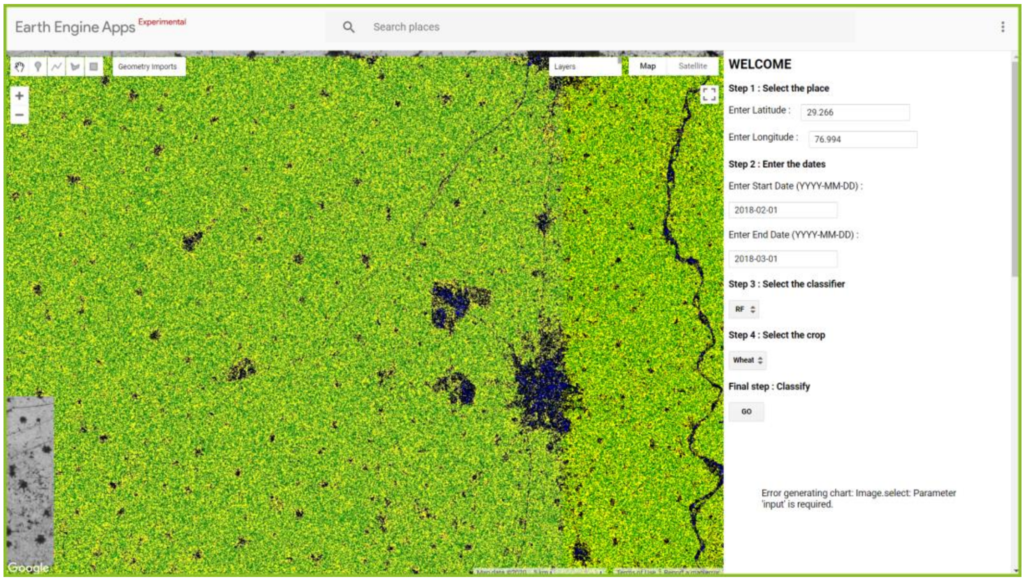


Fig 8.5 - Wheat Crop Classification Using RF

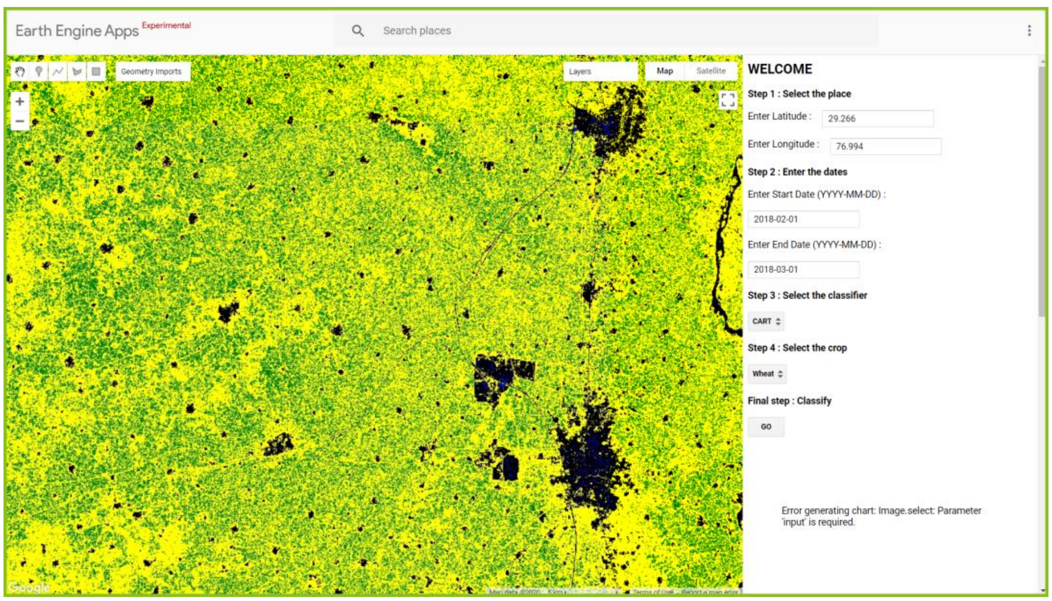


Fig 8.6 - Wheat Crop Classification Using CART

CHAPTER 9

CONCLUSION

CONCLUSION AND FUTURE WORK

This study has demonstrated that the combination of multi-temporal NDVI images acquired within the growing season can effectively delineate rice/wheat fields from surrounding land cover classes. A variety of multi-temporal Sentinel-2 derived NDVI time series data were used to map rice/wheat fields with three machine learning algorithms (CART, RF and SVM).

The classified outputs generated with classifiers showed a significant increase in the overall classification accuracies when NDVI data were introduced to the classification process.

Some of the possible future applications of this project can be:

- Estimation of domestic rice/wheat production.
- Control of crop lands used.
- Verification of information provided by farmers about crops seeded on fields.
- Mapping land usage in areas with no information from the farmers about crops seeded on fields.
- To facilitate greater understanding of agriculture land use for rice/wheat farming and the corresponding links to economics and food security.

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