Charles Sturt University

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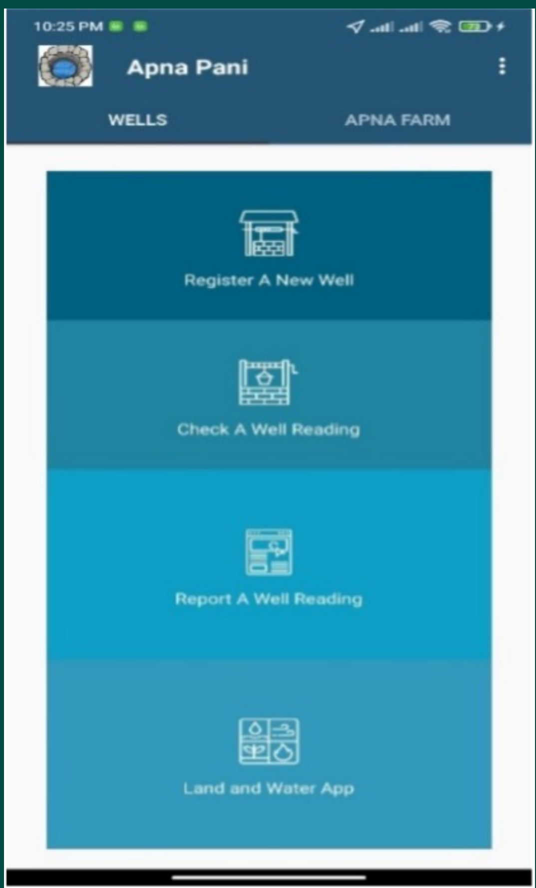
Agriculture Water Environment

Mobile and Web Applications for Land and Water Evaluation



Mobushir R. Khan, Edward G. Barrett-Lennard, Jehangir F. Punthakey

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Disclaimer

Executive Summary

Land capability assessment is paramount for sustainable agricultural production as it assists in making optimal farming decisions. Stakeholders need to plan what plant to grow and how to grow it. These decisions are linked to land capability, and allow the optimal use of land and water resources. Such data driven decisions not only ensure better economic outputs but also enhance sustainability. Stakeholders (farmers, government officials, researchers and policy makers) need substantial data and algorithms and data processing to make optimal plans on how best to use land resources. Our mobile and web-based app is an AI based system for evaluating land and water resources which is capable of performing the following tasks:

Data:

- Stores data entered by users where they have their own data sources (e.g. groundwater depth and quality, soil characteristics, and weather).
- Accesses existing data from selected locations already stored in the database; this is readily updatable by the users themselves.
- Fetches agrometeorological data from online sources such as world weather online, meteomatics and the reanalysis of climate model data.
- Accesses Remote Sensing (RS) data from the European Satellite Agency's Sentinel 2 and 3 data at 10 metre resolution with five days interval.

Analyses:

- Determines location and time dependent advisories on land operations based on land characteristics viz, soil, weather, and water.
- Conducts water analytics to compute crop water requirement as per FAO's methodology based on the Penman-Montieth algorithm.
- Uses RS analytics to compute indices for crop vigour/health (Normalised Difference Vegetation Index: NDVI), crop moisture (Normalised Difference Moisture Index), crop nitrogen (Normalised Difference Red-edge) and chlorophyll activity (Red-edge Chlorophyl Index).

The architecture of this presented AI based system is based on the following components:

Knowledge Base: This is the core component of Land and Water application for land assessment. It contains the required soil and water related knowledge and expertise rendered for the ACIAR LWR/2017/027 "Adapting to Salinity in the Southern Indus Basin" (ASSIB) project. A survey questionnaire was developed by members of the ASSIB team which forms the basis of this knowledge base. It includes facts, rules, heuristics, and relationships within the land capability assessment and allows the system to provide insights and recommendations on the optimal use of land resources.

Inference Engine: The reasoning mechanism developed applies logical rules to the knowledge base to deduce new information for making decisions. It interprets and processes the data (input by users, data already available in the database, and online resources) and applies reasoning to generate conclusions.

User Interface: The user-friendly interface allows for the interaction between the system and its users. It enables users to input data, ask questions, and receive suggestions and recommendations from the system.

Database: The raw data that the system used to make decisions is stored in the database and includes historical data (e.g., soil sampling results), and real-time data streams (or a combination of both, providing a comprehensive data repository for analysis.

Data Processing and Integration Layer: This layer handles the processing and integration of soil, water and weather data from input, database, and online respectively. It ensures that the data fed into the knowledge base is accurate, consistent, and in the right format for analysis.

The application presented is a mobile and web-based decision support system for enhancing farm production based on the assessment of water (quality and quantity), weather and soil characteristics. Further, it provides remote sensing-based vegetation health indicators at field-scale. Farmers are able to assess general crop health, canopy moisture, and nitrogen levels in the leaves. It also has four other features. Firstly, it provides daily weather data (maximum and miniature temperature, relative humidity, rainfall and windspeed). Secondly, important soil parameters (salinity, organic matter, nitrogen, potassium, phosphorus and pH) are provided. Thirdly, groundwater quality (SAR, RSC and EC) and quantity (depth) are provided. Fourthly, the farmers are asked to provide information about their farming operations and cropping pattern. These questions are based on the land and water capability framework which assists in not only the rapid assessment of land but also in optimising decision making. Lastly, the developed system integrates the aforementioned information and provides decision support on crop management.

Contents

1. Introduction

The developed application has two components, viz. a mobile and web-based land capability assessment and a web-based crop monitoring platform.

1.1. Mobile and Web-based Land Capability Assessment

Land capability assessment is a crucial tool used by environmental scientists, agronomists, land management professionals and policymakers to evaluate the suitability of land for agriculture production. This assessment takes into account a range of physical, chemical, and biological land characteristics to determine its potential and its limitations in supporting different land uses (Mendas & Delali, 2012; Brown et al., 2020; Esmaeili et al., 2021). Among the key factors influencing land capability, salinity and water availability are critical determinants of soil health and productivity.

Salinity refers to the concentration of soluble salts in soil or water, which can significantly affect plant growth, soil structure, and microbial activity (Daliakopoulos et al., 2016). High levels of salinity can lead to reduced agricultural productivity, land degradation and the loss of biodiversity. Therefore, understanding and assessing soil salinity levels are essential for determining land suitability for agricultural land uses (Amores et al., 2013).

On the other hand, water availability pertains to the quantity and quality of water accessible for irrigation, drinking, and ecological sustainability. It is a pivotal factor in assessing land capability, as water is a fundamental resource for plant growth, soil nutrient cycling, and overall ecosystem health. Variations in water availability due to climatic conditions, water management practices, and land use changes can significantly influence the capability of the land to support various activities. A key variable for us is the status of water availability, varying from extreme dryness (e.g. in arid environments) to waterlogging (e.g. areas with shallow watertables) and inundation (e.g. in coastal environments). In saline environments dry soils are extremely damaging to plant growth because the salt is dissolved in less soil water, and it is the salinity of the soil solution that impacts on crop growth (Setter et al., 2016). In saline soils that are waterlogged and inundated, soil hypoxia leads to increased salt uptake which exacerbates damage to plants (Barrett-Lennard, 2003).

In a land capability assessment exercise based on salinity and water availability, scientists and land managers analyse soil samples, water availability data, climate information, and other relevant data to classify land into different capability classes. This classification helps in making informed decisions regarding appropriate land use practices, sustainable agricultural development, and land conservation strategies, ensuring the optimal use of land resources while minimising environmental impacts. Based on this principle, a land capability framework (Figure 1 A-D) was developed in the ACIAR LWR/2017/027 “Adapting to Salinity in the Southern Indus Basin” (ASSIB) project.

The objective of this framework was to have a method to rapidly appraise the suitability of land and water in Pakistan for the production of crops, shrubs and trees (see Barrett-Lennard, in preparation). Our aim was not to predict accurately a crop’s yield given certain field conditions. Rather the aims were to:

1. Assess quickly the major risks to successfull crop,shrub or tree growth.
2. Suggest slight imprivements to soil management (e.g. choice of a better crop, application of gypsum, application of mulch, mounding) that could provide better outcomes.
3. Diagnose the likely cause(s) of salinity in a given landscape.

The efficiency of such frameworks can be enhanced manyfold through the use of mobile and web-based technologies (Atasoy, 2024). These technologies not only streamline and standardise the input data but also ensure wider adaptability. The development of mobile and web applications for land capability assessment based on salinity and water availability represents a significant advancement in the field of agricultural technology. These applications harness the power of digital technology to provide users with accessible, real-time, and site-specific data to make informed decisions about land use. By integrating data on soil salinity and water availability, these tools offer a dynamic platform for farmers, agronomists, land planners, and environmental scientists to assess the potential and constraints of land resources efficiently. Mobile applications bring the convenience of in-field assessment, allowing users to gather and analyse data directly from their smartphones or tablets. This on-the-go functionality enables immediate decision-making and can significantly enhance the precision of land capability evaluations. Users can input site-specific data, receive instant assessments, and access recommendations tailored to their land's unique characteristics, all from the palm of their hand.

Web applications, on the other hand, offer a broader platform for land capability assessment, often providing more comprehensive analysis tools and larger databases. They can integrate various data sources, including remote sensing data, climate models, and historical land use information, to give users a more detailed and holistic view of land capability. These platforms often support enhanced visualisation tools, such as interactive maps and graphs, facilitating a deeper understanding of the land's potential and limitations.

Both mobile and web applications typically feature user-friendly interfaces, making sophisticated land capability assessments more accessible to non-specialists. They can automate complex calculations and provide guidance on sustainable land management practices, helping users to mitigate the adverse effects of salinity and optimise water use. Moreover, by storing data in the cloud, these applications enable long-term monitoring and trend analysis, offering valuable insights for future land management planning. The development of mobile and web applications for land capability assessment signifies a move towards more sustainable and informed land use practices. By leveraging technology, stakeholders can better understand the intricate interplay between salinity, water availability and land potential, leading to more responsible and effective land management decisions.

The land and water application developed under LWR/2017/027 is based on mobile and web technologies. Firstly, through mobile and web interfaces, the user can:

- Access important agro-meteorological parameters including (maximum and minimum temperature, humidity, windspeed, sunshine hours, and rainfall).
- Add his/her own data about salinity and water availability status (wilting to waterlogging).
- Access soil parameters from the database if he/she is from the ASSIB project sites of Punjab Province.

Secondly, the inference engine supports the farmer in making important crop husbandry operations by linking the location specific soil and water parameters to the expert knowledge embedded through the land and capability framework.

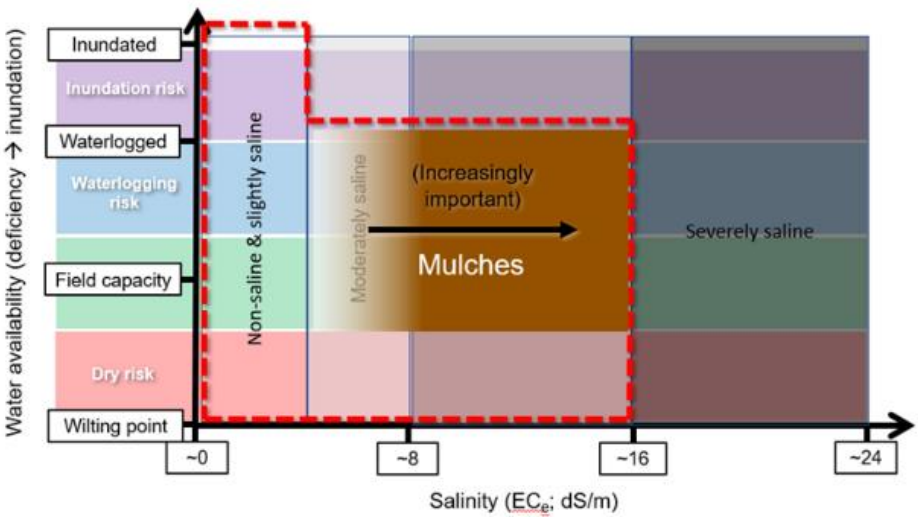


Figure 1A: Expert knowledge for decision support system embedded in the app (use of mulches)

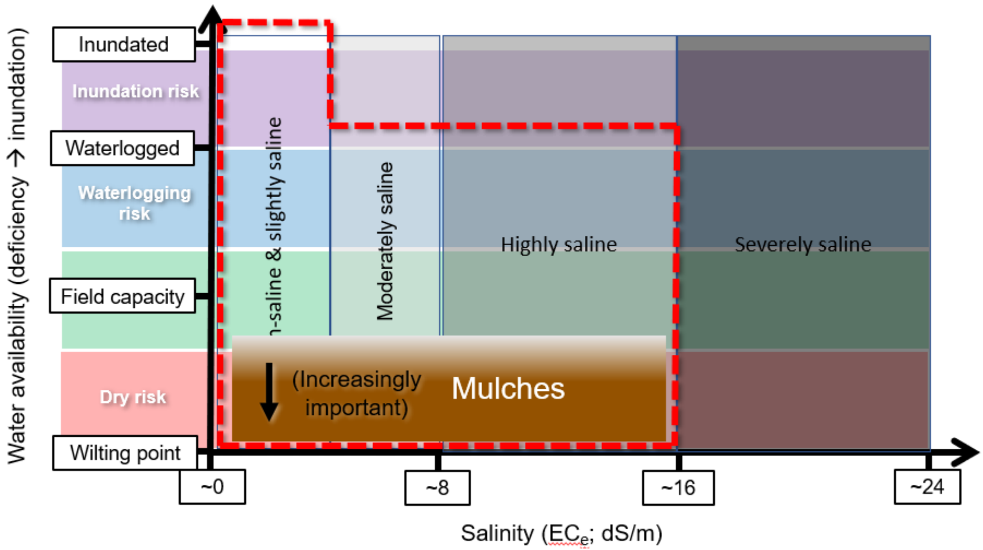


Figure 1B: Expert knowledge for decision support system embedded in the app (use of mulches in dry risk areas)

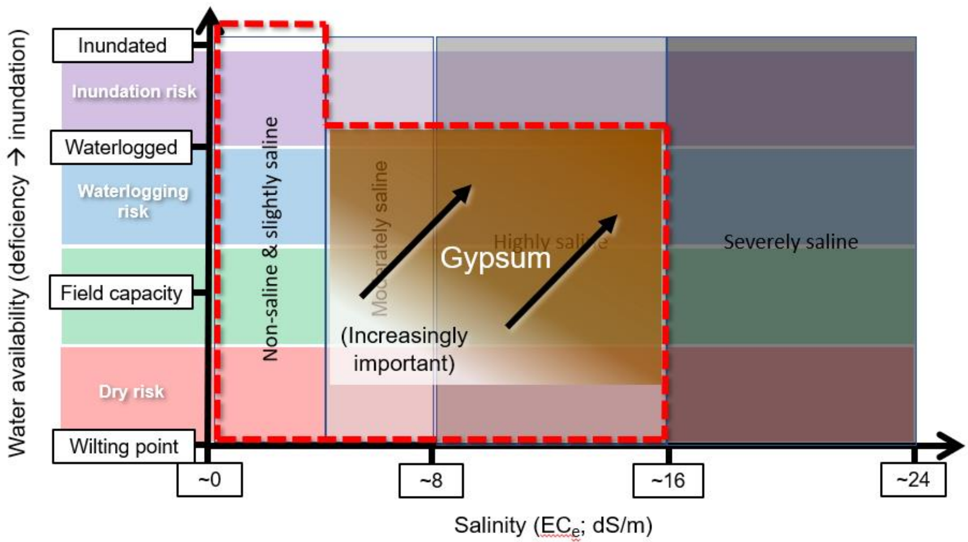


Figure 1C: Expert knowledge for decision support system embedded in the app (use of gypsum and its importance in various regions of risk)

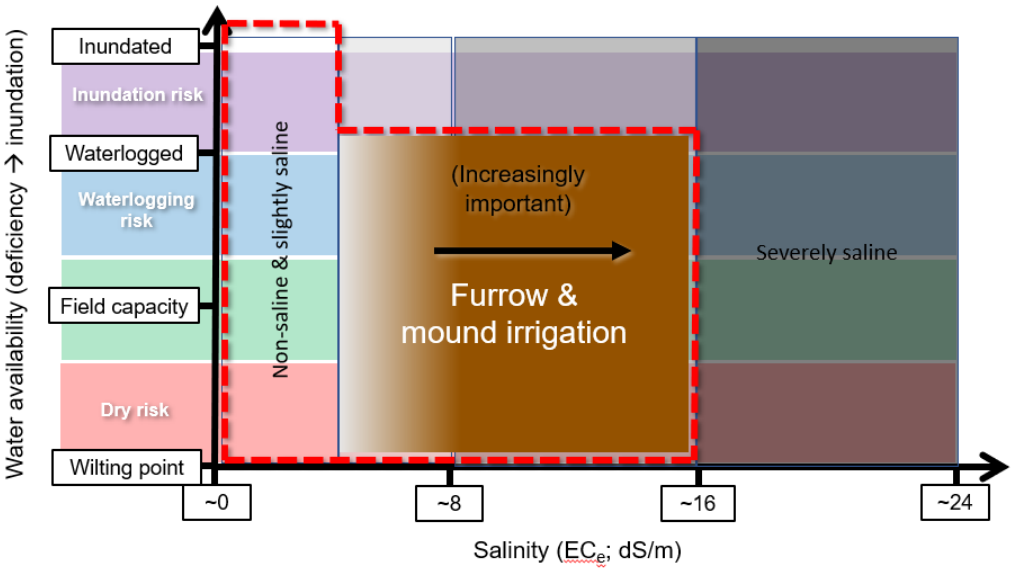


Figure 1D: Expert knowledge for decision support system embedded in the app (cultivation technology)

1.2. Field-scale Crop Monitoring Capabilities

The second component of the developed application is web-based tool which allows the user to monitor the changes in crop performance at a regular intervals of time. Usually, this is over 5 day intervals depending upon the weather conditions (Tariq et al. 2023). The web application connects automatically with the sentinel 2 satellite and analyses the following parameters for crop monitoring:

Normalised Difference Vegetation Index (NDVI)

This identifies problem areas of the field at different stages of plant growth for a timely response. Attention needs to be paid particularly to areas where NDVI values differ considerably and show a decline (Tian et al. 2023). The areas of a field that have an **extremely low** NDVI may indicate problems with pests, plant diseases or other stresses. Areas with an **abnormally high** NDVI may show the occurrence of weeds (Jacob et al. 2023).

Modified Soil-Adjusted Vegetation Index (MSAVI)

MSAVI allows the user to determine the presence of vegetation in the early stages of emergence so that germination success is known in a timely manner. **Maps can be developed for variable rate fertiliser application in the early stages of crop growth. This information is better for earlier periods of crop growth.**

Normalised Difference RedEdge (NDRE)

NDRE shows the photosynthetic activity of a field and is used to estimate nitrogen concentrations in plant leaves. The user can detect stressed and aging vegetation and identify plant diseases. It also makes it possible to optimise the timing of the harvest. **This information is better for middle and late periods of crop growth.**

Red-edge Chlorophyll Index (ReCl)

ReCl indicates the photosynthetic activity of a field as it is sensitive to the chlorophyll in leaves. It allows the user to identify the areas of the field that have yellowed or faded leaves, which may require additional fertiliser application. **This information enables the user to build maps for variable rate fertiliser application in the middle of the cropping season** (Mimenbayeva et al. 2023).

Normalised Difference Moisture Index (NDMI)

The NDMI shows the crop's water stress level, and the absolute value of the NDMI makes it possible to recognise immediately the areas where a field is experiencing water stress. This can be used with a combination of Weather analytics (also on this platform) to schedule irrigation.

NDMI values vary between -1 and 1, and each value corresponds to a different agronomic situation, independently of the crop. Generally, -1 is dry and 1 is humid.

This system enables stakeholders to monitor the outcome of various interventions implemented in response to local land and water conditions and provides avenues to compare the performance of many farms to perform yield gap analyses.

2. Methodology

The methodology for developing land and water application was based on agile principles which centred on flexibility, iterative development, and user engagement to ensure the delivery of a valuable and effective solution. The system overview of the application is shown in Figure 2.

The user interacts with the system through a user friendly interface which is developed in Android and written in Java. The user sends the necessary information to a cloud server where MYSQL server is running to store the necessary data. All of the information travels to and from the server via RESTful APIS.

When data is stored in the database, user data can be fetched any time and displayed to the user on his/her smart phone.

The sequence is in the following manner:

The user interacts with the system and makes a request; the request is sent to the server. The requested data is fetched from the database and accordingly the dynamic pages sends the data to the user web browser / mobile application. The following subsections discuss the major modules in detail.

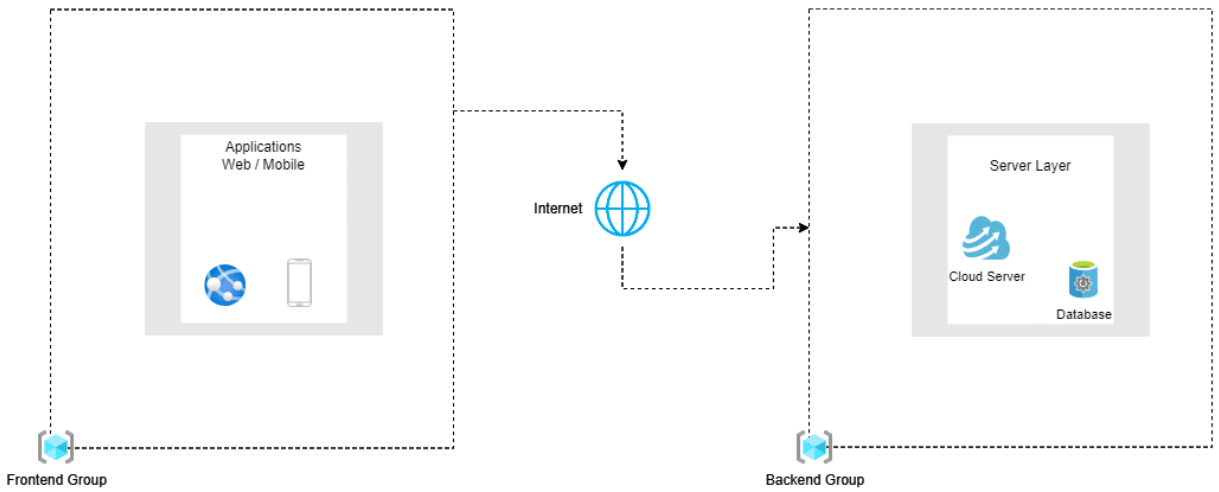


Figure 2: System overview

2.1. Land and Water

This section discusses the client side, which is accessible via an android mobile. The application is built on Android Studio and the code is written in JAVA using JDK (Java Development Kit). The mobile app sends data to the server using an internet connection either broadband or mobile data.

The App can be used via the Mobile App and the Web App.

The App shows some additional information which includes, soil data, crop profitability data, map annotations and Weather status.

2.2. Adopted Methodology

The diagrammatical approach (Figure 3) will help to understand the approach used while designing the app. To be able to use the app the user must have a valid account to login (Figure 3). If the user doesn't have an account, they can register the account in a few simple steps. After the successful login the user will be able to access the Land and Water Application Module.

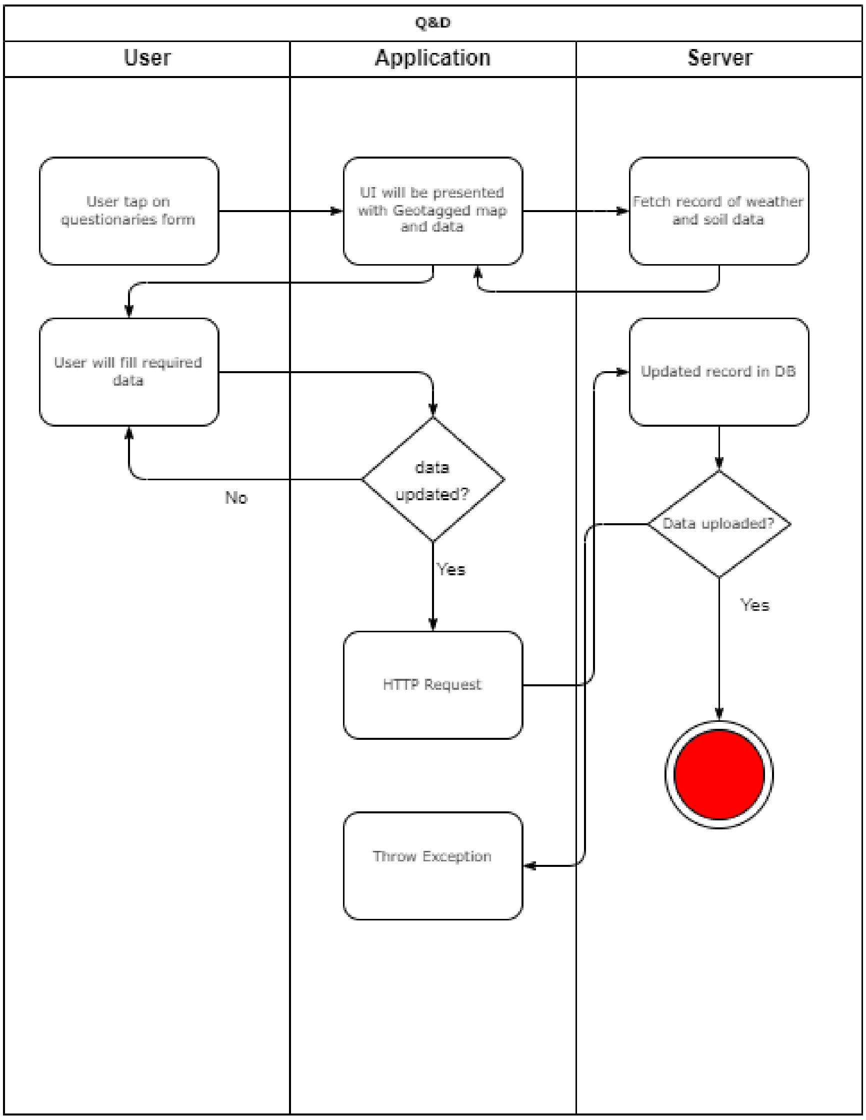


Figure 3: Mobile app flow chart

2.3. Algorithms

The earlier discussed modules work on the following Algorithms.

Algorithm 1: Record new data

Input: Farmer name, location, area in acres and questionaries.

Output: Server Response with success / error message.

Input from user.

Make HTTP POST REQUEST.

If {

Well location is already in the DB

Display "Error Message"

}

Else {

Register and return ID.

}

Algorithm 2: View Data

Output: Server Response with success / error message.

Make HTTP POST REQUEST.

If {

Well record is available in the DB

encode and return

}

Else {

Throw exception.

}

2.4. Web-based Crop Monitoring Tool

The interface is developed using JavaScript in the Google Earth Engine environment. Users can access the system online and need to specify only the area of interest (AoI, i.e. location of the field). Sentinel 2 and 3 satellite data have relatively high spatial resolution (10 m and 20 m grids) and are freely available.

There are two Sentinel-2 multispectral satellites as part of the European Agency (ESA) Copernicus mission, phased at 180 degrees to each other. The MultiSpectral sensor (MSI) collects 13 spectral bands at different spatial resolutions. The temporal resolution depends on how close the twin satellites are to each other: there is a 10-day revisit time with one satellite, and a 5-day revisit time with 2 satellites (Boori et al., 2020). For the bands recording wavelength in the visible and infrared, the spatial resolution is 10 metres.

The full list of the bands recorded by Sentinel 2 and their spatial resolution is presented in Table 1. The bands highlighted bold are the ones used for this activity. Table 1 describes the spatial and spectral characteristics of the data. Important wavelength regions are presented in the table in bold.

Table 1: Sentinel 2 spatial resolution (m) and spectral resolution (µm)

Band number	Wavelength (µm)	Spatial resolution (m)
1	Coastal/ Aerosol: 0.421 - 0.457	60
2	**Blue: 0.439 - 0.535**	**10**
3	**Green: 0.537 - 0.582**	**10**
4	**Red: 0.646 - 0.685**	**10**
5	**Vegetation Red Edge: 0.694 - 0.714**	**20**
6	**Vegetation Red Edge: 0.731 – 0.749**	**20**
7	**Vegetation Red Edge: 0.768 – 0.796**	**20**
8	**Near Infrared: 0.767 – 0.908**	**10**
8A	**Near Infrared: 0.848 – 0.881**	**20**
9	Water vapour: 0.931 – 0.958	60
10	Cirrus: 1.338 – 1.414	60
11	**Shortwave infrared: 1.539-1.681**	**20**
12	**Shortwave infrared: 12.072 – 2.312**	**20**

Note: Vegetation Red Edge is the spectral zone where reflectance abruptly increases from red to infrared

Source: http://www.gisagmaps.com/landsat-8-sentinel-2-bands/

3. Results and Discussion

3.1. Land and Water Application and its Functionalities

The Graphic User Interface (GUI) makes use of Google API for Google Maps which enables it to interactively use, and host Google Maps on the World Wide Web. The Application can be downloaded using http://mriaz-khan.com/survey-form/apk.apk or can be downloaded by scanning the QR code below. Upon installation of the application, the user is provided with three applications.

a. **Apna Pani** which can be used for management of groundwater resources. This is output of the ACIAR funded project # LWR/2015/036.
b. **Apna Farm** which can be used for conjunctive management of surface and groundwater. This is output of the ACIAR funded project # LWR/2015/036.
c. **Land and Water** is the presented application which is output of ACIAR funded project # LWR/2017/027.

This shows the continued legacy of previous ACIAR funded activities. The learning obtained in the previous projects is utilised in the generation of the land and water evaluation application.

Figure 4: Application package

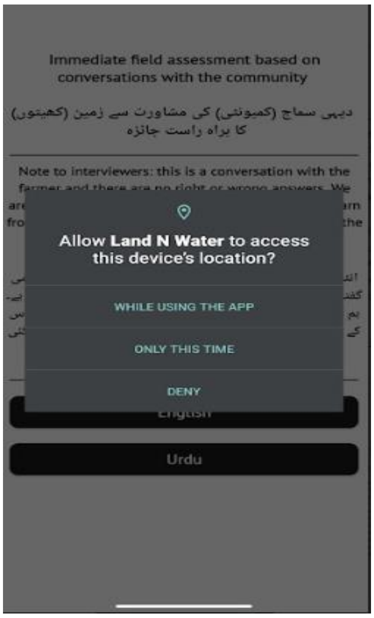


Figure 5: Permissions screen

Figure 6: Home screen

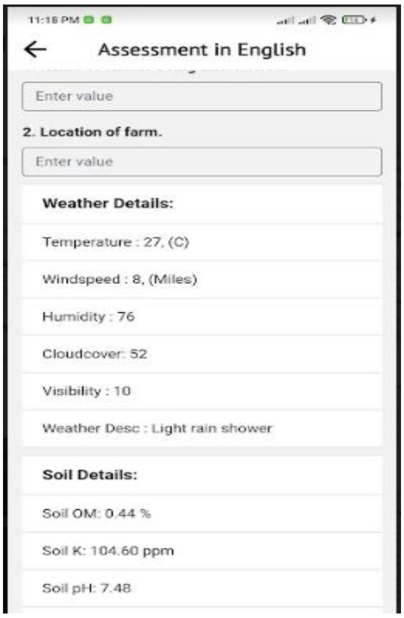


Figure 7: Form screen

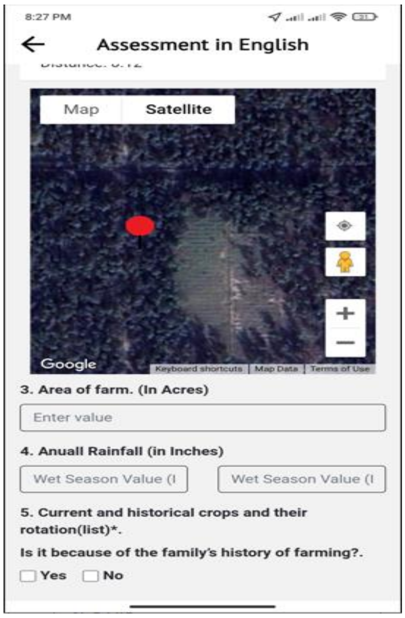


Figure 8: Map screen

The application presents the user with the form which helps to identify potential factors of farms. Additionally, it also displays the farm location on Google Maps.

The Red Icon indicates the farm. Along with the location, the application displays Weather information and Soil Details.

The application also can be used on web portal, user on the internet can access the web application using the URL: http://mriaz-khan.com/survey-form

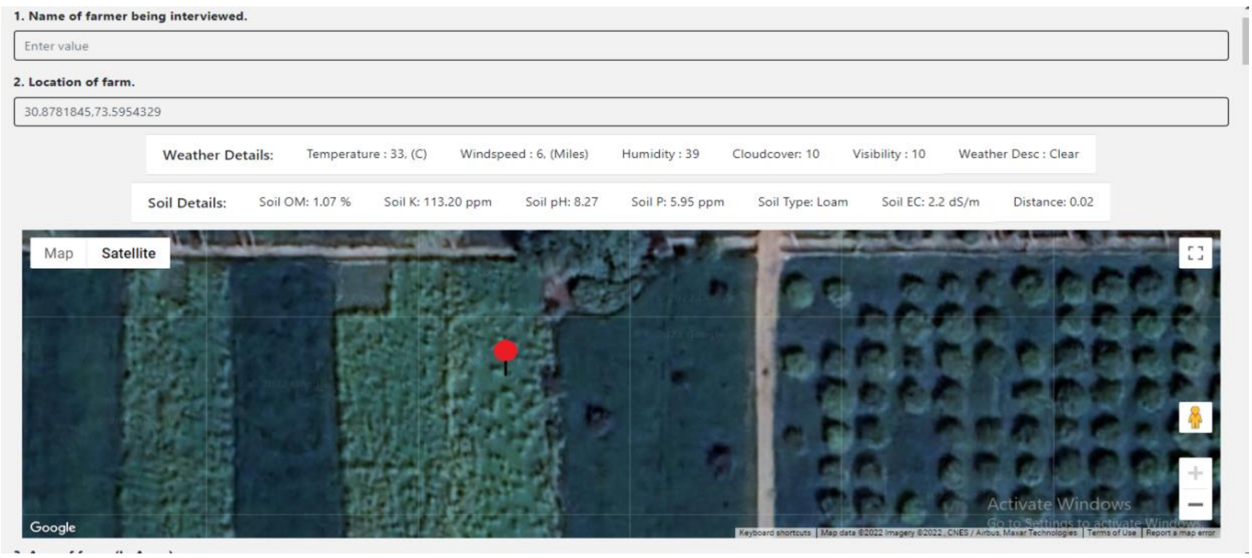
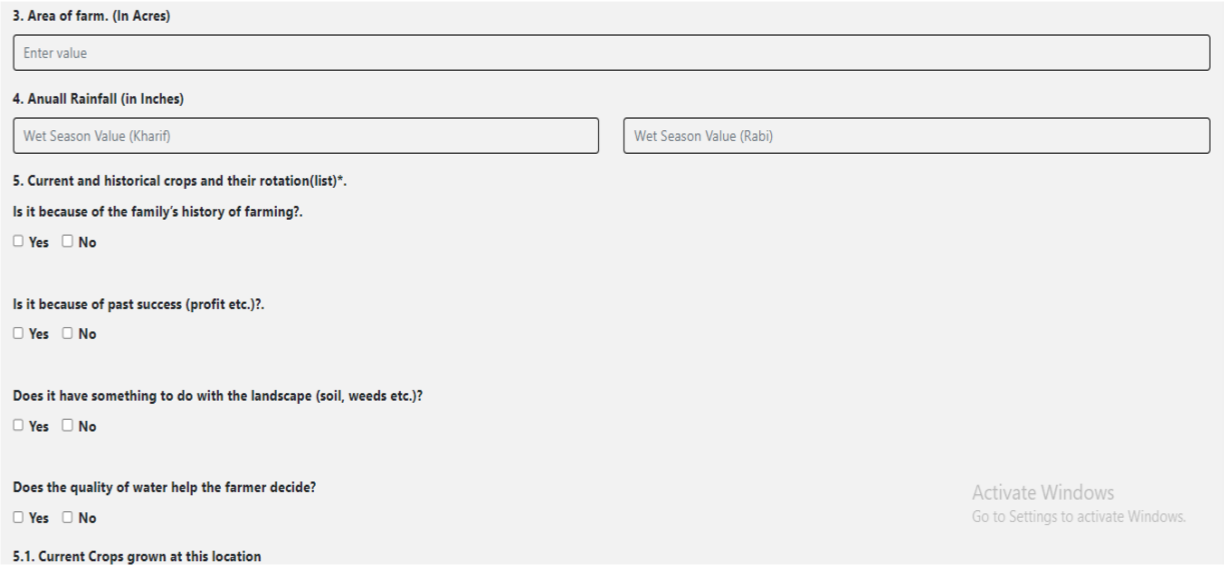


Figure 9: Web portal



3. Area of farm. (In Acres)

Enter value

4. Anuall Rainfall (in Inches)

Wet Season Value (Kharif) | Wet Season Value (Rabi)

5. Current and historical crops and their rotation(list)*.

Is it because of the family's history of farming?.

☐ Yes ☐ No

Is it because of past success (profit etc.)?.

☐ Yes ☐ No

Does it have something to do with the landscape (soil, weeds etc.)?

☐ Yes ☐ No

Does the quality of water help the farmer decide?

☐ Yes ☐ No

5.1. Current Crops grown at this location

Activate Windows
Go to Settings to activate Windows.

Figure 10: Web portal form

Both platforms takes inputs from users and uploads these to the Cloud. The Cloud then processes the data and generates an advisory for the data entered by the user combined with the data stored in the database for the current location. Thus, the application not only stores data, but also empowers real time users to make decisions for their farm operations.

Entered information can be accessed from http://mriaz-khan.com/ASSIB/. Every piece of data is geotagged and displayed in the form of a white and black marker. Users can geolocate data by dragging the camera of the map or by simplely searching the area either using location name or latitude and longitude.
When the user clicks on the marker it will display information stored against each marker (Figure 11).

Figure 11: Web portal to access data

Data Submitted By: Raiba (Mock)

Weather Details:	Soil Details:
Temperature : 33, (C)	Soil OM: 0.72 %
Windspeed : 2, (Miles)	Soil K: 143.07 ppm
Humidity : 67	Soil pH: 8.31
Cloudcover: 25	Soil P: 7.0075 ppm
Visibility : 5	Soil Type: Loam
Weather Desc : Smoke	Soil EC: 2.685 dS/m
	Distance: 0.26

nameOfUser	Raiba (Mock)
location of farm	30.1602917,71.4503809
area of farm	10
Annual Rain Fall Kharif	6.8

Figure 12: Data representation on web portal

Following advisory is rendered in case the user inputs less. The system guides him/her to obtain the relevant data and the inference engines generates the relevant advisory.

Advisory

Dry Risk:
If average annual rainfall is 12 inches or less, Water logging Risk:
Depth of groundwater is less than 1.5 meter
Inundation Risk: If your farm location is less than 1 km from the river/canal/sea there is risk if inundation
Salinity Risk: Identified by the following 0-4 Non Saline 4-8 Moderate Saline 8-16 Highly Saline 16-24 severely Saline
As the provided data is insufficient, the following general guidelines need to be followed:
A- If area is dry use mulches. Irrespective of EC value
B- If EC is 4 - 16 use mulches, except for waterlogged areas
C- If EC is 4-16, use mulches irrespective of dry risk
D- If rainfall > 12 and EC 4-16, use gypsum
E- Use gypsum, uptil EC is 16, (Note: increase the amount of gypsum with increasing salinity)
F- If EC is 4-16, use furrow & mound irrigation, irrespective of water related risks

Figure 13: Logic of advisory

The system automatically gives relevant advisory if the soil and water attributes are present in the database or have been supplied by the user. Please see the following two figures where the system has advised on two different locations. In case the user has not supplied any data if it is present in the database, the system will still access weather data and provide general guidance based on the logic of the advisory.

Figure 14: Advisory based on soil salinity

Figure 15: Advisory of irrigation based on salinity

3.2. Web-based Crop Monitoring Tool

The developed application is hosted at http://mriaz-khan.com/monitoring/ .

The users are presented with a user friendly GUI as shown below:

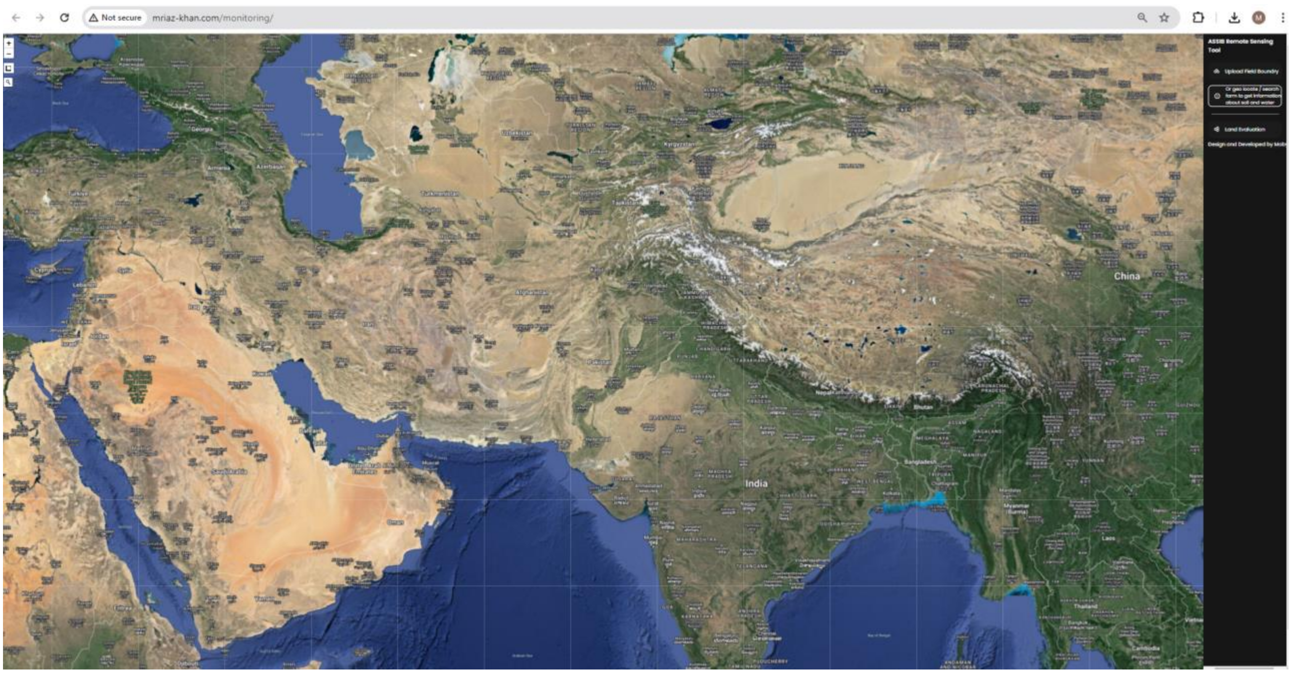


Figure 16: Graphic User Interface of the web-based RS tool

The registered user is required to add the boundary of the field (instructions are provided in the manual). See below:

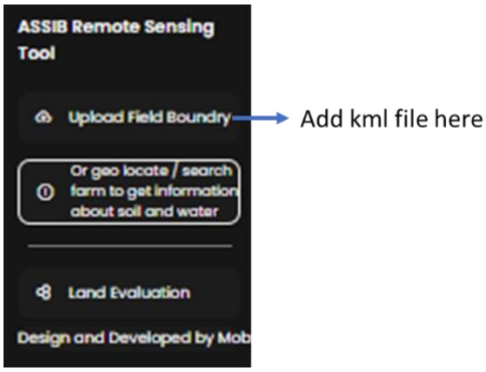


Figure 17: Adding field boundary

The system then takes a user to his/her location and provides immediately the soil, weather and water data if it is available in the data base as shown below:

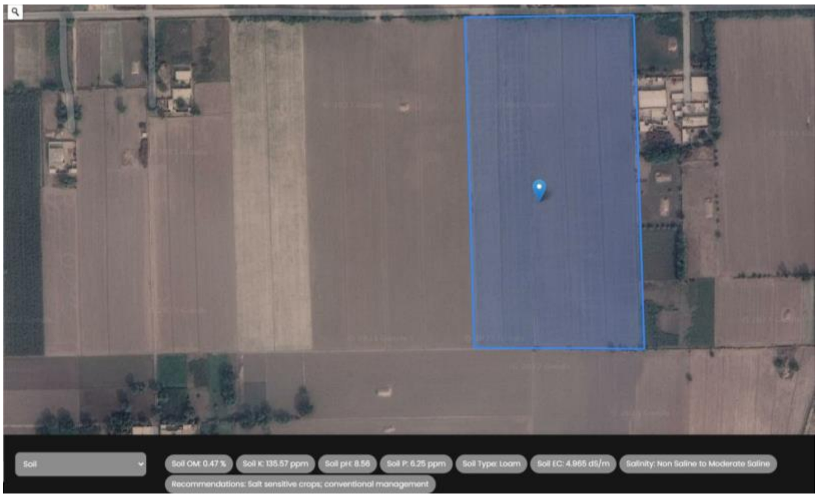


Figure 18: Location of a study site in Sindh along with its soil parameters

The crop monitoring module of the applications enables a user to monitor field from 2017 until the latest at five-day interval.

Figure 19: Graphic user interface of the crop monitory module

This assists in monitoring and evaluation of various interventions being adopted to live with salinity as shown below:

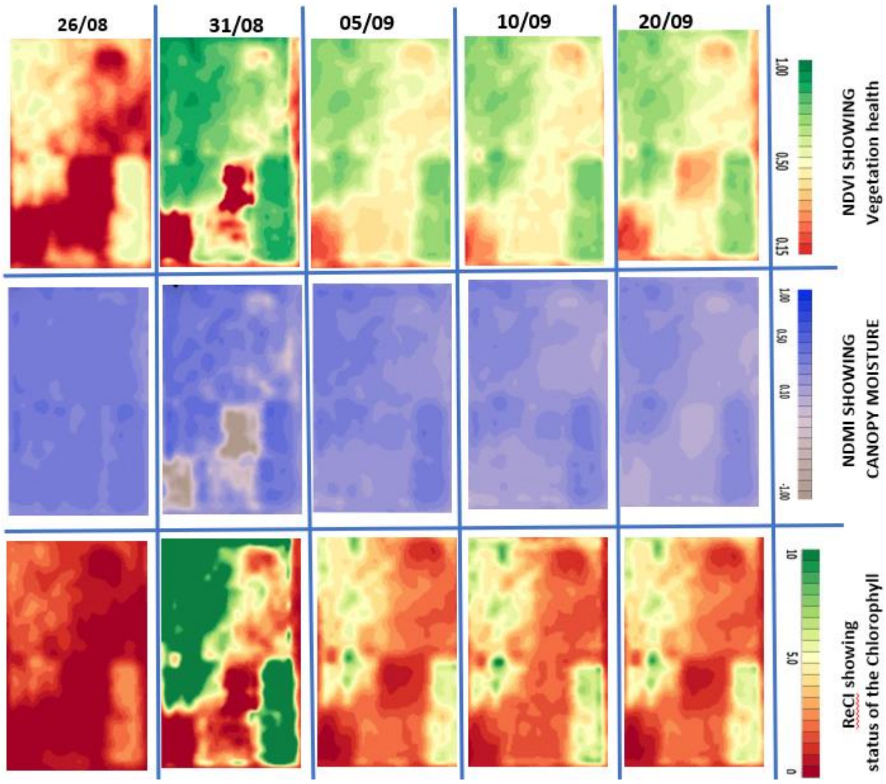


Figure 20: Temporal monitoring (5 days interval) of a study site

As mentioned earlier, the satellite data is available since 2017 onwards, therefore temporal signatures of two or more fields can be compared to evaluate the outcome biotic and abiotic factors of crop production.

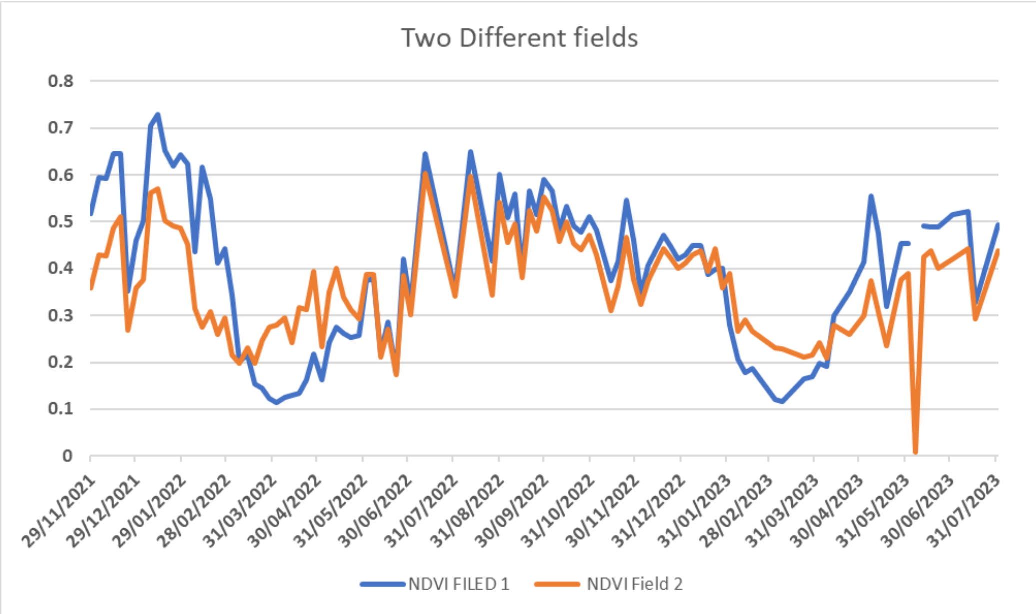


Figure 21: Comparing vegetation health of two different fields

4. Conclusion

The developed set of applications builds the capacity of stakeholders in the following manner:

- Provides current and 14-day forecast of any field.
- Provides soil and groundwater data of a field if valid data are already stored in the database
- Enables users to add their soil and groundwater data.
- Built-in inference engine evaluates the data from the database, online resources (weather) and the user input to provide advisory service on how best a user can live with salinity.
- Users can regularly monitor the performance of a field throughout the season to evaluate the outcome of his/her farm operations.
- The previously developed modules have also been embedded in the system so that users can compute the crop water requirements at any time, store and monitor their groundwater data, and perform land evaluation of their fields.

Future developments

A collaboration component is currently being designed to make the system more advanced and state-of-the-art. The collaboration component will facilitate interaction between different users as well as between users and experts. This will enhance decision-making by incorporating diverse perspectives and expertise. Further, in June 2024 three trainings of trainers/ master users will be organised in Rawalpindi (with academia and federal government), Lahore (with PID and Agriculture Department) and Multan (with project stakeholders) to roll out the applications.

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Gulbali Institute
Agriculture, Water and Environment

Charles Sturt University
Boorooma Street
Locked Bag 588
Wagga Wagga NSW 2678

1800 275 278 (free call within Australia)
+61 1800 275 278 (callers outside Australia)

gulbali@csu.edu.au

gulbaliinstitute

gulbali_inst

gulbaliinstitute

charlessturtuni

Charles Sturt University

Gulbali Institute
Agriculture Water Environment