IIT Bombay – PoCRA MoU III

Phase III Delivery Report

Part B – Contingency and Dashboard

IIT Bombay
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Development of Scale-Analysis-Trigger-Action Framework for Contingency Planning

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1. Introduction

This is a report of the C1-C3 components of MoU-III. The main objectives were to develop a prototype framework for the development of an IT framework which would (i) present planning, weather and other data sets in an integrated manner, and (ii) enable experts to contribute to the development of advisories.

Towards this, a Scale-Analysis-Trigger-Action (SATA) Framework was developed for contingency planning purpose through PoCRA IITB - MoU III. This framework mainly caters to the development of an integrated database environment suitable for overlay of contingencies, which can be visualized on map and delivered in the form of advisories. For this, contingencies are to be listed by their geographical scale, temporal conditions which define the contingency, the response and the actions which are required.

The SATA framework allows us to integrate various models, their inputs and outputs which operate at different spatial and temporal scales. A requirement of the framework is to allow various data-sets to be available to experts to formulate triggers. These data-sets are weather-related, field and farmer data such as crops chosen, sowing date, phenological conditions, infrastructure related, such as wells or percolation tanks in the vicinity, and finally, crop-water model data such as soil moisture, run-off etc. This is summarized in Table 1.

Table 1 Example Datasets

Dataset Name	**Spatial scale**	**Temporal scale**	**Attributes**
FFS	Selected locations	Monthly	Distribution, crop data, phenology
AWS	Circle	Hourly	Weather – Rain, Temperature, Windspeed, Humidity
Weather Forecast	District	5 days	?
MLP	Village	Quarterly	Engg. infrastructure, cropping pattern
Crop-Water	Point-level	Hourly	AET, Crop PET, Soil Moisture.
Geomorphology	Extensive	Fixed	Soil type, depth, slope

2. SATA Framework

This framework mainly consists of four main activities as follows –

1. Scale: This phase involves database infrastructure development which forms the basic building block for contingency. There are various input datasets available with the project which must be studied and arranged in a way so as to enable analysis for contingency formulation.

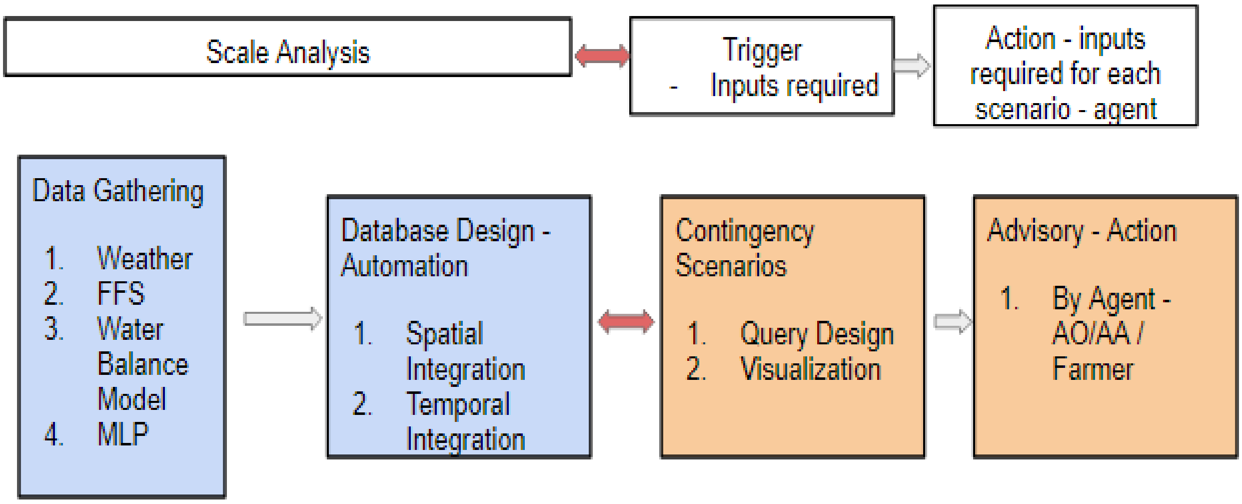


Figure 1 SATA Framework and Tasks Overview

Scale – Analysis phase is the IT part which involves preparation of a backend database. This has been done for MLP, AWS, Geomorphology and crop water datasets. The FFS database gathering is in process. New datasets like weather forecast, contingency scenarios lookups etc will be added to this when available.

2. Analysis: This phase involves spatial and temporal matching of databases to enable implementation of contingency queries and advisories at selected temporal and spatial scale. Currently the AWS hourly weather database has been aggregated to daily level to match the crop water model daily temporal resolution. Spatially the weather and crop water model outputs may be aggregated at village level/AWS circle level/FFS plot level/ cluster level depending on the spatial resolution of data attributes and selected scale of contingency in consultation with PMU.

Critical work done in this phase is the setting up of temporal automatic update mechanisms for real time view on dashboard.

3. Trigger: This phase involves interlinking of the databases to generate queries for selected contingency scenarios. The scenarios would consist of input conditions on weather, ffs, crop water model or another database. The occurrence of which will denote presence of contingency. Intermediate tables will be developed in this phase, which will be useful to display contingencies on dashboard.

Example scenarios as given by TNAU are –

Sample weather scenarios

Scenario	Rainfall mm	TMAX °C	TMIN °C	RH %	Wind km/hr
1	0	<20	<15	>40	<5
2	0	20 - 30	<15	>40	<5
10	0.1 - 30	<20	<15	>40	<5
14	0.1 - 30	30.1 - 35	15.1 - 20	>40	<5
19	>30	<20	<15	>40	<5
25	>30	30.1 - 35	20.1 - 30	>40	<5
32	0	30.1 - 35	15.1 - 20	>40	>5
40	0.1 - 30	20 - 30	20.1 - 30	>40	>5
51	>30	30.1 - 35	15.1 - 20	>40	>5
54	>30	>35.0	20.1 - 30	>40	>5

Figure 2 Sample weather scenarios for Contingency by TNAU

Each of this contingency will be mapped as an indicator showing the project areas affected by it. The contingency-scenarios are crop based, dependent mainly on weather parameters during various stages of crop cycle. Such contingency studies have been conducted by CRIDA to develop district level contingency plans. Other than this, insurance agencies also set triggers for weather-based insurance.

Figure 3 below – shows the entity relationship diagram of various datasets to implement contingency scenario-based triggers. Till now we have constructed an AWS dataset with its automatic updating mechanism. The task of incorporating FFS dataset and updated crop water balance using refined hourly model for contingency purpose is ongoing and will be done in Phase IV. The FFS database was studied and basic FFS tables - plot table, crop details table, visit table were designed to enable integration into dashboard. The schemas for these tables are added in appendix 1.

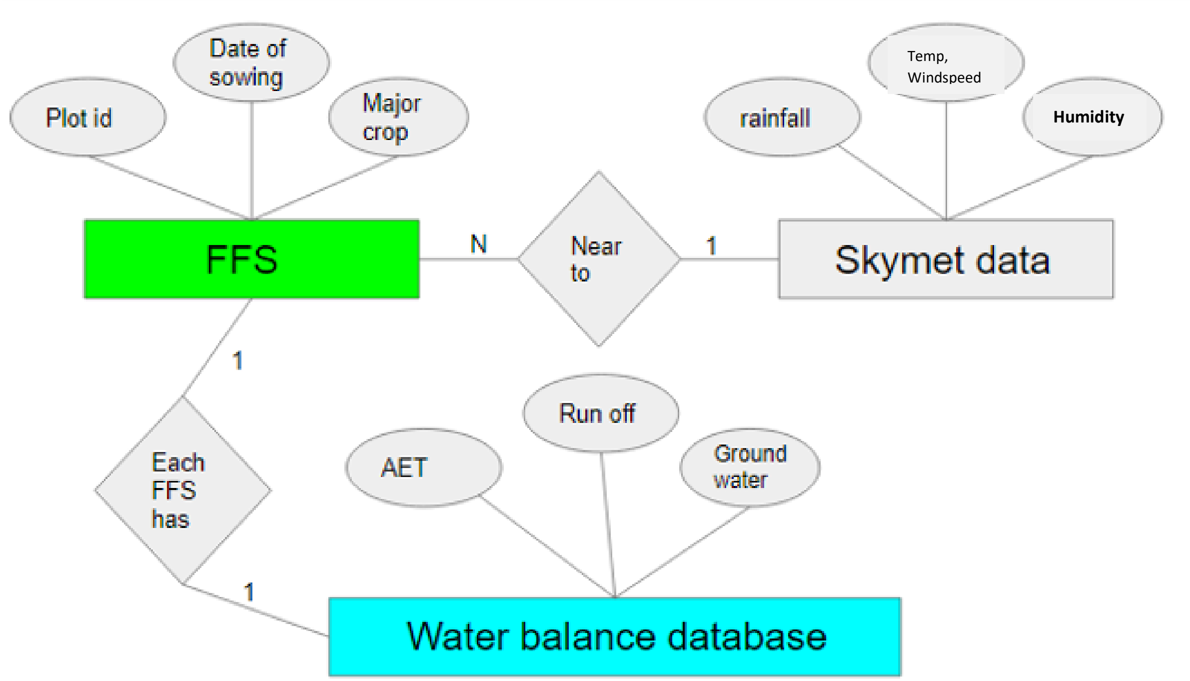


Figure 3 Entity Relationship Diagram for Datasets in SATA Framework

4. Action: This phase involves linking actionable advisories for various stakeholders to each of the trigger scenarios. So that advisories can be delivered in presence of contingency to respective stakeholders. Sample contingencies are presented in Section 3.

Based on the inputs from experts (SAU's, KVK's) the triggers and action advisories in the form of look up tables may be incorporated into the dashboard through SATA framework for visualizing contingencies by the PMU.

A prototype IT architecture for SATA framework may be demonstrated with sample contingencies, which can be extended further.

3. Sample Contingencies

Datasets were prepared and analysis was conducted to demonstrate sample contingencies for ground level data. FFS data was utilized to obtain date of sowing for major crops in the project area and weather dataset was analysed with linkage to crop stages. Few maps were prepared to show how contingency can be displayed and identified.

Table 2 Sample Contingencies

Sr.no.	Category	Contingency Maps - cotton/soybean	Conditions	Scale	Data
1	Rainfall	mm of rainfall before sowing	Total rainfall from June to sowing date is shown	FFS plots	Rainfall+FFS
2	Rainfall	Number of days of dry spell after 7 days of sowing	consider all dry spell which occur between 7th to 14th day after sowing	FFS plots	Rainfall+FFS
3	Rainfall	longest dry spell during reproductive stage	Crop stages defined for soybean/cotton as per TNAU	FFS plots	Rainfall+FFS+Crop
4	Rainfall	excess rainfall during harvesting stage	Excess rainfall amount trigger needed	FFS plots	Rainfall+FFS+Crop
5	Rainfall	highest rainfall event in harvesting stage for selected crop	Rainfall per day in mm will be shown	FFS plots	Rainfall+FFS+Crop
Disease and Pest - Current week					
6	Temperature	Cotton - kavadi	29 – 30 ° Celsius	FFS plots	Temperature +FFS
7	Temperature + humidity	Cotton - Dahiya disease	20 – 30 ° Celsius + humidity >80%	FFS plots	Temperature + humidity+FFS
8	Temperature + humidity	Cotton - Karapa disease	30 – 40 ° Celsius + humidity >85%	FFS plots	Temperature + humidity+FFS
9	Temperature	Soybean – Khodkuj, Mulkuj	Temperature above 30 ° Celsius	FFS plots	Temperature +FFS
Model – from planning perspective - Cumulative till date					
10	Areas with crop deficit	Model parameters are shown for cotton and	Crop deficit > GW by x	FFS plots	Model

	and low GW recharge	soybean on the dashboard. GW recharge/runoff for main crop in different areas can be compared with crop deficit for this.			
11	Areas with crop deficit and low runoff		Crop deficit > x and runoff < 0.5*storage capacity	FFS plots	Model+MLP

Sample Maps

1. mm of rainfall before sowing – Soybean

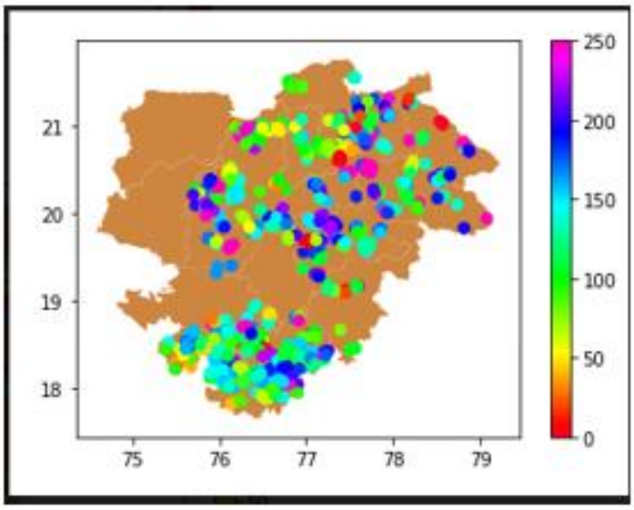
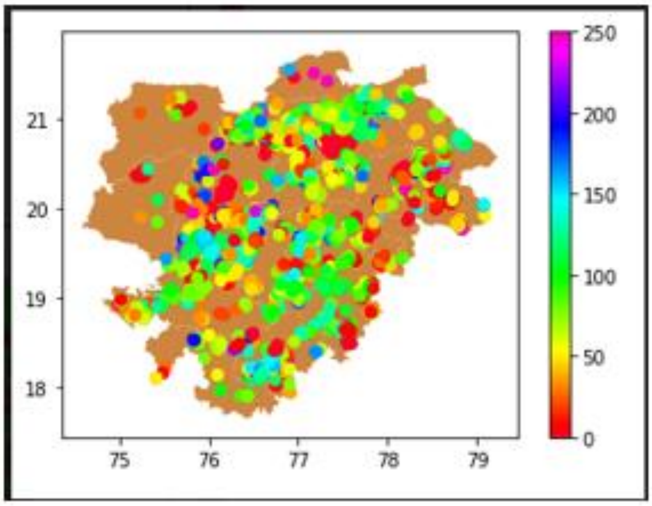


Figure 4 soybean FFS plots 2020



soybean FFS plots 2019

2.mm of rainfall before sowing – Cotton

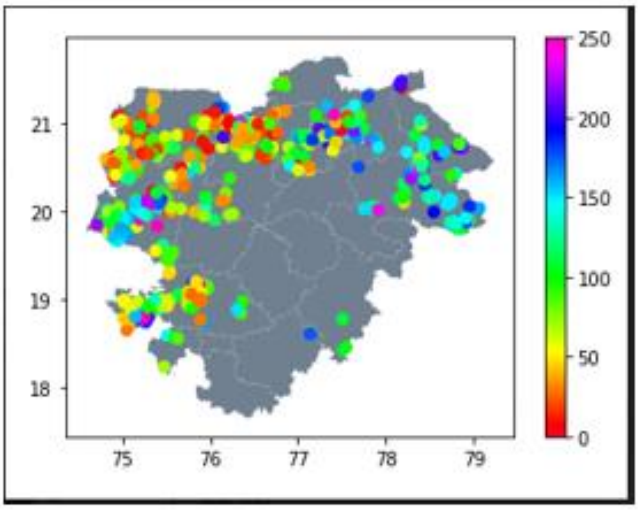
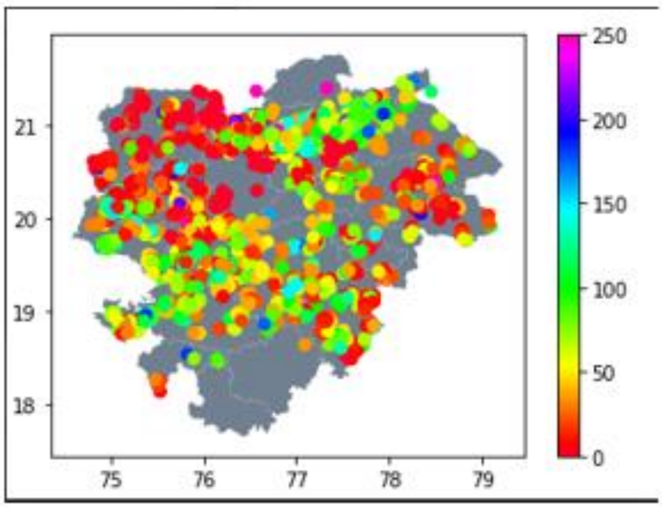


Figure 5 Cotton FFS lots 2020



Cotton FFS plots 2019

Both plots show that there has been a higher amount of early rainfall in 2020.

3.FFS plots with week of sowing 2020

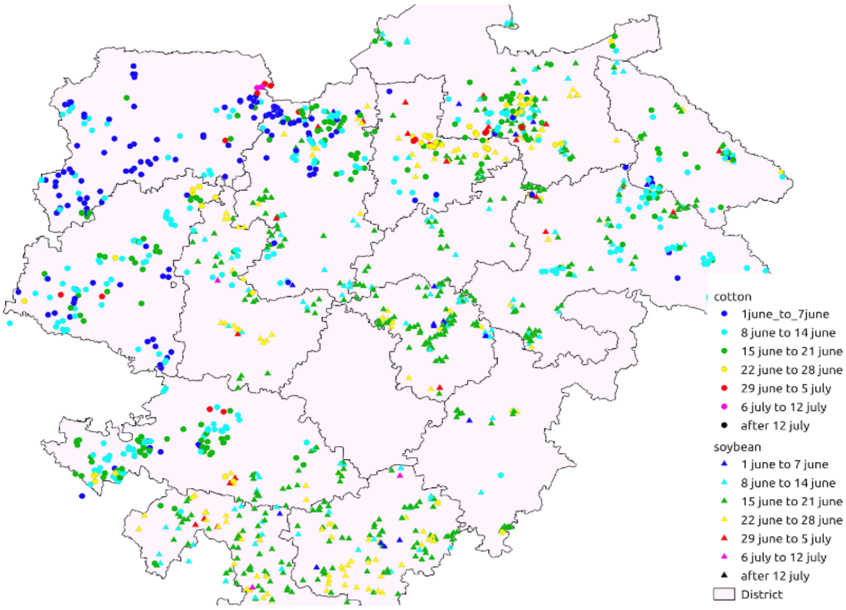


Figure 6 FFS plots with week of sowing 2020

This map shows cotton and soybean predominated areas. We can see that cotton has been predominantly sown in Marathwada region with sowing happening in the first week of June. Similarly soybean sowing can be seen to happen mainly in the second and third week of June.

3. Total rainfall during harvesting stage of crop - soybean 2019 (last 15 days in crop duration)

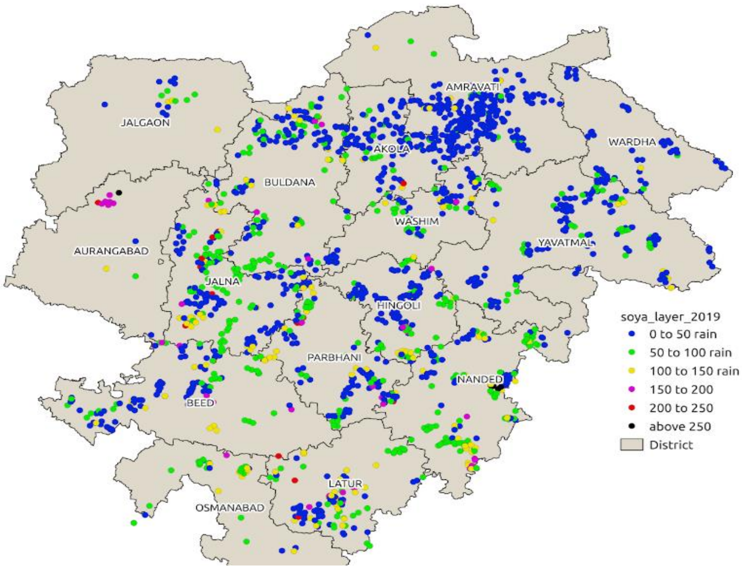


Figure 7 Total rainfall during harvesting stage of crop - soybean 2019 (last 15 days in crop duration)

The map shows considerable areas in the central region of the project receiving 50-100 mm of rainfall.

4. Graphs showing total rainfall in various stages of crop

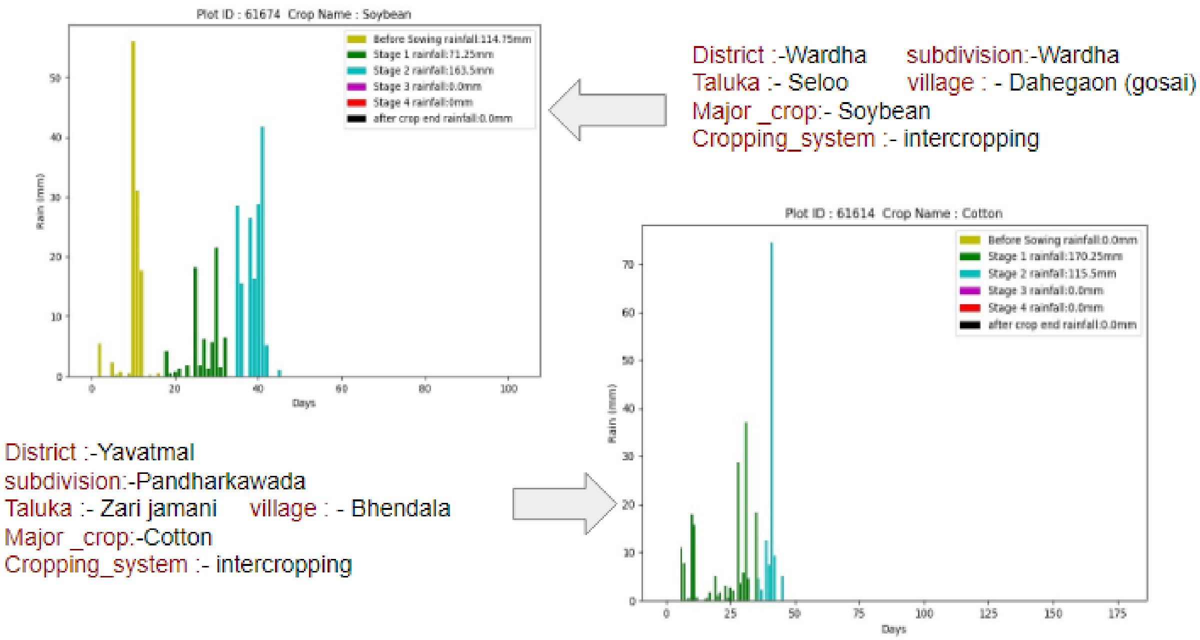


Figure 8 Graphs showing total rainfall in various stages of crop

These graphs show daily rainfall coloured by crop stages and also show total rainfall during different crop stages. These maps and graphs show the capability to demonstrate trigger based contingencies on availability of trigger scenarios – advisory inputs from agriculture experts.

5. Graphs showing temperature variation to monitor related contingencies

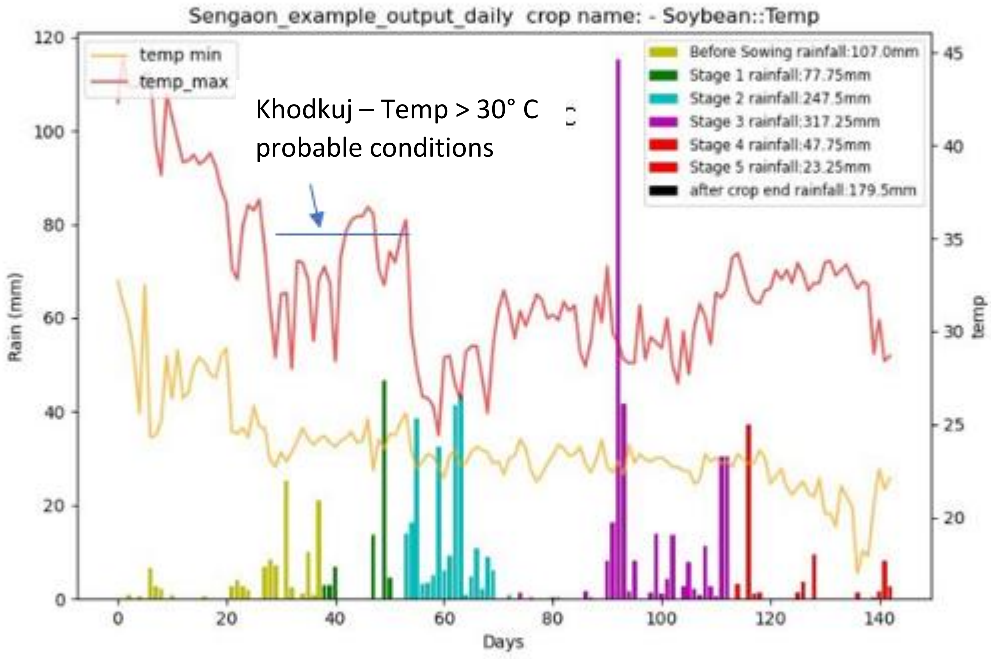


Figure 9 Temperature related contingency – daily resolution

This figure shows daily minimum and maximum temperature during various stages of crop - showing the conditions for various pest attacks.

6. Model related Contingencies

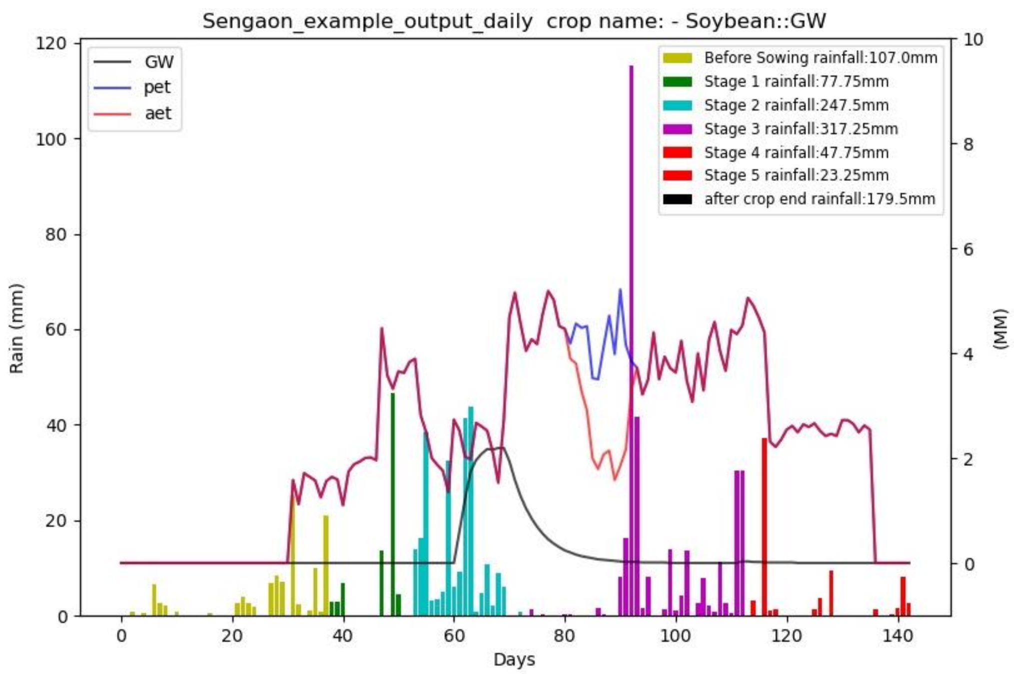


Figure 10 – GW-Deficit daily model – to monitor cumulative contingency

Seasonal cumulative monitoring of GW- Deficit can be done to map model related contingencies.

4. AWS missing data issue for intermittent skymet circles

This issue was analysed and it was found that it occurred due to null values obtained for respective skymet stations from skymet API, while if lower rainfall is seen, that is due to lower rainfall recorded for that skymet stations. Currently the skymet data is updated on dashboard with 2 day lag and fetched between 5-6 pm. Still there are missing data issues.

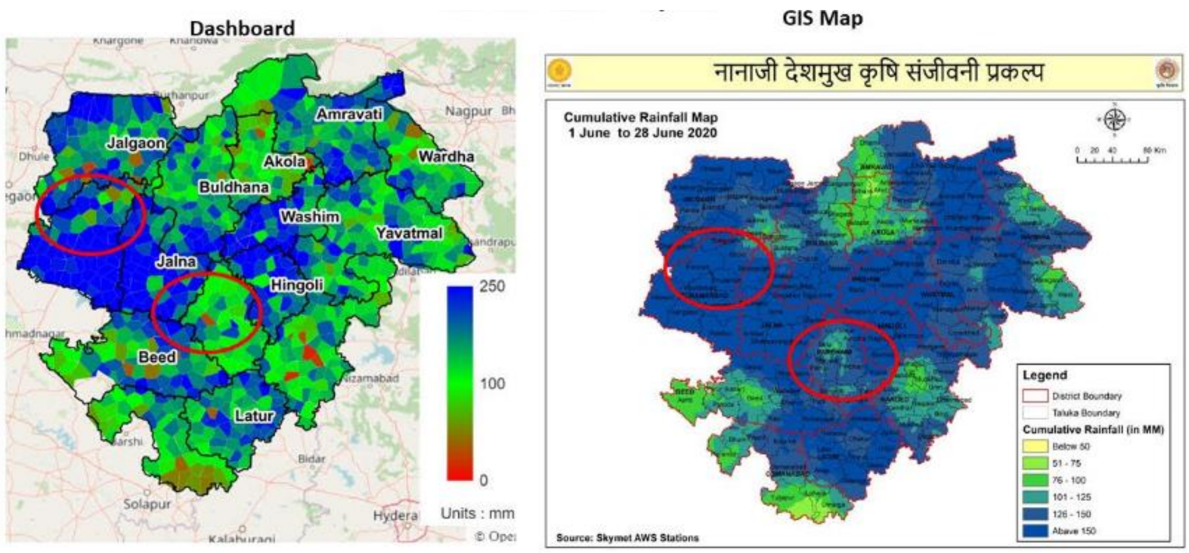


Figure 11 Intermittent no data issues

Steps for analysis and correction of missing data/null values-

1. First 10 nearest skymet stations to each station were located

2. Each skymet station was analysed date wise and the data for dates having null values was replaced with the data from nearest non-null skymet station.

Following maps show the variation after these correction steps –

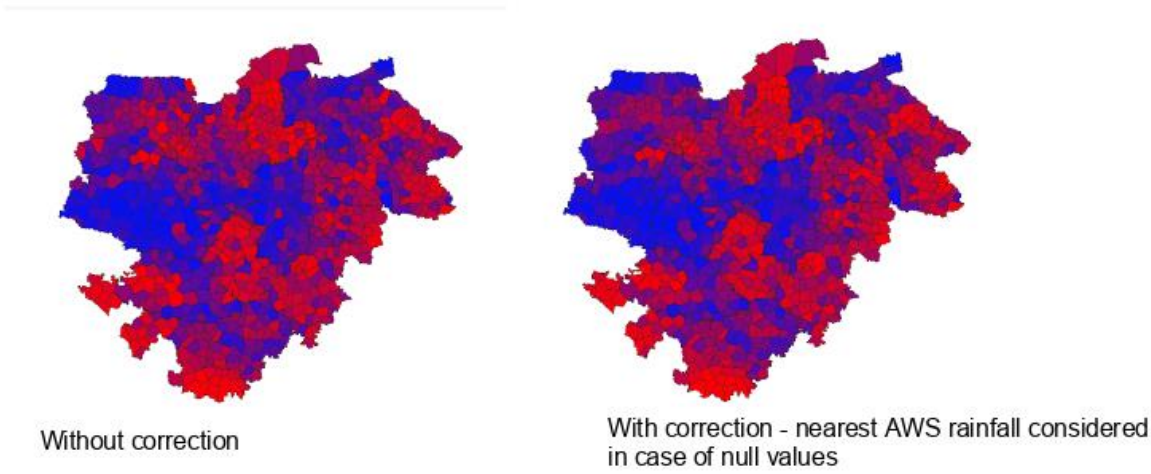


Figure 12 June 2020 Comparative Rainfall maps after analysis and correction

It was analysed to see how many circles had missing data issues in last year – 2019 and this year upto 19th July 2020.

1. 19th July 2020: 59 out of 928 circle
2. for 2019 : 98 out of 948 circles

Solutions required –

1. The weather data for the dashboard was updated in mid July 2020 to find that most of the missing data issues got resolved. This shows that weather data at skymet side is being updated later as well leading to such issues. Dashboard needs a fixed update mechanism with decided time of update. Inputs will be required from PMU to coordinate with Skymet for a time during the day when Skymet data should be fetched for the dashboard to lower the missing data issue.

2. The lower rainfall recorded is true to the data available through skymet.

5. Conclusion and Future Work

The Scale and Analysis phase of SATA framework has been demonstrated and implemented by building up a database for weather, MLP, model (daily version).The IT architecture for its visualization on dashboard is ready. Most of the databases are in Postgress/Post-GIS format and are easily viewed by any GIS system. All maps in this document were prepared by QGIS or other data analytic tools.

The ongoing work includes – integration of FFS database, display of database interlinked indicators to demonstrate scalable prototype of SATA framework. Sample contingencies based on interlinked indicators will be incorporated for demonstration in phase IV.

Appendix I: FFS database Basic Tables

Table 3 Plot Table

Plot code	season_name	Farmer id	year of inclusion	Latitude	Longitude	Census code	District	Taluka	Cluster code	Village Name	Circle Name	Farmer Name	Gat_number	Plot_area_ha	Soil type

Table 4 Crop details

Plot_code	Year	Season_name	Cropping system	Farmer_id	Major_crop_name	Major_crop_sowing_date	Major_crop_method_sowing	Major_crop_variety	Major_crop_yield	Major_crop_visit_count	Inter_crop_name	Inter_crop_sowing_date	Inter_crop_method_sowing	Inter_crop_variety	Inter_crop_yield_count	Inter_crop_visit_count	Harvesting Date	is harvesting done	visits planned	Irrigation Method	Irrigation sources

control Cropping system	control_Major_crop_name	control_Major_crop_sowing_date	control_Major_crop_method_sowing	control_Major_crop_variety	control_Major_crop_yield	control_Major_crop_visit_count	control_Inter_crop_name	control_Inter_crop_sowing_date	control_Inter_crop_method_sowing	control_Inter_crop_variety	control_Inter_crop_yield_count	control_Inter_crop_visit_count	control_Harvesting Date	control is harvesting done	control Irrigation Method	control_Irrigation sources

Table 5 Visits Table

Plot_code	Year	Season_name	Visit_number	Farmer_id	visit_date	Facilitator id	Facilitator name	major_Days_afer_sowing	major_Height	major_Canopy	major_irrigations	major_Branches_total	major_Branches_damage	major_Bud_total	major_Bud_damage	major_Flowers_total	major_Flowers_damage	major_Fruits_total

major_Fruits_damage	major_Boll_total	major_Boll_damage	major_Pests	major_PD ratio	major_Crop_condition	major_Soil condition	major_Wind condition	major_Weather_condition	major_Disease	major_Disease_severity	inter_Days_afer_sowing	inter_Height	inter_Canopy	inter_irrigations	inter_Branches_total

inter_Branches_damage	inter_Bud_total	inter_Bud_damage	inter_Flowers_total	inter_Flowers_damage	inter_Fruits_total	inter_Fruits_damage	inter_Boll_total	inter_Boll_damage	inter_Pests	inter_No_of_insect_pests	inter_Defenders	inter_No_of_natural_defenders	inter_PD ratio	inter_Crop_condition	inter_Soil condition	inter_Wind condition	inter_Weather_condition

inter_Disease	inter_Disease_severity	Rodent_damage	Control_major_Days_afer_sowing	Control_major_Height	Control_major_Canopy	Control_major_irrigations	Control_major_Branches_total	Control_major_Branches_damage	Control_major_Bud_total	Control_major_Bud_damage	Control_major_Flowers_total	Control_major_Flowers_damage	Control_major_Fruits_total

Control_major_Fruits_damage	Control_major_Boll_total	Control_major_Boll_damage	Control_major_Pests	Control_major_PD ratio	Control_major_Crop_condition	Control_major_Soil condition	Control_major_Wind condition	Control_major_Weather_condition	Control_major_Disease	Control_major_Disease_severity	Control_inter_Days_afer_sowing	Control_inter_Height	Control_inter_Canopy	Control_inter_irrigations	Control_inter_Branches_total	Control_inter_Branches_damage

Control_inter_Bud_total	Control_inter_Bud_damage	Control_inter_Flowers_total	Control_inter_Flowers_damage	Control_inter_Fruits_total	Control_inter_Fruits_damage	Control_inter_Boll_total	Control_inter_Boll_damage	Control_inter_Pests	Control_inter_No_of_insect_pests	Control_inter_Defenders	Control_inter_No_of_natural_defenders	Control_inter_PD ratio	Control_inter_Crop_condition	Control_inter_Soil condition	Control_inter_Wind condition

Control_inter_Weather_condition	Control_inter_Disease	Control_inter_Disease_severity	Control_Rodent_damage

The initial highlighted attributes in each table form its primary key.

Phase-3 Delivery report on GIS-Dashboard development status

Prepared by - Rahul Gokhale

Date: 12-08-20

IT-related deliverables and support forms a significant part of the MoU signed between PoCRA and IITB. In particular, components B1-B6 of the MoU are completely concerned with a GIS-dashboard web-application whose prototype implementation was submitted in the previous MoU.

1. Introduction

This document presents the work done on the development of the GIS-dashboard during phase-3 of the MoU. In this introductory section, we first recapitulate the development course and the work that was done before phase-3. Then we describe the tasks and targets that were set to be delivered in phase-3. Finally, we sketch an outline of this report.

Recapitulation

Based on the prototype implementation of a GIS-dashboard for PoCRA in the previous MoU, an extended and full-fledged implementation of a GIS-dashboard was planned in the current MoU. After the inception of the MoU, a change in the delivery-schedule done by PMU with respect to the phase-wise deliveries. In particular, while the original schedule required the inclusion of project-based indicators on the dashboard in phase-2 of the MoU, and that of other project-databases like FFS, DBT, etc. in phase-3 of the MoU, As per PMU's requirement, inclusion of FFS was preponed to phase-2 and project-based indicators was postponed to a later phase. The letter in this regard was sent on 18th May 2020 to the PMU for confirmation from IITB side.

Owing to issues with incorporating the existing live FFS database into the dashboard, such an incorporation was delivered in phase-2 in a demonstrative form using snapshot FFS data stored in the dashboard's backend database. It was also decided to iron out the issues with live incorporation during phase-3. As phase-3 evolved, it was realized that the issues with incorporation were a result not just of the differences in implementation but also of differences in the conceptualization of the FFS data (and FFS field-level activities to a certain extent).

Consequent to these observations, the deliverables for phase-3 were also refined, wherein although the overall deliverable remained the same, the details were decided through frequent meetings and other exchanges between PMU and IITB in order to deliver based on common understanding. This report documents the completion of these refined deliverables.

Deliverables for phase-3

Work in phase-3 was characterized by a change in the development paradigm, where the intervals between updates given to PMU on development work were shortened considerably. Frequent meetings and exchanges led implicitly to the setting of a work-schedule that was controlled at a micro-level. Consequently, the deliverables were submitted in the form of a stream of incremental (test-)releases of the dashboard (hosted at http://gis.mahapocra.gov.in/dashboard_testing); each release being a step forward in the development work from the previous one. This essentially was akin to the continuous-integration development paradigm and was used right from the nascent stages of the dashboard development.

The release stages (hence the deliverables) were as follows.

- **"Base" Release:** Also termed R0, this was a version that would lay out the overall web-page design for the dashboard. The basic elements for navigation and geo-visualization were put in place. These included the web-page title-bar, the left-panel for listing the datasets made available on the dashboard and a section for map-viewing that should be the centrepiece of user's attention. Basic layers like some base-layer (OpenStreetMap was chosen) and the administrative boundaries were included. Zoom-cum-pan facilities were also included for map-browsing.
- **"Weather" Release:** Also termed R1, this version incorporated the GIS-dataset of Skymet's automated weather-monitoring stations. This included the task of daily updation of weather data by fetching new data from Skymet's API and adding it to the dashboard's backend database for use anytime later. The processing necessary to update the project-indicators based on weather data was also incorporated. The legend for the available indicator-layers was developed to be manipulatable in order to enable geo-visual analysis.
- **"Water-Balance Estimates" Release:** Also termed R2, this version incorporated the GIS-dataset of the rasters estimated using the soil-water model being developed under PoCRA. While the user-facing part of this release added no more than another GIS-dataset and its indicators, the scope and amount of addition to the backend was the largest among all the datasets added so far. This included the use of weather data, incorporating the model-estimation code, developing an updation routine that would compute the model estimates and storing them for use in updation again for the next day and finally exporting and publication of these as raster layers.
- **Series of R2+ releases:** While the issues with incorporating the live FFS database were being resolved, it was decided to push out a series of 3-4 micro-releases, each of which would include more and more project-indicators that were based on weather and water-balance estimates. This led to the inclusion of sub-items under weather for the past data; viz, a set of weather-indicators each for the last (meteorological) week, the last (calendar) month and the cumulative-indicators based on the data for the entire period of the current season.
- **"Micro-Level Planning" village water balance Release:** The initial MLP exercise had been completed at the field-level in phase-1 villages. The generation of zone-wise water-balance estimates and of a part of water-budget charts required for the exercise in these villages had been done by the IITB team earlier. This prompted the decision to include the MLP dataset next. This included the GIS-layer of phase-wise PoCRA villages and project-indicators related to them. Two other GIS-datasets closely linked to MLP were also included; viz the drainage pattern and the geo-tagged set of field-structures built to manage surface-water.
- **"Snapshot FFS" Release:** Since the issues with the live FFS database were still under discussion and resolution, it was recently decided to include a snapshot version of the FFS database as a placeholder. The project indicators related to FFS have also been included but are based on the snapshot data and hence do not need daily updation.
- **"Cross-database indicator and Role-based Data Access" Release:** An important and useful inclusion in this final release of phase-3 is that of an illustrative cross-database indicator that can highlight dry-spell contingency during reproductive stages of a crop sown in an FFS plot. This release also includes the facility to display tabular data along with an illustrative example of role-based authenticated access to it.

While the above release-list mentions only the content of the additions/modifications done on the dashboard, with every previous release, there would be feedback related to the form of the dashboard's facilities. The current form of the dashboard includes many of those suggestions that have been implemented.

It should also be noted that while the release-based schedule was aligned to visible additions to the dashboard, it was common that the work required to develop the corresponding backend in order to achieve the release was disproportionate (and usually greater) compared to what additions would be visible on the dashboard.

Outline of the report

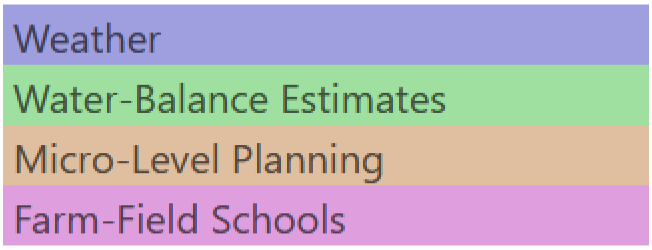
First, we describe the design and architecture of the dashboard at a conceptual level from the user's perspective. Next, we provide an illustrative description of the facilities made available on the dashboard. Following that, a brief account of the technical/IT design and implementation is presented with linkages to the user's perspective. The work done in this phase and to be done in later phases is summarized in the final section in order to provide a picture about the overall development work and schedule.

2. Conceptual Design

Like any utility software/website, the GIS-dashboard has multiple aspects though which users comprehend it. The current design of the dashboard has focussed on the following conceptual aspects relevant to a user.

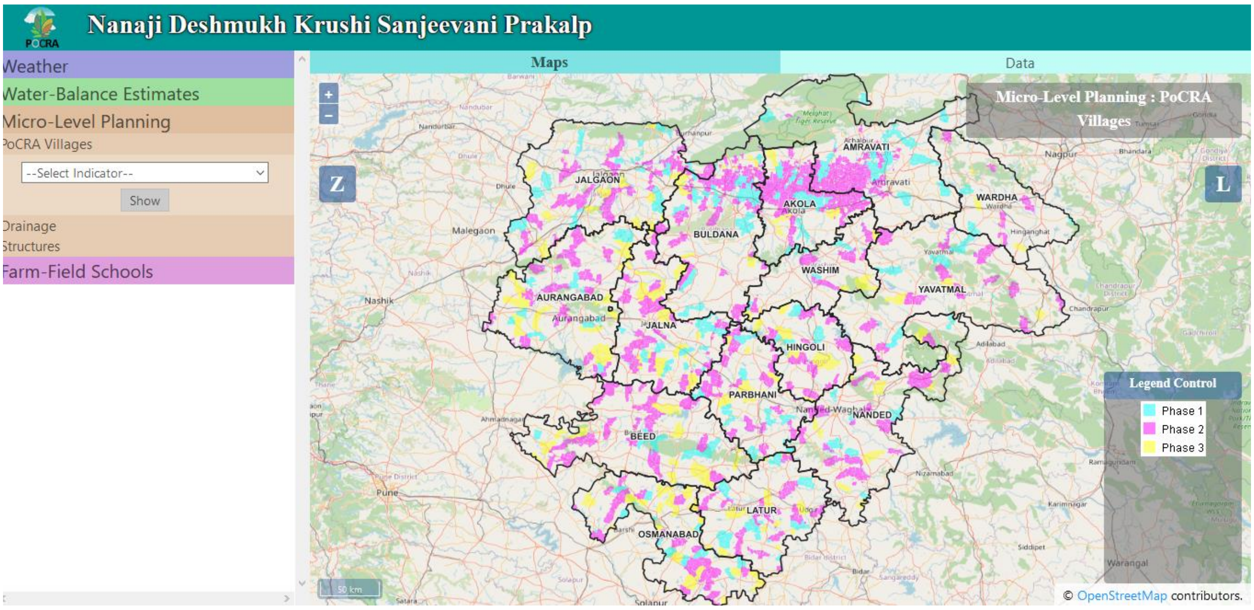
GIS-datasets

A user to the GIS-dashboard website for PoCRA is expected to look for GIS information about the various aspects within the scope of the project. The scope of the PoCRA's work is wide enough and includes data collection, research, field-level knowledge transfer as well as field-level interventions. The data/information about each such aspect forms a separate dataset that deserves its own management. Currently the dashboard hosts four datasets of the project in its left panel (cropped image seen in the adjoining figure). Their details will be presented in a later section.



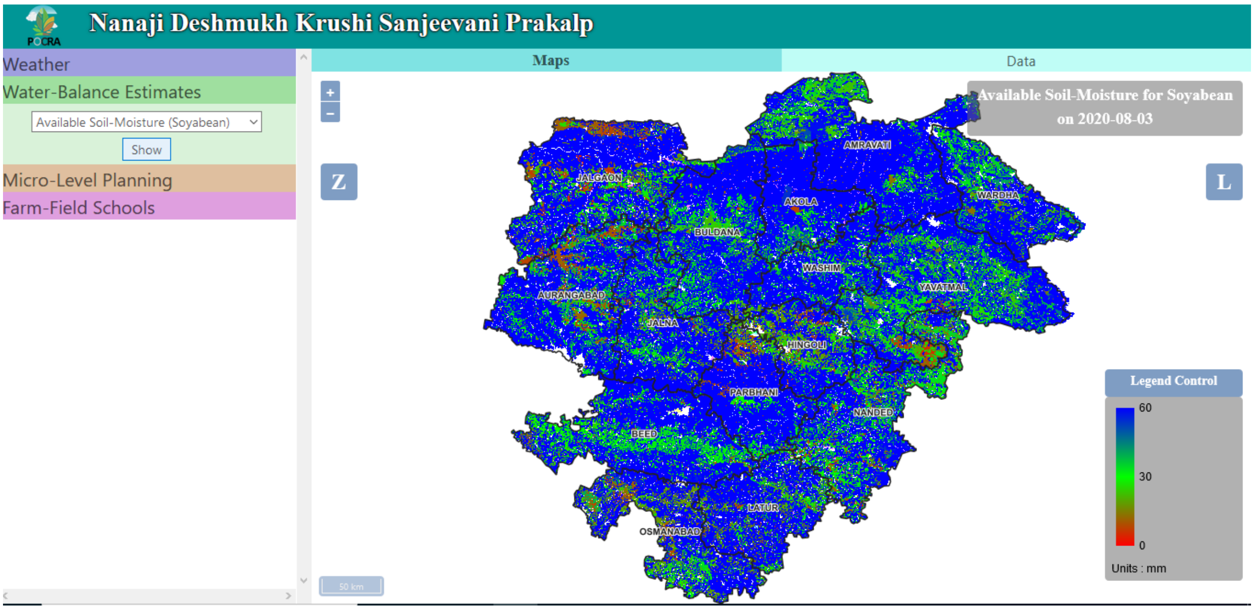
Maps/Geo-visualization

GIS and geo-visualization being the central theme of the dashboard, GIS plays a central role in each dataset. For example, the weather data obtained from weather stations is linked to their locations, thus forming a geo-tagged/GIS dataset. For this reason, as illustrated in the figure below, every dataset and its contents listed in the left panel of the dashboard have various map-layers associated with it.



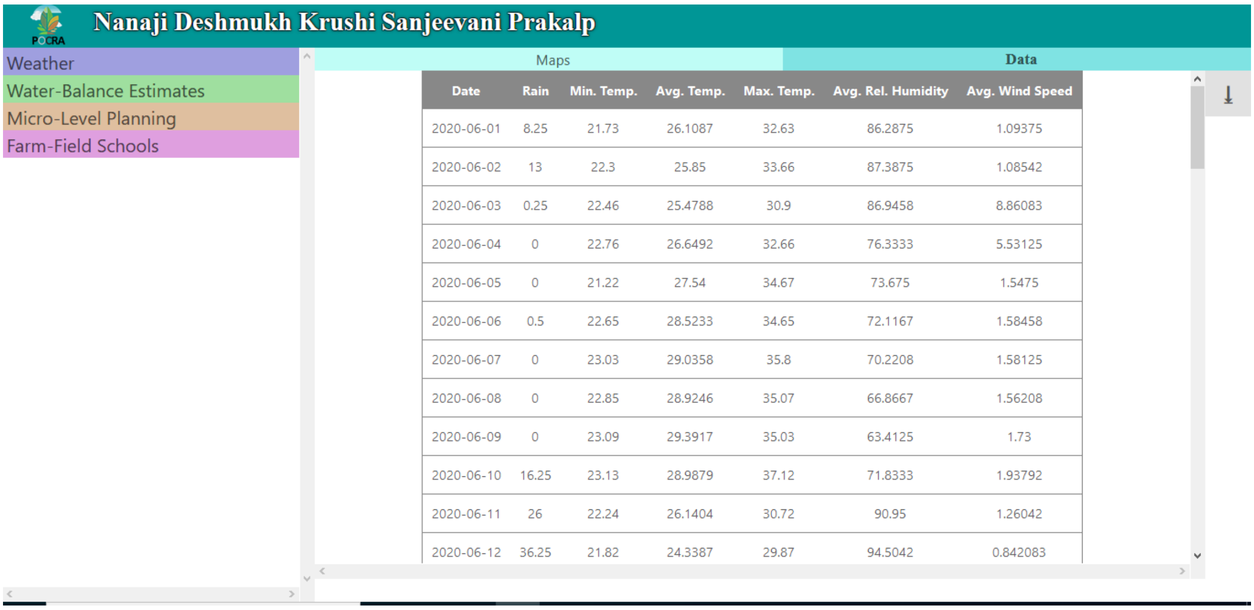
Project Indicators

One of the prime purposes of the GIS-dashboard is to monitor the status of the various aspects that affect or assess or provide decision support for the project's work. Such aspects are typically measurable and once they are geo-tagged, they can be mapped to provide geo-visualization. These have been referred to as project-indicators, one illustration of which is shown in the following figure. A user is then usually interested in such geo-visualization of project-indicators.



Data

After getting a regional perspective through geo-visualization, a user may be interested in the actual data values for various reasons. The most basic format for data display is in the form of tables. Such a display deserves a separate space on the webpage. As such, a separate tab has been incorporated in the dashboard for tabular and related data-display. The current design, as shown in the figure below, is elementary and will be developed further in later phases.



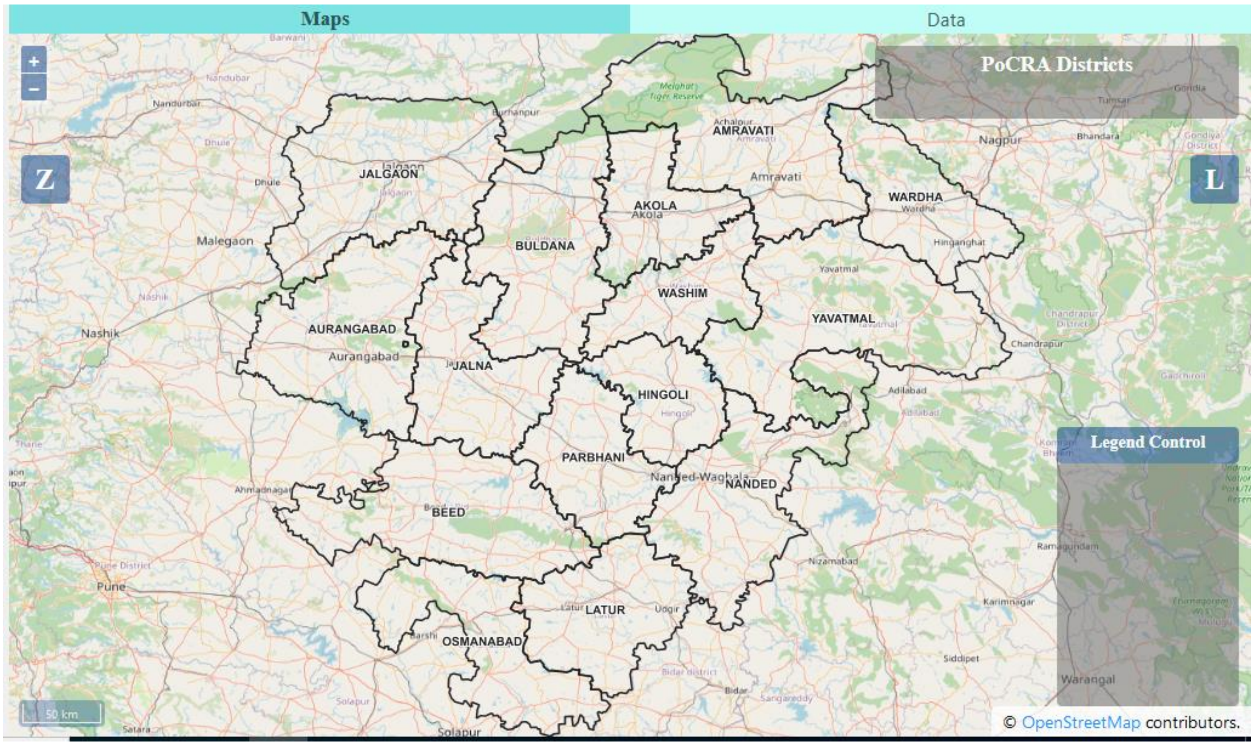
Date	Rain	Min. Temp.	Avg. Temp.	Max. Temp.	Avg. Rel. Humidity	Avg. Wind Speed
2020-06-01	8.25	21.73	26.1087	32.63	86.2875	1.09375
2020-06-02	13	22.3	25.85	33.66	87.3875	1.08542
2020-06-03	0.25	22.46	25.4788	30.9	86.9458	8.86083
2020-06-04	0	22.76	26.6492	32.66	76.3333	5.53125
2020-06-05	0	21.22	27.54	34.67	73.675	1.5475
2020-06-06	0.5	22.65	28.5233	34.65	72.1167	1.58458
2020-06-07	0	23.03	29.0358	35.8	70.2208	1.58125
2020-06-08	0	22.85	28.9246	35.07	66.8667	1.56208
2020-06-09	0	23.09	29.3917	35.03	63.4125	1.73
2020-06-10	16.25	23.13	28.9879	37.12	71.8333	1.93792
2020-06-11	26	22.24	26.1404	30.72	90.95	1.26042
2020-06-12	36.25	21.82	24.3387	29.87	94.5042	0.842083

3. Facilities

As a web-GIS application the GIS-dashboard provides various facilities for browsing and probing maps related to the project. Additionally, it also provides data-listing and download facilities for particular datasets.

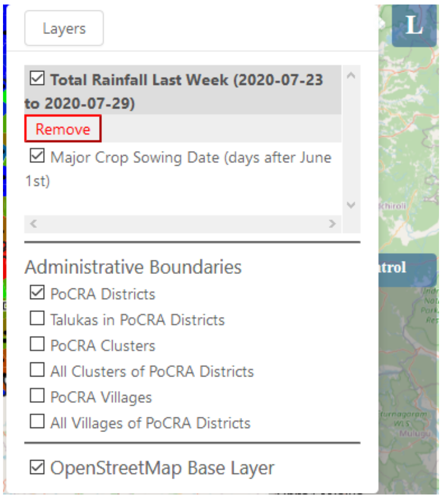
Browsing maps

The 'Maps'-view takes the largest space on the dashboard and is meant to be the centre of user's attention. In its default state(for example, just after loading the webpage), it shows the (map-)layer that displays boundaries of the 15 PoCRA districts. Various layers can be added to this view from the left panel by selecting various datasets or indicators therein.



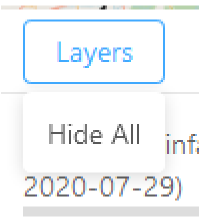
For various forms of map-browsing, the following control buttons, panels and information cards have been placed within the view.

Layers Panel



When the bluish button on the top-right marked with an ‘L’ is hovered-over, the layers-panel pops over left of the button as shown in the adjoining figure. This panel maintains a current list of (map-)layers that have been loaded into the maps-view.

It has three sections: base-map layers section (presently, only OpenStreetMap), administrative boundaries layers section and user-requested layers section. Each layer in the panel overlays all the others listed below it. Each newly requested layer by the user gets added to the top of the list. Each layer also has a visibility switch, displayed as a checkbox, that allows the user to toggle the layer’s visibility. Clicking the layer-name expands a layer-details section. It currently only has a ‘Remove’ button to remove the layer from the dashboard(both from the map and the layers-list), but is intended to accommodate layer-specific information and actions.

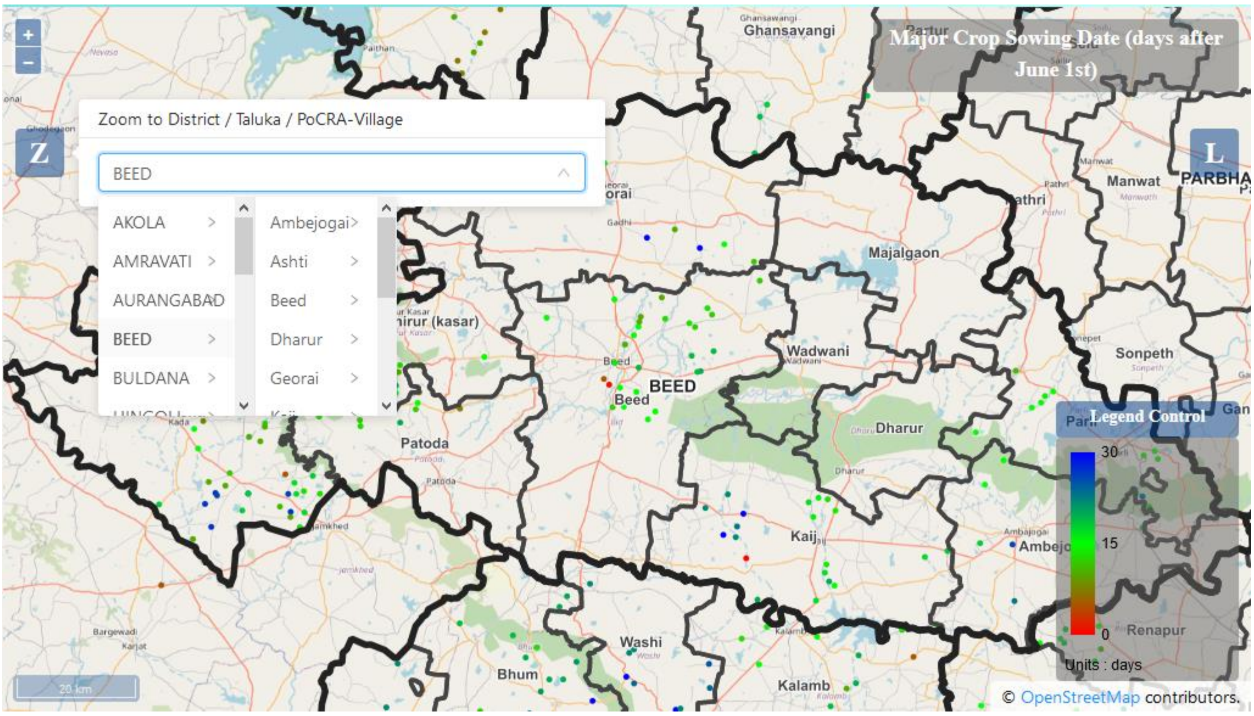


The title ‘Layers’ of the user-requested layers section is active and when hovered-over, a small menu pops-over. Presently, it only provides a ‘Hide All’ (layers) action to hide (uncheck visibility) all layers in one go.

Zooming and Panning

On the top-left, is a pair of buttons for zooming into (+) and out (-) of the map-view’s centre. A user having a mouse with a scroll can use it while pointing the mouse at a location in the map’s view to zoom in and out for that location. Panning is achieved using the mouse’s drag-n-drop action-sequence within the map-view.

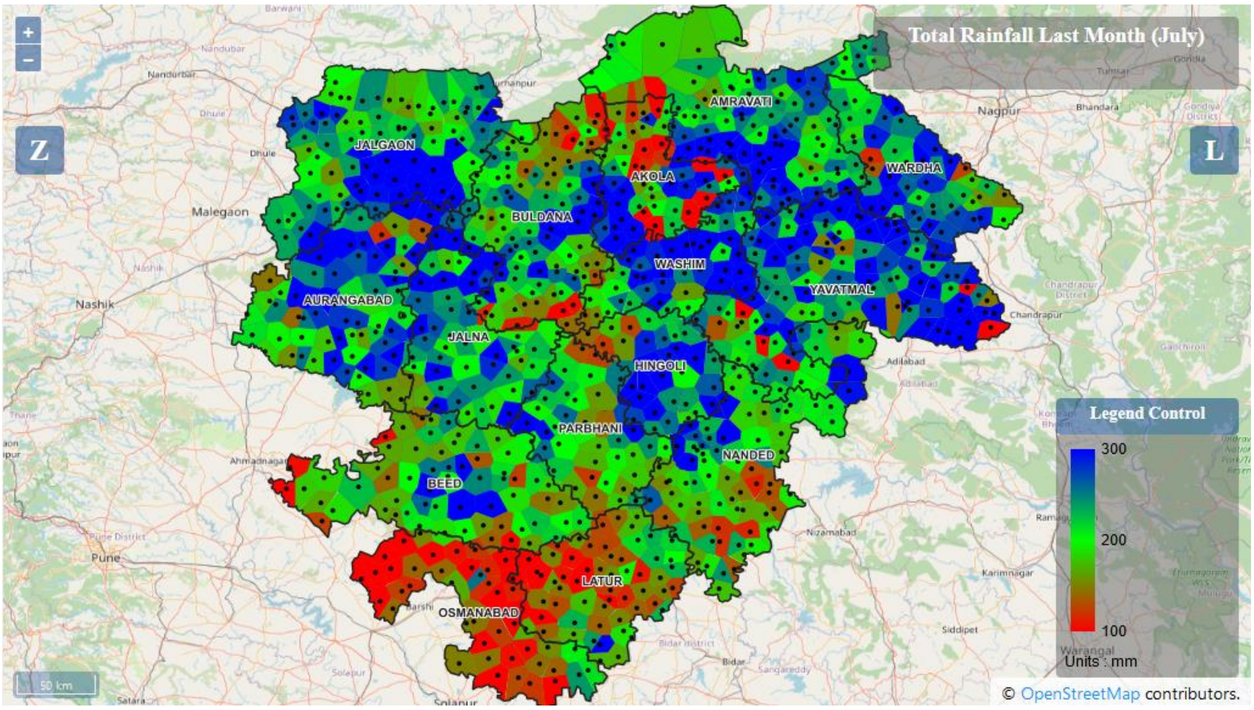
The project’s administration is based on a hierarchy of regional units. A three-level regional-hierarchy consisting of district, taluka and (PoCRA-)village is of frequent interest and deserves a corresponding region-based zoom-cum-pan facility on the dashboard. The button marked ‘Z’ on the top-left provides such a facility when clicked. As each region is selected, the map’s view is zoomed and panned to present that particular region to cover the map’s extent. Simultaneously, the lower-level regional units become available for further narrowing-down.



It may also be noted that the layers of taluka and (PoCRA-)village boundaries used in the above hierarchy have an zoom-based automatic visibility control, wherein for example, the taluka boundaries are made visible automatically when zoomed in sufficiently and invisible when zoomed out. Similar automatic visibility control is enabled for some other layers where appropriate; for example the drainage layer in the Micro-Level Planning dataset where the lower-order drainage starts becoming visible as the user zooms in.

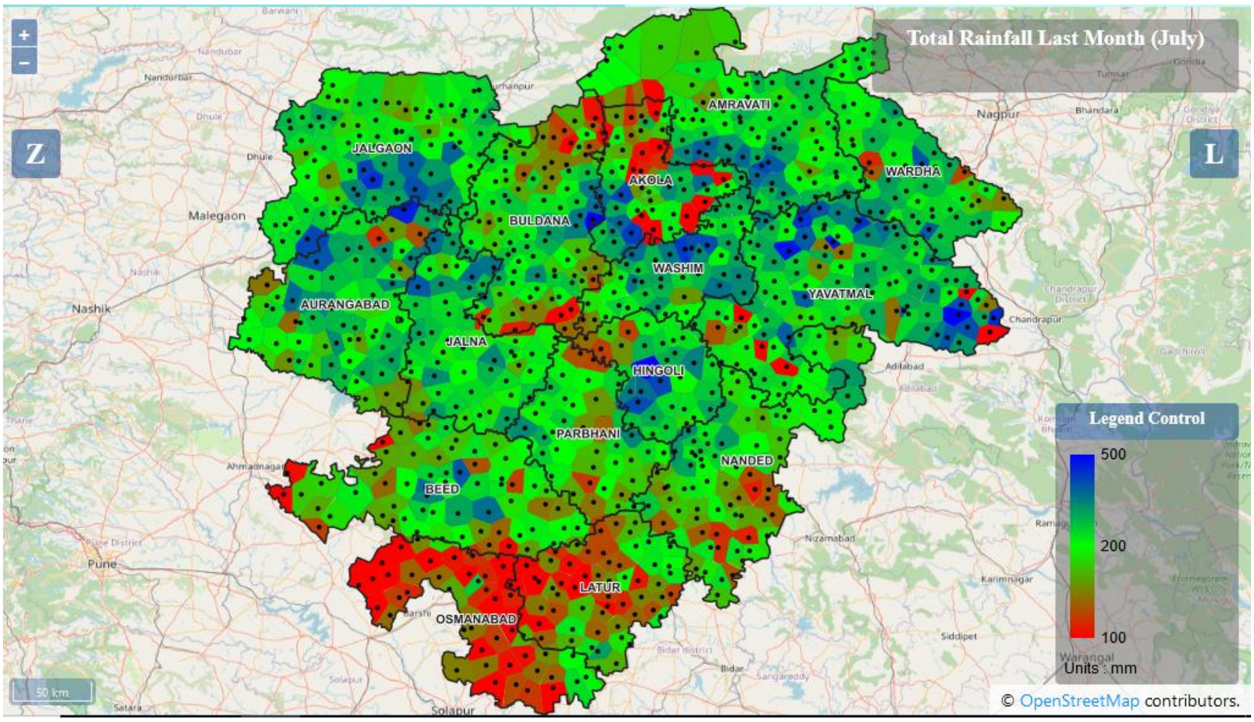
Legend Control

The quality of any geo-visualization facility can be improved by allowing the user to control the styling of the map-layers. This is especially true for PoCRA's GIS-dashboard, since there is a lot of GIS content that is displayed as pseudo-colour layers where the colouring of the layer's regions is determined by the layer's parameter values in that region. For example, the layer representing last month's total rainfall is colour-styled using the values of total rainfall in the previous month. The details of this styling are informed to the user through the legend on the bottom-right.



Exploratory geo-visualization can be enabled by allowing the user to control the legend. For example to check if there were any regions that had about 500mm rainfall in the last month, it would be useful to set the upper-limit of the legend to 500.

Such a facility can be availed on the dashboard by clicking the 'Legend Control' button just above the legend. Setting the upper-limit value to 500 (and changing any colours if desired) and clicking the 'Apply' button will produce a re-styled map as shown below. As can be seen below, there indeed are a few pockets coloured blue that indicates that the total rainfall in those pockets had been about 500mm.

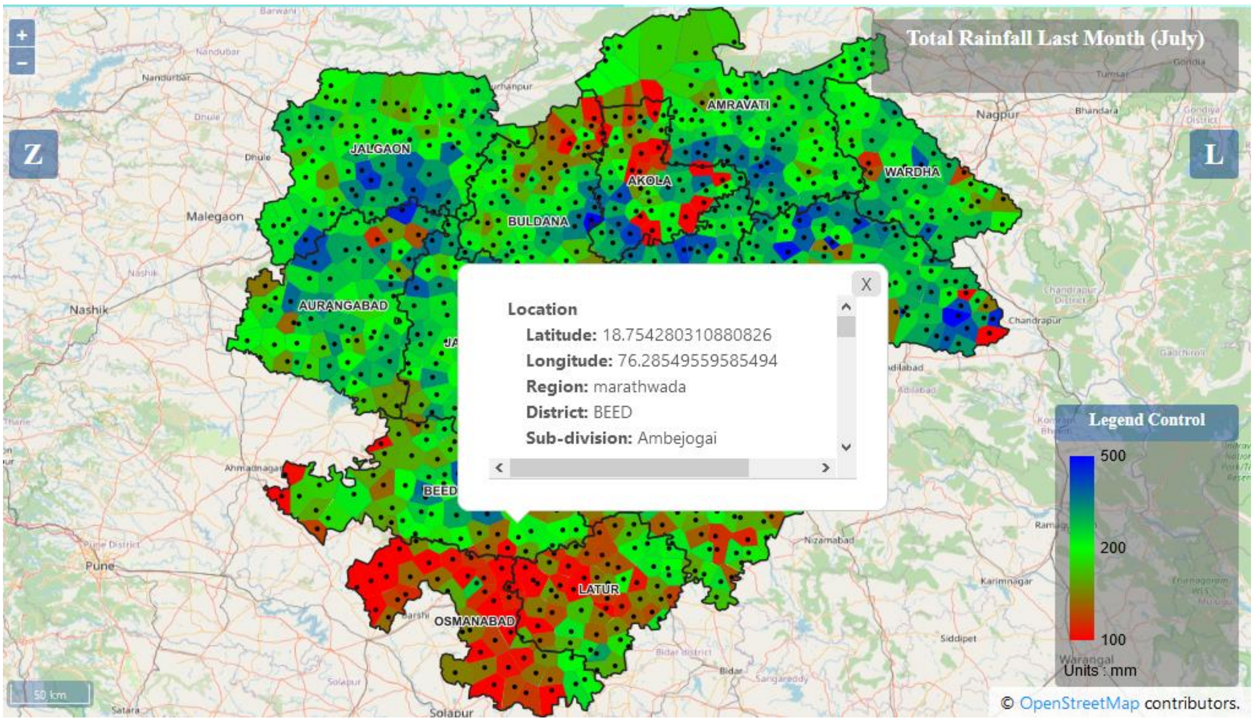


Finally, a quick note may be made about the title card displayed on the top-right, which shows the current top-most layer's name.

Location-/Point-level details

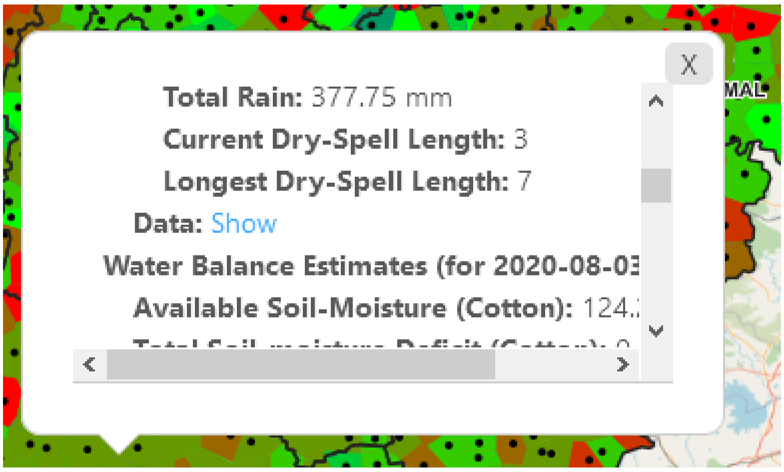
Typically, it follows after some browsing of various map-layers that the user wishes to see (possibly a subset of) a compendium of all available data at any particular location on the map. This facility is provided on the dashboard's map-view in a very trivial way; namely by clicking at the desired location on the map. As shown below, as the user clicks any location, an information card pops over the location. It contains the details of all the layers available in the left-panel (list of datasets).

It may be noted that, while most location-details are specific to the [latitude, longitude] pair of the clicked location, some have to be in terms of their proximity to the clicked location. For example, a user may click on the symbol for a MLP-structure to know it's details. However, being a human-computer interface, the clicked location will most probably not have the exact value for the [latitude, longitude] pair as is assigned to the MLP-structure in the database. If exact equality of this pair were to be used, then it would be almost impossible for a user to select the MLP-structure from the screen's displayed map-view. For such cases, the information is provided in terms of proximity; for example, as a list of all MLP-structures(along with their [lat, lon] pairs) within a radius of 1km from the clicked location.



Tabular Data

Apart from the basic compendium at a location, data may also be desired in a tabular format for various use-cases. One generic use-case may be a listing of the data that was used to generate a particular layer. For example, the total rainfall in the last month at each of the weather-monitoring stations which were used to generate the corresponding map-layer.



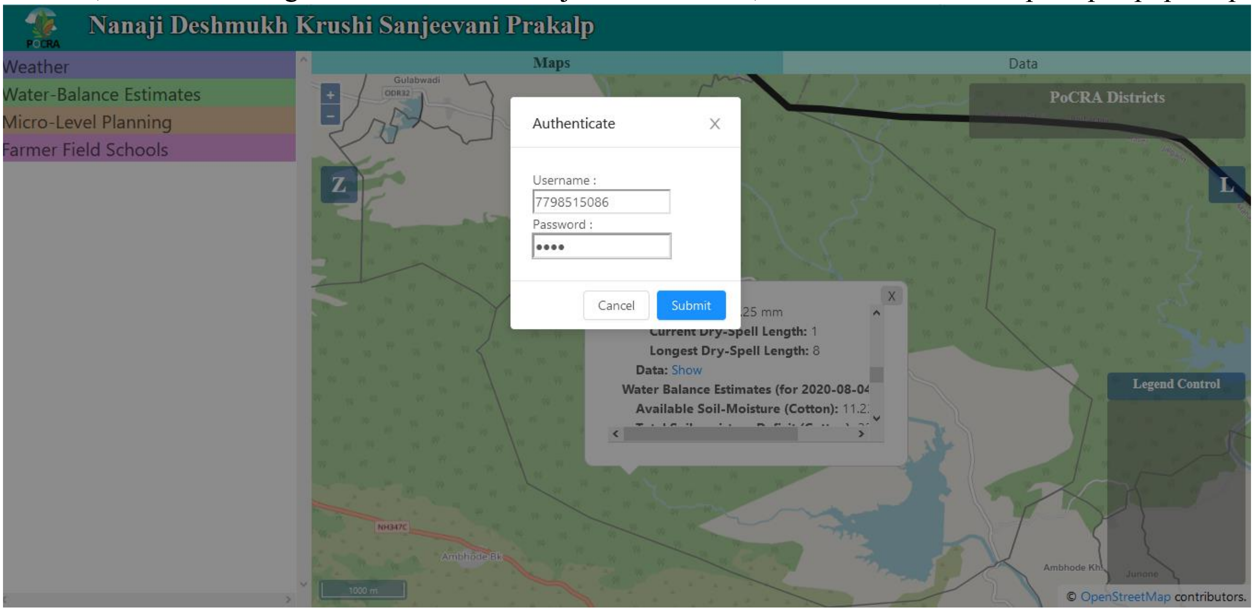
Instead, however, a user may also desire to dig deeper into the data for a given location.

For example, after seeing the map of longest dry-spell, the user may be interested in checking the sequence of daily rainfall values in the current monsoon season at a particular location of interest. The dashboard presently caters to this and related use-cases by providing a tabular listing of all daily weather parameters at any clicked location. Such a listing may be obtained for a location by clicking it, scrolling through the consequent pop-over's details and clicking the 'Show' link against the 'Data' key, that is listed under the Weather' section.

Role-based data-access

The viewing or use of detailed data for a region has been considered as privileged access that should be permitted only to the concerned authorities. As mentioned earlier, although the levels of data-details and their semantics vis-a-vis the user's role have not been charted out yet, it was feasible to demonstrate a basic role-based access facility.

In fact, after clicking the 'Show' link just mentioned, an authentication prompt pops up.



At present, as a demonstration, only a cluster-assistant is permitted to view and use weather data at any given location within the clusters assigned to him/her. Upon authentication, the dashboard's view switches to the data-view(the 'Data' tab beside the 'Maps' tab) and the daily weather details appear there in tabular format.

Maps | Data

Download

Date	Rain	Min. Temp.	Avg. Temp.	Max. Temp.	Avg. Rel. Humidity	Avg. Wind Speed
2020-06-01	0	28.1	33.3262	38.83	61.6042	2.47167
2020-06-02	2.5	23.94	28.3346	33.18	83.9958	1.55292
2020-06-03	15	23.54	25.7146	29.91	97.6708	6.13125
2020-06-04	34.5	23.69	26.3271	34.26	92.6167	5.96833
2020-06-05	0	22.22	27.4696	34.82	87.2125	1.66583
2020-06-06	0	23.97	29.5746	35.03	82.65	1.85333
2020-06-07	10.75	25	28.9383	35.57	86.9167	1.65333
2020-06-08	0	24.08	30.3438	37.49	80.2	1.64417
2020-06-09	0	24.7	30.5921	37.87	80.3792	1.15667
2020-06-10	15.5	25.79	31.3354	38.1	78.6083	1.95208
2020-06-11	0	26.81	32.5475	39.74	76.0958	2.18333
2020-06-12	1	25.08	28.78	34.26	92.7083	1.97292

Data Download

As a simple extension to this view-access, once authenticated, the user can also download the same tabular data in the CSV format by clicking the Download button on the top-right margin in the Data-tab.

4. GIS-Datasets

As mentioned in the description of conceptual design, the notion of grouping GIS data into fairly independent GIS-datasets is basic to the understanding and usage of dashboard's facilities. While the GIS-datasets currently listed in the left-panel of the dashboard are largely self-explanatory, we describe their salient details below.

Weather

Weather data is being collected and stored for consequent use in various analytical and decision-making tasks within PoCRA. Data is available for the following weather parameters: rainfall, temperature, relative humidity and wind speed. Described below are various aspects of the weather database related to collecting, processing and using it for the purpose of geo-visualization.

Automated Weather-monitoring Stations (AWS)

Skymet has installed Automated Weather-monitoring Stations (AWS) throughout the state of Maharashtra and made hourly data for 21 districts (that include PoCRA's 15 districts) available to PoCRA through a web-API. The dashboard application is designed to auto-update the weather data in its database on a daily basis by using this API.

Voronoi Partitioning

There are a total of about 950 AWSs installed in PoCRA's 15 districts. For geo-visualization, it is desirable to have a map-layer that covers the Entire Region(ER) of PoCRA's districts. This calls for a need to interpolate using the AWSs' values to generate a layer that covers ER. While interpolation methods usually generate a raster map, it has been an established practice during the dashboard's development to use nearest neighbour interpolation method, which generates a vector layer of the so-termed Voronoi polygons which cover the ER. There is a one-to-one mapping between the AWSs and the Voronoi polygons such that each Voronoi polygon contains exactly the AWS mapped to it. These Voronoi polygons are computed such that the AWS that each contains is the closest AWS for every point within that Voronoi polygon. For the purpose of diligent geo-visualization, the polygon-layer of pseudo-coloured Voronoi polygons is mapped along with the point-layer of AWSs overlaying it.

Data Availability

Each AWS is installed in a field-environment and apart from the quality of the AWS itself, the field-environment may present various situations when the AWS may not be able to record or transmit weather data to the Skymet's databases. Other times, some garbled data may be received, which needs to be weeded out. Also, it is possible that some AWSs are decommissioned and others newly installed in other locations. Such cases result in missing data. As such, when requested from Skymet's API service, the response may not contain data for every AWS that was ever installed.

The indicator-layers provided in the dropdown menu of the weather dataset have been generated using AWSs that provided data for the entire duration implied by the layer. For example, the layer representing maximum temperature in the last week is generated using AWSs which provided uninterrupted data for the entire duration of the last week. Due to this data availability issue, it should be noted that the set of AWSs for each of the following set of layers may be mutually different:

- Latest date's layers

- Last week’s layers
- Last month’s layers
- Cumulative layers

Crop Water-Balance Estimates

Water-balance estimates for the entire region are computed for display on the dashboard on a daily basis using a particular water-balance model that is under in-house development. Following is a brief description of the model and how it is used for generating region-wide estimates for publication on the dashboard.

Model

A simulation model meant to estimate the water-balance at a cropped location has been under development, right from the beginning of PoCRA as a project. This model is a daily time-step model that estimates the daily amount of various water-components at the soil-level like soil-moisture, runoff, crop’s evapotranspiration and groundwater recharge. It uses various field-level parameters at the location like the soil-texture, soil-depth, land-use/land-cover, terrain-slope and daily weather parameters like temperature (min, max, avg), rainfall in order to simulate the model.

Daily estimation

In order to generate a picture for the entire region, this location-based model may be simulated for the set of all points of a uniform grid that covers the entire region. In GIS terms, it would effectively mean that the inputs and outputs will be rasters having the same resolution as the grid. The model is thus effectively run using raster inputs to generate raster outputs.

The model is run daily to apply the newly available weather data to the last estimated water-balance state in order to generate the next day’s water-balance. The results are again stored back into the database to be used on the next day when new weather data would be available. Simultaneously, to serve their main purpose, these results are used daily to update the project-indicator layers that are published on the dashboard under the ‘Water-Balance Estimates’ dataset.

Micro-Level Planning

A Micro-Level Planning (MLP) exercise is carried out in each of the 5142 PoCRA villages. Under this exercise, zone-wise water-budgeting is done in the village along with allied water-management plans and activities in order to improve resilience to variations in year-long water-availability to the crops. The following GIS-datasets related to MLP have consequently been incorporated on the dashboard.

PoCRA villages water balance

This is the set of 5142 villages that have been included in the project. The villages have been categorized into three phases according to when the MLP exercises were planned to begin in the village during the overall project’s duration. As the MLP exercise is carried out and its implementation begins, it becomes possible to assess the progress in each village in terms of MLP-related project-indicators. These indicators are consequently published on the dashboard as layers with village-wise pseudo-colouring(colouring based on indicator values).

Drainage

The availability and use of water from overland flows is basic to any form of water-budgeting in a village. As such the drainage pattern in the entire region is a GIS-dataset that will have a significant use in planning any water-bearing or impounding structures. This dataset has thus been incorporated on the dashboard and in addition to the geometry of flows, it includes information on the hydrological-order of all drainage-segments which can enable more refined planning.

Water-structures

One of the important activities ensuing the planning stage is the construction of water impounding and storage structures within the village at suitable locations. For the purpose of assessment of effectiveness of these structures and hence the MLP exercise, it is a significant value-addition to have the structures geo-tagged and geo-visualizable. This has been done and a GIS-layer generated therefrom has been published on the dashboard. The layer shows the locations as well as the construction-type(like KT-weir, Gabion Bandhara, etc.) of all these structures.

Farmer Field Schools

The idea of Farmer Field Schools (FFSs) has been incorporated in the project as a significant means of knowledge sharing and dissemination to the farmers. The plan is to have one FFS in each PoCRA village. This is essentially a farm-plot selected to be cultivated and monitored throughout the project duration and used for knowledge exchange through farmer meetings prompted by a facilitator. As a research-extension to this idea, a ‘control’-plot is also selected within the village and conceptually paired with the FFS plot in the village for monitoring.

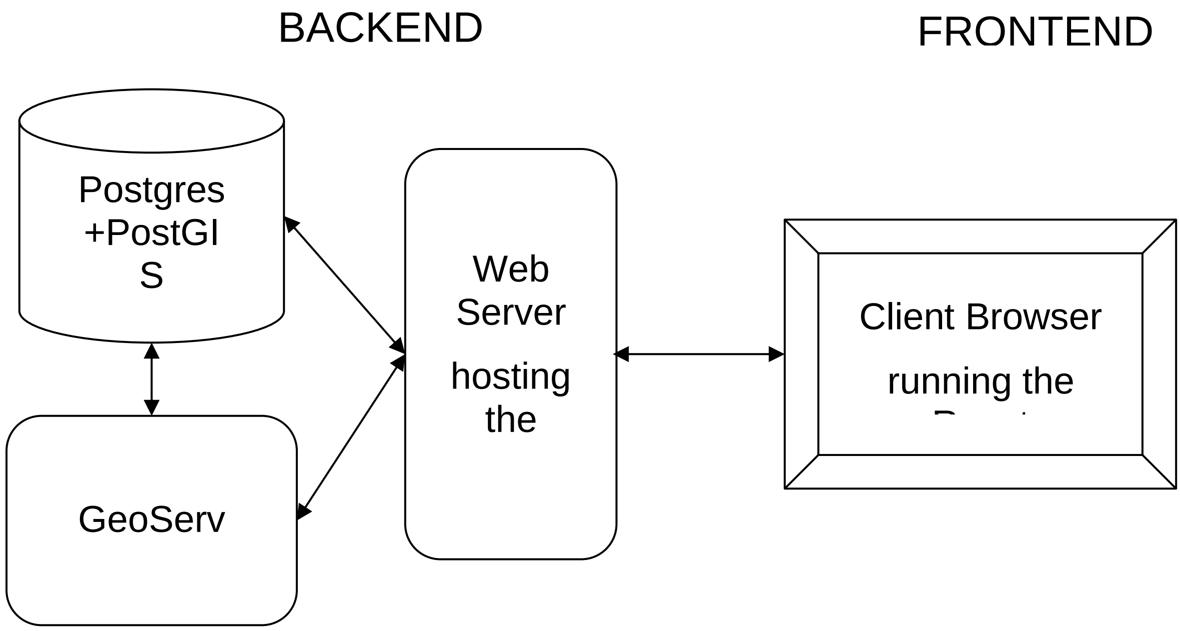
At present the base-database for FFS is under development. As such, in order to simultaneously continue work on incorporating it on the dashboard, a snapshot copy of some FFS data was used to get started. This snapshot contains static data related to the FFS plots and their locations and current season’s dynamic data related to cropping in these plots. Using this data a few project-indicator layers have been incorporated on the dashboard for initiation.

Cross-dataset indicator

While many of the project-indicators rely on the data only within a single dataset listed in the left-panel, many other project-indicators of interest need to use data from multiple datasets. At the same time, when it comes to geo-visualization, each of these cross-database indicators will have a natural GIS-entity-set to map their values to. As a start, one such indicator named ‘Longest Dry-Spell In Reproductive Stage’ has been incorporated into the dashboard. This indicator essentially uses the daily-rainfall data for each farmer field school plot, as obtained from the nearest available automated weather-station(s) to find the longest duration (in days) when there was negligible (< 2.5mm) rainfall everyday at the FFS plot during the reproductive stage of the major-crop sown there. It thus harnesses data from both Weather dataset as well as the Farmer Field Schools dataset.

5. Technical design

Like any web-application, the GIS-dashboard application has to address concerns at two ends: the client-browser with which the user interacts and the server which handles client’s requests for data and maps. As shown in the figure below, the dashboard application has been designed with a clear separation of these two concerns.



Above image shows the technical details of the application design and implementation.

Frontend

The frontend application is built using various open-source javascript/ES6 packages as follows.

- **React:** React is a framework-package for developing single-page web-frontend applications. This is the basis of the entire frontend code for the dashboard application that runs on the client's browser. Being a thriving package, it also has a thriving base of supporting and/or auxiliary packages to accomplish various web page designs and user interaction in the browser.
- **Openlayers:** Openlayers is an open-source package for rendering map-layers served by various web mapping servers in specific formats. It enables rendering vector layers as well as raster layers. It also provides an API that enables browsing the rendered map with zoom and pan as well as to enable probing particular locations in the rendered map. This package is the workhorse for all the client-side mapping facilities provided through the dashboard.
- **Antd:** Antd is a web-GUI design product and has an open-source library of React GUI components that are based on it. It has many useful GUI widgets that can significantly offload the development of a web-frontend. Mention should be made of widgets like Popover, Cascader(used in the region-wise zooming facility) and Modal.
- Apart from the above a few other packages have been experimented with. Among these, the only one presently in use is the 'react-colour' package with its ColourPicker used in the Legend Control on the dashboard.

Backend

The backend that serves the dashboard application is made up of three components: a database, a map-server and a web-server. Each of these is described below.

Database

The dashboard uses the Postgres Relational DataBase Management System (RDBMS) to store its datasets. It is a free and open-source product. It has an extension called PostGIS that supports storing as well as processing of spatial data.

A single database object(as a RDBMS-programming data-structure) has served all the purposes of the dashboard till now. There is one schema object within this database for each of the GIS-datasets described above(Weather, MLP, etc.). Each of these schemas hold the data-tables for its respective GIS-dataset.

The MLP and FFS GIS-datasets are managed by other partners in the project and have their own databases on different Postgres server instances in PoCRA's cloud platform. To use the required spatial and other data from these databases, the foreign-data-wrapper technology provided by Postgres has been used. Specifically, the 'postgres_fdw' extension to the postgres database allows (almost-)transparent access to other postgres databases, possibly on different servers, from within one postgres database. This only requires a one-time setup wherein the database-connection details required to access the other databases need to be specified.

There are two ways in which the database is modified. One is during the initial set-up and any subsequent modifications to the schemas as per dashboard's data requirements. The other is the daily automatic updates that are required to reflect the latest situation on the dashboard. This, in particular, includes updating the weather schema by adding newly available latest data, and adding result rasters generated by the daily model-based water-balance estimation.

Web-service

The user interacts with the dashboard's frontend and requests various data/maps. This process of handling requests is managed on the backend by the web-server and the application code. Presently, the instance of the dashboard application is hosted on an Apache httpd web-server. A server-side python application processes the requests and is based on the Flask web-development framework.

Currently, there are only a handful of requests that need to be handled by the Flask-based server-code. They are as follows:

- meta-data about the incorporated GIS-datasets and their various project-indicators; this is used to populate the left-panel on the dashboard.
- Extent of the entire PoCRA region as required to set the map-view when the dashboard-application loads initially.
- Information about the extents of each administrative region, which is used to zoom-cum-pan to the requested region (using the button marked 'Z')
- All the details at the user-clicked location to be served in a pop-up at the location
- Daily weather data at a location as served in the data-view.

GeoServer

GeoServer is a map-server that provides reference implementation for, among others, the Web Map Service (WMS) and Styled Layer Descriptor (SLD) standards published by the Open Geospatial Consortium

(OGC). The dashboard application uses WMS to request map-layers and (static-)legends and SLD to style the layers.

All the map-layers displayed on the dashboard are requested (routed through Apache), from GeoServer, which generates them using its connection with the PostGIS geometry tables for vector data and the connection with GeoTIFF files (exported from PostGIS) for raster data. In order to maintain a separate namespace that avoids interference with other applications using GeoServer, a separate workspace for the dashboard's map-layers and styles has been created in the installed GeoServer instance.

6. Summary

Phase-3 has witnessed a significant change in the development paradigm used for the dashboard. The basic idea in the new paradigm is to decide on the set of requirements to be fulfilled in the next release through liasoning and thus rolling out releases in a series of incremental changes.

Following the new paradigm, the dashboard in its present state of development provides services for geo-visualization of various layers in the project's GIS-datasets. An illustrative case of a cross-database indicator-layer has also been included. Most of the basic and a couple of advanced facilities for map browsing and geo-visual analysis have also been provided. Illustrative use-cases for role-based data-access, tabular data-display and data download have also been included.

In the remaining phases of the MoU, along with the basic maintenance and improvements like providing role-based functionalities, the dashboard is to be developed in two new conceptual ways. First is the incorporation of services for contingency-management based on a Scale-Analysis-Trigger-Action (SATA) framework. The other is to develop desktop tools for use by authorized PMU staff that would allow basic/simple but direct management of the contents of the dashboard and its backend. The details of these will be decided on the way as per the new development paradigm.