ABOUT THE ORGANISATION

GENESIS

Government of Karnataka had presented, in the august house, an Agricultural Budget for the year 2011-12, first of its kind for Agricultural sectoral budget in the country, and committed to the establishment of an Advanced Centre for Integrated Water Resources Management (AC-IWRM). The rationale in establishing an Advanced Centre for Integrated Water Resources Management (AC-IWRM) is to create an enabling environment for the state government to pursue the set objectives to move towards achieving water and food security in the state and increase the State's agricultural income. IWRM framework provides the opportunity to integrate the land and water related aspects at the sub-basin or river basin level.

The Advanced Centre for Integrated Water Resources Management (AC-IWRM) will act as a think tank to the Department of Water Resources. The Advanced Centre will engage in policy analysis, policy research, develop knowledge base within the state and WRDO for gearing up the department up to its future vision 2030. It will also serve as a platform / agency thru WRDO for coordination among main departments and other related government agencies, NGOs, private sector firms, water user associations and other organizations dealing with the water sector and leading up to implementation of the IWRM principles.

VISION

The vision of the Government of Karnataka for ACIWRM is:
scientific and sustainable management of water resources to get the maximum water, food and energy security by balancing the demands of various sectors and to ensure harmonious sharing and utilization of resources by mutual understanding and coordination of various stakeholders.

MISSION

- To be a global Centre of Excellence in enabling adoption of the principles of the Integrated Water Resources Management (IWRM).
- To facilitate the exchange of expertise, knowledge and experience in adoption of the IWRM Principles and to drive IWRM as a process.
- To provide a platform for enabling partnerships of various stakeholders and interested agencies in IWRM to carryout policy analysis, action research, capacity building and networking.

ACKNOWLEDGEMENT

We are extremely thankful to **ACIWRM (**Advanced Centre for Integrated Water Resource Management) for providing us the opportunity to do the internship project under this prestigious organisation. We were made extremely comfortable to be a part of the organisation during the ongoing of the internship project.

We express our sincere gratitude to **Dr.P.Somashekar Rao**, Director (Technical), ACIWRM , **Dr. Shashikumar N,** Water Resources Specialist , M S Raviprakash, Principal Coordinator for Engineers and **Dr.T.N.Reddy** Land and Water Management Specialist for providing me with the opportunity to complete my internship on the topic of water productivity. The knowledge and experience gained during this internship have been invaluable to me and will greatly benefit us in my future endeavours. We would also like to thank the department staff for their support and guidance throughout the internship. This has been a truly enriching experience.

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We are indebted to our beloved senior, **Ashish** gave insights regarding the different realms of approach to the project.

LIST OF ABBRIVATIONS

ACIWRM	Advanced Centre for Integrated Water Resources Management
IWRM	Integrated Water Resources Management
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information
QGIS	Quantum Geographic Information System
DEM	Digital Elevation Map
GIS	Geographic Information System
WRD	Water Resources Department
GOI	Government of India
GOK	Government of Karnataka
KSRSAC	Karnataka State Remote Sensing Application Centre
USGS	United states Geological Survey
MOSDAC	Meteorological and Oceanographic Satellite data Archival Centre
IMD	India Meteorological Department

CHAPTER-1 INTRODUCTION

1.1 HYDROLOGICAL CYCLE

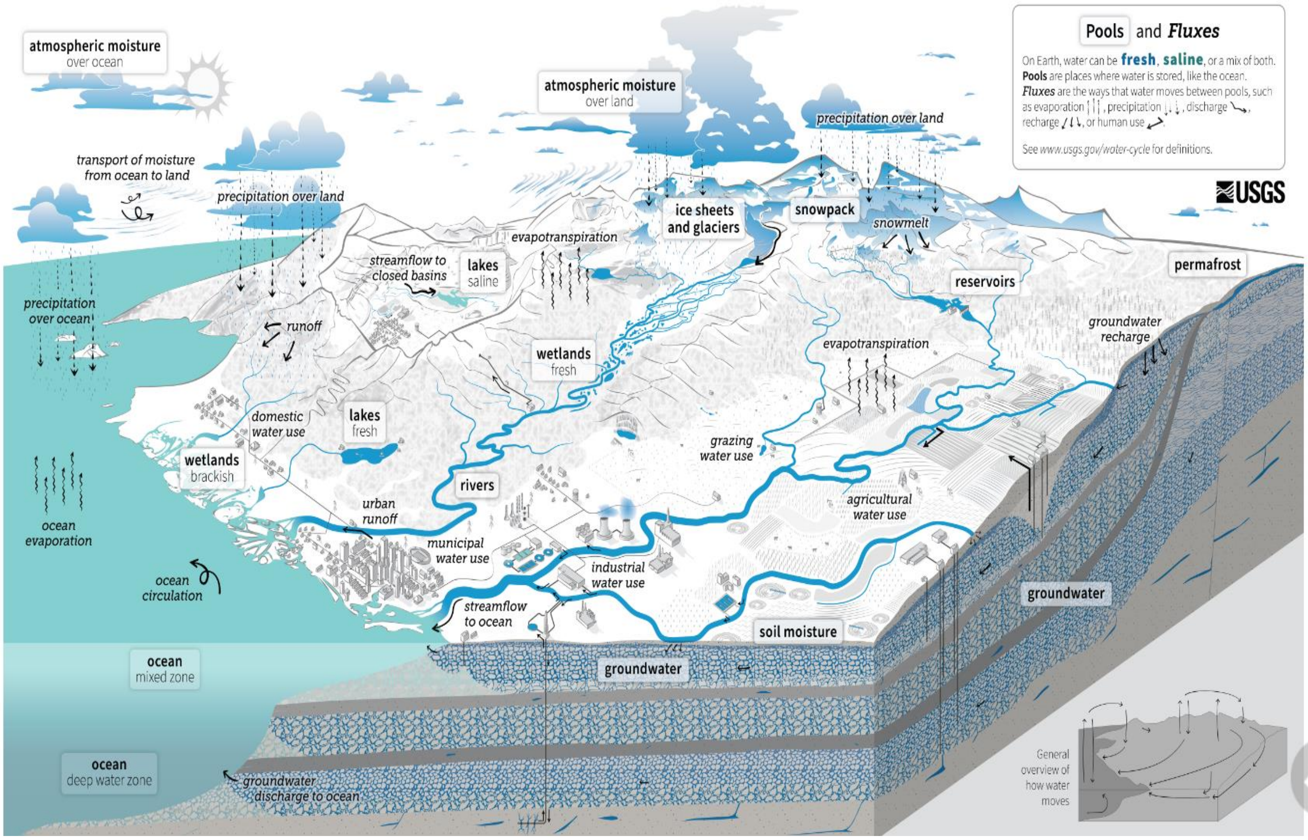


FIG.1.1 UPDATED HYDROLOGICAL CYCLE

A fundamental characteristic of the hydrologic cycle is that it has no beginning and it has no end. It can be studied by starting at any of the following processes: evaporation, condensation, precipitation, interception, infiltration, percolation, transpiration, runoff, and storage.

EVAPORATION

Evaporation occurs when the physical state of water is changed from a liquid state to a gaseous state. Evaporation can occur on raindrops, and on free water surfaces such as seas and lakes. It can even occur from water settled on vegetation, soil, rocks and snow. There is also evaporation caused by human activities.

CONDENSATION

Condensation is the process by which water vapor changes it's physical state from a vapor, most commonly, to a liquid. Water vapor condenses onto small airborne particles to form dew, fog, or clouds. Condensation is brought about by cooling of the air or by increasing the amount of vapor in the air to its saturation point.

PRECIPITATION

Precipitation is the process that occurs when any and all forms of water particles fall from the atmosphere and reach the ground. Precipitated water may fall into a waterbody or it may fall onto land. It is then dispersed several ways. The water can adhere to objects on or near the planet surface or it can be carried over and through the land into stream channels, or it may penetrate into the soil, or it may be intercepted by plants. When rainfall is small and infrequent, a high percentage of precipitation is returned to the atmosphere by evaporation.

INTERCEPTION

Interception is the process of interrupting the movement of water in the chain of transportation events leading to streams. The interception can take place by vegetal cover or depression storage in puddles and in land formations such as rills and furrows.

INFILTRATION

Infiltration is the physical process involving movement of water through the boundary area where the atmosphere interfaces with the soil. The surface phenomenon is governed by soil surface conditions. Water transfer is related to the porosity of the soil and the permeability of the soil profile.

PERCOLATION

Percolation is the movement of water though the soil, and it's layers, by gravity and capillary forces. The prime moving force of groundwater is gravity. Water that is in the zone of saturation is called groundwater. For all practical purposes, all groundwater originates as surface water.

TRANSPIRATION

Transpiration is the biological process that occurs mostly in the day. Water inside of plants is transferred from the plant to the atmosphere as water vapor through numerous individual leave openings. Plants transpire to move nutrients to the upper portion of the plants and to cool the leaves exposed to the sun. Transpiration is greatly affected by the species of plants that are in the soil and it is strongly affected by the amount of light to which the plants are exposed.

RUNOFF

Runoff is flow from a drainage basin or watershed that appears in surface streams. It generally consists of the flow that is unaffected by artificial diversions, storages or other works that society might have on or in a stream channel. The flow is made up partly of precipitation that falls directly on the stream , surface runoff that flows over the land surface and through channels, subsurface runoff that infiltrates the surface soils and moves laterally towards the stream, and groundwater runoff from deep percolation through the soil horizons.

STORAGE

There are three basic locations of water storage that occur in the planetary water cycle. Water is stored in the atmosphere; water is stored on the surface of the earth, and water stored in the ground.

Water stored in the atmosphere can be moved relatively quickly from one part of the planet to another part of the planet. The type of storage that occurs on the land surface and under the ground largely depend on the geologic features related to the types of soil and the types of rocks present at the storage locations. Storage occurs as surface storage in oceans, lakes, reservoirs, and glaciers; underground storage occurs in the soil, in aquifers, and in the crevices of rock formations.

1.2 DATA AVAILABILITY

COMPONENT	SATELLITE	RESOLUTION	PRODUCT	AVAILABILITY
PRECIPITATION	GPM	SPATIAL: 0.1*O.1 degrees TEMPORAL: 30 mins	LEVEL1-3 IMERG	FREE
	INSAT	SPATIAL: 1km TEMPORAL:15 mins	Level 0-3 HDF	FREE

LINK:

1. GPM : (https://disc.gsfc.nasa.gov/)

2. (https://disc.gsfc.nasa.gov/datasets/TRMM_3B43_7/summary)

3. INSAT: (https://mosdac.gov.in/bayesian-based-mt-saphir-rainfall)

COMPONENT	SATELLITE	RESOLUTION	PRODUCT	AVAILABILITY
EVAPOTRANSPIRATION	TERRA'S MODIS	SPATIAL:500m TEMPORAL:8 days	MOD16	FREE
	INSAT	SPATIAL: 1km		
		TEMPORAL:15 mins	Level 0-3 HDF	

LINK:

1. MODIS : https://lpdaac.usgs.gov/products/mod16a2v006/

COMPONENT	SATELLITE	RESOLUTION	PRODUCT	AVAILABILITY

GROUNDWATER	GRACE	SPATIAL:300KM TEMPORAL:1 month(30 days)	LEVEL 1a,1b,2 NetCDF	

COMPONENT	SATELLITE	RESOLUTION	PRODUCT	AVAILABILITY
SURFACE WATER	SENTINEL-2	SPATIAL:60m TEMPORAL: 5 days	LEVEL 1-2 XML	
	LANDSAT-8	SPATIAL:15m TEMPORAL:16 days		

COMPONENT	SATELLITE	RESOLUTION	PRODUCT	AVAILABILITY
SOIL MOISTURE	SMAP	SPATIAL:36km TEMPORAL: 2-3 days	LEVEL 0-4 DATA PRODUCTS	

1.3 CROP GROWTH STAGE

The duration in days between sowing and harvesting is termed as crop growth stage. The various stages are as follows:

1. The initial stage: this is the period from sowing or transplanting until the crop covers about 10% of the ground.

2. The crop development stage: this period starts at the end of the initial stage and lasts until the full ground cover has been reached (ground cover 70-80%); it does not necessarily mean that the crop is at its maximum height.

3. The mid - season stage: this period starts at the end of the crop development stage and lasts until maturity; it includes flowering and grain-setting.

4. The late season stage: this period starts at the end of the mid season stage and lasts until the last day of the harvest; it includes ripening.

In the current study we are focusing on study of paddy and sugarcane.

1.3.1 PADDY

Growth Stage	Paddy	
	Duration (Days)	Water Requirements (mm)
VEGETATION – SOWING, TILLERING, PANICLE	127	698
REPRODUCTIVE	16	420
HARVESTING	16	125

1.3.2 SUGARCANE

Growth Stage	Sugar Cane	
	Duration (Days)	Water Requirements (mm)
GERMINATION	10	35
TILLERING	15-20	70
GRAND GROWTH STAGE	270	1500
MATURATION AND RIPENING	90	3000

1.4 MONSOON TYPES

1.4.1 SOUTHWEST MONSOON

Cause: Intense low-pressure formation over the Tibetan Plateau because of intense heating during the summer season; permanent high-pressure cell in the South of the Indian Ocean (East to Northeast of Madagascar in summer).

SW monsoon winds bring heavy rainfall to most parts of the country.

Factors influencing the onset of SW monsoons:

1. Intense low-pressure formation over the Tibetan Plateau
2. The permanent high-pressure cell in the South of the Indian Ocean
3. Subtropical jet stream
4. African Easterly jet (Tropical easterly jet)
5. Inter-Tropical Convergence Zone (ITCZ)

Factors influencing intensity of SW monsoons**:**

1. Strengths of the low pressure over Tibetan plateau and the high pressure over the south Indian Ocean
2. Somali Jet
3. Somali Current
4. Indian Ocean dipole
5. Indian Ocean branch of the Walker Cell

1.4.2 NORTHEAST MONSOON

Cause: High-pressure cells over the Tibetan and the Siberian Plateaus

NE monsoon winds bring rainfall to the southeast coast of the country (Tamil Nadu coast and Seem Andhra's south coast).

Factors responsible for the formation of the NE Monsoons:

1. Formation and strengths of the high-pressure cells over the Tibetan and the Siberian Plateaus during winters
2. Migration of the Inter-Tropical Convergence Zone (ITCZ) to the south of India
3. The high-pressure cells in the southern Indian Ocean migrating to the west and weakening

1.5 CROP-WATER PRODUCTIVITY

Overall, 78 per cent of freshwater available in the country is diverted towards agriculture but still only 48 per cent of the gross cropped area has been brought under irrigation. Paddy and sugarcane crops together occupying one-fourth of the gross cropped area consume over 60 per cent of the total irrigation water supplied to agriculture, leaving most of the other crops water deprived.

Given that Indian agriculture is prone to droughts, the frequency and intensity of which are expected to increase with climate change, there is a need to make the best use of the country's limited water resources. The present Government has been concerned with the issue and has prioritised agriculture water use through schemes like "Har Khet ko Pani - Water for every field" and "per drop more crop". It has also taken the bold step of connecting rivers in order to maximise the use of available fresh water resources. However, in addition to improvements in existing policies, programmes, and technologies, a change in the mindset of its people is critical for better water management in agriculture. The goal of agricultural development should not be to increase productivity per unit land, but rather to increase productivity per unit water, particularly irrigation water.

1.6 Global LULC

ESRI developed 10-classifications based on Sentinal-2 imagery of 10m resolution using machine learning model

1. Water
2. Trees
3. Grass
4. Flooded vegetation
5. Crops
6. Scrub land
7. Built-up area
8. Snow
9. Cloud
10. Bare ground

1.7 SOFTWARES

1.7.1 PySEBAL

PySEBAL implements Surface Energy Balance Model for Land (SEBAL) in python to estimate spatially explicit Actual EvapoTranspiration maps from remotely sensed data. In addition the library also computes various outputs like Above Ground Biomass Production (AGBP) and Biomass Water Productivity AGBP is computed using fAPAR and LUE factors as inputs. The library is extensively tested on Landsat 7 and 8 data, however it should also support MODIS and PROBA-V/VIIRS. The library supports python 3 and run in both Windows and Linux operating systems.

1.7.2 QGIS

QGIS (or Quantum GIS) is an open source geographic information system, meaning that it can be downloaded and installed on your desktop free of charge. It runs on Windows, Mac OS X, and Linux. There are also numerous plug-ins that extend the functionality of QGIS. QGIS has a lot of documentation. All documentation is in English but some documents such as the user guide are also available in other languages.

QGIS can be used to analyze and map water productivity in various ways. For example, you can use QGIS to:

a) Visualize water resources and infrastructure, such as dams, wells, and irrigation systems, to identify areas where water is being used efficiently or inefficiencies are present.
b) Create maps of crop yields and water use to identify areas where water productivity is high or low.
c) Use remote sensing data to generate maps of vegetation cover and water use to estimate evapotranspiration and water use efficiency.
d) Analyze the impact of climate change and other factors on water productivity by using QGIS to visualize and analyze historical and projected data on precipitation, temperature, and other variables.
e) Create maps of irrigation areas, and then use it to overlay with the digital elevation model (DEM) to identify areas of waterlogging, or areas with poor drainage.

Overall, QGIS can be a powerful tool for analyzing water productivity and making data-driven decisions to improve the use of water resources.

CHAPTER 2

PROJECT 1 :- CROP-WATER PRODUCTIVITY

2.1 Definition of Crop Water Productivity

Water productivity is a measure of how efficiently water is used in the production of a crop or other economic good. It is typically measured as the ratio of the amount of the economic good produced (such as crop yield) to the amount of water used to produce it. Improving water productivity can involve a variety of strategies, such as using more efficient irrigation techniques or selecting crops that are better adapted to local conditions.

2.2 AREA DESCRIPTION

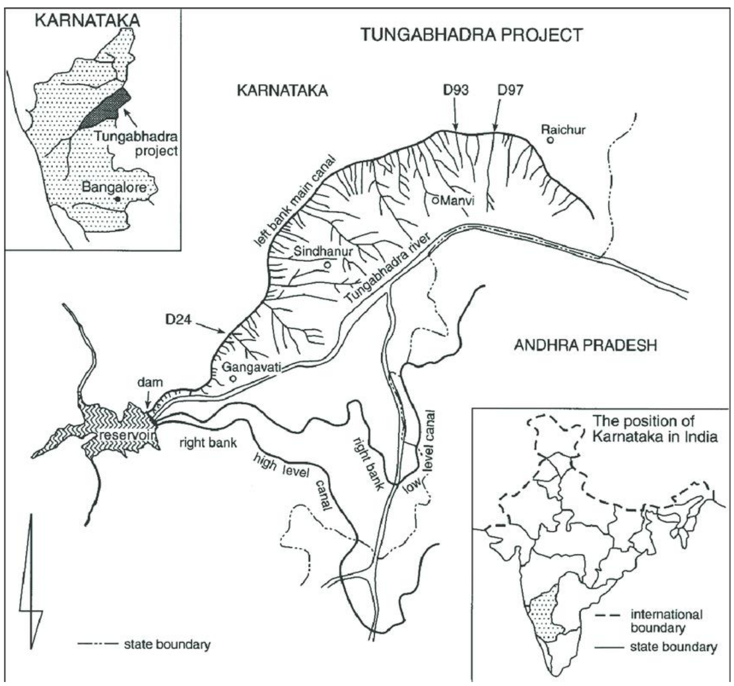


FIG. Mollinga, P.P. and Veldwisch, G.J. 2016. Ruling by canal: Governance and system-level design characteristics of large-scale irrigation infrastructure in India and Uzbekistan. Water Alternatives 9(2): 222-249

The Tungabhadra Left Bank Canal irrigation system is a reservoir-based protective irrigation scheme located on the Tungabhadra River, a tributary of the Krishna River, in South India, presently in the State of Karnataka.

2.3 OBJECTIVES

- Optimizing the use of rainwater for increased crop production
- Maximizing the utilization of existing irrigation schemes in a sustainable manner
- Designing new irrigation schemes in a sustainable manner
- Developing practical tools to enhance CWP at any irrigation condition.

There are several measures that can be taken to enhance crop water productivity:

Irrigation efficiency: Implementing efficient irrigation systems such as drip or micro-irrigation can reduce the amount of water required for crop growth.

Water management: Adopting proper water management practices such as alternate wetting and drying in rice cultivation can reduce water use while maintaining crop yields.

Crop selection: Choosing crops that are drought-tolerant or require less water can also help to increase crop water productivity.

Soil management: Improving soil health through practices such as mulching and conservation tillage can help to retain water and improve crop growth.

Weather forecasting: using weather forecasting and early warning systems to schedule irrigation and other crop management activities can increase the use efficiency of water.

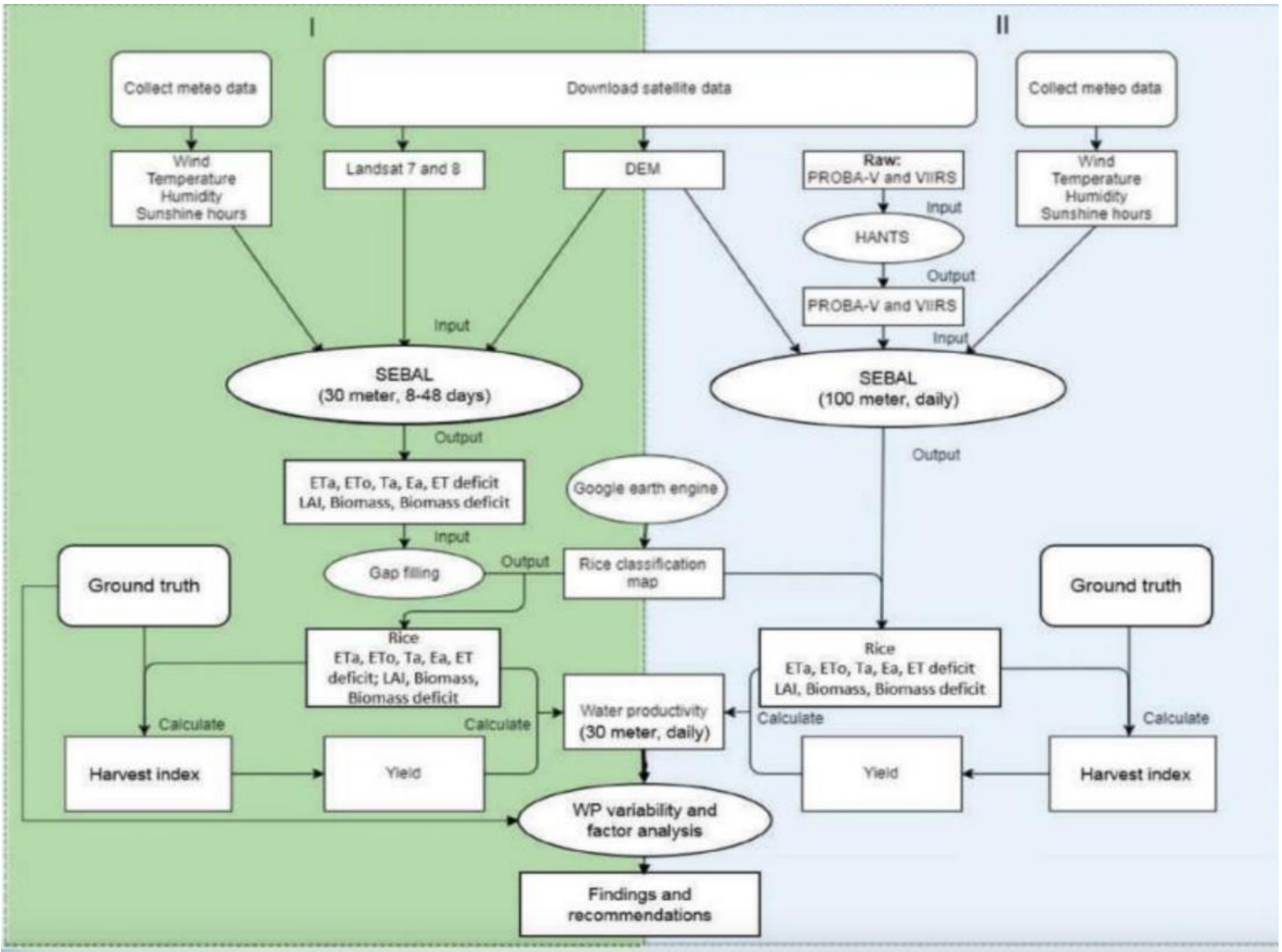
Crop breeding: Developing crop varieties with improved water use efficiency can also enhance crop water productivity.

Enhancing CWP at plant level: most significant improvements come from breeding technology

Accounting CWP: land-use planning, improved irrigation scheduling, conjunctive management etc.

Policy tool for promoting CWP: government intervention, sufficient operation and maintenance, policies and incentives, etc

These measures must be considered to be reasonable and combined. Measures must be integrated with other AWM practices (such as water use efficiency, water harvesting, etc.) to maximize benefit of improved CWP at project implementation.



2.4 PySEBAL data requirements

2.4.1 Satellite Data

Currently PySEBAL support data from Landsat 4/5/7/8, MODIS, PROBA-V/VIIRS sensors/satellites. In this documentation currently PySEBAL using Landsat data as input is explained. But data from other satellites can be easily used by replacing the Landsat data,

Satellite data for our project was downloaded from https://earthexplorer.usgs.gov/

The United States Geological Survey (USGS) Earth Explorer website (https://earthexplorer.usgs.gov/) is a valuable resource for downloading satellite data. The website allows users to search for and download data from a variety of satellite missions, including Landsat, MODIS, and ASTER. The data can be used for a wide range of applications, including land cover mapping, crop monitoring, and natural resource management. Some of the data available on the website include:

Imagery: The website provides access to multi-spectral and hyperspectral imagery from various satellite missions, which can be used for land cover mapping and vegetation analysis.

1. **Digital Elevation Models (DEMs)**: The website provides access to various types of DEMs, including SRTM, ASTER, and NED, which can be used for topographic analysis and terrain visualization.
2. **Weather Data**: The website provides access to various weather data sets such as precipitation, temperature, and solar radiation, which can be used for crop monitoring and agrometeorological analysis.
3. **Field Measurements** : The website provides access to various field measurements data such as vegetation indices, NDVI, EVI, LAI, which can be used for crop monitoring and mapping.

Overall, the USGS Earth Explorer website provides a wealth of satellite data that can be used for a wide range of applications and research projects.

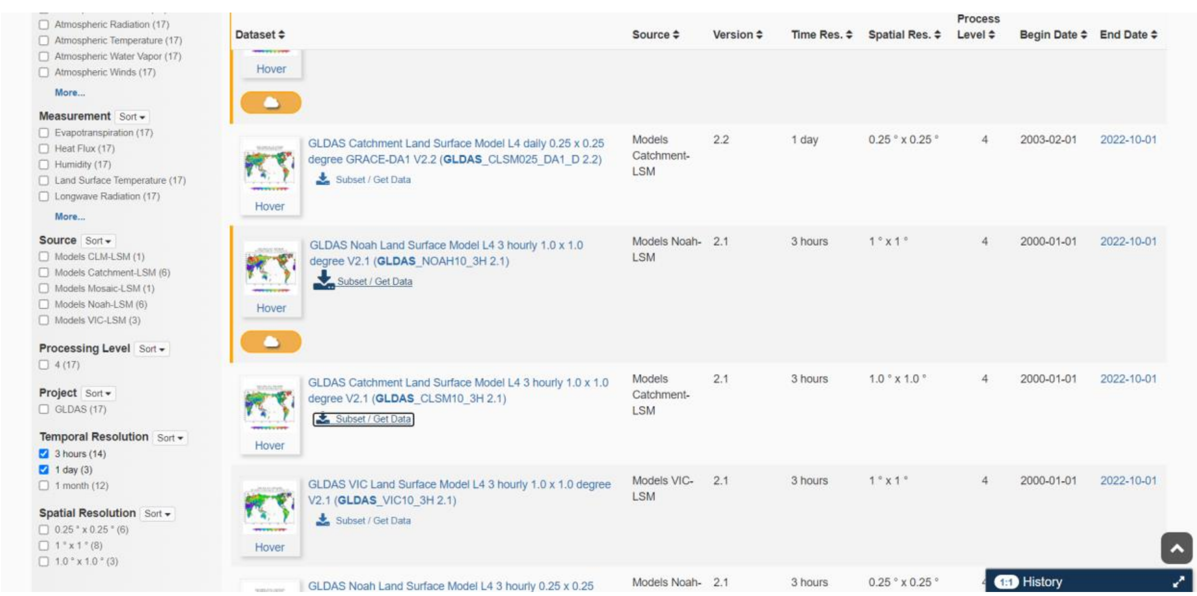
With suitable path row and number Satellite image was downloaded.

2.4.2 Meteorological Data

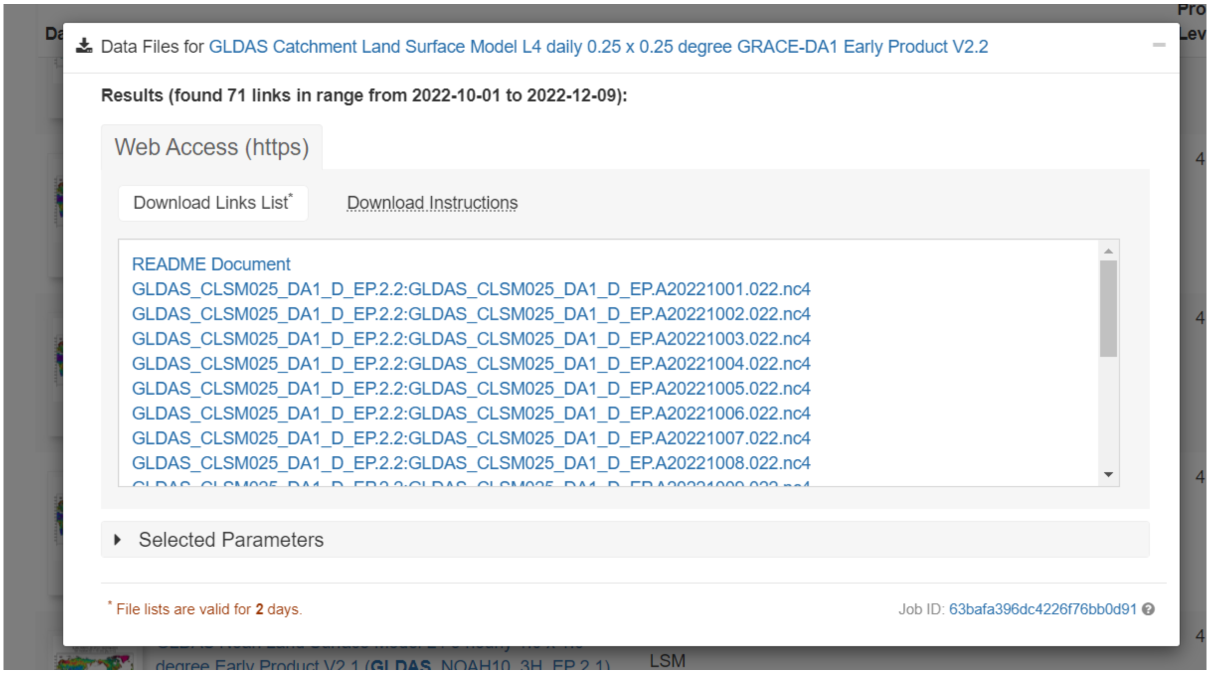
The Global Land Data Assimilation System (GLDAS) is a dataset produced by NASA that provides global data on various meteorological and hydrological variables, such as precipitation, temperature, and soil moisture. The dataset is available for download from the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) website at the link you provided. The data is available in a variety of formats and can be used for a wide range of research and applications.

Meteo data for our project was downloaded from https://disc.gsfc.nasa.gov/datasets?keywords=GLDAS.

STEP 1: Choose the required date and get the data. Also choose temporal resolution towards the left side of the screen.



Step 2 : Get daily data as well as 3 hours data based on the requirement.



Step 3: Data is downloaded with login credentials of Earthdata website.

2.4.3 Soil Data

We developed a JavaScript code to download Soil data of region of interest. This helped us to scale down the time required to download each layer by HiHydrosoil website.

```
var wcsat = ee.ImageCollection("projects/sat-io/open-
datasets/HiHydroSoilv2_0/wcsat");//filterBounds(aoi);
var wcres = ee.ImageCollection("projects/sat-io/open-datasets/HiHydroSoilv2_0/wcres");
var wcpf2 = ee.ImageCollection("projects/sat-io/open-datasets/HiHydroSoilv2_0/wcpf2");
var wcpf4_2 = ee.ImageCollection("projects/sat-io/open-datasets/HiHydroSoilv2_0/wcpf4-2");
var image = wcsat.median().clip(aoi);
var palettes = require('users/gena/packages:palettes');
Map.addLayer(wcsat.first().multiply(0.0001),{min:0.05,max:0.19,palette:palettes.cmocean.Haline[7]},'
wcsat',false)
Map.centerObject(aoi,8);


 Export.image.toDrive({
   image: image,
    description: 'TBLB',
    folder:'GEE_Downloads',
```

```
  scale: 30,
  maxPixels: 130000000000,
  region:aoi,

 });
```

2.5 Data preparation

4 input files were made to give in data input.

1. General input
2. Meteo Input
3. Soil input
4. Landsat input

2.6 EXCEL SHEET PREPARATION

Sheet 1: General Input

1. **InputMap** - set the path to your satellite data
2. **OutputMap** - Where you want to save PySEBAL outputs (if not existing, PySEBAL will create the folder)
3. **Image_type** - satellite type
4. **NameDEM -** set the path to DEM file (Note that you need to provide the file name with extension(.tif))

Sheet 2: Meteo_Input

1. **Temp_inst** - set the path to instantaneous air temperature (including file name and extension)
2. **Temp_24** - set the path to daily average air temperature (including file name and extension)
3. **RH_inst** - set the path to instantaneous Relative humidity (including file name and extension)
4. **RH_24** - set the path to daily average Relative humidity (including file name and extension)
5. **Wind_inst** - set the path to instantaneous wind speed (including file name and extension)
6. **Wind_24** - set the path to daily average wind speed (including file name and extension)
7. **Rs_inst** - set the path to instantaneous downward shortwave radiation (including file name and extension)
8. **Rs_24** - set the path to daily downward shortwave radiation (including file name and extension)

Sheet 3: Soil_Input

1. **Saturated soil moisture content -** set the path with filename and extension
2. **Saturated soil moisture content subsoil -** set the path with filename and extension
3. **Residual soil moisture content** - set the path with filename and extension
4. **Residual soil moisture content subsoil -** set the path with filename and extension
5. **Field_Capacity** - set the path with filename and extension
6. **Wilting point** - set the path with filename and extension

Sheet 4: Landsat_Input

1. **Name Landsat Image** - Name of the landsat image bands (for example without _B1.TIF)
2. **Landsat Number -** 4/5/7/8 depending which landsat
3. **Bands Thermal** - 1/2, In case of Landsat 8, it is 2
4. **tscold_min** - Min percentile to compute minimum threshold for cold pixel from temperature layer (Default is 5)
5. **tscold_max -** Max percentile to compute maximum threshold for cold pixel from temperature layer (Default is10)
6. **ndvihot_low** - Min percentile to compute minimum threshold from NDVI layer (Default is 2)
7. **ndvihot_high** - Max percentile to compute maximum threshold from NDVI layer (Default is 5)
8. **temp_lapse_rate -** Temperature lapse rate for correction of surface temperature

Number of Rows in the input excel sheet is equal to the number of landsat images you want to process. If youhave 10 images, the row numbers are from 2 to 11.

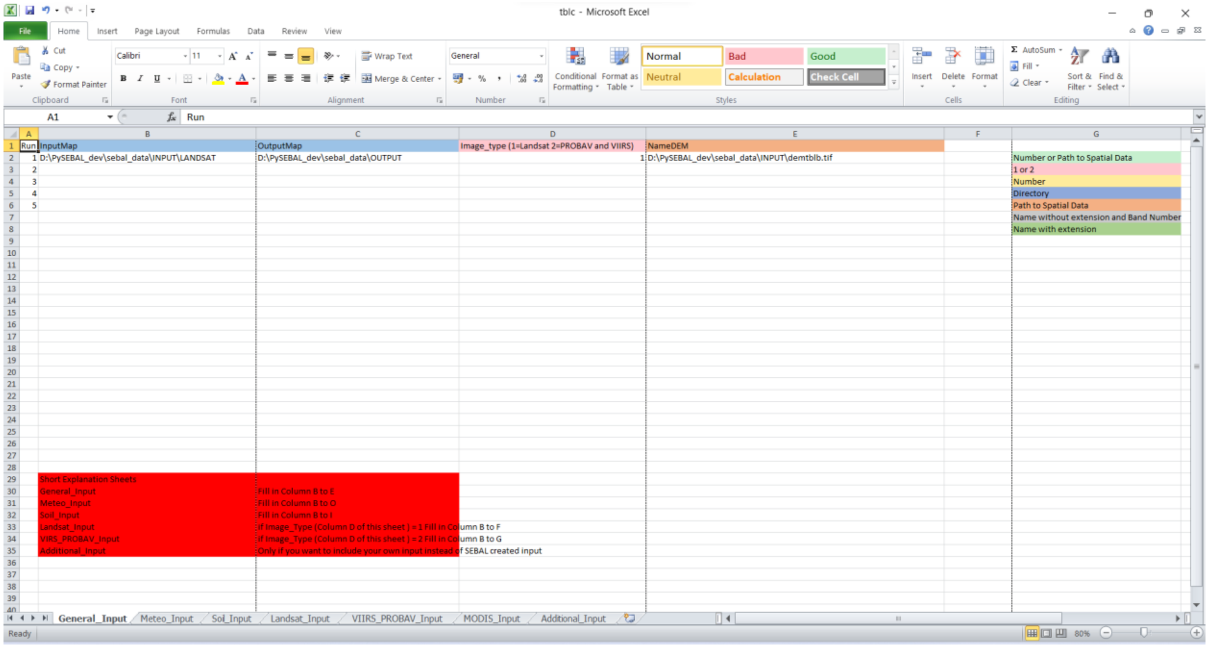
2.7 Edits in Run_py3 file

We need to make following changes in this file:

Line 14 - Set the path to prepared excel sheet

Line 15/16 -Set start and end row numbers for running all the landsat images in one go.

File location of the files as per field name is attached as shown in the figure.



After the preparation of excel file, it should be executed.

2.8 Run PySEBAL

Run the program by making appropriate changes with row numbers using

python Run_py3.py code.

The aggregation and gapfill script available with PySEBAL will perform the monthly aggregation, filtering, temporal and spatial interpolation on outputs of PySEBAL runs.

CHAPTER 3

RAINFALL DATA VALIDATION

3.1 INTRODUCTION

The knowledge of the amount and distribution of rainfall in time and space is an essential element of water and energy balance studies, planning of agriculture, and research in meteorology and climatology. It is an important input into runoff computations, flood forecasting and various engineering design computations. Proper collection and processing of rainfall data is a prerequisite to carrying out any hydrological analysis. Rainfall data are essential for a large number of applications. The data provide direct inputs for understanding and modelling. This offer information for relevant applications such as agriculture and urban drainage systems and add insights across sectors of heavy rainfall, floods and landslides. Rainfall is arguably the most frequently measured hydro-meteorological variable. It is also one that is most useful, particularly in the countries like India, where long term observed records of variables representing other components of the hydrological cycle are either non-existent or scant. Therefore, there often arises a need to estimate the amount representing these other variables like runoff, evaporation, transpiration, infiltration, based on the measured rainfall and available assessment procedures.

The India Meteorological Department (IMD) is the prime organisation for collection, storage and dissemination of all data related to meteorological variables in the country, which maintains their network of rain gauges and weather stations. As water resources projects are often carried out at remote locations, this sometimes leads to forcible use of data maintained by other state organisations like the Water Resources Department, the Agricultural Department, the Disaster Management Department, Universities and the like.

It is a common experience that the rainfall data in its raw form contain many gaps and inconsistent values. The procedures to check and validate the rainfall records are not very well studied in the academic institutions at the undergraduate engineering programmes. Nor are they compiled into a single organised document that is readily available.

3.2 DATA VALIDATION

3.2.1 Role of data validation

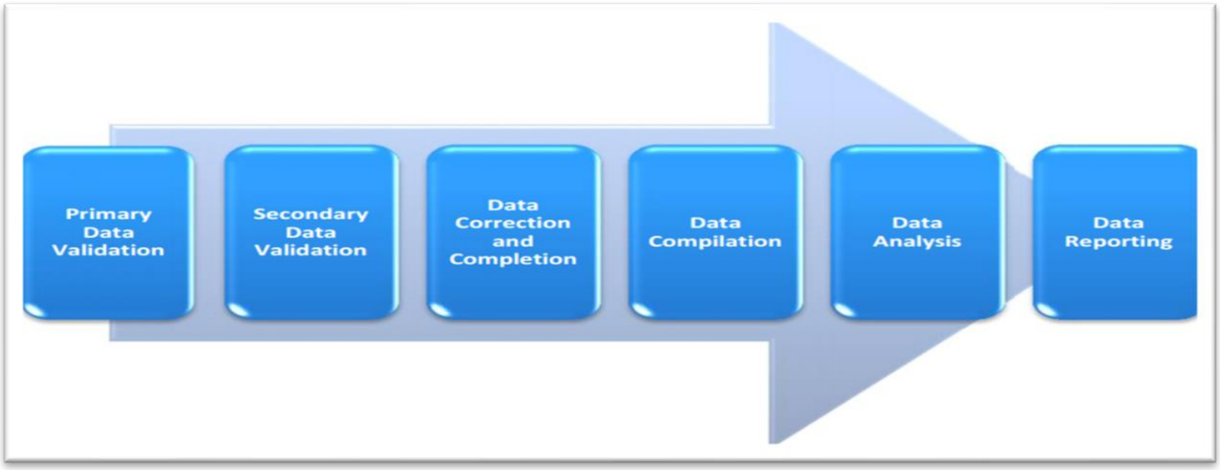
The statistics of hydro-meteorological data underpin the water management policies and practices of Water Resource initiatives of a nation. However, hydro-meteorological observations are subject to errors arising at various levels from field measurement, data entry, data computation, transfer or correction. Data Validation is a process to ensure that the value stored is reliable and the best possible representation of true value of variable at the measurement site at a given time or in a given interval of time. The processes under Data Validation are multi-level and parameter specific, broadly covered under a series of functionalities

❖ Data Validation is carried out mainly for three reasons:

1. To correct errors in the recorded data wherever possible,

2. To assess the reliability of a record where it is not possible to correct errors

3. To identify the source of errors and to ensure that such errors are not repeated in future.



Source: Rainfall Data Validation manual

3.2.2 Primary data validation

Primary data validation is presumed to be carried out immediately after the observations are made or data extracted from charts or downloaded from loggers. This ensures that any obvious errors coming from the observer or instrument are spotted at the earliest and resolved. Primary validation is primarily involved with comparison of variable observation records restricted within a single data series with pre-set limits, statistical range, or in conformance with the expected hydrological behaviour. However, data from stations in close proximity may also sometimes be available and this may be used in primary validation. Primary data validation highlights those data which are not within the expected range or are not hydrologically consistent. These data are then revisited in the data sheets or analogue records to see if there were any errors while making computations in the field or during keying-in the data. If it is found that the entered value(s) are different than the recorded ones, then such entries are immediately corrected. Where such data values are found to have been correctly entered, they are then flagged as doubtful with a remark against the value in the computer file, indicating the reason for such doubt.

3.2.3 Data analysis

Procedures used in data validation and reporting have wide analytical use. The following are examples of the available techniques:

- Basic statistics (e.g., mean, standard deviations, etc.)
- Statistical tests
- Fitting of frequency distributions
- Flow duration series
- Regression analysis
- Rainfall Depth-Area-Duration
- Rainfall Intensity-Frequency-Duration.

3.3 PRIMARY VALIDATION OF RAINFALL DATA

Primary validation of rainfall data can be carried out at the Sub-divisional level and is concerned with data comparisons at a single station:

• For a single data series, between individual observations and pre-set physical

3.3.1 LIMITS

• Between two measurements of a variable at a single station, e.g., daily rainfall from the standard rain gauge and an accumulated total from a digital recorder.

Before carrying out the Primary Validation, it is presumed that data entry checks have already been conducted to ensure that there has been no transcription error from field sheets to the database. Some doubtful values may already have been flagged by the field supervisor. The high degree of spatial and temporal variability of rainfall compared to other climate variables make validation of rainfall more difficult. This is particularly the case on the Indian sub-continent, experiencing a monsoon type of climate involving convective precipitation.

- ❖ Data validation procedure and follow up actions.

This type of validation can be carried out in tabular or graphical form. For both approaches, the values of hourly data are aggregated to daily values to correspond to those observed using a standard rain gauge. A comparison is made between the daily rainfall observed using standard and automatic gauges. Percent discrepancy can be shown by having a second axis on the plot. Tabular output for those days for which the discrepancy is more than 5% can be obtained. A visual inspection of such a tabulated output will ensure screening of all the suspect data with respect to this type of discrepancy.

Example 3-1

Consider the daily totals of hourly rainfall (observed by an autographic rain gauge) and the daily rainfall observed by the standard rain gauge (SRG) at station Askheda of Pargaon catchment. The graphical and tabular comparison of these two data series for the period from 1/9/1996 to 31/10/99 is given in Table 3.1 and Figure 3.1, respectively. It is clear from these graphical and tabular outputs that there has been a marked difference between the reported daily rainfall as observed from a standard rain gauge and that obtained by compiling the hourly values, tabulated from autographic chart, to daily level.

Table 3.1: Comparison of daily rainfall obtained from SRG and ARG at the same

station Aksheda

Year	Month	Day	SRG	ARG	% DIFF
1996	9	1	0	0	0
1996	9	2	0	0	0
1996	9	3	0	0	0
1996	9	4	0	0	0
1996	9	5	0	0	0
1996	9	6	18.7	18.5	-1.069519
1996	9	7	0	0	0
1996	9	8	3.7	4	8.1081081
1996	9	9	0	0.2	0

1996	9	10	0	0	0
1996	9	11	0	0	0
1996	9	12	0	0	0
1996	9	13	5	0	-100
1996	9	14	0	4.8	0
1996	9	15	3.9	0	-100
1996	9	16	3.8	4.8	26.315789
1996	9	17	7.2	3.5	-51.38889
1996	9	18	0	6.9	0
1996	9	19	2	0	-100
1996	9	20	0	2	0
1996	9	21	0	0	0
1996	9	22	0	0	0
1996	9	23	14	0	-100
1996	9	24	13.2	14.8	12.121212
1996	9	25	3.8	13.5	255.26316
1996	9	26	6.8	3.5	-48.52941
1996	9	27	3	7.2	140
1996	9	28	0	3	0
1996	9	29	2.7	0	-100
1996	9	30	0	2.4	0
1996	10	1	0	0	0
1996	10	2	19	18.3	-3.684211
1996	10	3	75.8	0.5	-99.34037
1996	10	4	2.8	1.5	-46.42857
1996	10	5	4	4.5	12.5

1996	10	6	0	0	0
1996	10	7	0	0	0
1996	10	8	0	0	0
1996	10	9	0	0	0
1996	10	10	0	0	0
1996	10	11	0	0	0
1996	10	12	0	0	0
1996	10	13	0	0	0
1996	10	14	0	0	0
1996	10	15	0	0	0
1996	10	16	0	0	0
1996	10	17	0	0	0
1996	10	18	0	0	0
1996	10	19	0	0	0
1996	10	20	2	1.8	-10
1996	10	21	50.3	50.1	-0.397614
1996	10	22	0.7	1.5	114.28571
1996	10	23	70	70.5	0.7142857
1996	10	24	9	8.9	-1.111111
1996	10	25	0	0	0
1996	10	26	0	0	0
1996	10	27	0	0	0
1996	10	28	0	0	0
1996	10	29	6	6	0
1996	10	30	0	0	0
1996	10	31	0	0	0

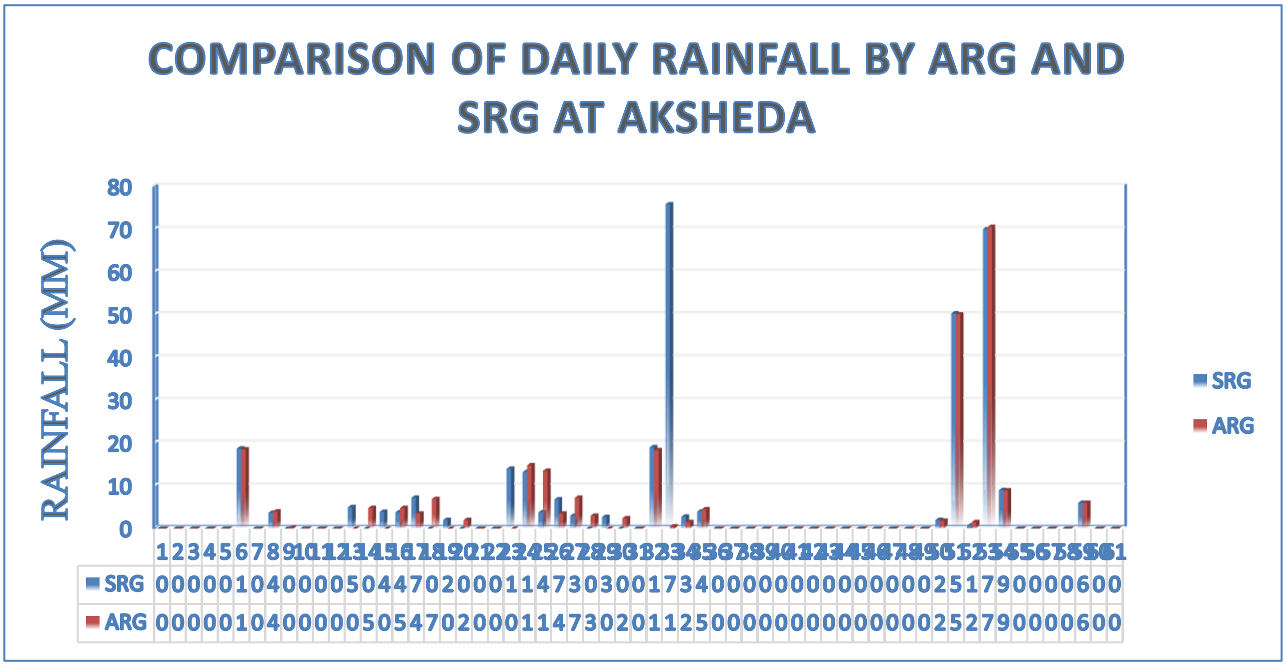
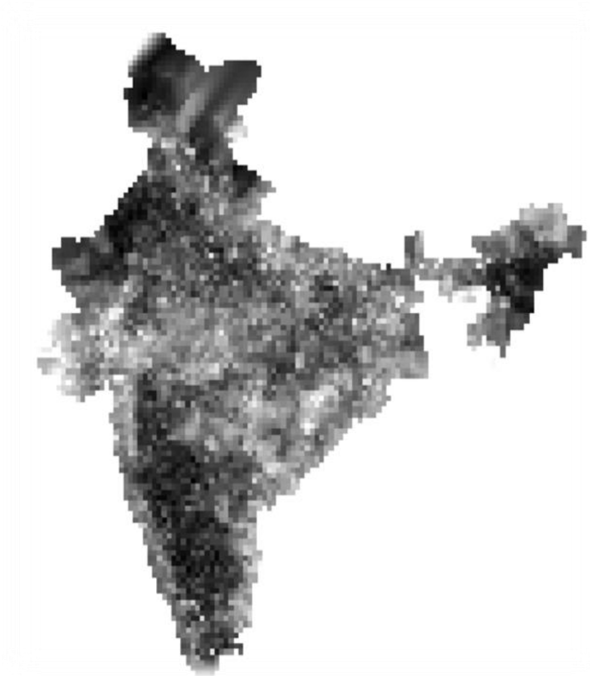


Figure 2: - Fig illustrates Daily Rainfall vs ARG&SRG at Aksheda

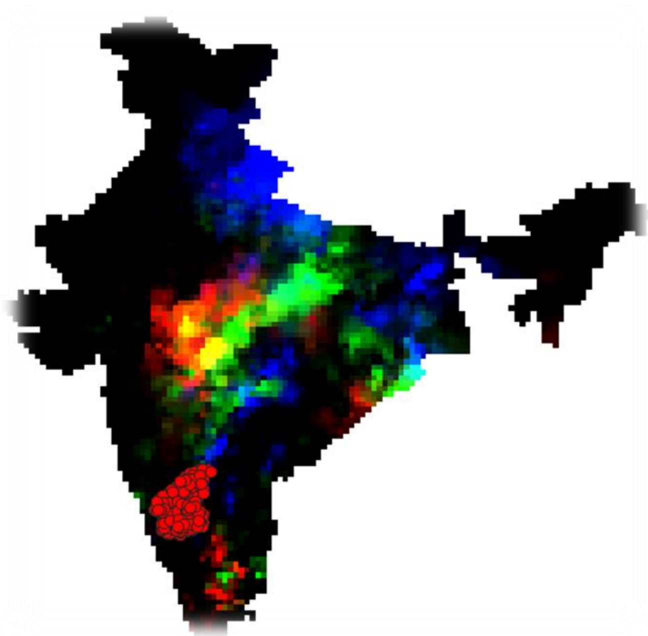
Rainfall is one of the most commonly shared experiences on Earth. When rainfall is long and heavy, it can lead to rapid flooding, which is dangerous for the nearby population. Rainfall is also necessary, since it provides water to plants and ultimately fills rivers. Because rainfall is both a needed resources and a threat, it is important to better understand this natural phenomenon.

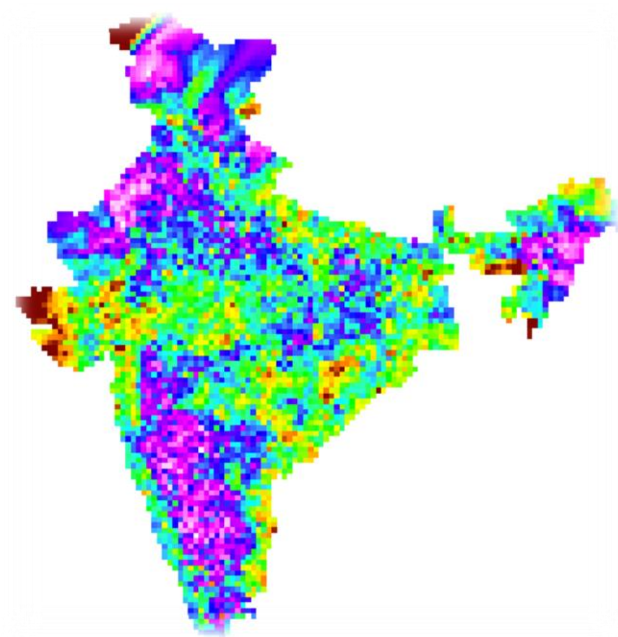
3.2.2 PLOTTING RAINGAUGE FOR TUNGABHADRA REGION USING Q-GIS & ARC-GIS.

- ❖ Figure Showing unrectified and Un geo-referenced file.

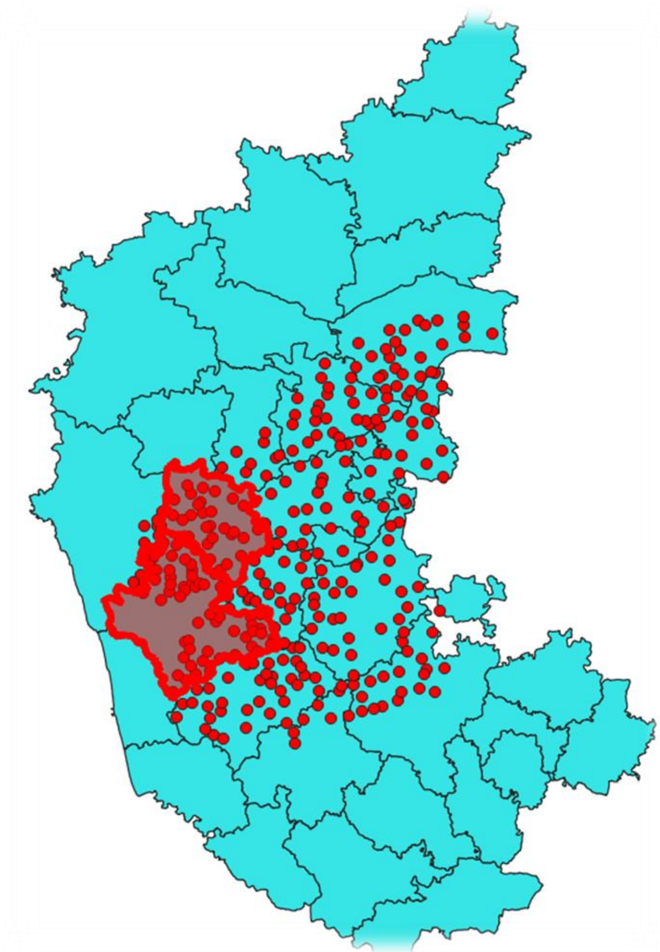


- ❖ This is Geo-referenced with Rainfall of year 2015 data





❖ Rainfall data as point data for our Area of Interest.



❖ Area of interest suggest that Rainfall is maximum as prescribed by the standards as shown in the above images.