Watershed Management Directorate
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Study on Improvement in Hydrological Regime of Mountain Watersheds in UDWDP II (GRAMYA)

External Hydrological Monitoring Consultancy for
Uttarakhand Decentralized Watershed Development Project Phase II

Final Impact Evaluation Report

WAPCOS LIMITED
(A Government of India Undertaking)
Ministry of Jal Shakti
ISO 9001:2015

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A Global Leader in Consultancy and Engineering, Procurement & Construction (EPC) providing Integrated & Customised Solutions for Sustainable Development of Water, Power and Infrastructure Projects

March, 2022

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AMENDMENT RECORD

Version	Date	Author	Reviewed by	Approved by
1.0	06.01.2022	Venugopalan Nair, Investigator	• Sanjay Gupta, Co-Principal Investigator • Dr. Mahendra Singh, Natural Resources Economist • WMD • World Bank	WMD Feedback by World Bank (Dr. S Mudddu)
2.0	28.01.2022	Venugopalan Nair, Investigator	• WMD	Feedback incorporated
2.1	12.03.2022	Venugopalan Nair, Investigator	• Sanjay Gupta, Co-Principal Investigator • Dr. Mahendra Singh, Natural Resources Economist	

CHANGE DESCRIPTION

Affected sections	Page no.	Key changes
Executive summary	3	Paragraph added on impact of structural intervention in the watersheds.
Chapter 6	68-75	Structural intervention data collected up to 31.01.2022 and chapter has been modified with updated data
Conclusions	78	One paragraph in summary added and data portions modified with respect to structural interventions in the watersheds

EXECUTIVE SUMMARY

Under the Gramya II, the Watershed Management Directorate, Government of Uttarakhand has appointed WAPCOS for monitoring the hydrological scenarios in the eight representative Micro-watersheds (MWS) from the Baseline year of 2014 till the Final Impact Assessment year of 2021 due to the structural and non-structural interventions made in the watershed through this project. WAPCOS has studied the hydrological regime of these eight representative micro watersheds and submitted reports during Inception, Baseline, Concurrent Monitoring, Midterm, Annual Impact Evaluation stages of the Project. This Final Impact Evaluation Report gives details of all the impacts on the hydrological regime due to the structural and non-structural interventions made in the watershed. For arriving at the Final Impact Evaluation, a vast amount of hydrological, meteorological, agricultural, and social data sets was collected. These data sets were used to monitor the hydrological regime of the area. The hydrological monitoring study has been conducted in eight micro watersheds which is representative of micro watersheds spreading across eight hilly districts of Uttarakhand. For the purpose of hydrological monitoring, 16 Automated Rain Gauges, 4 Automated Weather Stations, 8 Weirs for stage discharge measurement through currents meters etc. were established in the eight representative MWSs. All the data sets required for the project have been updated up to 30.09.2021. Water budgeting has been attempted using SWAT model. All the water balance components of the SWAT output are estimated as percentage of precipitation to compare the outcome between watersheds and between different periods of the project such as Baseline to Final Impact Evaluation stage.

The SWAT output has been validated with observed discharge to compare yield obtained out of model to that of measured values. The results show an average difference of 2.4 mm, which is meager and hence the model is considered to be valid. Moreover evapo-transpiration from agricultural land use is compared with that of model and shows a percentage difference of 12%. Hence the model output is acceptable for further processing.

Almost all watersheds show reduction in surface flow which is about 7.1%. All the watersheds show improvement in lateral flow to an average of 0.9% which shows the impact of structural intervention in the watersheds through conservation structures. All the watersheds show improvement in aquifer recharge with an average value of 9%. Also, watersheds show improvement in base flow of stream with an average value of 8.4%. Overall yield of the micro-watersheds increased to 5.1% which is 9.7 million cubic meters with reference to base line period.

Water need assessment has been made for domestic, livestock and crop water requirement. The analysis shows that all watersheds are water surplus and much more water is available than the requirement. The current requirement is only a minor portion of the availability and conservation measures in the upstream are not affecting the downstream flow of the

watersheds.

Time series analysis of land use land cover shows that there is an average increase of 5.1% of agriculture, 0.37% of forest cover and 1.77% decrease in land with or without scrub. All the watersheds are showing decrease in sediment yield. The reduction is in the ranges of 12 to 33% and average reduction is 19% which is amounting to 13.9 ton/ha/year. Water source discharges of 2054 sources were monitored from base line to Final Impact Evaluation period. Pre- monsoon discharges have shown an increment of about 13.33 to 25% with respect to the base line period of 2014 and post monsoon shown an increase of 13.79 to 33.74%.

There are several structural interventions made in the watersheds to conserve, harvest, distribute and augment the water resources. These structural interventions have brought out 0.43 million cubic meters of water holding capacities within the 8 representative micro watersheds. The capacity generated for the 82 micro watersheds are same for all the watersheds as 1.15 million cubic meters. An area of 2732 ha of land has been converted from rainfed to irrigated agriculture due to these structural interventions in the 8 representative micro watersheds. For all the 82 micro watersheds the land brought under irrigation through these activities is 5647 ha.

Water applied to crops by farmers was compared with crop water requirement estimated through norms and found that farmers are applying slightly less amount of water. For this study water applied by farmers was measured on field for wheat and rice crops and measurement through irrigation tanks for the crop of tomato. Water use efficiency studies show that through sprinkler irrigation 18.8% water can be saved. Case study of Dhaspad village shows that water conservation and water security can bring in about 62% more production. Hydrological interventions studies show that about 3,60,000 cum of water storage and conservation measures have been achieved through this project. Also 2,158 ha of land is converted from rainfed to irrigated status through these interventions.

CHAPTER 1: BACKGROUND TO FINAL IMPACT EVALUATION REPORT

1.1 Introduction

The Government of Uttarakhand has implemented the second phase of Uttarakhand Decentralized Watershed Development Project called Gramya-II in eighty two micro watersheds identified for the purpose. The project area is spread over 2,63,837 ha in 82 MWS belonging to 509 Gram Panchayat in 18 Developmental Blocks, of 8 hilly districts in Uttarakhand. The project is likely to benefit 55,605 households with a population of about 3,00,553. The project is envisaged to bring benefits into the life of 1066 revenue villages with a population of about 0.3 million. The selected micro watersheds are shown in Fig.1.1 and details are given in Table 1.1.

One of the key objectives of the project was to increase the efficiency of natural resource use and productivity of rainfed agriculture by the communities. The second component of the project was watershed treatment and rainfed area development. Water is key resource to deal with any of the watershed development project. In this regard, WAPCOS has been entrusted with hydrological monitoring for the eight representative micro watersheds selected for the purpose to evaluate the impact of watershed treatment on this dynamic resource and its influence on the communities residing there. Hydrological monitoring is a tool to monitor the sustainability of watershed treatment at micro watersheds.

Table 1.1 Details of Gram Panchayat in 8 representative MWS

S. No.	Milestones	Time of submission	Status
1	Inception Report	2014	Completed and accepted
2	Base Line Report	2014-2015	Completed and accepted
3	Concurrent Monitoring Report	2017-2018	Completed and accepted
4	Mid Term Report	2018-2019	Completed and accepted
5	Annual Impact Evaluation Report	2019-2020	Completed and accepted
6	Final Impact Evaluation Report	2021-2022	Completed

1.1 Summary of Base line studies

During base line data collection the following activities were completed by WAPCOS.

- Preparation of drainage maps of the 8 representative micro watersheds
- Preparation of land use land cover map of the micro watersheds
- Collection of soil map of the micro watersheds
- Established baseline discharge of the water sources
- Established 4 automated weather stations and 10 automatic rain gauge stations
- Completed a socio-economic survey
- Collected digital elevation models of the area
- Established SWAT as a model for the water balance studies
- Conducted water balance study for the representative micro watersheds
- Submitted base line reports for 8 representative micro watersheds

The social aspects covered are summarized below

Aspects	Dewangad	Lathiyagad	Loharkhet	Paligad	Saintoligad	Sarugad	Sindhiyagad	Uttarsu
Land Ownership	93% Male	84% Male	84% Male	75% Male	83% Male	95% Male	92% male	71% Male
Level of education	91% +2 & above	89% +2 & above	95% +2 & above	95% +2 & above	96% +2 & above	91% +2 & above	96% +2 & above	95%+2 above
Dominant age group	36-50	36-50	36-50	36-50	36-50	36-50	36-50	36-50
Livestock	31 % cow 4 % buffaloes 60 % goat	48 % cow 13% buffaloes 40 % goat	46 % cow 9% buffaloes 44 % goat	70% cow 16% buffaloes 14% goat	67% cow 3% buffaloes 23% goat	80% cow 2% buffaloes	70% cow 17% buffaloes 17% goat	43% cow 26% buffaloes 32%goat
Type of house	74%	50%	36%	10%	30%	18%	68%	12%

	concrete	concrete	concrete	concrete	concrete	concrete	concrete	concrete
Electrification	98%	99%	99%	97%	93%	94%	98%	92%
No of cattlesheds	169	205	203	202	206	206	200	214
Access to potable water	100%	96%	90.64%	96%	99.03%	98%	80%	99.50%
Access to irrigation	30%	20%	11%	20%	20%	20%	11%	10%
No of water sources	34	85	15	60	14	8	25	43
Water requirement (cum per year)	419906	63538.46	271544.3	437907.5	129223.14	134628.4	86398	76308
Agriculture	Rice, Wheat, Potato, Maize, Cabbage, Urad, Peas, mustard	Rice, Finger Millet, Wheat, Maize and Soybean	Rice, Wheat, Millet, and Potato	Rice, Millet, & Wheat	Rice, Wheat & Millet. Urad, Barley Potato Soybean, Mustard	Rice, Wheat Millet, Urad, Potato Soybean Mustard	Rice, millet, Amaranthus, Wheat, Barley, Mustard, Lentil.	Rice, Wheat, Millet Maize, Jhangora Peas, Barley Beans, and Potato
Cropping intensity (%)	183	133	117.11	113.89	127.46	115.58	151	129.29

Land use land cover

LULC	Dewangad	Lathiyagad	Loharkhet	Paligad	Saintoligad	Sarugad	Sindhiyagad	Uttarsu
Forest (%)	25.9	54.46	58.53	60.93	16.6	74.87	22.13	35.85
Agriculture (%)	6.5	13.79	5.99	11.4	22.91	8.43	23.13	25.4
Land with or without scrub (%)	64.46	29.07	32.42	23.94	55.06	14.89	48.87	32
Built up (%)	0.23	0.39	0.11	0.1	0.53	0.1	0.21	0.47
Water (%)	2.34	1.79	2.83	3.46	3.88	1.44	5.28	5.72
Road (%)	0.56	0.49	0.12	0.17	1.01	0.27	0.36	0.56

Summary of water balance studies

Component	Dewangad	Lathiyagad	Loharkhet	Paligad	Saintoligad	Sarugad	Sindhiyagad	Uttarsu
Surface runoff (%)	23.01	35.79	23.86	30.56	17.94	14.45	29	25.48
Lateral flow (%)	10.1	4.78	19.13	7.01	7.23	15.28	8	8.05
Return flow (%)	23	8.18	18.05	8.88	15.96	17.74	15	17.28
Aquifer recharge (%)	25.99	10.93	20.72	11.89	20.5	21.03	18	19.86
ET (%)	41.46	47.6	40.74	52.04	56.55	50.41	47	48.62
Sediment Yield (ton/ha)	23	22	354	195	27	11	47.37	73
Water yield (%)	56.12	48.76	56.58	46.46	41.14	47.47	52	50.83

Water requirement verses availability

Component	Dewangad	Lathiyagad	Loharkhet	Paligad	Saintoligad	Sarugad	Sindhiyagad	Uttarsu
Surface runoff (%)	23.01	35.79	23.86	30.56	17.94	14.45	29	25.48
Lateral flow (%)	10.1	4.78	19.13	7.01	7.23	15.28	8	8.05

1.2 Summary of midterm report

Water conservation interventions

Recharge pits: About 6700 recharge pits are constructed in the 8 representative micro watersheds. This has created a capacity of 22,000 Cum of water. With the assumption of 30 repetitive minimum fillings, it is estimated to conserve 0.67 million cum of water from these watersheds. So, it is estimated that 3.08 million cum of water will be conserved per year through 31,122 recharge pits in 82 micro watersheds.

Contour trenches: About 120,500 contour trenches are constructed in the 8-representative watershed with the aim to conserve considerable amount of water. This has created a capacity of 94,000 cum of water. Considering 30 repetitive filling a volume of 2.8 million cum of water per year can be conserved. Holistically 9.2 million cum of water is conserving in 82 such watersheds with the help of 410,912 contour trenches.

Shallow dugout ponds/Chal khal: about 1900 such structures are developed in the pilot micro watersheds with a capacity of 17,000 cum of water. The yearly water conserving capacity

1.5 million cum. For 82 such micro watersheds about 1.68 million cum of water is conserving through 6247 such ponds.

Water harvesting interventions

Irrigation tanks: 237 irrigation tanks were established in the pilot micro watersheds and through which water is harvested from perennial sources. A capacity of 2700 cum of water is developed to cater the irrigation need of about 190 ha of land. Holistically 1012 irrigation tanks were established in the 82 micro watersheds 810 ha of land is getting irrigated by this method.

Roof top rainwater harvesting: About 1900 roof top rainwater harvesting structures are made available to the community through gram panchayats in 8 pilot micro watersheds. About 4145 cum of water harvesting capacity is developed in this way. With repetitive filling 0.12 million cum of water is harvesting in 8 representative micro watersheds per year. 0.58 million cum of water is harvested throughout 82 micro watersheds through 7826. This water is used for domestic purpose and additionally 38 ha of land is irrigating through this method in 8 micro watersheds and about 156 ha all together in 82 micro watersheds.

LDP tank: 86 LDP tanks have been established in 8 representative micro watersheds to develop a capacity of 1720 cum of water for irrigating about 86 ha of land. In 82 micro watersheds as a whole have 301 ha of land irrigated through this method by using 301 LDP tanks.

Village ponds: Some of the already existing village ponds which were dysfunctional were brought into use after necessary renovation to cater the needs of irrigation, domestic use and usage for livestock. 78 ha of land is irrigated through this method.

Water source augmentation interventions

Spring augmentation: With the help of water conservation practices some of the major springs available in the micro watersheds were augmented to put in use for the community. Discharge of about 1485 water sources were monitored for 4 years for pre-monsoon and post monsoon discharges. Pre-monsoon discharge has increased to a range of 13.8% to 22.2%. The percentage increment in post monsoon period is ranging from 13.8% to 27.8%. This water is used by the community for domestic, livestock and water for people passing through the difficult hilly terrain along with filling the irrigation tanks and other water storage facilities in the area.

Water distribution interventions

Irrigation pipes: Water from the source point to fields was fetched by installing 35 km of irrigation pipes in 8 micro watersheds under study. Using this water 141 ha of rainfed land is brought under irrigation. Similarly 204 km of pipe lines were laid down at 82 micro watersheds and 816 ha of land

has been brought under irrigation in all the micro watersheds.

Irrigation channels: Water from the source point to fields was also brought by installing 34 km of irrigation channels in 8 micro watersheds under study. Using this water 205 ha of rainfed land is brought under irrigation. Similarly 1044 ha of land has been brought under irrigation throughout 82 micro watersheds by constructing 174 km of irrigation channel.

Summary of interventions					
	8 Pilot micro watersheds		**82 micro watersheds**		
Sl.No.	**Intervention**	**Structure**	**Output/year**	**Structure**	**Output/year**
	Water conservation interventions				
1	Recharge pits	6750	0.67 cum	31122	3.08 million cum
2	Contour trenches	120500	2.8 million cum	410912	9.2 million cum
3	Shallow dugout ponds	1897	0.5 million cum	6257	1.68 million water
	Water harvesting interventions				
4	Irrigation tanks	237	190 ha	1012	810 ha
5	LDP tanks	86	86 ha	301	301 ha
6	Village ponds	78	78ha	78	78ha
7	Roof top RWH structures	1918	0.124 million cum 38 ha	7826	0.58 million cum 156 ha
	Water Augmentation				
8	Source augmentation (pre-monsoon	159	15 to 22.7%	1485	13.8 to 22.2%
	Source augmentation (post monsoon)		17 to 29%		13.8 to 27.8%
	Water distribution interventions				
9	Irrigation pipes (km)	35	141 ha	201	816 ha
10	Irrigation channel (km)	34	205 ha	174	1044 ha

Total water conserved	13.96 million cum
Total water harvested through roof top RHS	0.58 million cum
Total land converted from rain fed to irrigated	3205 ha
Increase in discharge of water sources (lpm) Pre-monsoon	13.8 to 22.2%
Increase in discharge of water sources (lpm) Post monsoon	13.8 to 27.8%

Impacts and benefit of recharge through hydrological structures

- Increased soil moisture
- Root zone water availability for forestation, fodder crops, cash crop and other horticultural activities
- Replenish water sources downstream.
- Arresting the sheet flows by reducing soil erosion
- Act as a nutrient trap.
- Water made available for irrigation near to the community so that woman folk can work in the field easily.
- More water means more agriculture and more income to the community and thereby livelihood improvement.
- Pattern of agriculture changes from self-sustaining to commercial with the availability of more water.
- Roof top rainwater has reduced efforts of the women to fetch water for domestic purpose.
- Some of the barren land converted to crop land

The interventions in the micro watersheds are showing their effects on land use land cover. The results are not so discernible through satellite image interpretation. Most of the intervention programs are in initial stage and some gestation time is required to reflect holistically in the catchment. However marginal increment in agriculture and forest cover and reduction in land with or without scrubs are evidenced in satellite images. 37 ha of agricultural land and 9 ha of additional forest land is noticed in the area. 27 ha of land with or without scrub is also converted to agricultural land. Most of the interventions are for conversion of rainfed areas into irrigated land, it is not reflected in satellite image as these areas are already fallow land and interpreted as agricultural land. More discernible results expected towards end of the project.

Water budgeting has been attempted in this study. The data sets used are GIS layers, such as land use land cover, soil, dem, study and boundary, drainage, slope maps etc. Weather data used in the study include rainfall, average minimum and maximum temperature, humidity, solar radiance and wind velocity. GIS based SWAT model has been used for the water budgeting of micro watersheds. In this model driven approach all the spatial layers and data sets have been prepared in a GIS environment and model is run in the same platform to get the output.

The results of water budgeting studies indicate that average yield of the 8-micro watershed during base line period was 42.4 million cum whereas during midterm it increased to 44.18. The difference of about 1.78 m cum is an average again for the watersheds which is contributing towards moisture retention. Almost all watersheds show reduction in surface runoff. More than 60% of the watersheds show increase in lateral flows. Wherever reduction in lateral flow is noticed, it is marginal only to a range of 0.3 to 0.4%. 75% of the watersheds are showing increase in aquifer recharge which directly contribute to water sources as well as soil moisture. It is an indicative

that conservation, harvesting and augmentation in the catchment area and largely helping percolating of water to subsurface routes. 75% of the watersheds show increase in ET which shows marked increase in bio mass. This may be due to efficient use of water in agricultural activities such as mulching, drip and sprinkler irrigation, and overall land and water management.

Average sediment yield of the representative micro watersheds was 71.6 ton per ha per year and this has reduced to 69.3 ton per ha per year. Holistically 17% reduction in sediment load is happening in the watersheds.

Curve numbers derived for the micro watershed indicates that Sarugad and Lathiyagad have more infiltration capacity than rest of the micro watersheds. Runoff coefficients for all watersheds were also established in the study.

Agricultural Activity and Crop Production

The hill farmers in Uttarakhand mainly practiced subsistence agriculture due to the diverse agro-climatic conditions until the interventions made by Gramya. With extensive hydrological interventions made by Gramya II and distribution of HYV (High Yield Variety) of seeds by its partner organizations, there is turnaround in the overall agricultural practices. Most of the farmers in these MWS have started producing cash crops (High Yield crops) that give higher yields in smaller land portions. These are mostly high yield vegetative crops like Green Peas, French Beans, Capsicum, Cauliflower, Cabbage, Radish, Tomato, Brinjal, besides the highly productive Potato, Onion, Turmeric, Ginger and Garlic. Due to holistic approach of hydraulic interventions and irrigation techniques, farmers have adopted crop rotation thereby increasing the Gross Cropped Area and the Cropping Intensity.

The Gross Cropped Area of the 8 Representative Micro Water sheds is around 11,350 ha. For 82 Micro Watersheds the Gross Cropped Area is estimated to be 11,6337.5 ha.

Cropping Intensity

MWS	Dewangad	Lathiyagad	Loharkhet	Paligad	Saintoligad	Sarugad	Sindhiyagad	Uttarsu
Mid Term - Cropping Intensity (%)	198.44	167.71	140.01	143.86	152.42	140.94	174.99	151.62

There has been increment in Cropping Intensity in the MWSs as the gross cropped area has increased and the sample farmers are able to grow diverse crops through rotation.

Barren land Turn Around: -Major initiatives have been made by Gramya-2 across the MWSs to convert parts of barren lands into horticulture, agriculture, forest areas or also to develop fodder crops or Napier.

An estimated 1039 ha area of previously barren land has been converted in the 8 representative Micro Watersheds and 10,650 ha is estimated to be converted in the 82 Micro Watersheds.

Densification of Forests: -An estimated 287 ha of land has been covered under densification in the 8 MWS and 2942 ha in the entire 82 MWS.

Homestead land (Gharbadi): -An estimated 441 ha has been developed in the 8 representative MWS (approximately 0.8% of the total area of 8 MWS) and an estimated 4523 ha in the entire 82 MWS.

Rural Infrastructure: -For efficient transportation and mobility of villagers and livestock, 105 numbers of small bridges or culverts have been constructed and 92 km of village roads have been paved in the 8 representative MWS.

For 82 MWS, the estimated numbers of small bridges or culverts and village roads constructed and paved are 1076 and 943 respectively.

1.3 Summary of Final Assessment Findings

Instrumental weather data have been collected, analyzed and prepared a gap free daily weather data set for rainfall, minimum temperature, maximum temperature, humidity, wind velocity and sun shine hours for the reporting period.

Land use land cover maps have been prepared with the help of 2019-20 images. A comparison indicates an average 5% increase in agricultural land, 0.3% increase in forest and 1.3% reduction in land with or without scrubs in the watersheds with respect to baseline period. There is no marked difference in land use changes when comparing with the midterm period.

Water budgeting analysis shows that overall surface runoff has increased 1.5%, lateral flow decreased 0.7%, evapotranspiration decreased 4.3%, yield increased 4.9%, aquifer recharge increased 3.3%, storage increased 0.5% with respect to baseline period. Sediment yield situation remains the same.

Evapotranspiration has been evaluated for agricultural land use separately through model as well as using empirical formula. The deviations in both methods found to be within the range of 0.21 to 0.38 with an average of 18%. Previous deviation was 21%.

Livestock population and agricultural data for the current year evaluated for water requirement and overall requirements estimated for each watershed, when compared with yield of the watersheds, it is found that all of the watersheds are water surplus.

Hydrological interventions executed were monitored for 8 representative micro watersheds. Total capacity developed so far is 219.825 cum and area brought under irrigation through this process is 1085 ha.

Source water monitoring indicates a range of 12.29% to 22.22% increase in discharge during pre-monsoon and 13.47 to 27.4% increase in discharges during post monsoon periods for the 8 representative micro watersheds.

Stage discharge measurements were done at Paligad and Sindhiyagad micro watersheds. The daily discharge was cumulated for monthly discharges and compared with model output. The deviation of the model values with respect to measured values are -2% to 32%

Summary of Project Indicators

PDO Level Results Indicators	Unit of Measurements	Baseline	Midterm	Final Assessment
Direct indicators				
1: Increase in water discharge				
Pre monsoon	%	0	13.8 -22.2%	12.29-22.22%
Post monsoon	%	0	13.8 - 27.8%	13.47-27.4%
2. Increase in biomass	%	27.69 ton/ha	29.72 ton/ha , Increment 7.35 %	33.55 ton/ha, increment 21.2%
3: Increase of rainfed area under irrigation	ha	5262	8467	10,621 (5,359 ha increase over baseline)
4: Increase in productivity in irrigated and rainfed crops	%	0	Irrigated 37.2%, rain fed 27.2%	Irrigated 60.0%, rain fed 33.1 %
Intermediate indicators				
(i): Hydrological monitoring systems fully installed and functional in sample MWS	No	0	All installed systems are in working condition	All installed weather Stations are in working condition
(ii) Targeted traditional natural water sources rejuvenated	No	0	1530 in 82 MWS out of which 1485 rejuvenated	2054 in 82 MWS out of which 2034 rejuvenated
(iii): Natural resource conservation techniques adopted in the targeted areas		Nil	Recharge pits, contour trenches, dug out ponds, Gabion structures, Rainwater harvesting structures, Afforestation	Recharge pits, contour trenches, dug out ponds, Gabion structures, Rainwater harvesting structures, Afforestation

1.4 Scope of work for the Final Impact Evaluation Report

Following are the scope of work for the final impact Evaluation report

- Updating of the weather data
- Collection of stage discharge data and its analysis
- Preparation of land use land cover mapping using latest satellite images
- Running of SWAT model for 8 representative micro watersheds and establish water balance
- Establishment of model output for small watershed which cater to weir sites where stage discharge measurements were established
- Calibration and validation of SWAT results
- Time series analysis of land use and water balance components
- Summarization of watershed interventions for conservation, augmentation and distribution of water resources
- Final impact evaluation of watershed intervention in the hydrologic regime of the watersheds.

CHAPTER 2: DATA COLLECTION

2.1 Introduction

Any kind of hydrological monitoring involves collection of vast amount of hydro meteorological and other data sets. Here, more data means more accuracy. Both primary data sets and secondary data sets are required for the study. Hydrological monitoring involved study of dynamics of the water resources within the micro watersheds. This dynamicity is established through various modeling as well as other statistical analysis. For these activities a set of hydrological as well as meteorological data sets along with thematic data sets are required. Following primary and secondary data have been used for the present final impact evaluation studies.

Primary data

- Weather data
  - Rainfall
  - Humidity
  - Wind velocity
  - Sun shine hours
  - Maximum and minimum temperature
- Stage discharge data
- Structural interventions
- Source discharge
- Crop data
- Water application by farmers

Secondary data

- Historic weather data
  - Rainfall
  - Humidity
  - Wind velocity
  - Sun shine hours
  - Maximum and minimum temperature
- Satellite images
- Digital Elevation Models
- Soil data

2.2 Weather data

Weather parameters are important data sets for any of the hydrological monitoring projects. In order to collect the accurate weather parameters WAPCOS has established several weather stations across the micro watersheds. Four number of Automated Weather Stations (AWS) and 16 Automated Rain Gauges (ARG) are installed across 8 representative micro watersheds. The data sets derived from the weather stations are

- Rainfall

- Maximum and minimum temperature
- Humidity
- Wind velocity and
- Sun shine hours

Historic weather data are also collected and clubbed with the currently observed data to prepare a seamless data set from 01.01.2008 to 30.09.2021. The weather data sets for the individual micro watersheds are given in Annexure 2.2.1. The annexure is incorporated in the form of an .xls files along with the report. The plots of the data have been arranged in map plate no. 2.2.1

Weather data play an important role in SWAT modeling as well as computation of potential evapo transpiration through CROPWAT. The weather data obtained from instruments were analyzed and treated statistically to remove the noise data and computed for daily data sets. Some of the data gaps have been ascertained to the mal-function or nonfunctioning of the stations and the same were rectified using adjacent station data. A test homogeneity performed over the data and inter data and inter watershed correlations were established to pick up any abnormality in data and to ensure that the collected data were homogenous enough to use in various models and analysis.

2.2.1 Rainfall

Daily rainfall data from January 1, 2008 to September 30, 2021 were compiled. Data charts for the representative micro watersheds are given in map plates. Average annual rainfall, number of rainy days, daily maximum rainfall of the year etc are tabulated for all 8 representative micro watersheds and is given in Table 2.1

Table 2.1 Rainfall details of 8 representative micro watersheds.

MWS	District	Average annual rainfall	Average annual rainy days	Maximum rainfall (mm)
Dewangad	Dehradun	1569	145	138.2
Lathiyagad	Pithoragarh	1149	132	97.6
Loharkhet	Bageshwar	1833	174	138.56
Paligad	Tehri	1374	151	247.3
Saintoligad	Pauri	1077	127	167.7
Sarugad	Uttarkashi	1197	213	78.69
Sindhiyagad	Almora	1744	170	70.48
Uttarsu	Rudraprayag	1462	131	138.2

Fig.2.1 to 2.3 shows micro watershed wise annual average rainfall, number of rainy days and maximum rain on a single day event across the evaluation period of January 1, 2008 to September 30, 2021

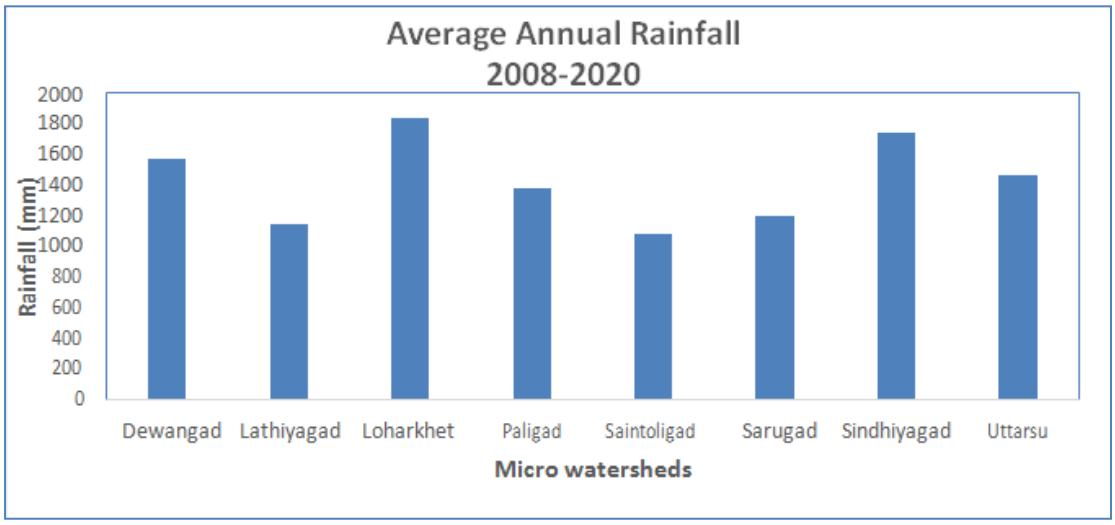


Fig.2.1 Average annual rainfall (2008 to 2020) across micro watershed

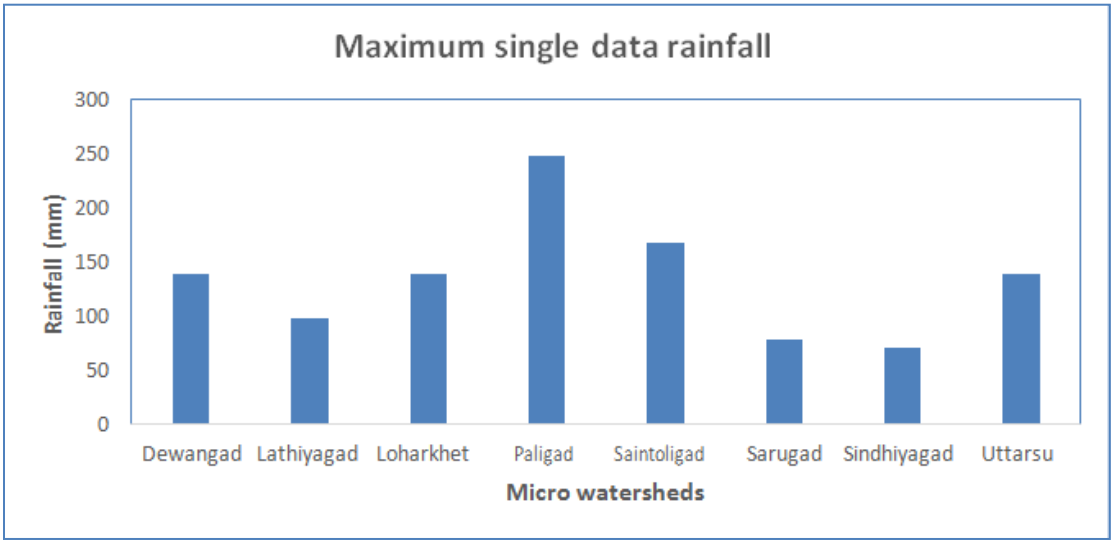


Fig.2.2 Maximum single day rainfall event

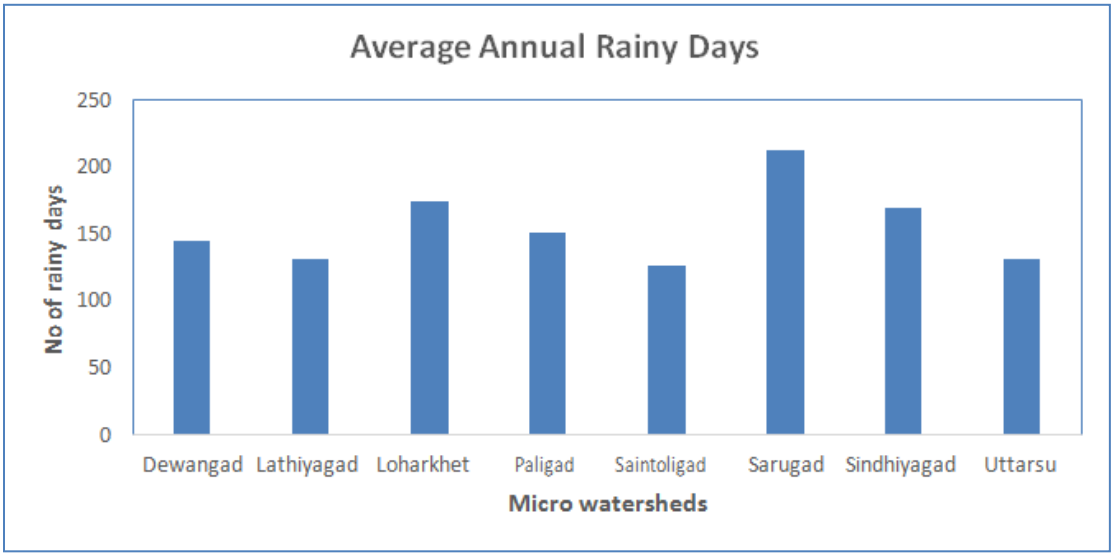


Fig.2.3 Number of rainy days

2.2.2 Maximum and minimum temperature

Daily temperature variations from January 1, 2008 to September 30, 2021 were monitored and maximum and minimum temperature were recorded. These are two important weather parameters required in the hydrological models and have great influence on other weather parameters such as humidity, solar irradiance etc. These recordings were made for all 8 representative micro watersheds through available weather stations established in the area for this purpose.

2.2.3 Humidity

Humidity is an important weather parameter in SWAT hydrological model. Humidity data have been collected for all representative micro watersheds as relative humidity as a decimal fraction. Humidity greatly influences the evapotranspiration, so these data have been used both in running models as well as estimating evapotranspiration.

2.2.4 Solar Irradiance

Solar irradiance data are derived from collected sun shine hours of 2008 to September 2021 using modified Angstrom-Prescot formula based on research in Nepal Himalayan region. These data are important input for the SWAT model. The conversion formula is given below.

Solar irradiance in mj/m2/day = 31.86 x (0.21+0.25 x (n/N))

where n is sun shine hours and N is duration of day. The average duration of the day is taken as 12 hours

2.2.5 Wind Velocity

Wind velocity is another weather parameter which is essential for running SWAT model. Daily average wind velocity is measured in meters per second and used in the model. Wind velocity also affects other weather parameters as well as hydrological process.

2.2.6 Overall climate

The State of Uttarakhand lies in the southern slope of Himalayan ranges. Climate varies from sub-tropical forest at the foot hills to glaciers at the northern portion of the State. The analysis of the data shows that 80% of the rainfall is received during the monsoon. The observed rainfall of the region shows slight increase in amount as compared to historical data. The reason for the same may be the location of measurement. In the present study rain gauges were established in the required micro watersheds itself whereas historic data is an average of the districts where the micro watersheds exist. Other weather parameters are not showing marked difference in trend.

2.3 Land use land cover mapping

A detailed land use land cover data has been prepared for all 8 representative micro watersheds. The land use land cover maps were updated using latest procured satellite image of 2020-2021. Following criteria have been maintained for the creation of land use land cover maps. This has facilitated land

use classes comparison on a time series analysis. Only key land use classes which are having impact on hydrological regime have been considered for the analysis. These are agriculture, forest and land area with or without scrubs.

Following considerations have been made while mapping the land use land cover.

- Land use land cover schema adopted during baseline and midterm reporting has been maintained.
- Agriculture, Settlements, Transportation network in the form of roads, forests, land with or without scrubs and water are the main classes of the schema.
- Land use detailing is up to level 1
- Schema has selected for the purpose of running SWAT model.
- In the model corresponding SWAT classes have been selected.

The procured images were geo-referenced and made spatially correct with respect to previous images for spatial accuracy. Once the images were geo-referenced, enhancement techniques were run on the image to bring more clarity to the images. Later these images were interpreted for various land use land cover classes. Detailed land use maps are given in Map Plate no. 2.3.1 for all representative micro watersheds. The image procurement dates are given in table below for all 8 representative micro watersheds. The land use area plots are given in Map Plate No. 2.3.2. Area statistics are given in Annexure 2.3.1

Table 2.2 Satellite image procurement dates for 8 representative micro watersheds

MWS	District	Image procurement date
Dewangad	Dehradun	12/26/2020
Lathiyagad	Pithoragarh	4/28/2021
Loharkhet	Bageshwar	11/22/2020
Paligad	Tehri	4/11/2021
Saintoligad	Pauri	11/30/2020
Sarugad	Uttarkashi	9/27/2021
Sindhiyagad	Almora	4/11/2021
Uttarsu	Rudraprayag	12/7/2020

2.4 Stage discharge data

Stage discharge data is an important part for the hydrological monitoring of the watershed dynamics. In the present study WAPCOS has established one weir in each representative micro watershed to for the stage discharge measurement. The following considerations were made while selecting the sites for stage discharge measurement.

- It should encompass a catchment of representative land use of the micro watershed
- Away from big boulders and other flow diversions

- Entire water to be flown through the channel and no take away from the channel for any purpose
- Site needs to be with near laminar flows
- Site to be accessible at all weather conditions
- It should be large enough to make measurements and small enough to do the weir construction
- There should be no objection from local authorities

Location details of the selected sites are given in Table 2.4. The site selection reports are given in Annexure 2.4.1. The photographs of the constructed weirs are given in Map Plate no.2.4.1. The stage discharge data have been tabulated in Annexure 2.4.2. The collected data have been used for the verification of modeled results of the project. In the model the data have been used for calibration as well as validation of the data.

Table 2.3 Weir locations at eight representative micro watersheds

Sl No.	District	MWS	GP	RV	Latitude	Longitudes
	Dehradun	Devangad	Mona	Khoya Channi	30.70997364°	77.88028827°
2	Pithouragarh	lathiyagad	Baltir	Baltir	29.81416667°	80.13833333°
3	Bageshwar	Loharkhet	Suding	Suding	30.03321947°	79.95508897°
4	Tehri	Paligad	Tewa	Tewa	30.542509°	78.176003°
5	Pauri	Saintoligad	Kandai	Ghandoli	29.90580573°	78.83235587°
6	Uttarkashi	Sarugad	Dhobalg	Kaflikhan	30.9786995°	78.07507918°
7	Almora	Sindhiyagad	Chandun	Sindhiyakhet	29.521339°	79.937274°
8	Rudraprayag	Uttarsu	Samkoti	Koti	29.521339°	79.937274°

2.4.1 Training of stage discharge measurement

Once the weirs for stage discharge measurements were completed in each watershed, a training was conducted on 6 of the micro watersheds. Training was imparted on discharge measurement using current meters. Minimum 5 team members of the project staff and community members area were trained to do the hydrological monitoring through field measurements. Training was imparted on theoretical as well as practical aspects. This training was conducted on field with actual measurements.

2.4.2 Data processing

The stage discharge data have been collected by trained project staff using current meters. The data were obtained on a daily basis and transferred to lab for further processing and estimations. The estimations were done by using Area Velocity method which is commonly employed for stage discharge measurements. A sample measured data for Sindhiyagad micro watershed has been plotted below.

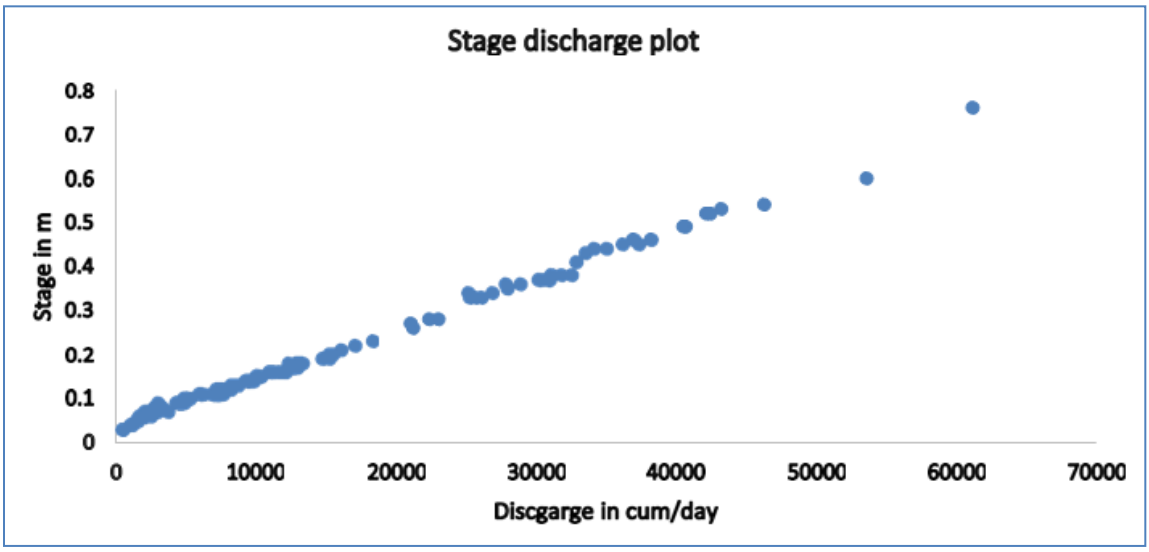


Fig.2.4 Stage discharge data of Sindhiyagad micro watersheds

2.5 Structural intervention

In order to ensure water security and livelihood improvement for the people of the watersheds, a number of structural interventions have been made in the watersheds. These interventions are for water conservation, water augmentation, water harvesting and water distribution. The list of structural interventions made in the project are listed below. The details of the structural interventions made in each watershed along with capacities generated are given in Final Impact Evaluation chapter.

- Water harvesting interventions
  - Irrigation tanks
  - LDP tanks
  - Roof top rainwater harvesting
  - Village ponds
- Water conservation interventions
  - Recharge pits
  - Contour trenches
  - Dugout ponds
  - Village ponds
- Water augmentation interventions
  - Spring augmentation
- Water distribution interventions
  - Irrigation channels
  - Irrigation pipes

2.6 Source discharge

As part of the hydrological monitoring 159 sources spanning across 8 representative micro watersheds are monitored to know the dynamics of the source discharge. The details are given in

chapter 4. The project team also collected source discharge data for 1485 discharge sources to know the discharge variations from base line period to final evaluation period.

2.7 Crop data

Crop data are essential for the determination of overall water requirement of the micro watersheds. The purpose is to estimate the crop water requirement. Crop information regarding the type of crop and acreage in which it is sown are collected for eight representative micro watersheds. The details of the data are shown in Chapter 3.

2.8 Water application by farmers

The data related to water applied by farmers for selected crops in few micro watersheds were also collected during the hydrological monitoring. The purpose of these data was to compare, the crop water requirement estimated by norms and how on field farmers are applying and also to establish water saving if any in the micro watersheds.

CHAPTER 3: WATER BUDGETING

3.1 Introduction

The necessity of hydrological monitoring in watershed projects arises out of need of quantification of the water, a key resource for development, which is highly dynamic in nature. The quantification of water resource can be achieved through water budgeting activities. Watershed is a closed system with a single outlet and is considered as a unit to tackle the measurement of water within it. Like any other budgeting process there are several and input and different kinds of output from the system. The basic principle involved in water budgeting is

Input – Output =+/- Storage

Input in hydrological context is precipitation in the form of rainfall. Snow fall and snow melt which may be a small portion is not considered in the present study as measuring mechanisms are not readily available. The input to the system undergoes a very complicated processes and pathways to finally emerge as stream flows in the outlet of the micro watersheds. During this journey various natural and anthropogenic process are involved with the utilization of water. Quantifying water utilization for this process is also part of the water budgeting activity. The major natural processes are evapo transpiration a n d infiltration to soil layers. Part of the infiltrated water will go back to the surface in the form of lateral flow, and part will infiltrate further down to reach shallow ground water tables. Again, from shallow water tables a part will emerge to surface in the form of return flow through capillary action of the soil layers and part percolated further down to reach deep aquifers and serves as groundwater. The output from the system is in the form of surface flows and ground water.

To quantify all this information using various weather and thematic parameters is difficult to establish manually. So, this project adopted Soil and Water Assessment Tool (SWAT) as a tool for the water budgeting activity. SWAT is developed by USDA and is employed world wide for the purpose of water budgeting and soil and nutrient dynamics. As the resources of a watershed are physical in nature SWAT is a model which uses physical parameters as input to simulate water and resource dynamics of the watershed. SWAT uses a variety of physical parameters such as weather parameters, soil parameters, land management parameters, topographic parameters etc. SWAT can employ where stream gauge data is not available as this is not an input to the system. SWAT allows a number of physical processes running over the watershed to be simulated. In SWAT the micro watershed will be further sub divided into sub catchments. This will allow various land use practices and soil properties of the area to be partitioned and spatially integrated. The sub catchments are further divided into Hydrologic Response Units (HRUs).

This allows dominant land use, soil and slope with similar hydrologic response to be aggregated together and several HRUs will represent the whole watershed. Water budgeting is the driving force of SWAT. The hydrological cycle simulated by SWAT is given in the schema

below in Fig.3.1.

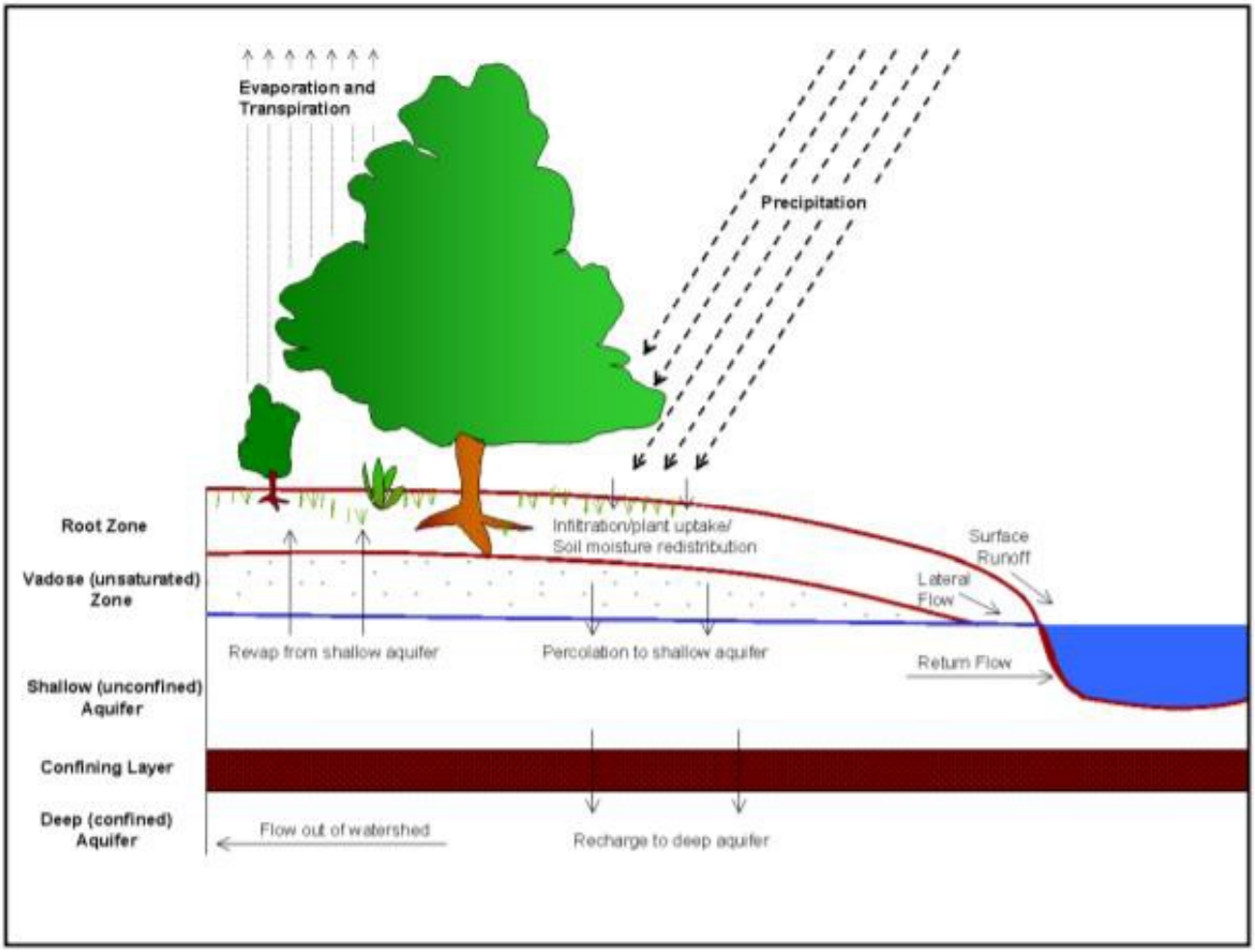


Fig.3.1 Schema of SWAT model

3.2 Setting up of SWAT model

SWAT model has been adopted in the project as the water budgeting model from the base line period onwards. During the final impact evaluation also a new set up has been created for running the SWAT model. All weather data as explained in chapter 2 have been arranged. Thematic information like, land use land cover, soil and digital elevation models were updated with current and latest satellite images as explained in the chapter 2 has also been arranged for running the model. All the data sets have been arranged in folder structure for the purpose. The model has been successfully run for the eight representative micro watersheds and results are given in following sections. The SWAT output is given in Map Plate no.3.3.1

The validation of the output is one of the important steps in any modeling process. As SWAT is giving output in the form of hydrological components, these components need to be validated separately. As the region is hilly it is not possible to validate the ground water component. So in this study the yield of the micro watersheds was validated against the discharge data collected at weir sites.

Separate SWAT model was run for the locations of weir as output points of the micro watersheds. This has been done to ensure that the stage discharge data collected correspond to same area as the modeled output. Validation has been run on these two data sets. The results obtained are given in Annexure 3.3.1 and Map Plates 3.3.2. The validation results are tabulated in Table 3.1 and a sample of Sindhiyagad micro watershed is shown in Fig.3.2. The results show that maximum deviation is 18.79 mm and hence the results accepted for further processing.

Table 3.1 Comparison of modeled and observed yield of micro watersheds

S. No.	Micro watershed	Range of difference between observed and modeled yield (mm)
1	Dewangad	0.62-14.67
2	Lathiyagad	0.77-18.79
3	Loharkhet	0.54-14.13
4	Paligad	0.53-14.57
5	Sindhiyagad	0.12-16.86

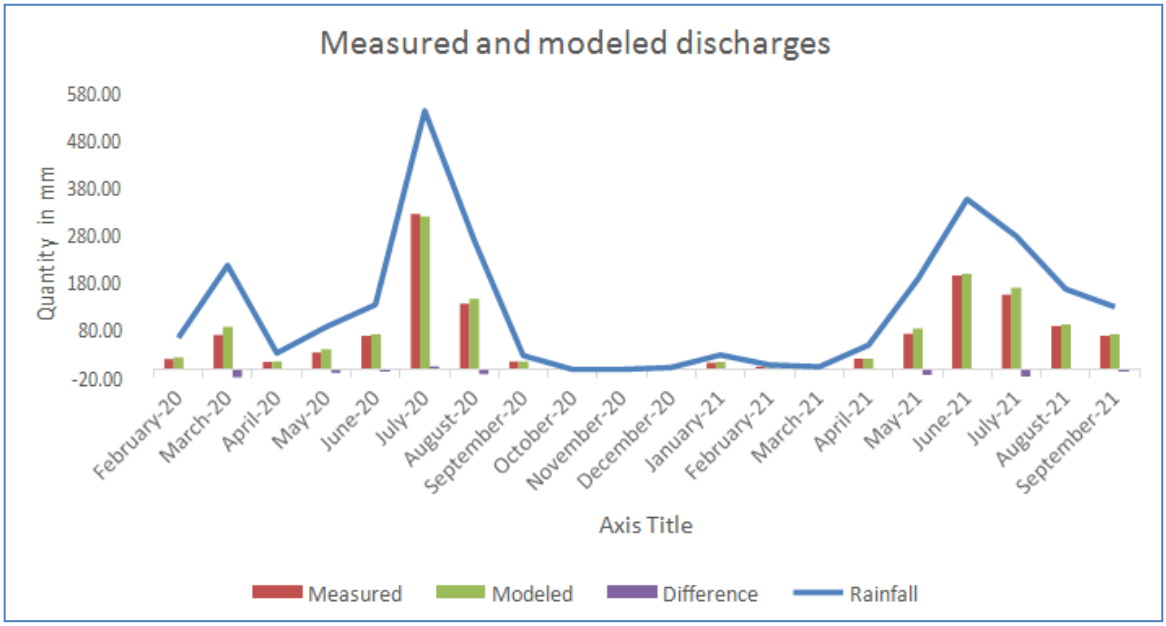


Fig.3.2 Measured and modeled yield of the micro watershed

3.3 Analysis of water balance components

The output generated out of SWAT model has been analyzed for its various components. This has given present hydrological status of the micro watersheds and is able to compare with the results of the same which has been analyzed in chapter 4. The SWAT output is summarized in Table 3.1

Table 3.2 Summary of SWAT output during final impact Evaluation

MWS	District	Final Impact Evaluation (mm)							
		PPN	SR	LF	AR	RF	ET	CN	Area
Dewangad	Dehradun	1618	333	167	417	343	693	74	67.1
Lathiyagad	Pithoragarh	861	58	78	247	210	469	73	38.18
Loharkhet	Bageshwar	1786	247	248	565	490	708	72	128.74
Paligad	Tehri	1418	273	149	338	286	684	73	56.98
Saintoligad	Pauri	1098	265	84	252	206	551	76	37.28
Sarugad	Uttarkashi	1188	108	117	294	244	664	72	68.79
Sindhiyagad	Almora	1722	305	183	577	521	630	76	73.63
Uttarsu	Rudraprayag	1499	475	136	446	400	413	76	30.55

Where,

MWS	Micro Watersheds
PPN	Precipitation
SR	Surface flow
LF	Lateral flow
AR	Aquifer recharge
RF	Return flow
ET	Evapotranspiration
CN	Curve number

Surface runoff: Surface runoff or the overland flow is the volume of water flow through the slopes of the land. SWAT computes the surface runoff using SCS Curve Number method. In this method curve number varies exponentially with the moisture content of the soil layers and once saturation point reached runoff will take place. SWAT computes surface runoff using soil, land use and daily rainfall data along with other influencing weather parameters.

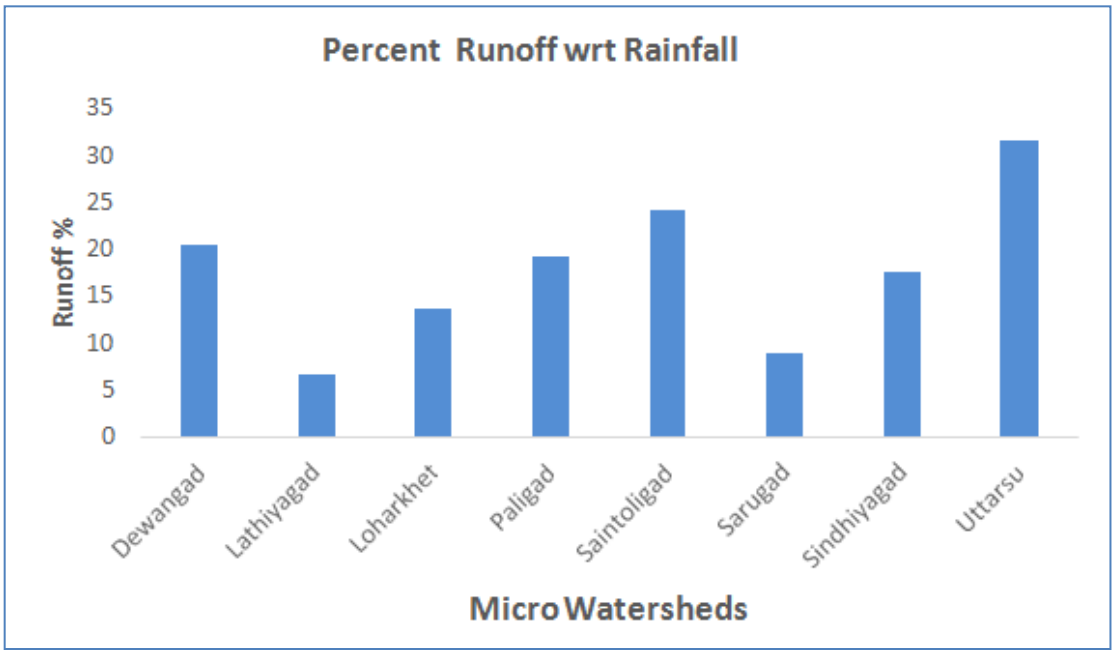


Fig.3.3 Runoff percent with respect to rainfall

Lateral flow: Lateral or subsurface flow is an interflow in which water first moves down to soil layers (0-2m) and emerges out and joins stream flow. Lateral flow initially moves into soil but not reaching zone of saturation or shallow ground water. It is mainly due to capillary action of the soil against the gravitational forces to hydrostatic pressure. So SWAT uses a kinetic energy model to estimate lateral flow of soil layers. It is a function of rainfall, slope and nature of soil.

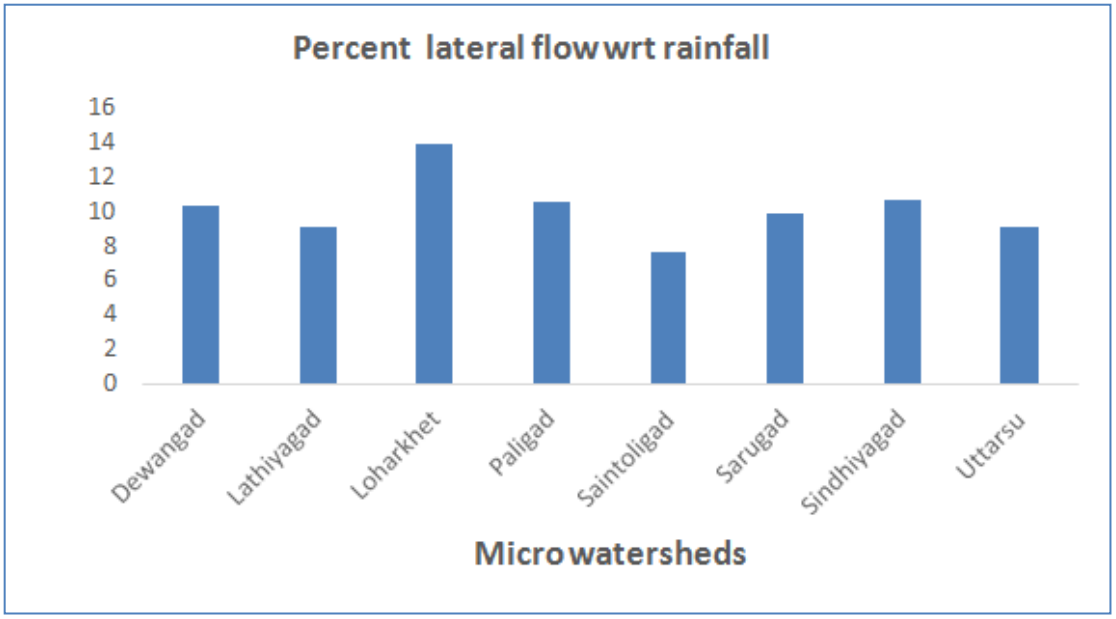


Fig.3.4 Lateral flow percent with respect to rainfall

Aquifer recharge: Water that moves past the shallow soil depths and cross the capillary fringe zone, reaches the water table and forms part of the shallow and deep aquifer recharge. SWAT employs an

exponential decay function to estimate the volume of water rainfall which reaches the aquifer zones. Part of this water will go back to the streams in the form of return flows, part will percolate further down to reach deeper aquifers and part will be taken into soil and lost as evapo transpiration through soil. Both steady and unsteady flow equations are used within the SWAT model to return flow which is also called base flow to the streams. The volume of water that moves up against the gravitational force will also be accounted within the SWAT and is estimated using various algorithms meant for the same.

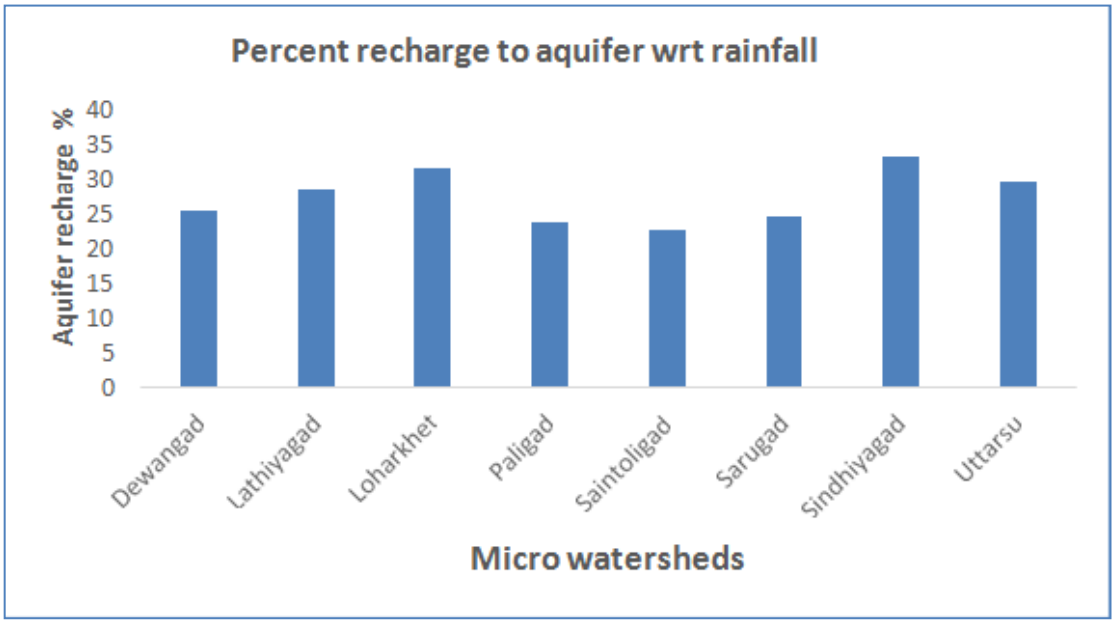


Fig.3.5 Aquifer recharge percent with respect to rainfall

Curve Number: Curve number or CN is an empirical parameter widely used in hydrology for prediction of surface runoff or infiltration of excess water available in the watershed. It is a function of soil permeability, land use and antecedent soil moisture conditions. This value generally ranges from 30 to 100 and smaller the number higher will be the infiltration. The values are ranging between 70 and 80. This indicates surface runoff is the dominant hydrologic process in these micro watersheds.

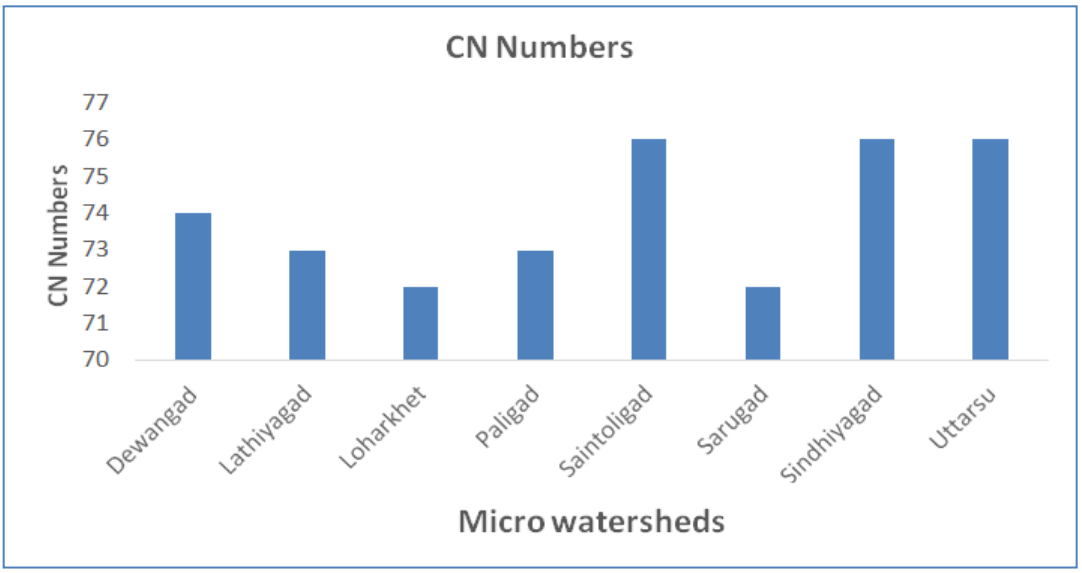


Fig.3.6 CN Numbers

Evapotranspiration: **It** is a combination of water loss processes by land surface called evaporation and by green vegetation called transpiration. Evaporation is the process by which liquid water converted to vapor from an evaporating surface. These surfaces can be of any kind of land use category such as water bodies, agriculture, forests, pavements etc. The energy required for the evaporation process is derived from solar radiation and affected by wind speed, humidity, ambient temperature. So weather data is required for the determination of evaporation and so its data collection is a necessary prerequisite. In case of agriculture, irrigation and upward transport of water from the shallow water table are the other factors to be considered.

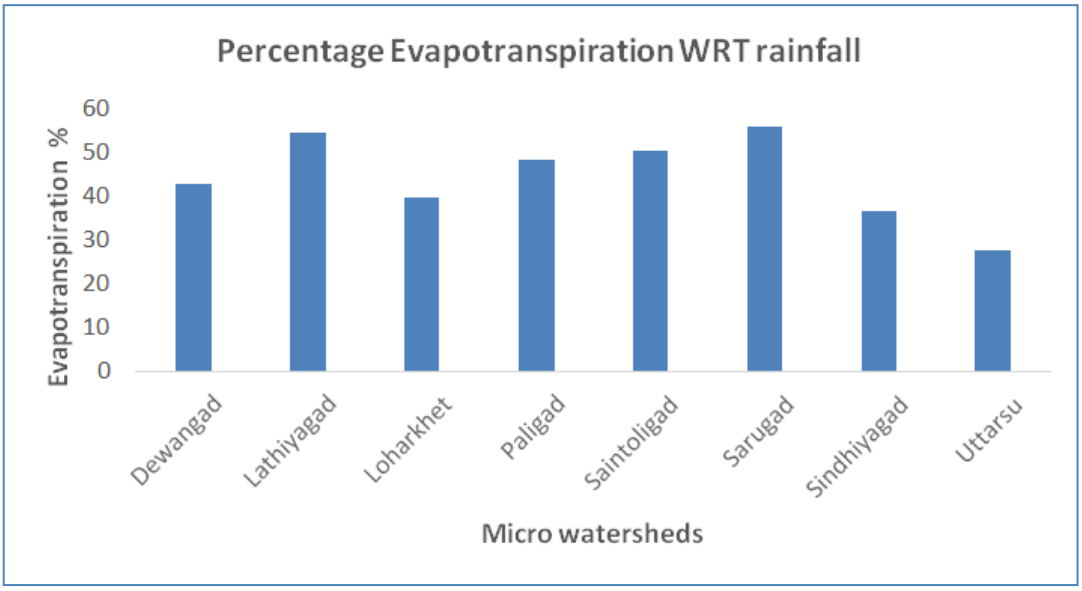


Fig.3.7 Percentage evapotranspiration with respect to rainfall

The difference between evapotranspiration and precipitation is the water available for human use and therefore it is very critical parameter. Impact of climate changes and land use changes will effectively

reflect in this parameter and hence it is of great importance.

3.4 Analysis of sediment yield

Erosion and sediment movement are matters of great concern in any of the watershed development projects. SWAT uses Modified Universal Soil Loss Equation (MUSLE). USLE deals with the kinetic energy with which rainfall impacts the soil surface and detach particles of soil from *in situ* locations to transported and deposited new locations. This kinetic energy portion is difficult to measure. So, Universal Soil Loss Equations has been modified to accommodate the impact of rainfall using annual rainfall values. Thus, MUSLE is evolved. SWAT uses following factors to estimate the sediment yield of the micro watersheds.

- R factor
- K factor
- LS factor
- C Factor
- P factor

Through a multiplicative model SWAT will estimate the soil yield. R factor has been derived from rainfall data which is part of the weather data input to the system. K factor is derived from the soil layer and LS factor derived from Digital Elevation Model and C and P factors are derived from the land use land cover layers.

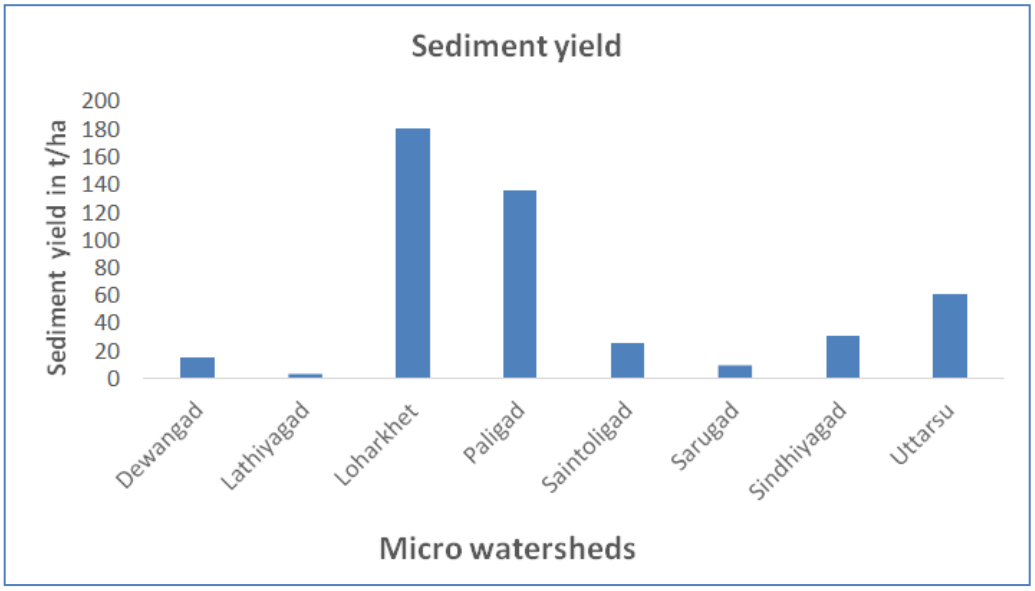


Fig.3.8 Sediment yield across micro watershed

3.5 Validation of ET

Potential evapotranspiration (PET) is the amount of evapotranspiration in a given time by a large vegetation of short green crop completely shading the ground, of uniform height and with adequate moister at all the times in the soil. As potential evapotranspiration is not dealing with specific crops, and many crops can be fit into the short green crop category are limitations of this concept. So the concept of

reference crop evapotranspiration (ETo) is evolved. Reference crop evapotranspiration is the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m and a fixed surface resistance of 70 s/m (moderately dry soil resulting from weekly irrigation) and an albedo of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height actively growing, well-watered and completely shading the ground. Standard method for determining the Evapotranspiration is Penman-Monteith method. This is the only method globally accepted by FAO, International Commission for Irrigation and Drainage, and World Meteorological Organization. Actual evapo-transpiration is computed using the formula.

ETc = Kc x ETo

Where,

ETc Actual evapotranspiration

Kc Crop coefficient for individual crops

ETo Evapo-transpiration of reference crop as a climate factor

Crop coefficient of various crops has been directly taken from FAO notes (http://www.fao.org/3/X0490E/x0490e0b.htm#numerical%20determination%20of%20kc) and those crop coefficient which is not available in the notes has been collected from other cross references. Crop coefficient values are given in Annexure 3.5.1. In the present analysis

An average Kc value has been considered and estimated from initial, mid and harvesting stages Kc values for each crop. ET0 has been computed using the weather parameters, minimum temperature, maximum temperature, humidity percent, wind velocity and sun shine hours. SWAT software is used for the estimations. The ETo values thus obtained are given in Annexure 3.5.2. Using Kc values and ET0, ETc has been calculated using multiplicative numeric model. The estimated ETc values are given in Annexure 3.5.3 for all the eight representative micro watersheds. The challenge of comparing model evapotranspiration and empirically estimated evapotranspiration was overcome by segregating land use land cover wise evapo transpiration from SWAT modeled output.

Evapo-transpiration due to agriculture is used to derive daily evapo transpiration due to crops available in the micro watersheds. The required data are given in annexures and comparative statement is given in table below.

Table 3.3 Comparison of empirically derived and swat model evapotranspiration

MWS	District	Average ET (mm/ day)	Model ET (mm/day)	Difference (mm/day)	% Difference
Dewangad	Dehradun	1.85	1.87	-0.02	1.00
Lathiyagad	Pithoragarh	1.43	1.28	0.15	10.14
Loharkhet	Bageshwar	1.73	1.92	-0.19	11.01
Paligad	Tehri	1.62	1.73	-0.11	6.88
Saintoligad	Pauri	1.43	1.48	-0.05	3.46
Sarugad	Uttarkashi	1.91	1.79	0.12	6.33

Sindhiyagad	Almora	1.46	1.64	-0.18	12.22
Uttarsu	Rudraprayag	0.99	1.05	-0.06	6.27

3.6 Water demand verses availability

Out of the total precipitation, whatever left after evapotranspiration will be available for human, livestock and plant consumption. Water is an essential commodity used by man, animals and plants. Mankind required water for drinking and other domestic purposes. Animals also need water with various quantities under various growth stages and situations for drinking. Agriculture required water for irrigations.

In the present study human water requirement is estimated using available population data. Population data was collected from records of base line survey, available records and current survey. Though the norm of per capita per day rural consumption (lpcd) is 55 liters in order to ensure water security aspects 135 lpcd is considered for the analysis which is urban standard.

The reason for this consideration is that water consumption of most of the rural households is very similar to their urban counterparts in recent years.

Table 3.4 Estimation water requirement for human consumption

MWS	District	Population	Water requirement (cum/year)
Dewangad	Dehradun	2369	116732
Lathiyagad	Pithoragarh	7863	387449
Loharkhet	Bageshwar	11673	575187
Paligad	Tehri	7349	362122
Saintoligad	Pauri	9542	470182
Sarugad	Uttarkashi	3398	167436
Sindhiyagad	Almora	18623	917648
Uttarsu	Rudraprayag	13892	684528

Livestock information is collected through available records and sample survey through door-to-door visits. Per day water requirement for individual likestock is collected from cross references mostly from Food and Agricultural organizations established workouts. Using these data water requirement for livestock is estimated. Standard water requirement for livestock is given in Table 3.5. Watershed wise water requirement for livestock is detailed in Annexure 3.6.1 and summarized results are given in Table 3.6

Table 3.5 Standard water requirements considered for livestock

Livestock	Water requirement (lit/day)
Cow	40

Bullock	40
Buffalo	40
Goat	5
Sheep	5
Donkey	20
Poultry	1
Horse	20
Mule	20

Table 3.6 Water requirements for livestock

MWS	District	Water requirement (cum/year)
Dewangad	Dehradun	12697
Lathiyagad	Pithoragarh	46767
Loharkhet	Bageshwar	9128
Paligad	Tehri	33753
Saintoligad	Pauri	107015
Sarugad	Uttarkashi	9300
Sindhiyagad	Almora	87653
Uttarsu	Rudraprayag	6282

In case of crop water requirement Kharif, Rabi and Zaid crops were considered. Crop data and area statistics is given in Annexure ?. Crop water coefficients were collected through cross references. Area statistics were collected from Watershed Directorate and in turn from Agriculture Department. Crop water requirement is estimated by multiplying the coefficient by crop sown areas. The crop water requirement is detailed in Annexure 3.6.2 and summarized in Table 3.7. The total water requirement is tabulated in Table 3.8.

Table 3.7 Crop water requirement

MWS	District	Water requirement (cum/year)
Dewangad	Dehradun	7897230
Lathiyagad	Pithoragarh	204500
Loharkhet	Bageshwar	42630820
Paligad	Tehri	7442820
Saintoligad	Pauri	686400
Sarugad	Uttarkashi	4817365
Sindhiyagad	Almora	29255495
Uttarsu	Rudraprayag	6566832

Table 3.8 Total water requirement for the watershedss

Sl. No.	Micro Watershed	District	Water requirements cum/year				Total in million cum/year
			Livestock	Population	Crop	Total	
1	Dewangad	Dehradun	116732	12697	7897230	8026659	8.0
2	Lathiyagad	Pithoragarh	387449	46767	204500	638716	0.6
3	Loharkhet	Bageshwar	575187	9128	42630820	43215135	43.2
4	Paligad	Tehri	362122	33753	7442820	7838695	7.8
5	Saintoligad	Pauri	470182	107015	686400	1263597	1.3
6	Sarugad	Uttarkashi	167436	9300	4817365	4994101	5.0
7	Sindhiyagad	Almora	917648	87653	29255495	30260796	30.3
8	Uttarsu	Rudrapraya	684528	6282	6566832	7257642	7.3

Thus water requirement for individual representative micro watersheds was determined and compared with water availability within the watershed. The yield of the watersheds is considered as the available water after removing the evapo transpiration loses. The water yield is the sum of surface, lateral and returns flows. Yield of the watersheds are shown in Table 3.9.

Table 3.9 Total water available for usage for the watersheds

Sl. No.	Micro Watershed	District	Availability in million cum/year
1	Dewangad	Dehradun	56.6
2	Lathiyagad	Pithoragarh	13.2
3	Loharkhet	Bageshwar	126.8
4	Paligad	Tehri	40.3
5	Saintoligad	Pauri	20.7
6	Sarugad	Uttarkashi	32.3
7	Sindhiyagad	Almora	74.3
8	Uttarsu	Rudraprayag	30.9

Comparing these two-results water balance is made for the micro watersheds. The results are given in Table 3.10 and shown in Fig.3.6

Table 3.10 Water demand versus availability for representative micro watersheds

Sl. No.	Micro Watershed	District	Requirement in million cum/year	Availability in million cum/year
1	Dewangad	Dehradun	8.0	56.6
2	Lathiyagad	Pithoragarh	0.6	13.2
3	Loharkhet	Bageshwar	43.2	126.8

4	Paligad	Tehri	7.8	40.3
5	Saintoligad	Pauri	1.3	20.7
6	Sarugad	Uttarkashi	5.0	32.3
7	Sindhiyagad	Almora	30.3	74.3
8	Uttarsu	Rudraprayag	7.3	30.9

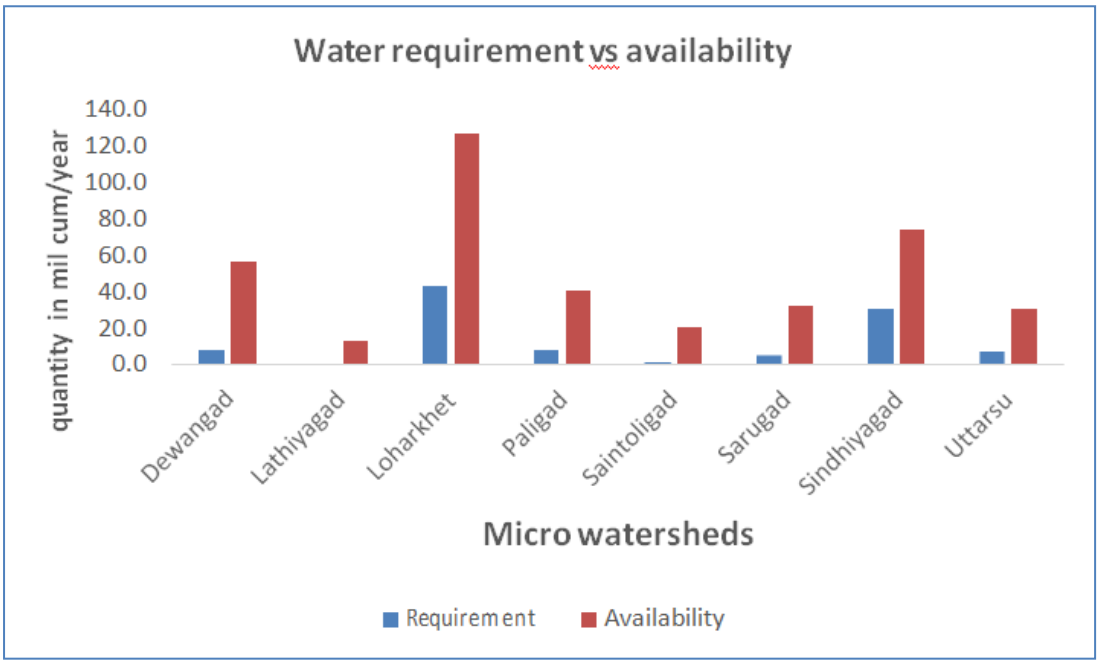


Fig 3.9 Water requirement and availability for representative micro watersheds

CHAPTER 4: TIME SERIES ANALYSIS

4.1 Introduction

The hydrological monitoring in the representative micro watersheds starts with a base lining during 2015. Concurrent monitoring of hydrological aspects was carried throughout the project duration. Results of the same were registered during midterm period that was during 2018 and thereafter annual impact evaluation during 2020 and final impact evaluation at the end in 2021. The changes in various aspects of the hydrological monitoring are possible through time series analysis. This chapter details the changes happening in hydrological regime during project period and gives an information on impact of the project on hydrology of the watersheds. As the hydrological monitoring carried out in a structured and continuous way so that data on hydrological aspects were recorded under various phases of the project. Structural interventions in the watersheds are vital component of this project and the aim was to improve water availability to the community and hence improve the livelihood of the people residing in these watersheds. These structural inventions include construction of various water harvesting, water conserving, water augmenting and water distributing physical structures. Their actual efficiency will only be known, if we have the sequential data from base line to end of the project. The changes happening to land use land cover, water balancing components, source discharges, sediment yield etc are detailed here.

4.2 Changes in land use land cover

WAPCOS has been collected satellite images under various phases of the project to monitor changes happening in the area due to project activities. Separate land use land cover maps were prepared during base line (2015), mid term (2018) annual impact Evaluation (2020) and towards the end of 2021, the final impact evaluation period. The primary objective of the land use land cover mapping was to get an input for SWAT modeling. So the classification schema has been selected to suite the model requirement. Following are the six classes recognized for this purpose

- Agriculture
- Forest
- Land with or without scrub
- Roads
- Water bodies
- Settlements

Of these six classes changes in agriculture, land with or without scrub and forests were sensitive to the model and hence considered as the key land use classes. These were monitored during entire duration of the project. The details of the land use land cover changes are given in Annexure 2.3.1 and Map Plate 2.3.2. The percentage changes in key classes are given in Annexure 4.2.1 and depicted in Map Plate 4.2.1

The micro watershed wise percentage changes in key land use classes are give in Table 4.1. The

changes in agriculture, forest and land with or without scrub is given in Fig.4.1, 4.2 and 4.3 respectively. Overall changes in key land use classes are depicted in Fig 4.4.

Table 4.1 Percentage changes in key land use classes

Percentage variation in land use classes				
MWS	**District**	**Agriculture**	**Forest**	**Land w/without scrub**
Dewangad	Dehradun	10.02	0.93	-1.53
Lathiyagad	Pithoragarh	8.68	-3.23	6.21
Loharkhet	Bageshwar	6.66	0.42	-2.58
Paligad	Tehri	2.87	0.05	-2.28
Saintoligad	Pauri	1.98	0.13	-0.93
Sarugad	Uttarkashi	9.27	0.61	-9.20
Sindhiyagad	Almora	0.79	2.26	-1.21
Uttarsu	Rudraprayag	0.55	1.77	-2.68
Average		5.10	0.37	-1.77

The analysis shows that there is an average increment of 5.1% in agriculture, 0.37% in forest cover and there is a reduction of 1.77% in land with or without scrub. These changes are shown in Fig 4.4.

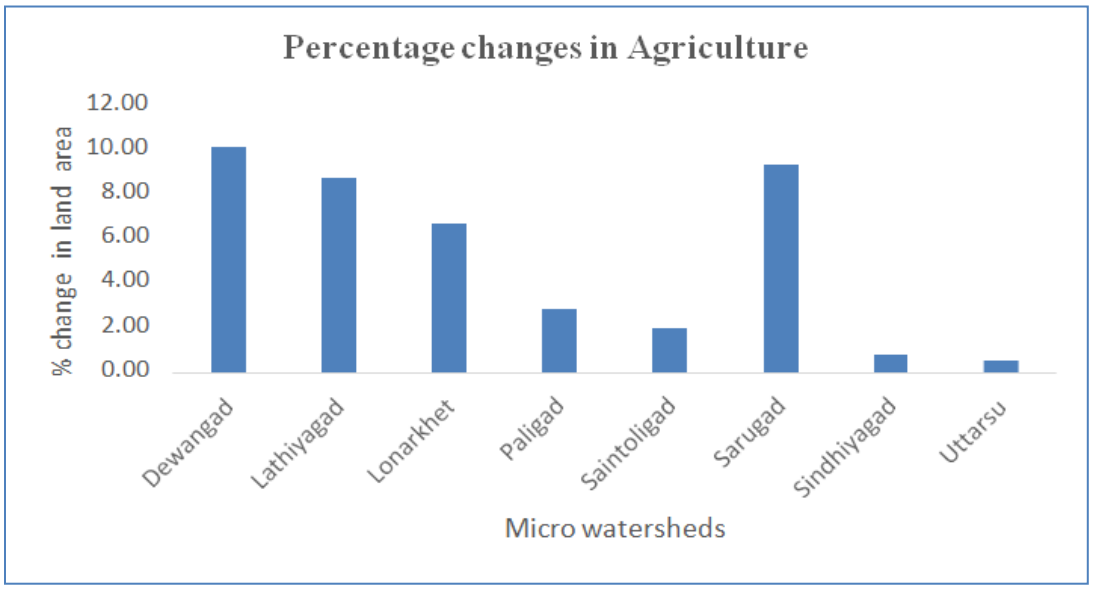


Fig.4.1 Percent changes in area under agriculture

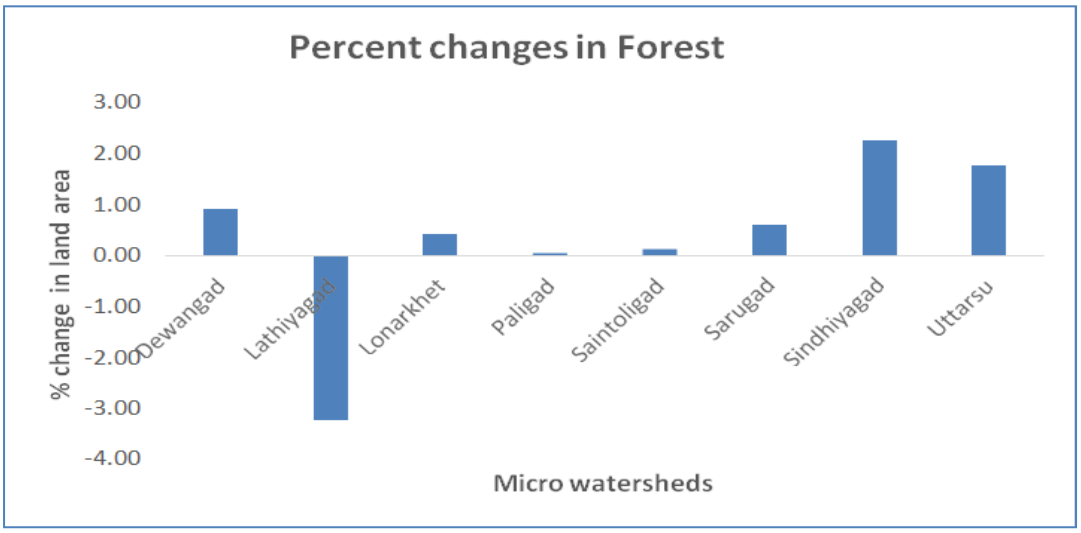


Fig.4.2 Percent changes in area under forest

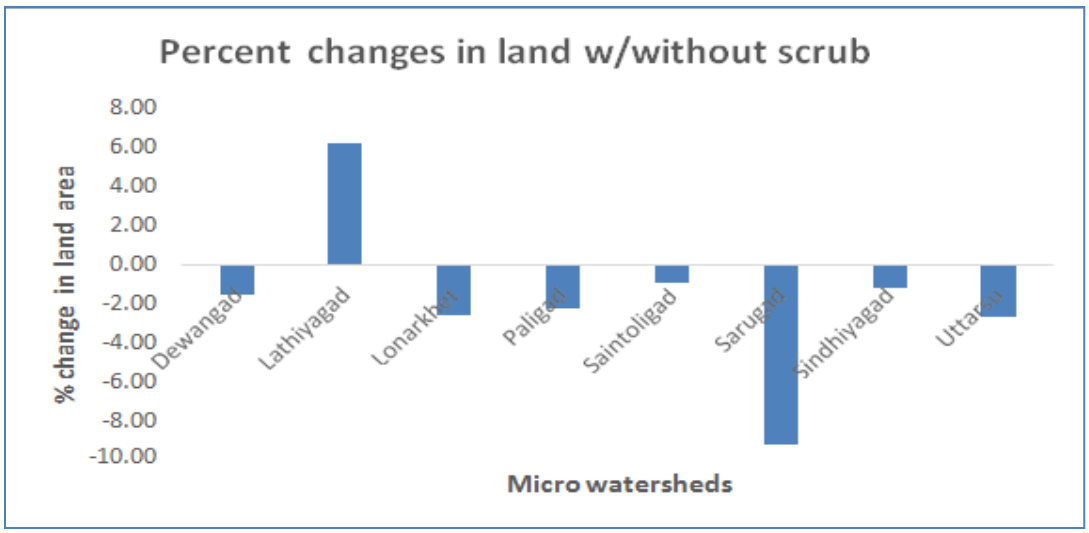


Fig.4.3 Percent changes in area under land with or without scrub

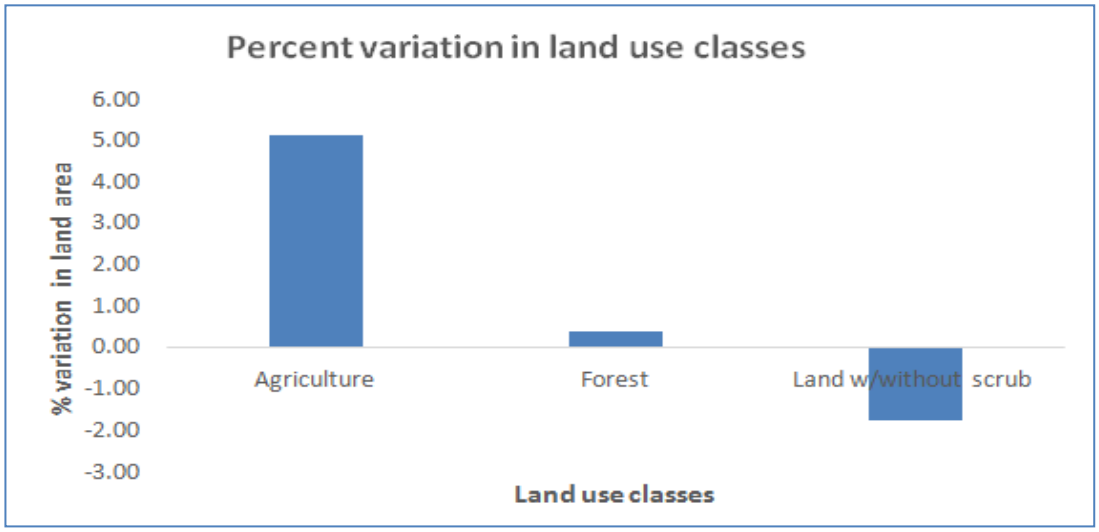


Fig.4.4 Average percent variations in key land use classes

4.3 Changes in water balance components

The water balance components were monitored continuously from base line period using SWAT model. In order to maintain and compare the output SWAT setup has been maintained with same way throughout the project period. Analyzed results available for 2015, 2018, 2020 and 2021 which represent baseline, midterm, annual impact assessment and final impact assessment respectively. Time series analyzed results are shown in annexure 4.3.1. The Fig.4.5 to Fig.4.10 shows the analysed results in graphical form.

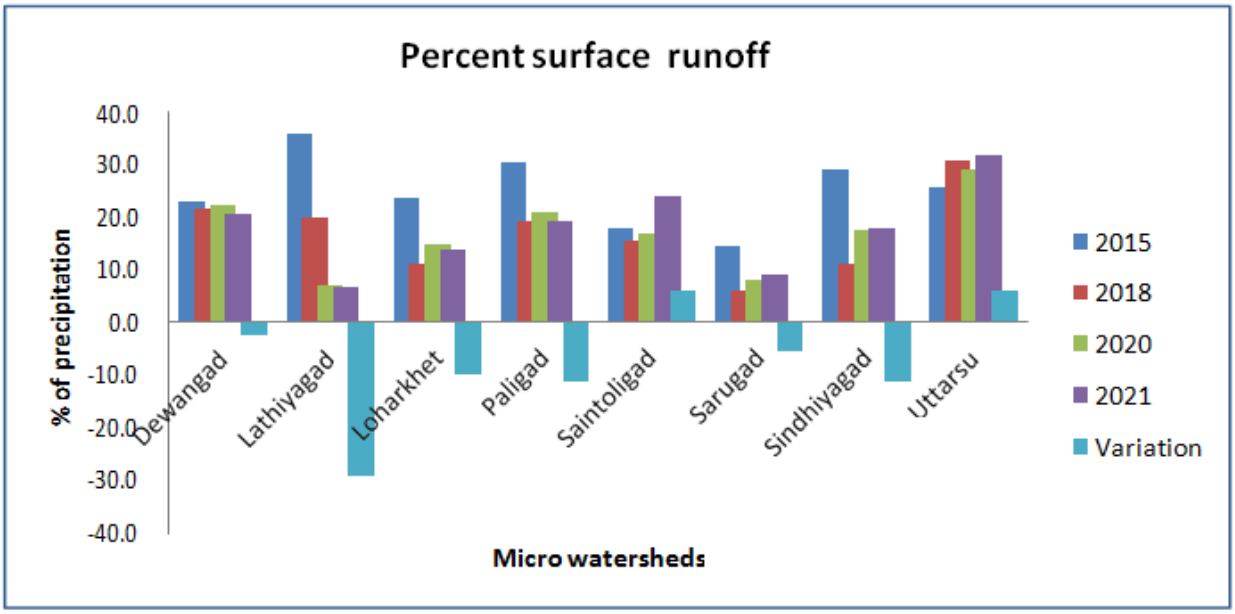


Fig.4.5 Surface runoff as percent of precipitation

The above figure shows that 87% of the watersheds are showing reduction in surface flow. This will be an indicator that conservation practices of the watersheds are showing its results in the form of reducing surface runoff and retaining water within the watersheds. The analysis has been done as percentage of precipitation to remove the biases associated with rainfall. This has facilitated comparison of surface flows within the watershed across various time periods as well as across watersheds.

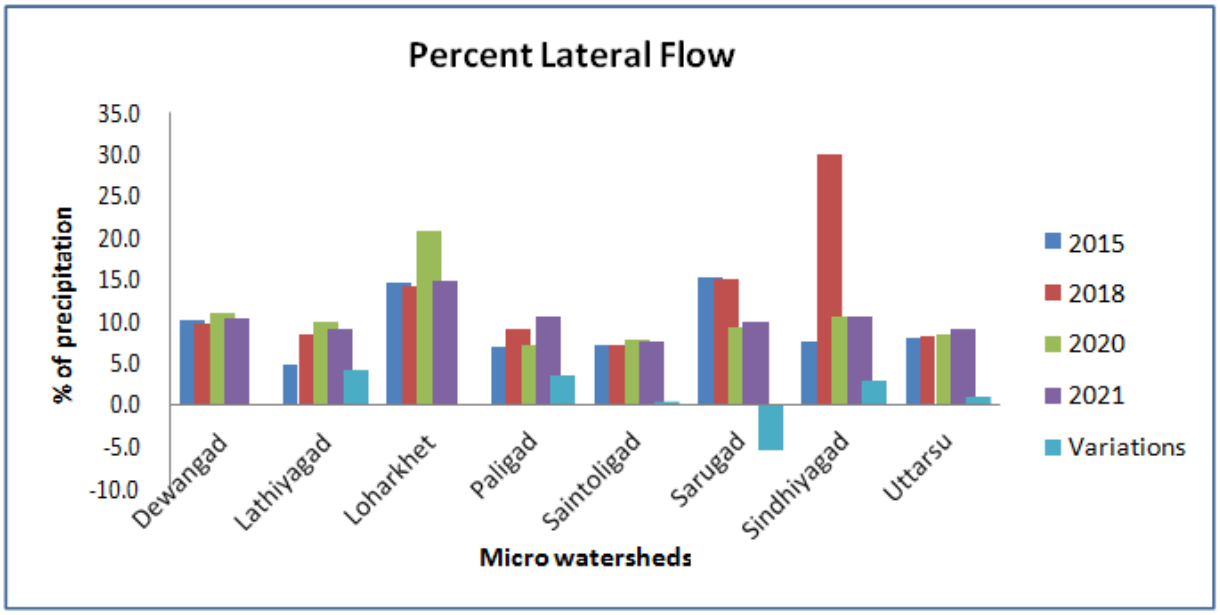


Fig.4.6 Lateral flow as percent of precipitation

Lateral flow shows general increase throughout the micro watersheds except Sarugad.

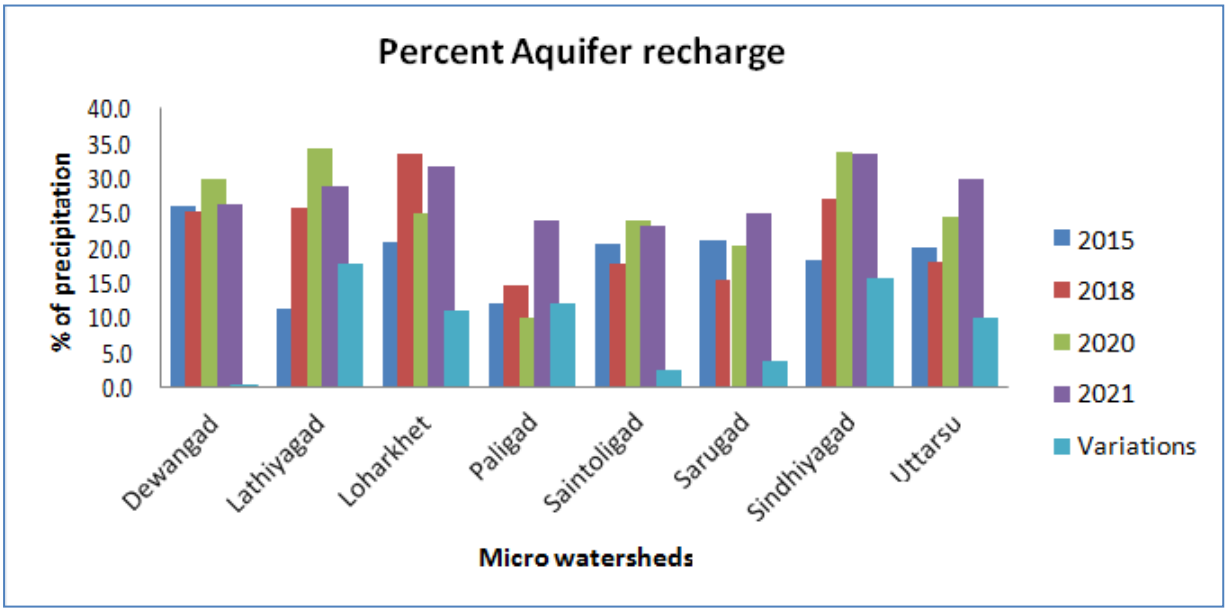


Fig.4.7 Aquifer recharge as percent of precipitation

Aquifer recharge variations show positive values for all the micro watersheds which indicates that water conservation in watersheds is yielding its results. Recharge to aquifers has increased when comparing with base line recharge.

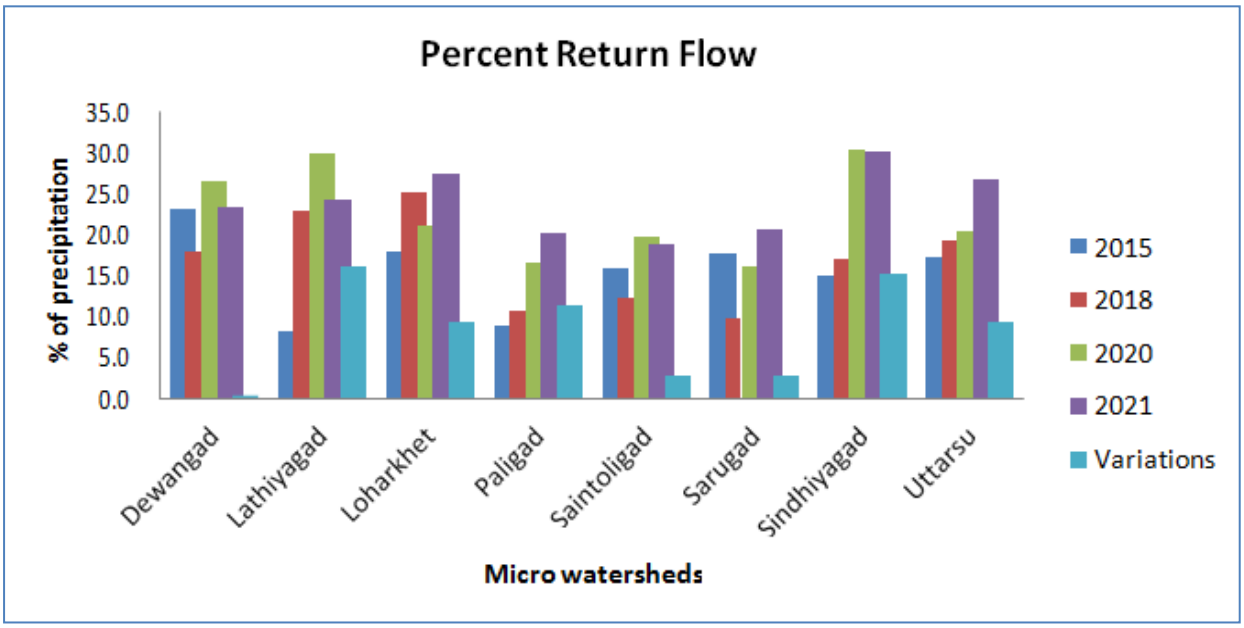


Fig.4.8 Return flow as percent of precipitation

Base flow in the form of return flow shows increase in all of the micro watersheds. Base flow increment shows increase in shallow aquifer recharge and lateral flows.

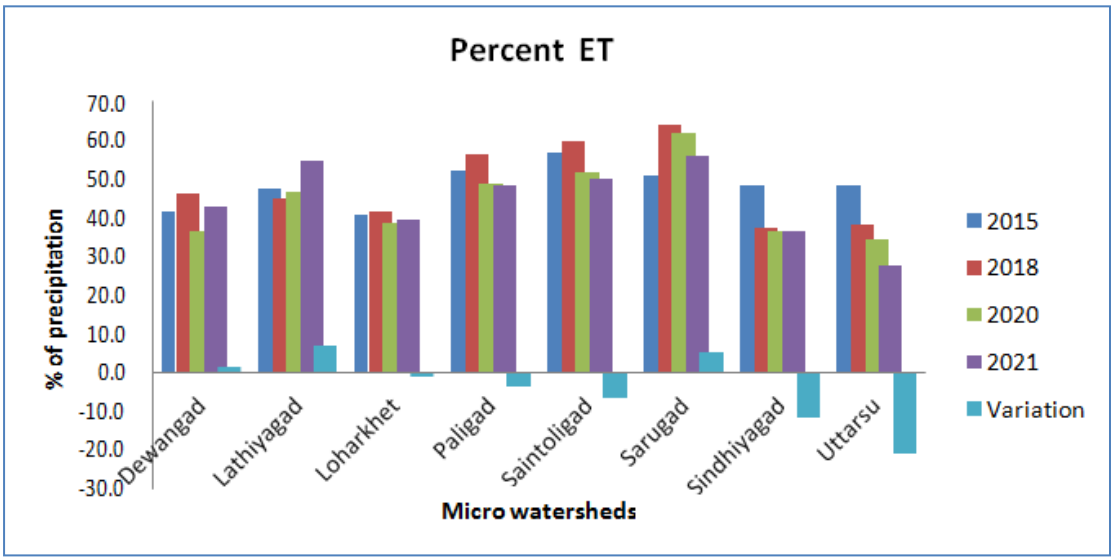


Fig.4.9 ET as percent of precipitation

Evapotranspiration shows increase in 50% of the watersheds and decrease in other 50% watersheds. The fluctuation in this regard is due to usage of satellite images of different seasons for different project years from the base line year to final impact evaluation year 2021.

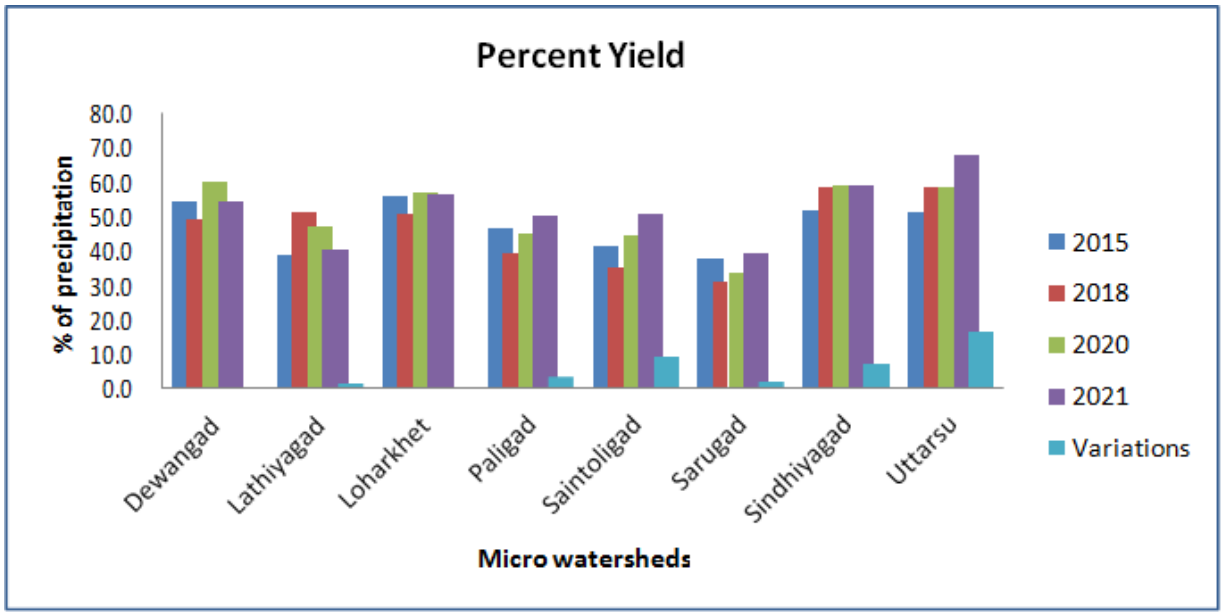


Fig.4.10 Yield of micro watersheds as percent of precipitation

Yield of the micro watershed consists of sum of the lateral, surface and return flow. Water which flows towards stream as sheet flow forms the surface flow part. Water which percolates to top soil layers and flow out from there constitute the lateral flow and water which goes beyond the top soil layers and joins the saturation portion is the shallow aquifer part of the yield. A sizable portion of this shallow aquifer water will flow towards streams through hill slopes and forms the base flow of the streams which is called return flow. In the analyzed watershed though the surface flow show decrease, lateral and return flows shows increase hence yield of the watershed also increased.

4.4 Changes in sediment yield

The erosion potential of the watersheds was also analyzed in the study. The sediment yield measured with the help of modified universal soil loss equation has been analyzed from base lime period to final impact evaluation. The variations in sediment yield are given in Table 4.2 and shown in Fig.4.11.

Table 4.2 Variations in sediment yield for representative micro watersheds

Variations in total sediment load in t/ha/year						
MWS	**2015**	**2018**	**2020**	**2021**	**Variation**	**% Variation**
Dewangad	22.4	18.1	18.4	15.05	-7.4	-33
Lathiyagad	3.5	2.8	2.9	2.9	-0.6	-17
Loharkhet	207.3	179.6	178.9	180.8	-26.5	-13
Paligad	187.0	146.0	146.9	136.2	-50.8	-27
Saintoligad	28.9	24.8	24.3	25.5	-3.4	-12

Sarugad	10.5	8.7	8.9	9.1	-1.5	-14
Sindhiyagad	38.0	32.0	32.8	31.0	-7.0	-18
Uttarsu	75.0	62.8	62.0	61.2	-13.8	-18

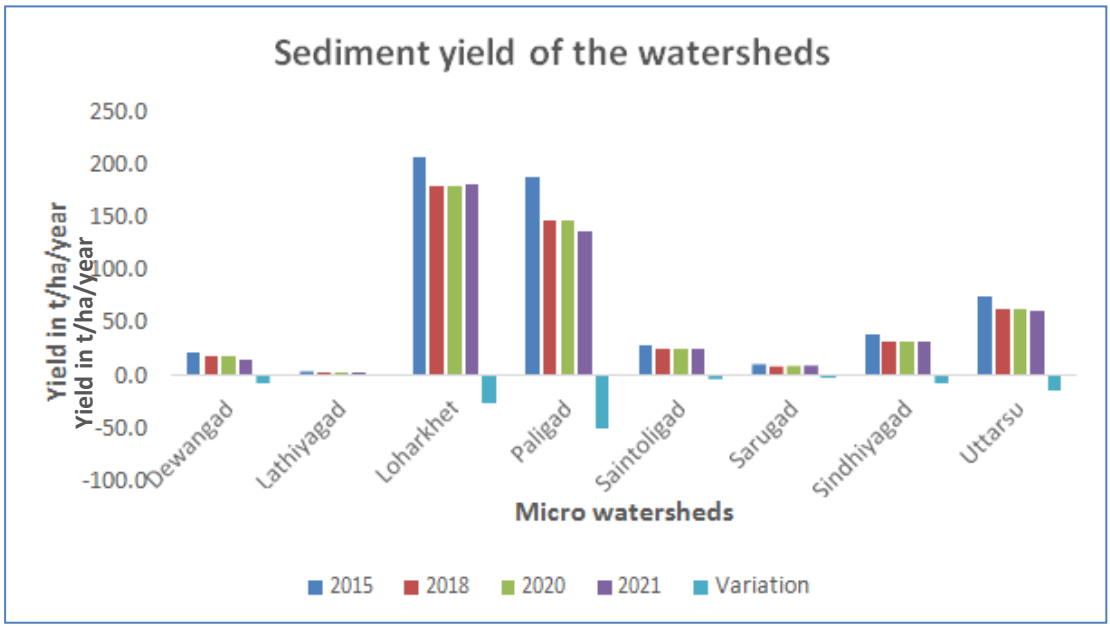


Fig.4.11 Sediment yield of micro watersheds

All the micro watersheds show reduction in sediment yield. This is indication of afforestation, soil conservation measures and interventions made in the micro watersheds. Fig.4.12 shows percent variation in sediment yield.

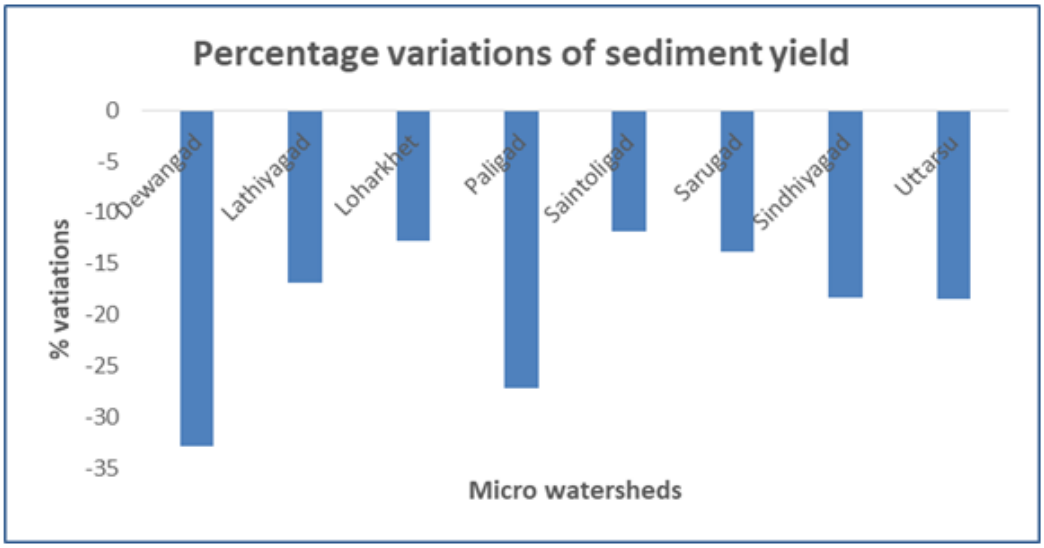


Fig.4.12 Percent variations in sediment yield

The analysis of the above diagram shows that percent reduction in sediment yield across micro watersheds ranged from 12 to 33% and average reduction in sediment yield was 19%.

4.5 Changes in source water discharge

As part of the hydrological monitoring to assess the impact of structural and non-structural interventions in the micro watersheds about 159 water sources were monitored for their discharge. The discharge was measured mostly by bucket method or float method. These observations have been clubbed with data collected by watershed directorate. Both pre monsoon and post monsoon discharges have different rate of discharges and hence these are analyzed separately. The compiled data of pre monsoon and post monsoon periods are tabulated in annexure 4.5.1. In case of pre monsoon data, 2021 source discharge is compared with respect to base year and variations estimated and converted to percentage variation to know the overall impact of the treatment of the watersheds with structural and non-structural interventions. A trend analysis has been carried out for pre and post monsoon discharge data and is shown in Fig.4.13 and 4.14

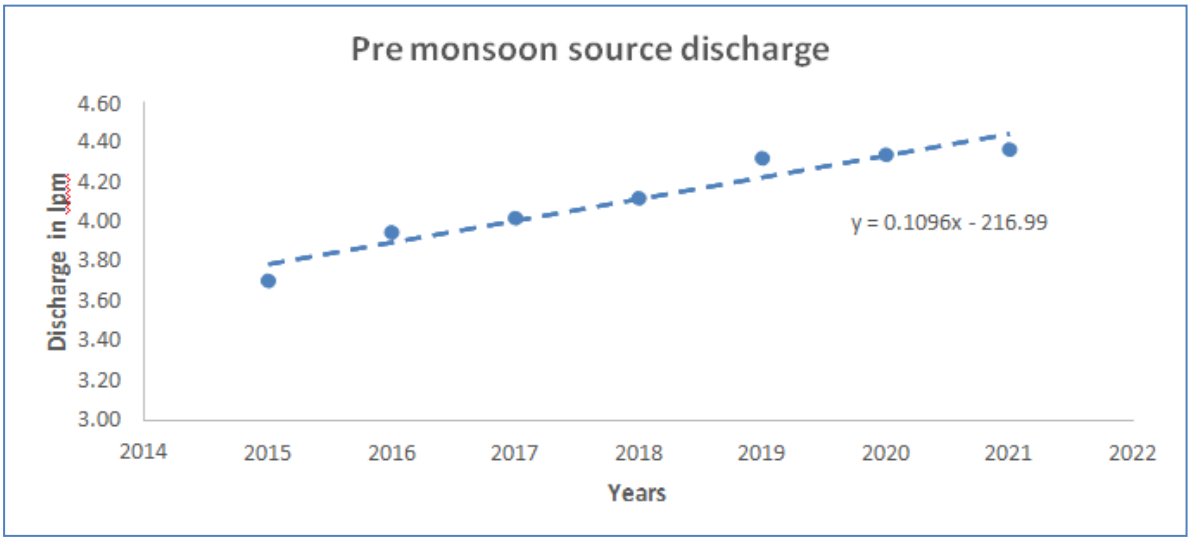


Fig.4.13 Average Pre monsoon discharge plot

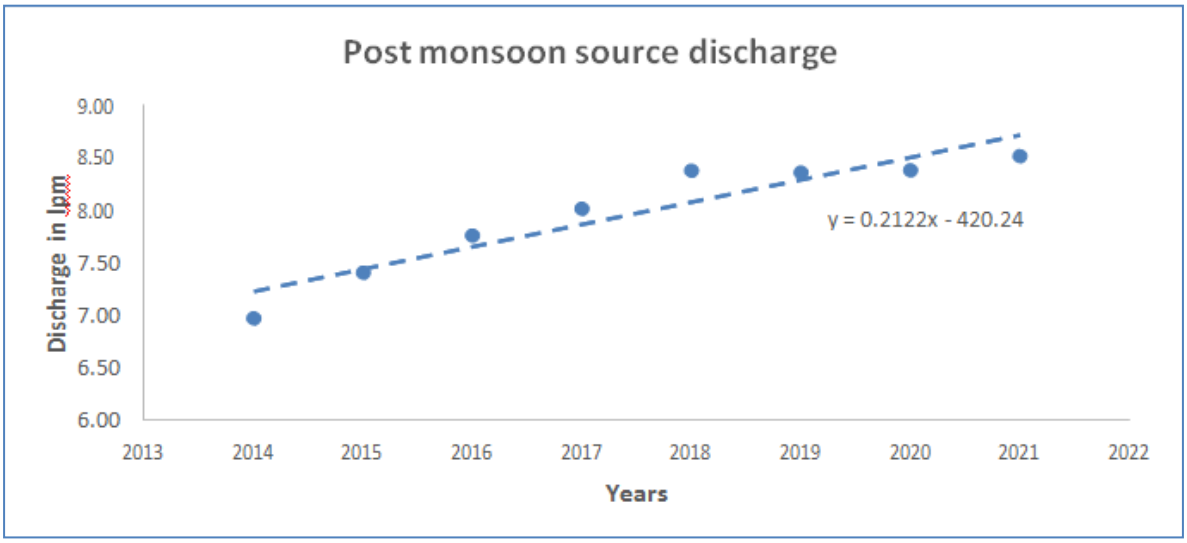


Fig.4.14 Average Post monsoon discharge plot

The analysis of the plots shows that both post and pre monsoon discharges are showing positive trends. Pre monsoon discharge has shown an increment of about 13.33 to 25% with respect to the base line period of 2014 and post monsoon shown an increase of 13.79 to 33.74%.

CHAPTER 5: WATER SAVING STRATEGIES

5.1 Introduction

This chapter deals with the efforts in the project area for water saving activities. The water saving activities have been attempted for selected crops on experimental basis without compromising the production. For this purpose, the experimentally proved crop water requirement has been compared with water used by farmers for their crops. Crop water requirement is defined as the depth of water in mm need to meet the water consumed through evapo-transpiration (ETc) by a decease free crop growing under non restricting soil conditions and achieving full production potential under given environmental growing conditions. In its simple terms crop water requirement is the total water demand for a crop to grow.

Crop Water Requirement = Evapotranspiration + Application losses + Special needs In other words

CWR = IRR + ER + ΔS + GWC

Where

CWR Crop water requirement

IRR Irrigation applied

ER Effective rainfall

ΔS Moisture difference in the beginning and end of the crop cycle GWC Ground water contribution

In the present study ground water contribution is nil and moisture at beginning and end of the crop cycle is assumed to be same and hence is considered as zero. Now the crop water requirement is the sum of irrigation applied and rainfall received during growth period of the crops.

The objective of this study is to compare the crop water requirement scientifically established and on field practice by farmers for selected crops under various water saving measures adopted in the project. An attempt has been also made to evaluate the water security plans made for Dasper village.

5.2 Comparison of crop water requirements

In the present study few selected crops at different micro watersheds were taken for crop water requirement established as per norms worked out of agricultural research for the area and actual application of water to the crops by farmers of the area. Following criteria is used for selecting the crop.

- It should be representative crop of the area
- One crop from each watershed is considered
- It should not be a rainfed crop, at least partially it needs to be an irrigated crop
- If irrigation is applied by different methods for the same crop in same area water saving can also be worked out.

- It is possible to measure the quantity of water irrigated.

Following are the micro watersheds and the crops taken for the study.

Table 5.1 Crops taken for comparison of crop water requirement by norms as well as by actual application

Sl. No.	MWS	District	Crops	Farmers (Sh/Smt)
1	Uttarsu	Rudraprayag	Wheat	Vinod Prasad Metani Asha Devi Devi Prasad Bhatt
2	Saintoligad	Pauri	Tomato	Jaipal Singh Surender Singh Vijay Singh Jaspal Singh
3	Sarugad	Uttarkashi	Rice	Yeshpal Singh Sobat Singh

Table 5.2 Crop water requirement (per ha) comparisons

Sl.No.	MWS	District	Crop	CWR by Norms (m^3)	CW Applied by farmers (m^3)	Difference (m^3)
1	Uttarsu	Rudraprayag	Wheat	110	81.55	28.45
2	Saintoligad	Pauri	Tomato	2800	2820	20
3	Sarugad	Uttarkashi	Rice	11000	11689	689

Wheat crop of Uttarsu Micro Watershed: One nali (200.67sqm) of wheat crop at Munna dewal village is observed for water utilization. As per the researched norms per ha water utilization of wheat crop is 550 mm. The cropping started on October 1, 2020 and harvested in April 20, 2021. Farmers irrigated the area 3 times to a depth of about 102 mm. In between rainfall was also received in the area. Fig.5.1 shows the water received in the field through rainfall and with irrigation by farmer. The irrigation by farmers was measured on field using a scale as depth of standing water column.

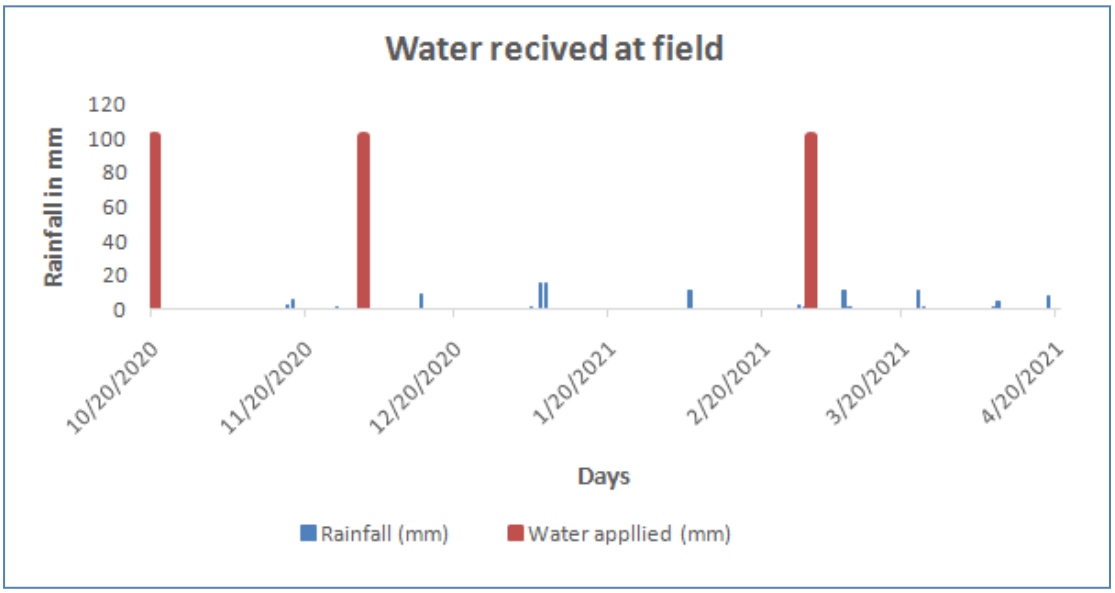


Fig.5.1 Water applied to wheat crop

The data pertaining to rainfall and as applied by farmer are given in Annexure 5.2.1. Water applied is estimated as per the Table 5.3.

Table 5.3 Estimation of water utilization for 0.02ha of wheat crop

Parameters	Rainfall contribution	As applied by farmer
Total water received (mm)	119.5	304.8
Effective water available (mm)	101.58	304.80
Area (ha)	0.02	0.02
Volume of water (ham)	0.002038306	0.006116422
Volume of water (cum)	20.38	61.16
Total (cum)	**81.55**	

Tomato crop of Saintoligad micro watershed: Tomato crop was grown in 20 nalis of land at Syoli Gram panchayat, Marla Mahadev village. This rainfall was available in plenty as compared to normal periods. Hence farmers have applied less water in this season. However water applied has been monitored. The cropping started on first week of April and last harvest was in the end of August. Farmer has applied water two to three days after rainy days. The rainfall received by the crop along with water applied is shown in Annexure 5.2.1. The amount of rainfall and water applied by farmers are given in Fig.5.2.

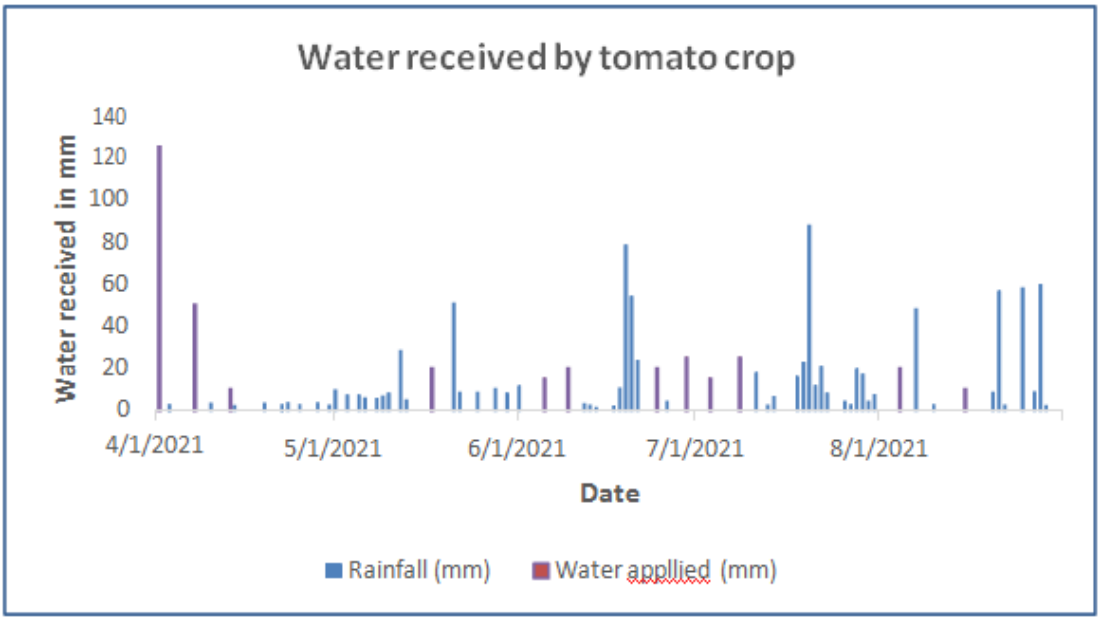


Fig.5.2 Water applied to tomato crop

The estimated quantity of water is shown in Table 5.4

Table 5.4 Estimation of water utilization for 0.4 ha of tomato crop

Parameters	**Rainfall contribution**	**As applied by farmer**
Total water received (mm)	876	355
Effective water available (mm)	350	355
Area (ha)	0.4	0.4
Volume of water (ham)	0.14	0.142
Volume of water (cum)	1400	1420
Total (cum)	2820	

Rice crop at Sarugad micro watershed: 50 Nali (about 1 ha) of rice crop at Kharsari area is observed for water utilization. As per the researched norms per ha water utilization of rice crop is 1100 mm. The cropping started in middle of May 2021 and harvested in middle of October 2021. Farmers irrigated the area every second day to maintain minimum 3inch standing water. In between rainfall was also received in the area. Fig.5.3 shows the water received in the field through rainfall and with irrigation by farmer. The water applied by farmer was measured using incremental water column over the field.

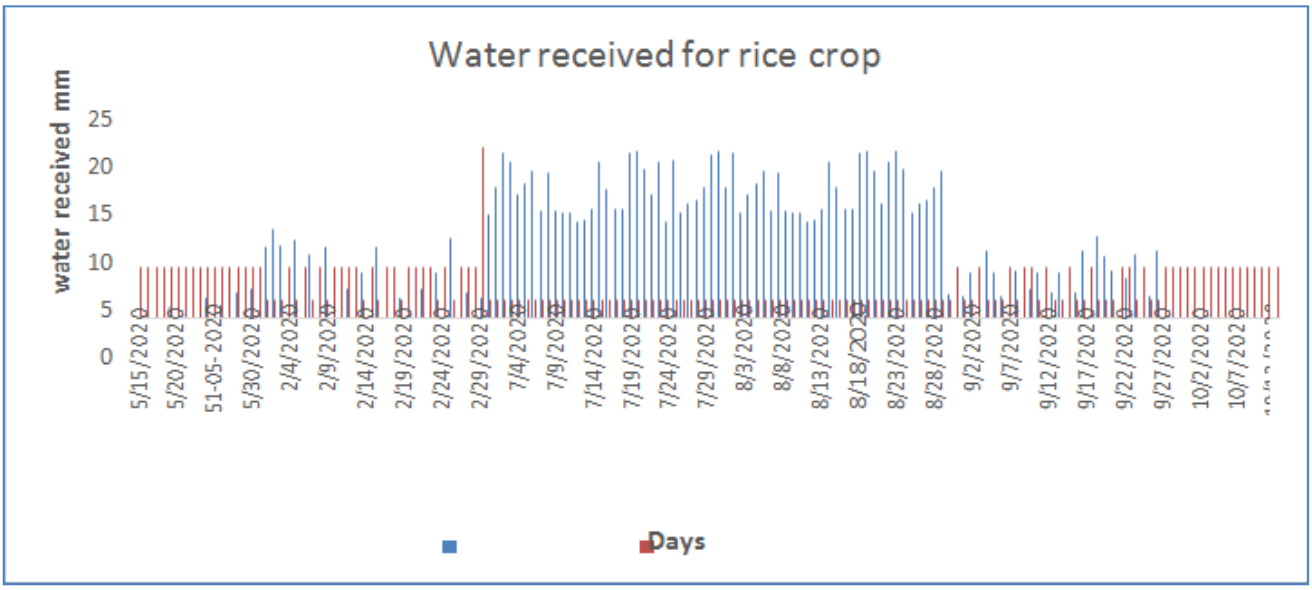


Fig.5.3 Water applied to rice crop

The data pertaining to rainfall and as applied by farmer are given in Annexure 5.2.1. Water applied is estimated as per the Table 5.5.

Table 5.5 Estimation of water utilization for 1 ha of rice crop

Parameters	Rainfall contribution	As applied by farmer
Total water received (mm)	1239.66	550
Effective water available (mm)	619.8	550
Area (ha)	1	1
Volume of water (ham)	0.6189	0.55
Volume of water (cum)	6189	5500
Total (cum)	**11689**	

5.3 Water use efficiency studies

Water use efficiency study has been carried out for tomato crop. 20 Nalis of land has been irrigated in water spread method and 20 nalis have been irrigated with sprinklers. Water usage of both has been recorded and results are summarized in Annexure 5.2.1

Table 5.6 Estimation of water utilization with spreading and sprinkler methods

Parameters	Spreading method	Sprinkler method
Total rainwater water received (mm)	876	876
Effective water available (mm)	350	350
Area (ha)	0.4	0.4
Volume of water (ham) -rainfall	0.14	0.14

Water irrigated (mm)	355	215
Volume of water irrigated (ham)	0.142	0.086
Total water utilised (cum)	2820	2260
Water saved (cum)	530	
Water saved (%)	18.8	

5.4 Water security for Dhaspad village

Background: Dhaspad was any other village in Almora district before start of Gramya II project with scarcity of water for domestic usage and for maintenance of the livestock. Village is having 44 households. It encompasses an area of 6 ha. Most of the men folk are ventured outside to plains for their job and village is mostly left with elders, ladies and children. As water is not available in the immediate vicinity and they can not go far off places for cultivation and its maintenance they stopped cultivation. The females of the village need to visit nearby water bodies for giving bath to their livestock which used to consume time and human animal conflicts were quite common. Water availability was through village water supplies and few springs nearby which was not sufficient for cultivation, domestic and livestock management.

Interventions: Following are the hydrological interventions applied in the village during the course of project.

- Solar life pump
- 37 roof top rainwater harvesting structures at house hold level
- 6 rainwater harvesting tanks
- 19 LDPE tanks
- 4 village ponds revived
- 1 Geo membrane tank
- 3 irrigation tanks on a community level

Hydrology of the interventions: The above hydrological interventions have dramatized the area. Now, the water scarce area become water secure. The source from where the solar lift pump operates is having a discharge of 95 lpm. Only one tenth of its discharge is required by the village for its water security. This is perennial source. Earlier the villagers have almost abandoned the farming as there was not enough water and area was slowly turning as barren. Whatever little cultivation happening was just for self-use. Now water is available very close to them and they have started cultivation. With availability of water all 3 seasons have crops in their land. The water holding capacity generated in the village is given in Fig.5.4.

Table 5.7 Capacities developed at Dhaspad village

Structures	No. of structures	Capacities (Th litters)
RTRWHS	37	92.5
RWHT	6	180
LDP tanks	19	228
Village ponds	4	100
Geo membrane tanks	1	20
Irrigation tanks	3	75
Total		**695.5**

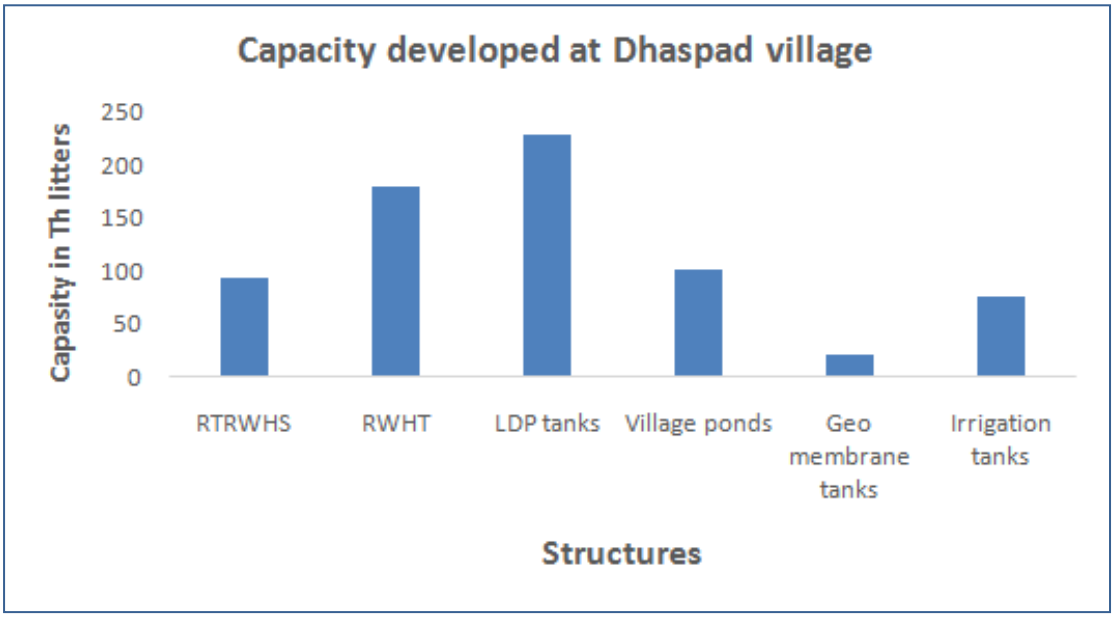


Fig.5.4 Water holding capacity within the village

Operations of the water resource by the community: The capacities for holding water are an addition to their already existing resource. So, villagers use it as a secured resource which can be taken at any period of necessity. The solar pump is operated in a rotation by farmers' group. On an average the pump will be operated 6 hours a day for 200 days in a year. The tanks will be filled in a rotational way so that water will be available to all the farmers at all times of necessity. Solar lift pump will be filling a major tank and all other tanks are filled with the help of gravity flow.

Changes in agriculture due to hydrological intervention: The Table 5.8 shows sharp increase in agricultural activities within the village. An assessment shows 62% increase in agricultural activity as more water in hilly terrain means more cultivation.

Table 5.8 Changes in agriculture by hydrological interventions

Sl. No.	Crops	Cropped area in ha	
		Before 2014	At 2021
1	Tomato	0.4	0.8
2	Capsicum	0.62	0.84
3	Bean	0.5	0.7
4	Radish	0.3	0.56
5	Chillies	0.5	0.74
6	Pea	1	1.84
7	Onion	0.44	0.74
8	Garlic	0.36	0.58
9	Ginger	0.42	0.74
10	Turmeric	0.5	0.74
11	MAP (E.purpurea)	1	1.5
12	Green leaves	0.36	0.64
Total		**6.4**	**10.42**

Benefits of water security in the village: There are many tangible and intangible benefits associated with providing village with sufficient water. The major tangible benefits are listed below.

- It is a life saving irrigation to the village, otherwise village is getting barren.
- Major occupants of the village are elders and ladies, water availability near to their home made them to cultivate and look after their produce effectively.
- The people of the area need not to travel long distance for water for their livestock as we as their domestic use.
- When sufficient water was not available, ladies need to walk long distance in early morning, which created many men animal conflicts.
- Female folk will get lots of leisure quality times for their family as water is not an issue now.
- Now villagers are cultivating in all three seasons
- They could also generate crops commercially.
- Life style of the people improved

CHAPTER 6: HYDROLOGICAL INTERVENTIONS

6.1 Introduction

An understanding of the hydrological interventions made in the watersheds is essential to the impact of such interventions in the hydrological regime of the micro watersheds. This is one of the key aspects to intervene the watershed through structural and nonstructural way. The objective of these interventions is to improve the water availability to the people of the area so that their land productivity and quality of life is improved. This chapter deals with the structural interventions adopted in eight representative micro watersheds and an estimation of the capacities developed and impact visible to the area. As part of the hydrological monitoring these structures were also monitored for their intended usage in conserving and augmenting this resource. The purpose of the structural interventions is to conserve, harvest, augment and distribute water resources so that it will be available to the people where it is needed.

Hence the structural interventions have been classified into the following categories.

- Water harvesting structures
- Water conservation structures
- Water augmenting structures
- Water distributing structures

The details regarding all these structures are summarized below in the following sections. Micro watershed wise structures constructed, their capacities and area brought under irrigation are given in Annexure 6.1.1.

6.2 Water harvesting structures

Water harvesting structures are constructed to harness water and store it in small tanks for the immediate usage for the people of the area for their agricultural and domestic requirements. The major structures constructed for the purpose are

- Irrigation tanks
- Roof top rainwater harvesting tanks
- LDP tanks
- Village ponds

All these structures are made to increase the water holding capacity of the villages of the watersheds. It has increased farming activity in the region by providing additional perennial Irrigation tank: A number of irrigation tanks were made available to the community to grow crops in water deficient areas and non-rainy months. Capacities of these structures are generally ranging from 15000 to 30000 ----?. Source for filling these tanks, in general, are nalas and gadheras. In all the cases water is reaching the tanks with gravity flows. A total of about 651 irrigation tanks were constructed in eight representative micro watersheds and developed a water holding capacity of 9765 cum of

water. Approximately 521 ha of rainfed land is converted to irrigated land through this method.

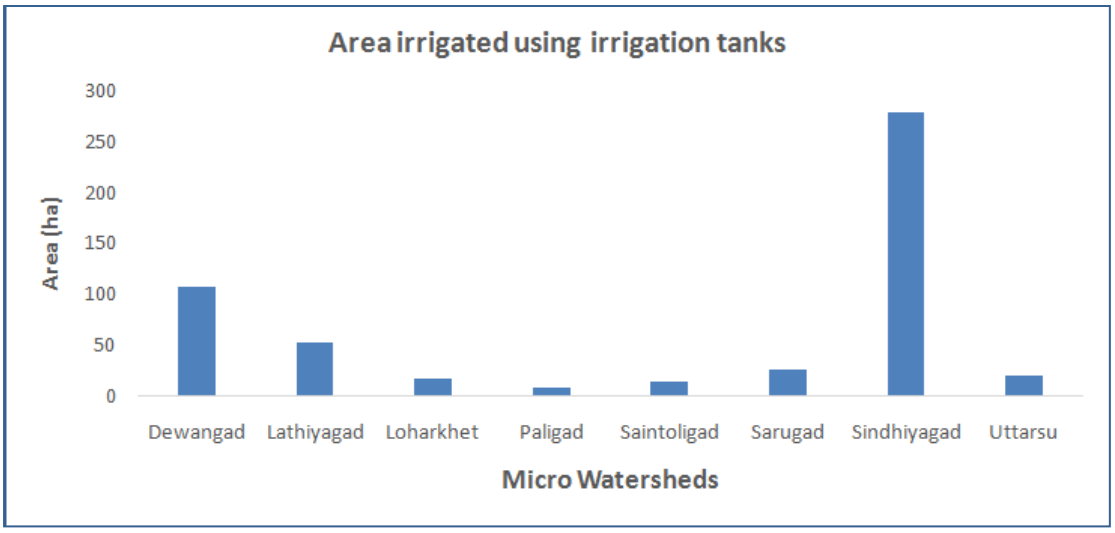


Fig.6.1 Area irrigated using irrigation tanks

Roof top rainwater harvesting structures: This is a simple mechanism of collecting roof water to a channel and directed towards a sealed tank, the water of which can be used in lean periods and non-rainy days. Mostly these are constructed in individual houses. Culturally people are reluctant to use this water for drinking. Communities are using this water for domestic usage and for agriculture. Capacity of the tanks is 2500 liters. A total of 6514 roof top rainwater harvesting structures were installed at various individual houses. Average roof size is 500 square feet. A total capacity of 16,285 cum of water is harvested through this method. Some amount of this water is used for irrigation of the land adjacent to the houses. About 261 ha of land is irrigated in this way in 8 representative micro watersheds.

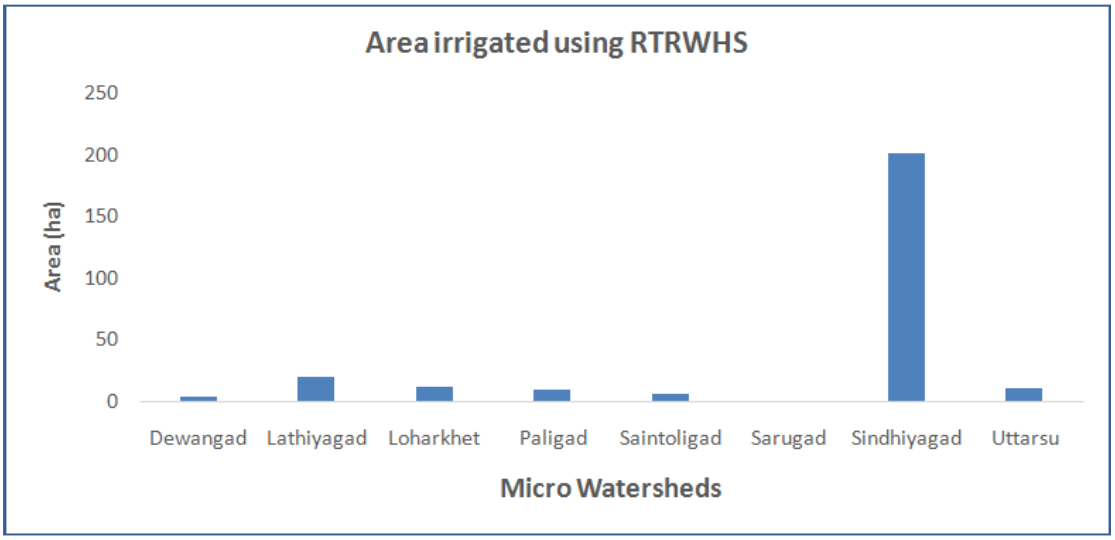


Fig.6.2 Area irrigated using RTRWHS

LDP Tanks: As the slope does not allow water to retain in natural unlined tanks in hilly region, the low-density polythene tanks were constructed to store water. This will be, in general, used

for irrigation in other wise rainfed regions. Further distribution of water is done through gravity flow to lower fields. The capacity of the LDP tanks is 20,000 liters. About 208 such tanks are established in the representative micro watersheds. 4160 cum of water holding capacity is developed in this way. 208 ha of land is getting irrigated through these tanks in representative micro watersheds.

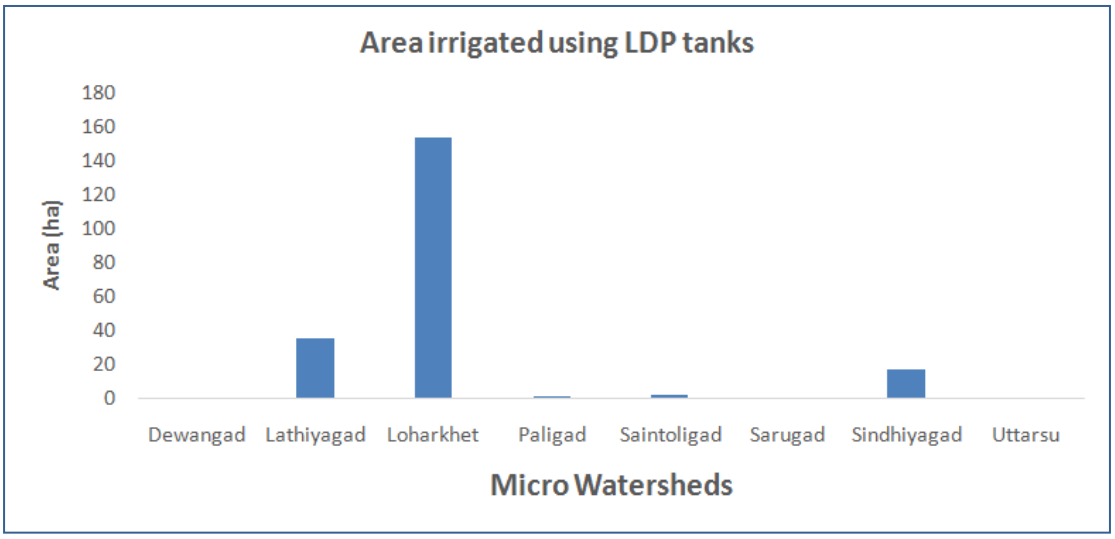


Fig.6.2 Area irrigated using LDP tanks

Village ponds: Gramya II has rejuvenated some of the existing village ponds for the use of irrigation. This has increased the agricultural production in those villages and improved the livelihood of communities. This water is used for agriculture. The existing 192 village ponds were not functioning due to various reasons. Through this project these village ponds were repaired and 192 ha of land has been brought under irrigation. Unlined bottomed ponds were used as percolation unit.

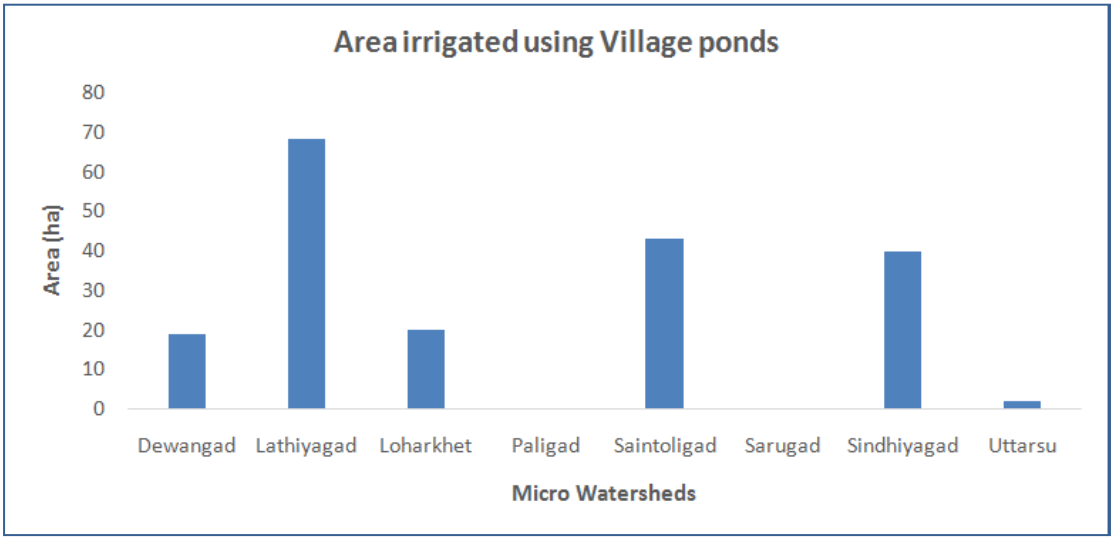


Fig.6.3 Area irrigated using village ponds

6.3 Water conservation structures

Recharge pits: These are used for water conservation and retaining the soil moisture to support the densification of forest, development of fodder and cash crops. Total Capacity developed through recharge pits is 98944 cum of water in eight representative micro watersheds.

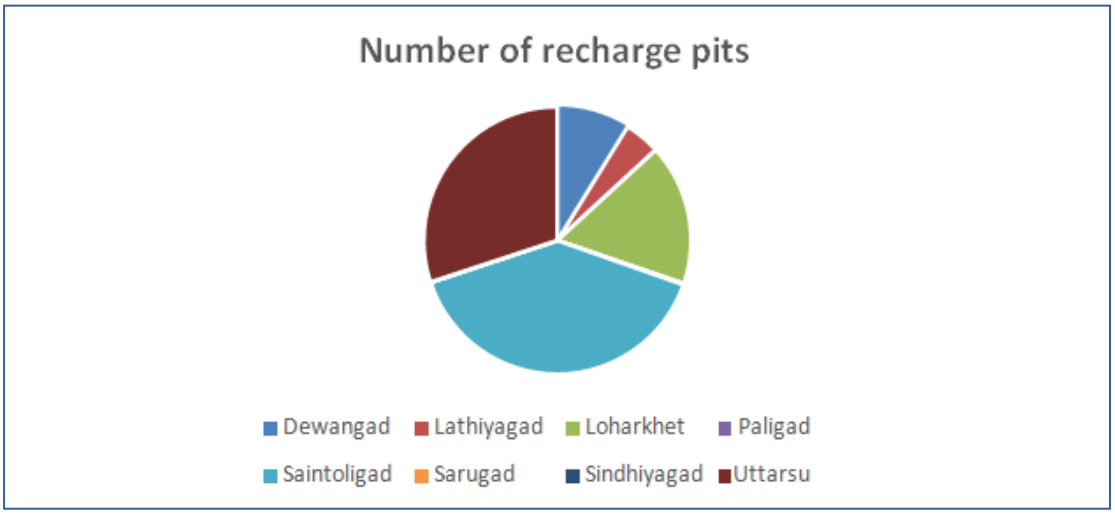


Fig.6.4 No of recharge pits across 8 representative micro watersheds

Impact and benefit of recharge through pits are

- Increased soil moisture
- Root zone water availability for afforestation, fodder crops, cash crop and other horticultural activities
- Replenish water sources downstream

Contour trenches: These are small depressions made on the surface of the earth for water harvesting and to retain the moisture. It helps in arresting the sheet flow and in moisture retention especially in orchards. A capacity of 251,220 cum is generated in 8 representative micro watersheds of the project by constructing 334,960 contour trenches.

Impacts and benefit of recharge through contour trenches are

- Increased soil moisture
- Root zone water availability for afforestation, fodder crops, cash crops and other horticultural activities
- Replenish water sources downstream.
- Arresting the sheet flows thereby reducing soil erosion
- Act as a nutrient trap.

Shallow dugout ponds/ Chal Khal: These are very shallow dug out ponds having a maximum depth of 1 m. Mostly it serves the purpose of water hole for animals and moisture retention and supplement springs and water sources lying down stream. About 3183 dugout ponds were constructed through the project hydrological intervention activity. A capacity of 28,647 cum of water

is created in the pilot micro watersheds.

6.4 Water augmentation structures

Spring augmentation: Springs are zones of natural oozing out of water in mountainous terrain. Most of the springs are formed in geologically weak locations and its recharge area can be at far distance. Most of the places these tickling waters may be got wasted and unnoticed and flow as surface runoff. In Gramya II all such springs are located and developed, that people can use it for drinking purpose. Most of the locations these springs are permanent source and is also acting as a water hole for animals. All the water conservation efforts are to augment the spring flows so that sustainability of this resource can be assured.

With the help of water conservation practices some of the major springs available in the micro watersheds are augmented to put in use for the community. Most of these springs are sources of water and hence monitored for their sustainability by measuring their discharges which is described in chapter 4. 188 springs were augmented which were otherwise flowing as tickles of water all over the hill slope. This water is not used by the community for domestic, animal drinking and but also used as water for people passing through the difficult hilly terrain.

6.5 Water distribution structures

Irrigation pipes: Irrigation pipes were laid down in the key areas of the watershed to provide additional water source for the community. Improvement in area of cultivation and livelihood enhancement of the community is aimed through this. Increased irrigation facilities have improved agricultural products. Most of the programs were community managed ones. This has facilitated rainfed agriculture in multi seasonal cropping and has brought additional revenue to the beneficiaries. Total length of the pipe lines laid down is 240 km and 959 ha of land is brought under multi crops from rainfed agricultural practice.

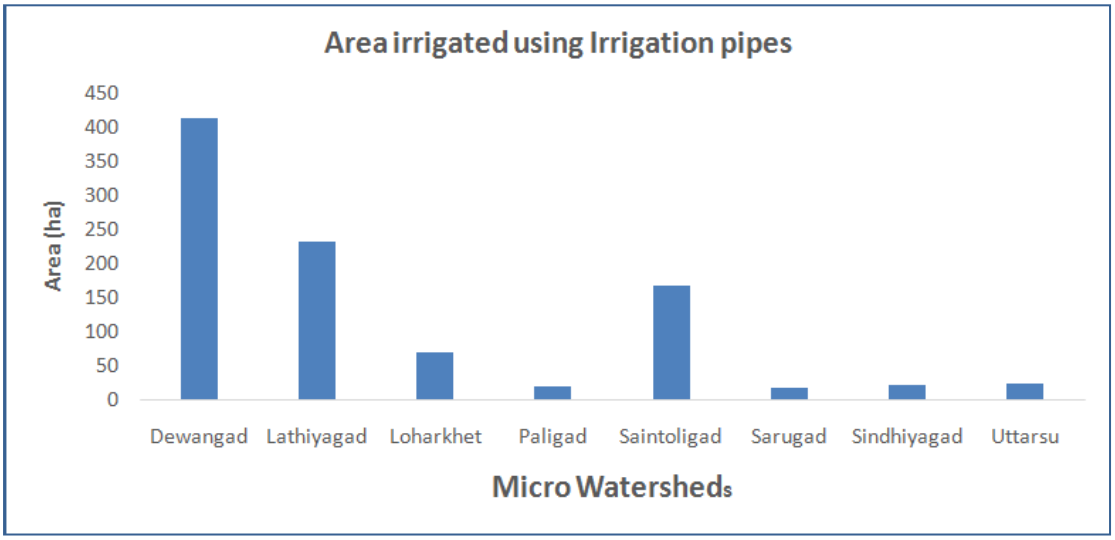


Fig.6.5 Area irrigated with irrigation pipes

Irrigation Channels: Gramya II has created irrigation channels and repaired some of the existing irrigation channels to effective use of the otherwise waste resource. These are lined channels taking water from a small stream to fields in hilly terrains. A total of 99 km of channels are constructed for irrigation and an additional 591 ha of land is irrigated in this way.

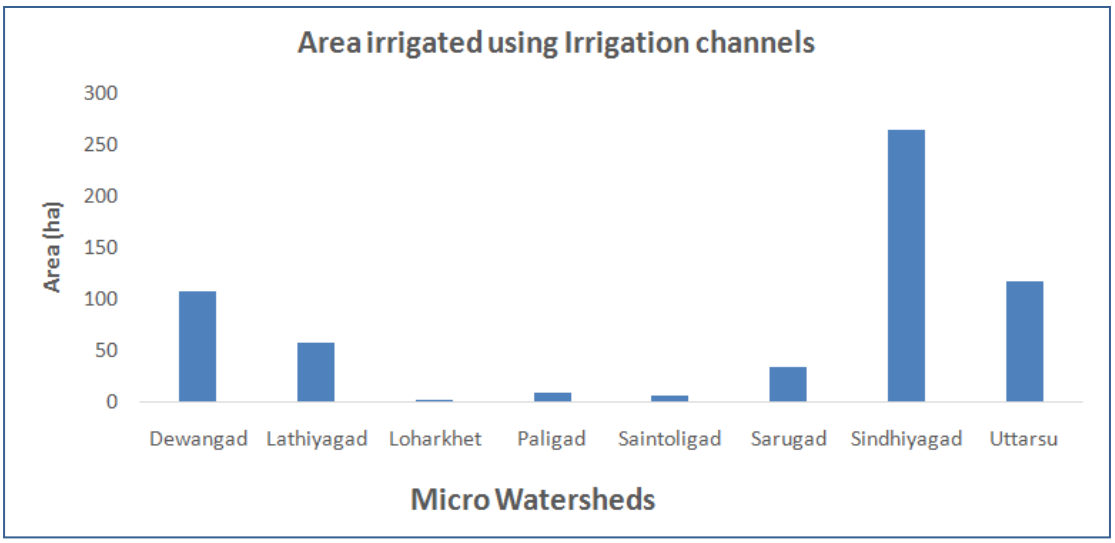


Fig.6.6 Area irrigated with irrigation channels

These structural interventions have brought out 0.43 million cubic meters of water holding capacities within the 8 representative micro watersheds. The capacity generated for the 82 micro watersheds are same for all the watersheds at 1.15 million cubic meters. 2732 ha of land has been converted from rainfed to irrigated agriculture due to these structural interventions in the 8 representative micro watersheds. For all the 82 micro watersheds the land brought under irrigation through these activities is 5647 ha.

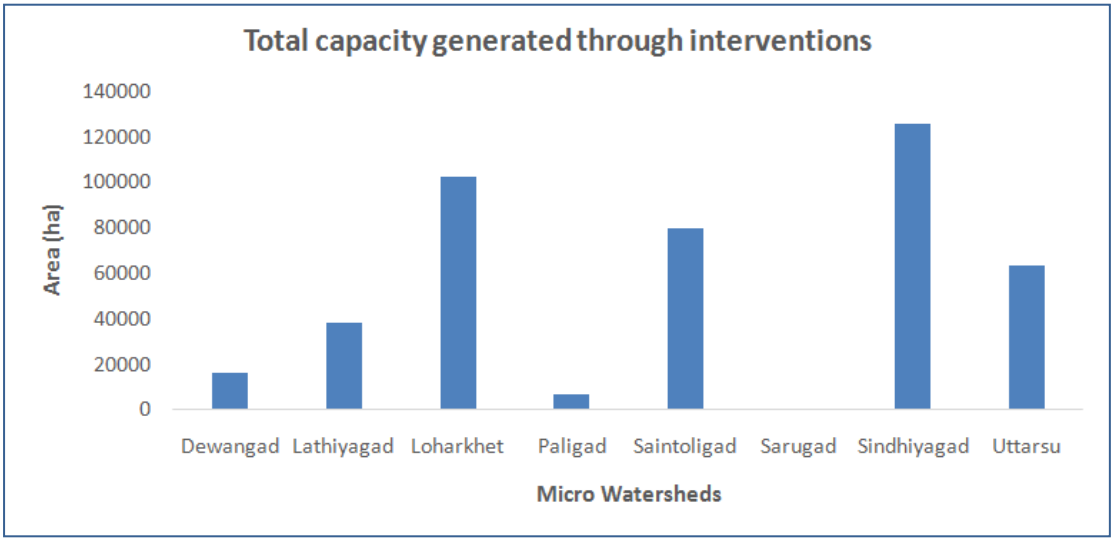


Fig.6.7 Watershed wise capacity generated through structural intervention

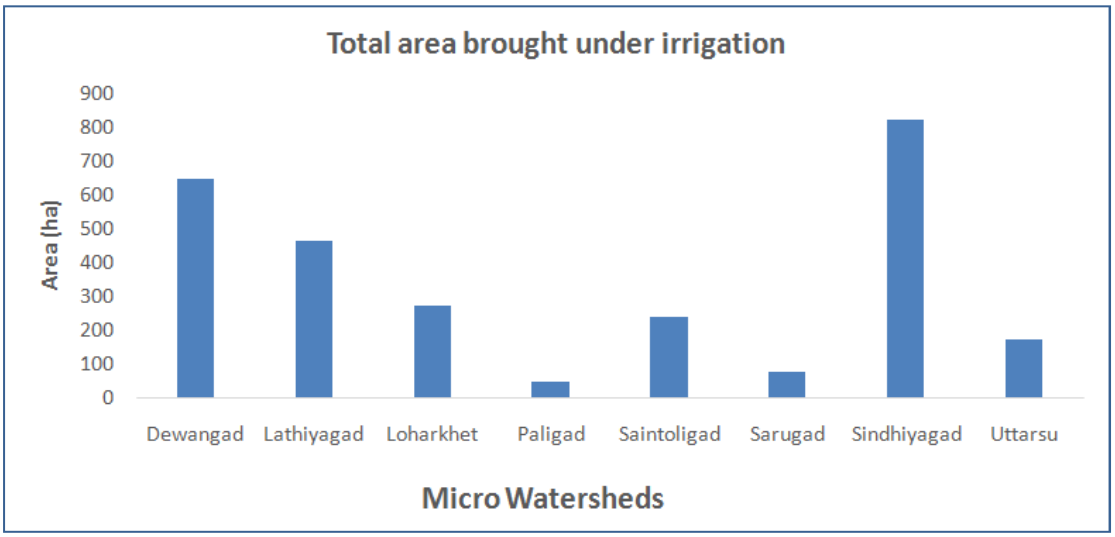


Fig.6.8 Watershed wise area brought under irrigation from rainfed areas

CHAPTER 7: FINAL IMPACT EVALUATION

7.1 Introduction

Under the project Gramya II WAPCOS has been monitoring the hydrological scenario from the base line year of 2014 to final impact evaluation year of 2021. WAPCOS has studied the hydrological regime of the eight representative micro watersheds and submitted reports during inception, base line, concurrent monitoring, midterm, annual impact evaluation, stages of the project. This chapter deals with the findings of the final impact evaluation major conclusions derived and key lessons in the form of recommendations for future similar projects. For arriving at final impact evaluation, a vast amount of hydrological, meteorological, agricultural, and social data sets was collected. These data sets were used to monitor the hydrological regime of the area.

7.2 Conclusions

The important conclusions derived from this hydrological monitoring study are listed below.

- The hydrological monitoring study has been conducted in eight micro watersheds which is representative of micro watersheds spreading across eight hilly districts of Uttarakhand.
- For the purpose of hydrological monitoring, 16 automated rain gauges, 4 automated weather stations, 8 weirs for stage discharge measurement through currents meters etc. were established in the eight representative micro watersheds.
- The instrumental data from the weather stations and historical data have been merged and made one data set of meteorological data. The weather data have been updated up to September 30, 2021 and used for various analyses and modeling. The homogeneity of the data sets has been statistically tested with inter parameter correlation and inter watershed correlations.
- Satellite images were collected and land use land cover map has been updated for all the micro watersheds.
- Stage discharge data from 6 gauging stations were collected. Training has been imparted to the project staff and communities in taking stage discharge measurements.
- All the structural interventions of the micro watersheds were monitored and recorded; their capacities estimated.
- Source discharge of about 2054 locations was monitored through data collection and analysis.
- Crop data of all eight representative micro watersheds were collected and analyzed for crop water requirement and also to estimate evapotranspiration from agricultural activities.
- Water usage by farming community is also monitored
- Water budgeting has been attempted using SWAT model. All the water balance components of the SWAT output are estimated as percentage of precipitation to compare the outcome between watersheds and between different periods of the project such as base line to final impact evaluation stage.
- Validation of the SWAT model with observed stage discharge data shows that an average

deviation is only 2.4 mm, which is an acceptable limit.

- All of the watersheds show reduction in surface flow and average reduction is 7.1%.
- Most of the watersheds are topographically controlled and very few are geologically controlled watersheds.
- All the watersheds show aquifer recharge as dominant process however due to high slopes 80% of this water is returning to the surface in the immediate vicinity itself.
- Average aquifer recharge increased by 9%.
- Sediment yield studies shows that Bageshwar and Tehri districts have more sediment yield when comparing with other micro watersheds. Overall, 12-33% reduction in sediment yield is observed in the micro watersheds. Average sediment yield is 19% which is about 13.9 t/ha/year.
- Overall yield of the micro watersheds has increased by 5.1%.
- Base flow to the streams has also increased with an average value of 8.4%.
- Evapotranspiration has been reduced by 3.8%.
- Water need assessment has been done for domestic, livestock and crop water requirement. The analysis shows that all watersheds are water surplus and much more water is available than the requirement.
- Time series analysis of land use land cover shows that there is an average increase of 5.1% of agriculture, 0.37% of forest and 1.7% decrease in land with or without scrub.
- 50% of the watersheds showing decrease and 50% show increase in evapotranspiration.
- Pre monsoon discharge has shown an increment of about 13.33 to 25% with respect to the base line period of 2014 and post monsoon shown an increase of 13.79 to 33.74%.
- Crop water applied by farmers was compared with crop water requirement estimated through norms and found that farmers are applying slightly less amount of water.
- Water use efficiency studies show that through sprinkler irrigation 18.8% water can be saved.
- Case study of Dhaspad village shows that water conservation and water security can bring in about 62% more production.
- There are several structural interventions made in the watersheds to conserve, harvest, distribute and augment the water resources. These structural interventions have brought out 0.43 million cubic meters of water holding capacities within the 8 representative micro watersheds. The capacity generated for the 82 micro watersheds is same for all the watersheds at 1.15 million cubic meters. 2732 ha of land has been converted from rainfed to irrigated agriculture due to these structural interventions in the 8 representative micro watersheds. For all the 82 micro watersheds the land brought under irrigation through these activities is 5647 ha.

7.3 Final impact Evaluation

The project has exerted tremendous inputs in the micro watersheds in the form of structural and non-structural interventions. Most of these interventions aimed to improve and augment the water resources and thereby improve the livelihood of the people residing there. The project has its influence in all aspects of the human life of the area and water was a dominant and influential factor which affects the life of people residing in these hilly micro watersheds. Final impact evaluation is as follows:

- In the eight micro watersheds overall 5.1 % increase in agriculture observed with reference to base line period. In case of forest an increase of 0.37% and 1.7% reduction in land with or without scrub is observed. As the project brought down various water harvesting structures it facilitated increase in agriculture. Forest densification may be behind the increment in forest cover. Some of the land with or without scrub (barren) is converted to agriculture which attributed to its reduction.
- SWAT model shows a reduction in surface runoff in almost all micro watersheds. Various water conservation soil protection measures may be the reason for the same.
- Lateral flow, shallow aquifer recharge, and return flow has increased in almost all watersheds which again may be attributed to the presence of conservation structures and soil protection measures employed in the watershed. Increase in return flow will definitely increase base flow and hence sustainability of the surface water bodies will be ensured.
- In case of evapotranspiration various watersheds shows different trends when comparing with base line data. Land use land cover prepared with different seasons data as compared to base line period may be the reason for the same.
- Overall yield of the watersheds increased with respect to base line period. Aquifer recharge and lateral flow increase compared to reduction in surface runoff may be the reason for the same.
- All the watersheds are showing decrease in sediment yield. The reduction is in the ranges of 12 to 33% and average reduction is 19%. Various soil protection measures may be the reason for this reduction in sediment yield across the watersheds.
- Pre monsoon discharge has shown an increment of about 13.33 to 25% with respect to the base line period of 2014 and post monsoon shown an increase of 13.79 to 33.74%. This increase in the source water discharge clearly shows the overall improvement in the hydrological regime of the micro watersheds. Water conservation and soil protection measures have yielded this increase and sustainability of these sources.
- Comparative analysis of the water requirement of crops against how farmers are irrigating the land shows that farmers are irrigating nearly similar amount and no over or under irrigation is noticed.
- Water saving technology such as sprinkler irrigation is saving about 18.8% of water. So water use efficiency improves through such methods of irrigation.

- Green technology initiative such as solar lift pump and water security through the same has improved agricultural activities to more than 62%. Not only improvement in agriculture, it also made change in the village from self-sustainable agriculture to commercial agriculture so that livelihood of people has improved.
- There are several structural interventions made in the watersheds to conserve, harvest, distribute and augment the water resources. These structural interventions have brought out 0.43 million cubic meters of water holding capacities within the 8 representative micro watersheds. The capacity generated for the 82 micro watersheds is estimated at 1.15 million cubic meters assuming that all the watersheds have the same trend in capacity generation. 2732 ha of land has been converted from rainfed to irrigated agriculture due to these structural interventions in the 8 representative micro watersheds. For the whole 82 micro watersheds the land brought under irrigation through these activities is estimated at 5647 ha.

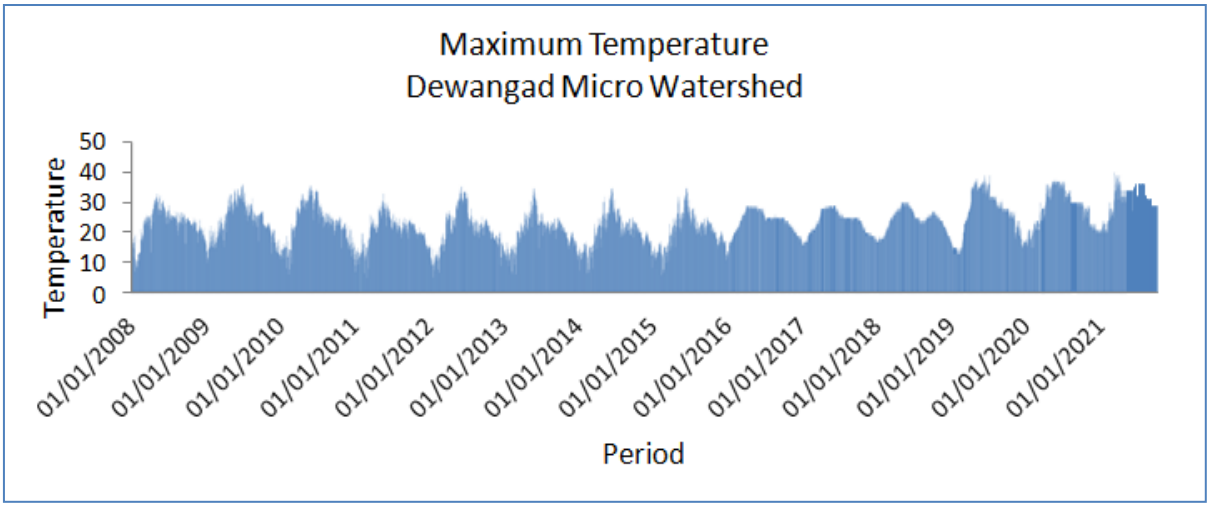
7.4 Recommendations

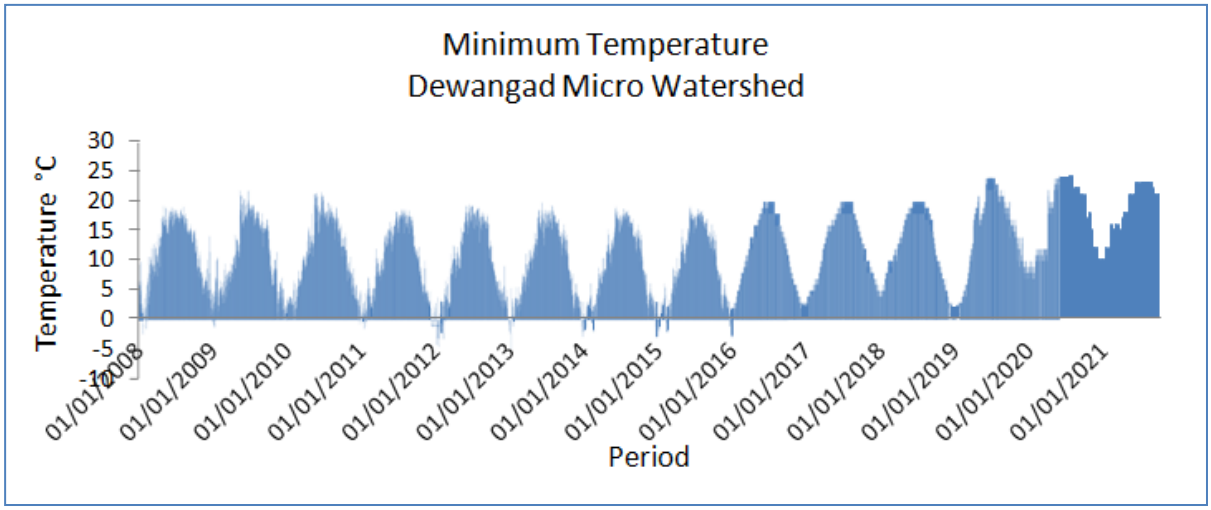
Based on the experience gained in this project following are the recommendations for the upcoming similar initiatives:

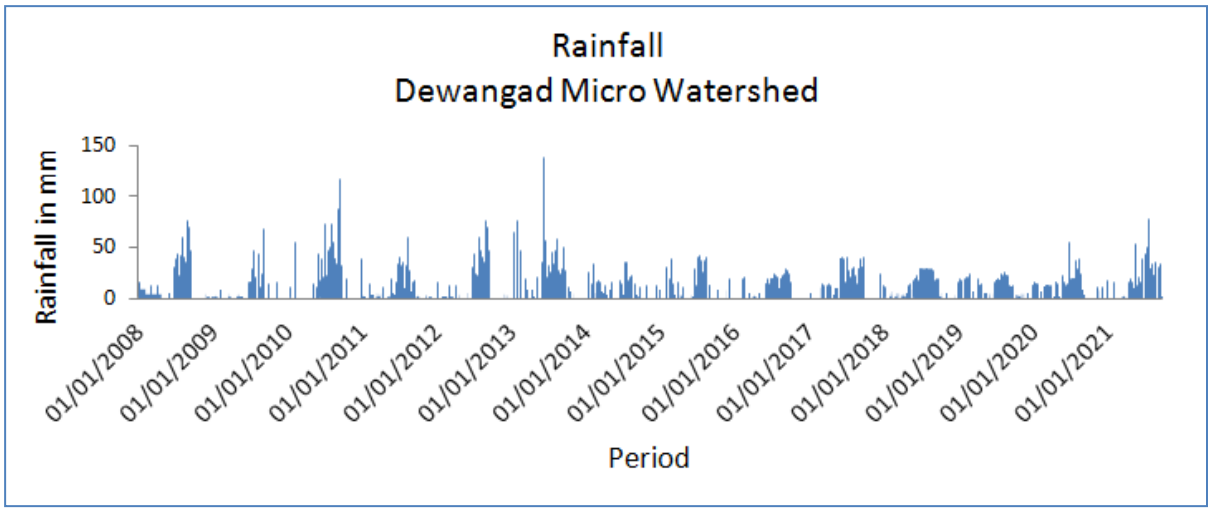
- Need to increase and make permanent the meteorological and hydrological gauging stations, at least one in each micro watershed
- Gauging stations should be automated
- More training is required to the project staff to make hydrological measurements
- Water use efficiency studies could not be taken up to a large scale in the present project, such initiatives should be strengthened in future projects.
- Every watershed has at least one sample village where water security is ensured so that other villages can learn lesson and follow the same.
- More soil moisture measuring mechanisms are required.

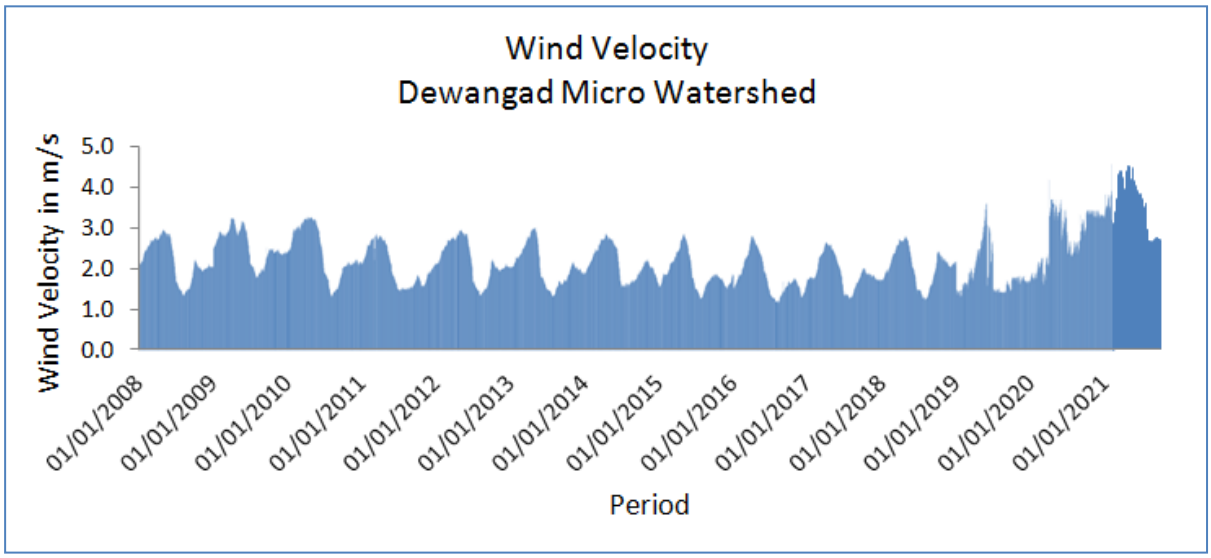
Map plate: 2.2.1 Weather data plots for 8 representative micro watersheds

Weather data of Dewangad Micro watershed





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Dewangad Micro Watershed
Wind Velocity in m/s
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1.0
0.0
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01/01/2010
01/01/2011
01/01/2012
01/01/2013
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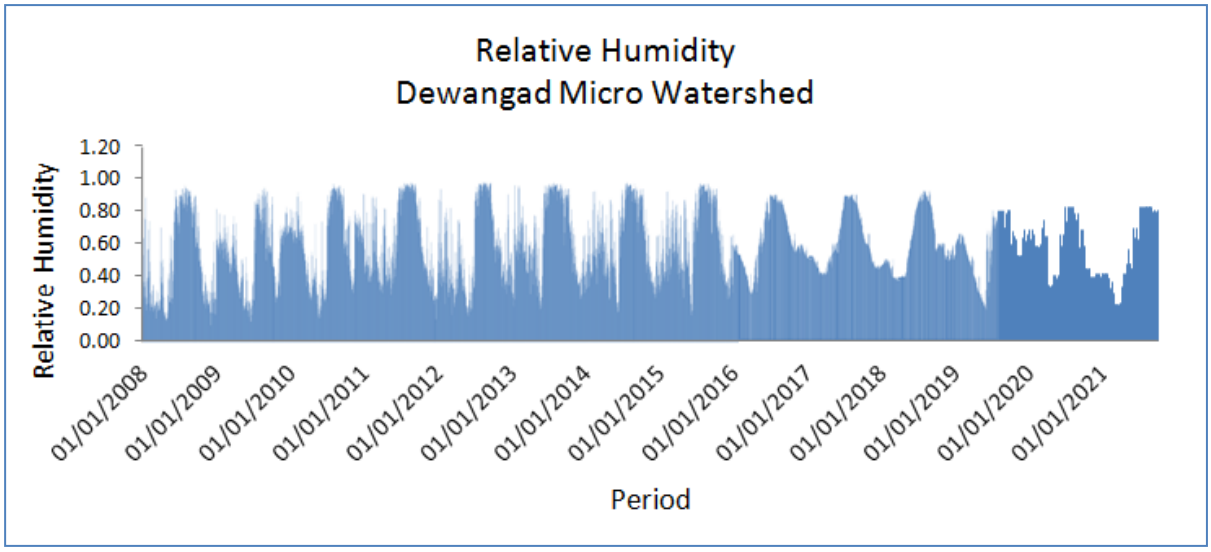
01/01/2019
01/01/2020
01/01/2021
Period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Dewangad Micro Watershed
Relative Humidity
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0.20
0.00
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01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
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01/01/2016
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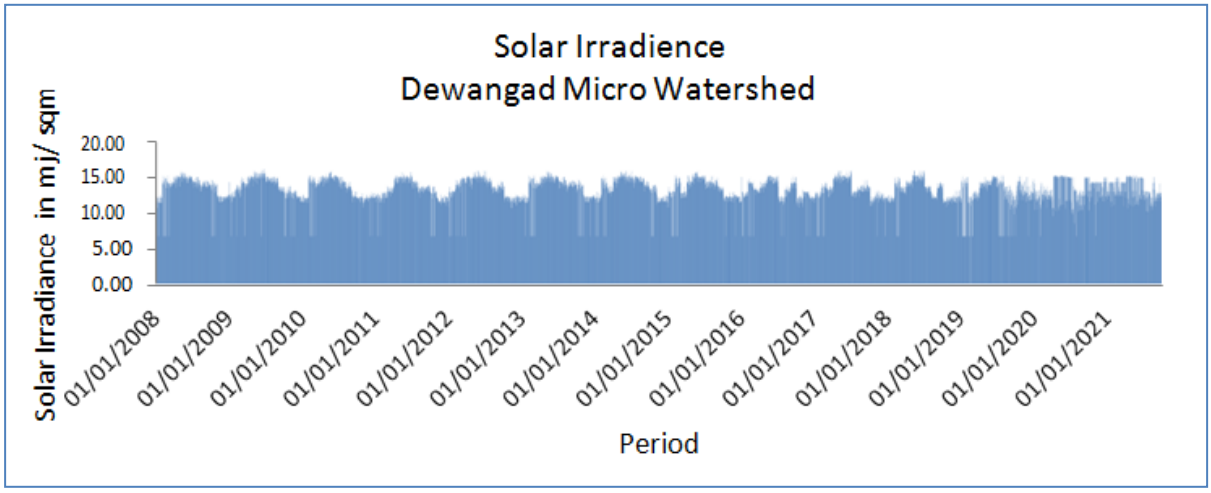
01/01/2020
01/01/2021
Period


Solar Irradience
Dewangad Micro Watershed
Solar Irradiance in mj/ sqm
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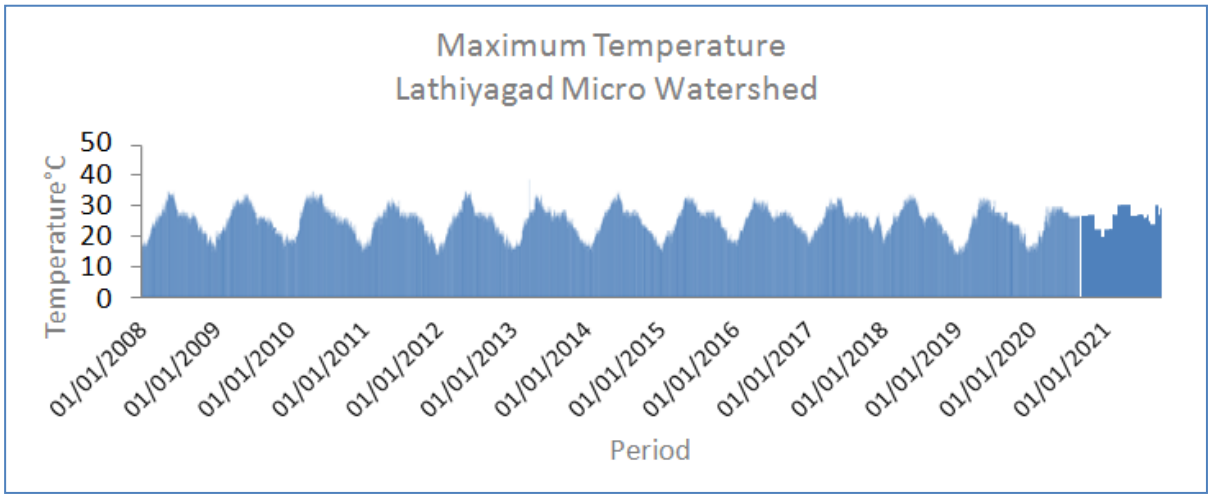
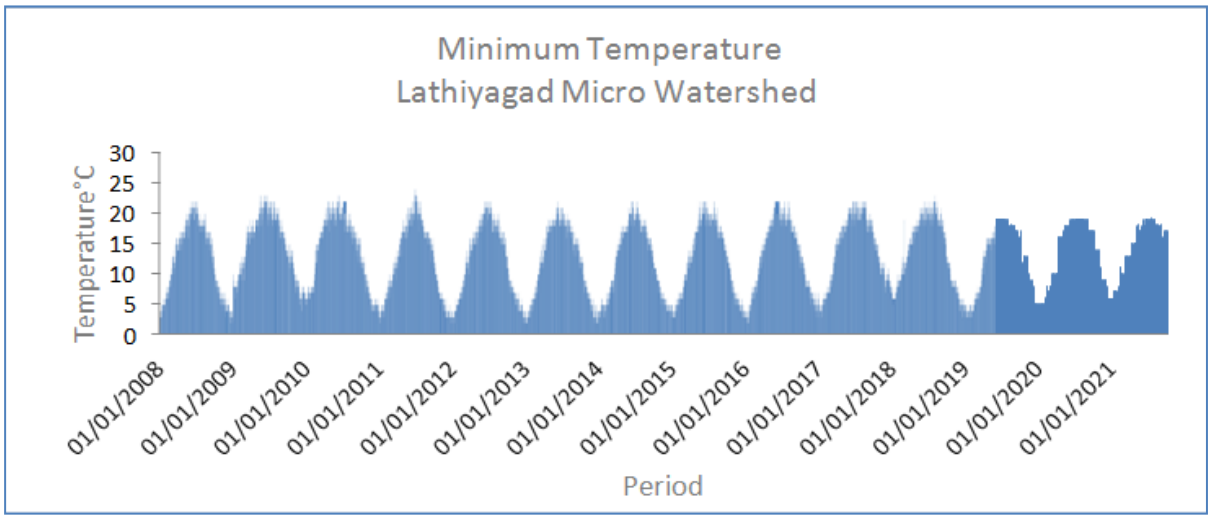
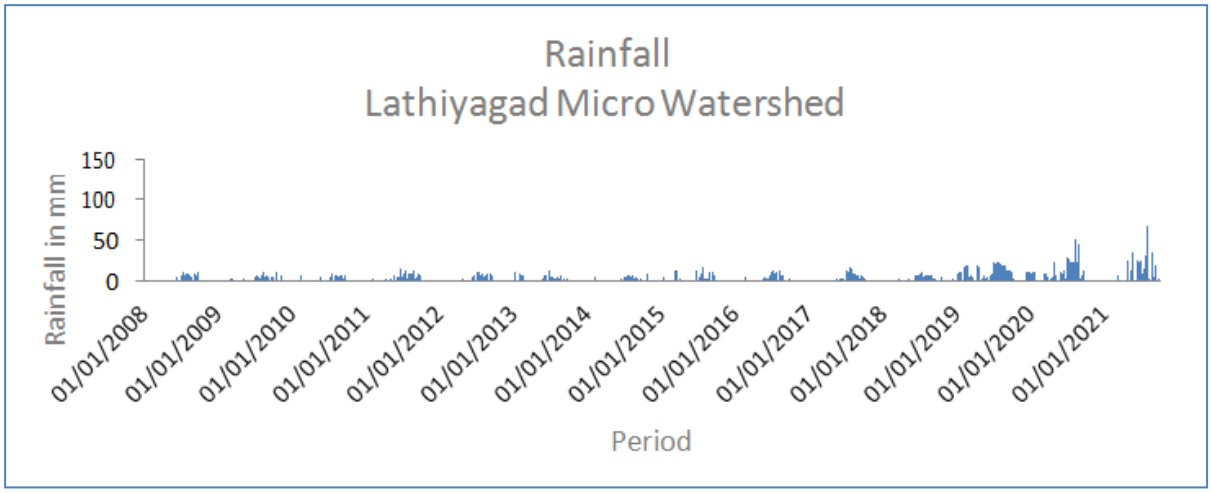
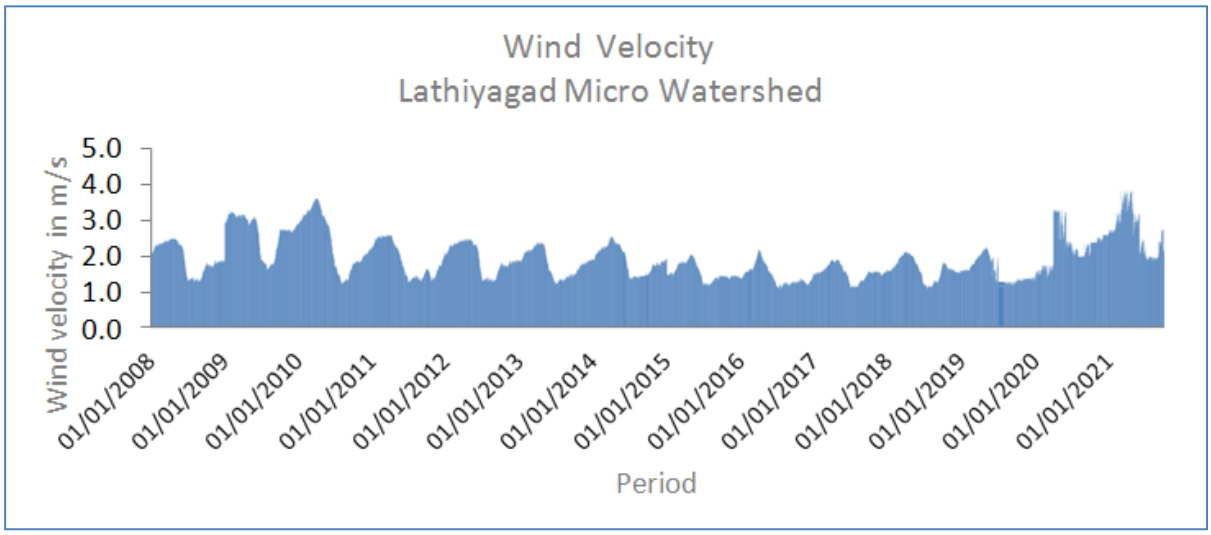
10.00
5.00
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

Weather data of Lathiyagad Micro watershed








Wind Velocity
Lathiyagad Micro Watershed
Wind velocity in m/s
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4.0
3.0
2.0
1.0
0.0
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01/01/2010
01/01/2011
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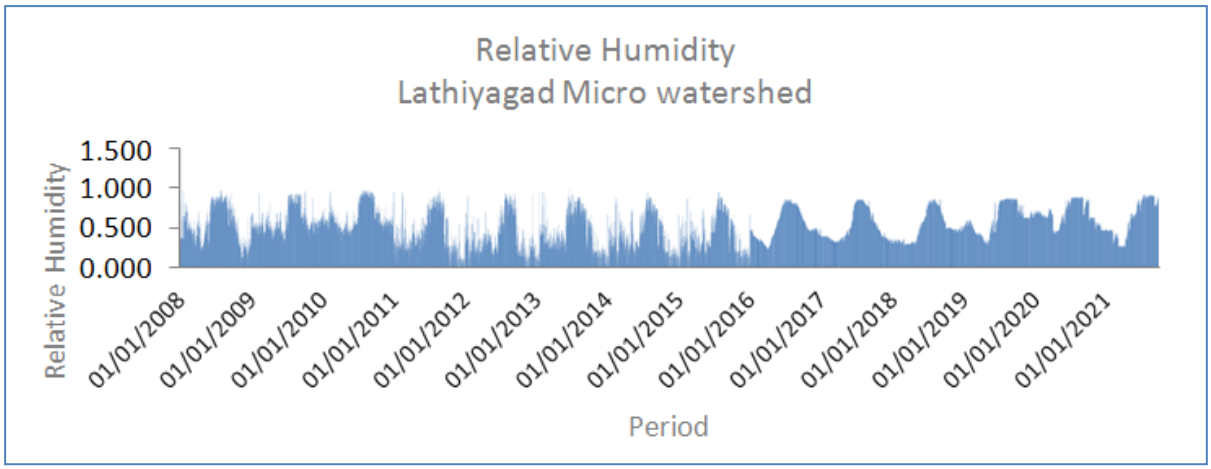
01/01/2019
01/01/2020
01/01/2021
Period


Relative Humidity
Lathiyagad Micro watershed
Relative Humidity
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1.000
0.500
0.000
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01/01/2009
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01/01/2011
01/01/2012
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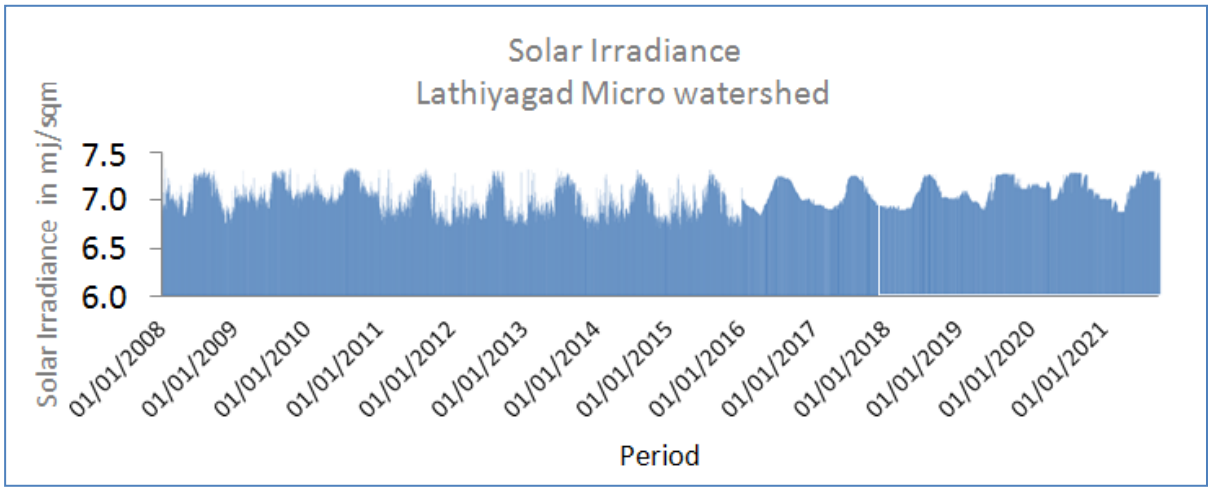
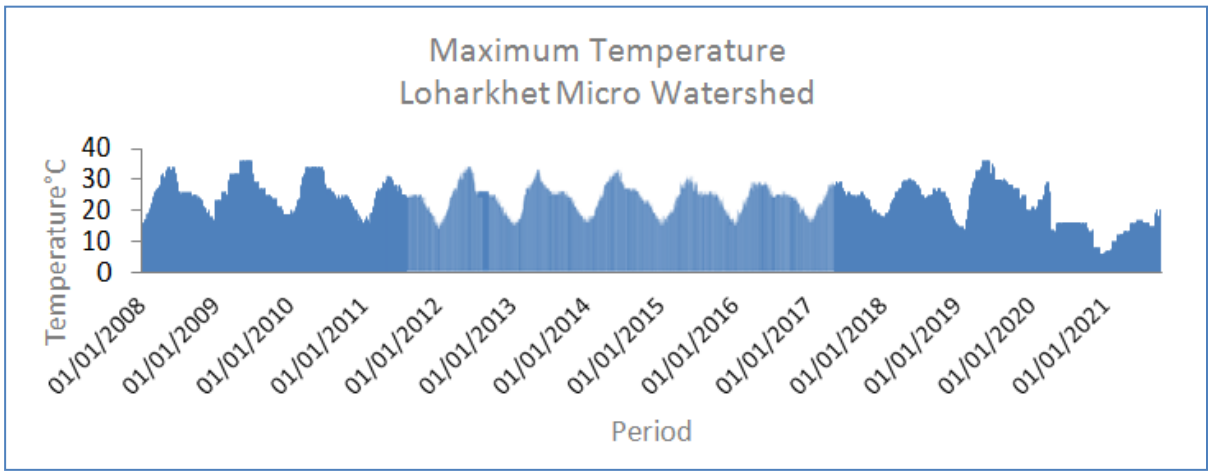
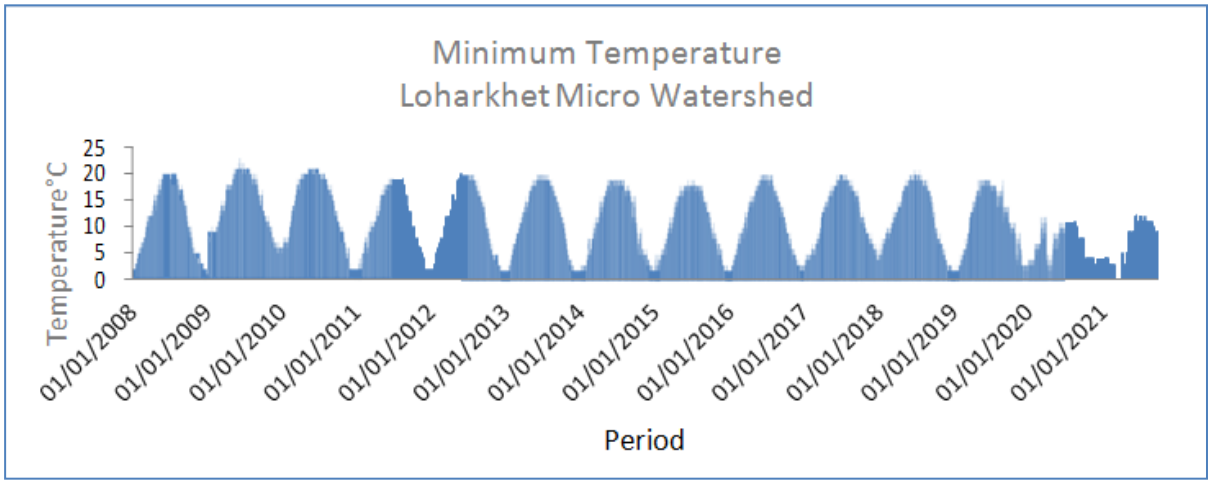
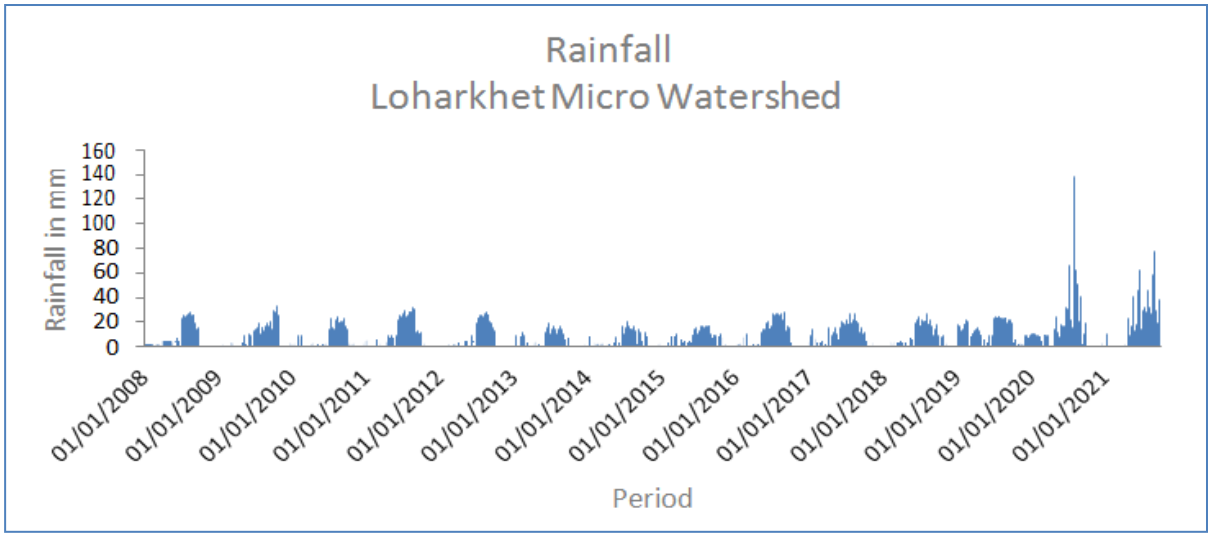
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

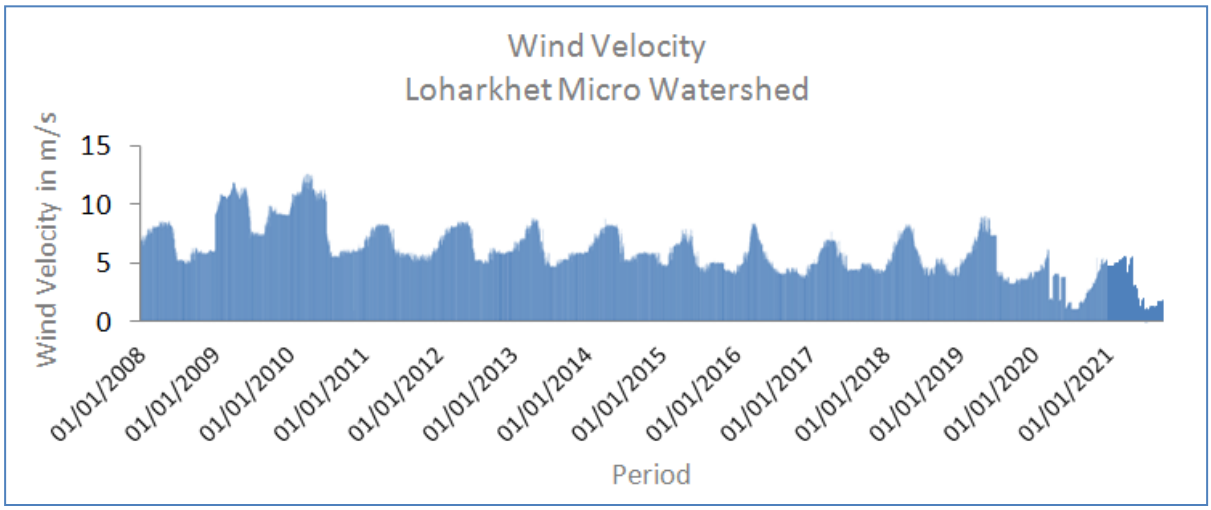

Solar Irradiance
Lathiyagad Micro watershed
Solar Irradiance in mj/sqm
7.5
7.0
6.5
6.0
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

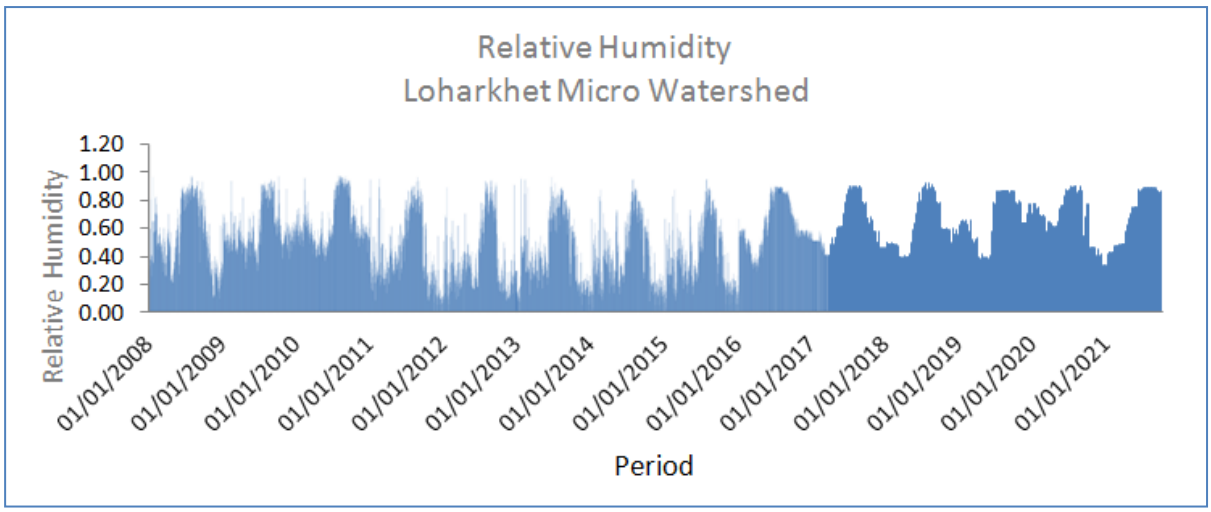
Weather data of Loharkhet Micro watershed

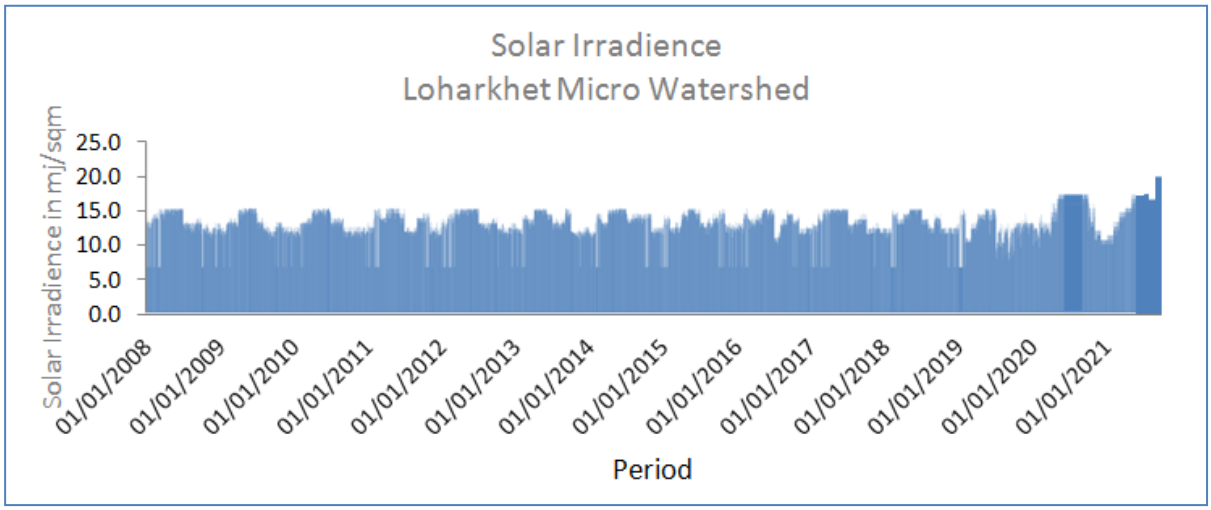




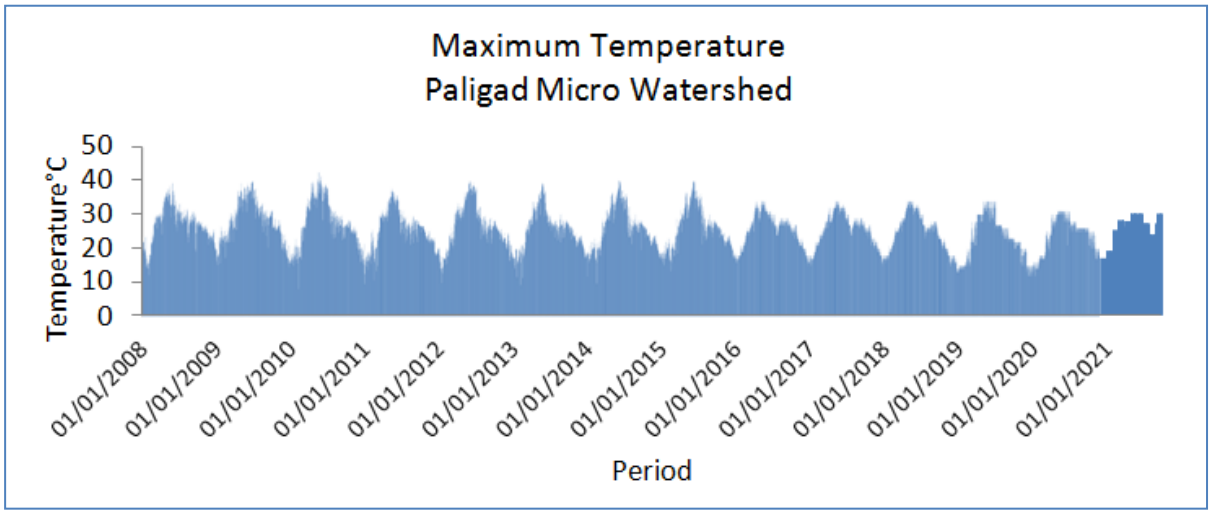


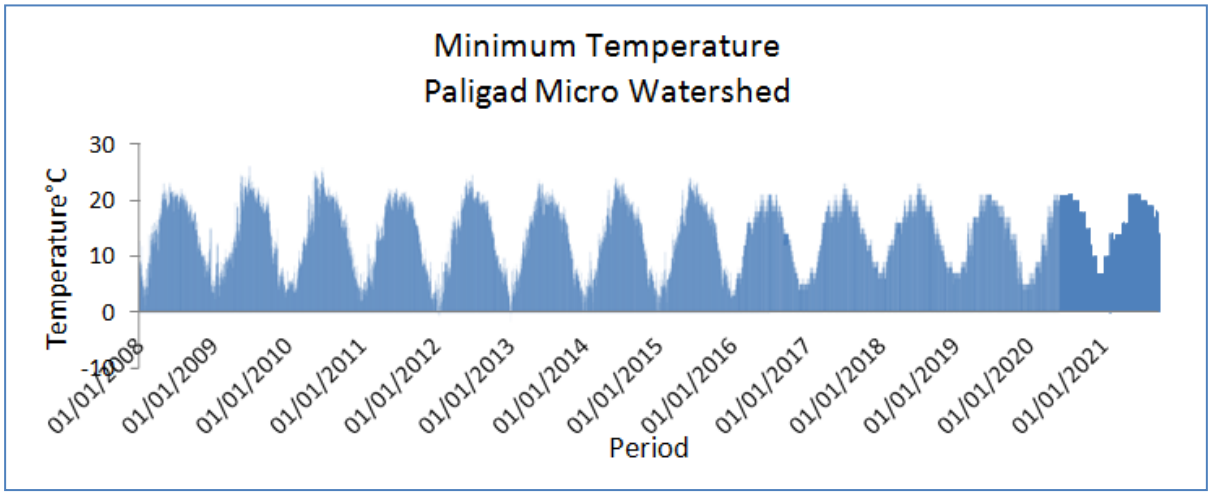

Wind Velocity
Loharkhet Micro Watershed
Wind Velocity in m/s
15
10
5
0
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

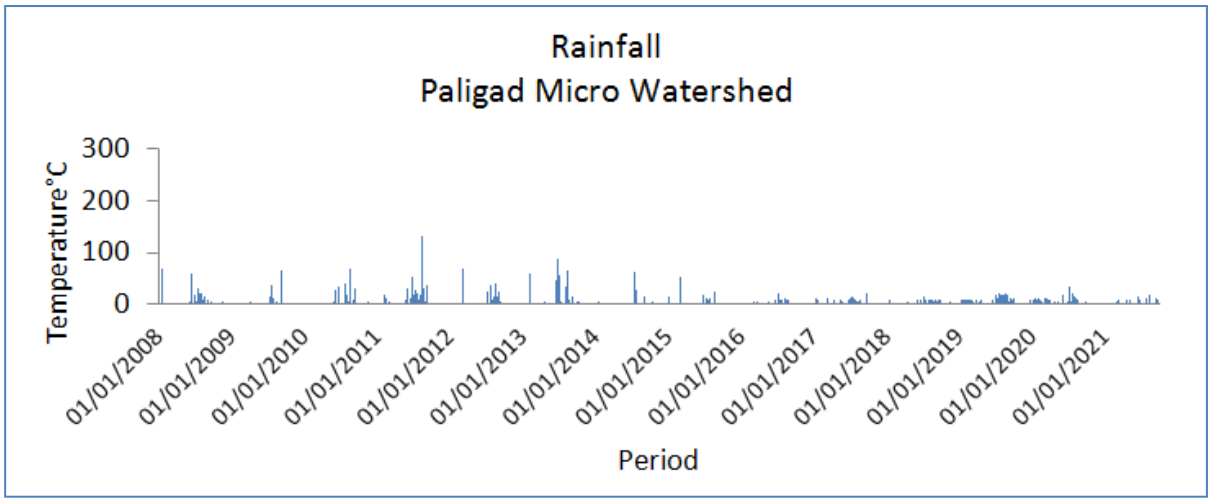

Relative Humidity
Loharkhet Micro Watershed
Relative Humidity
1.20
1.00
0.80
0.60
0.40
0.20
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

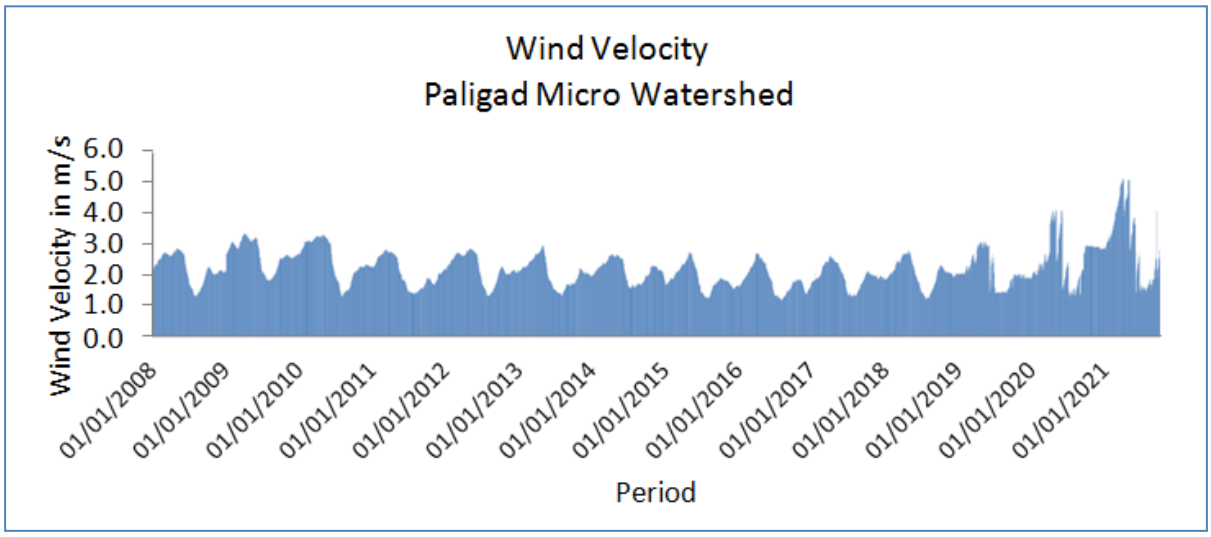

Solar Irradience
Loharkhet Micro Watershed
Solar Irradience in mj/sqm
25.0
20.0
15.0
10.0
5.0
0.0
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

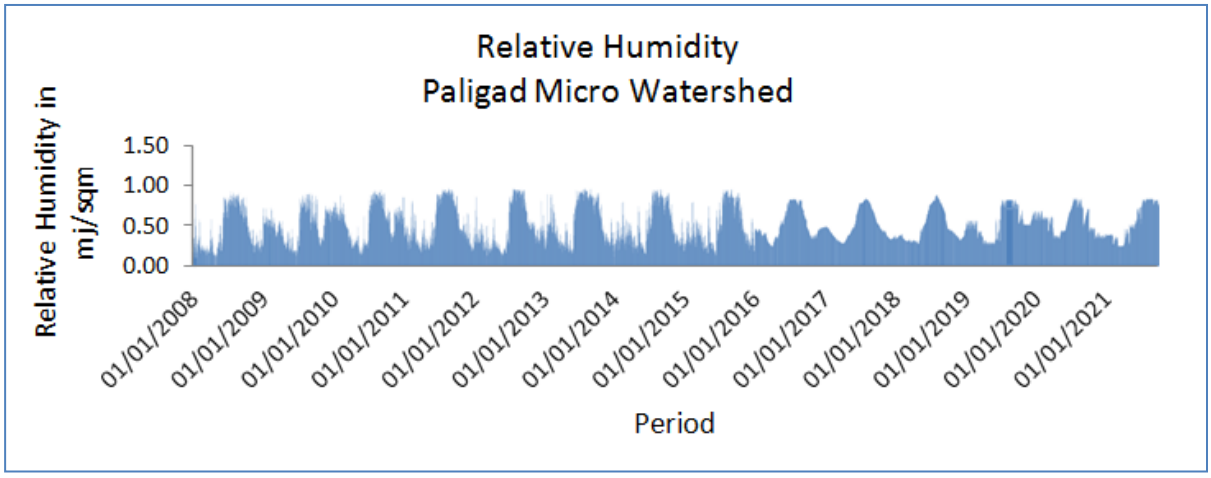
Weather data of Paligad Micro watershed

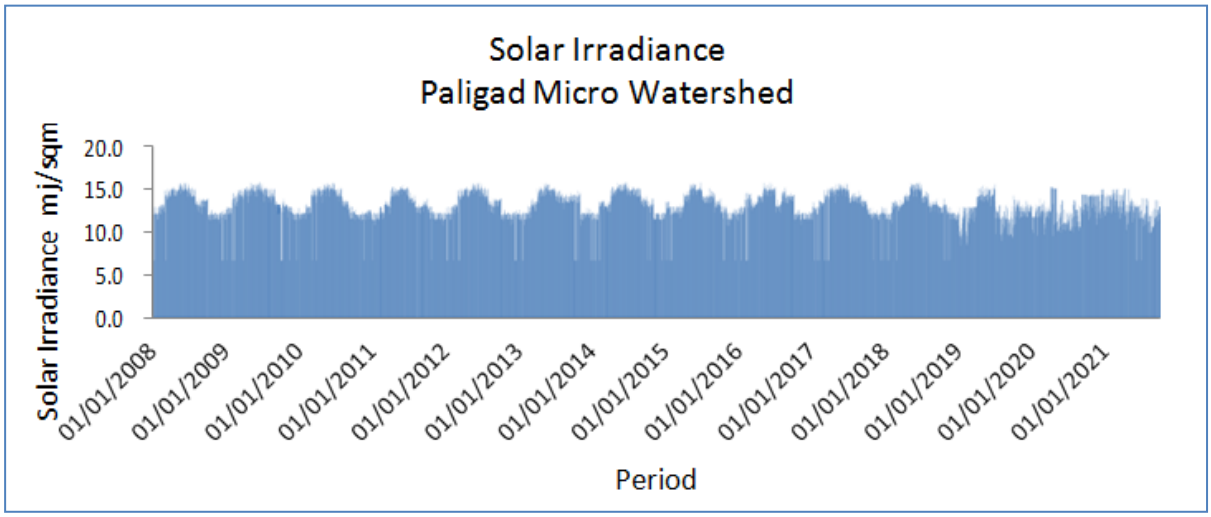




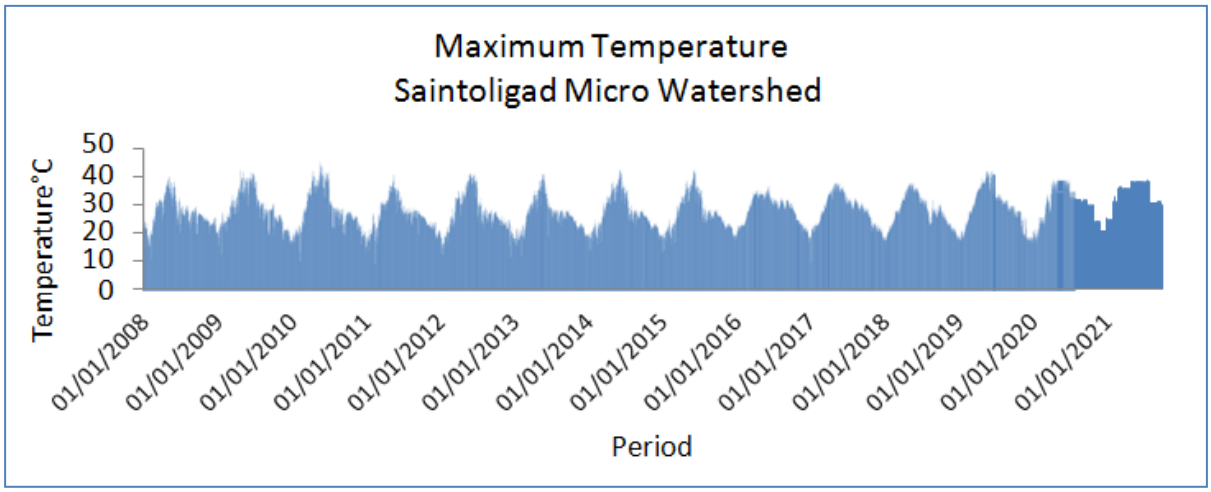


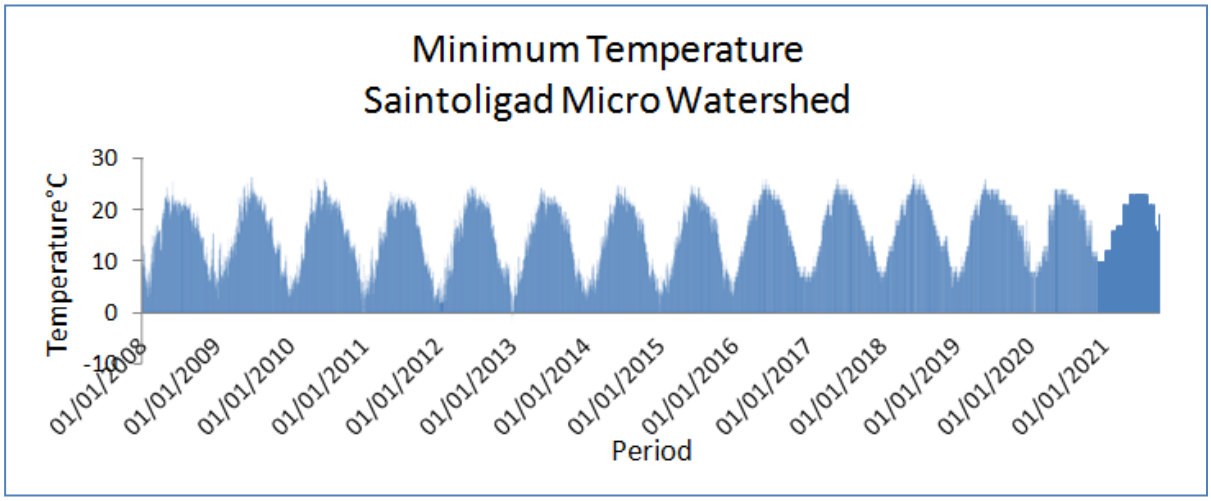

Wind Velocity
Paligad Micro Watershed
Wind Velocity in m/s
6.0
5.0
4.0
3.0
2.0
1.0
0.0
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

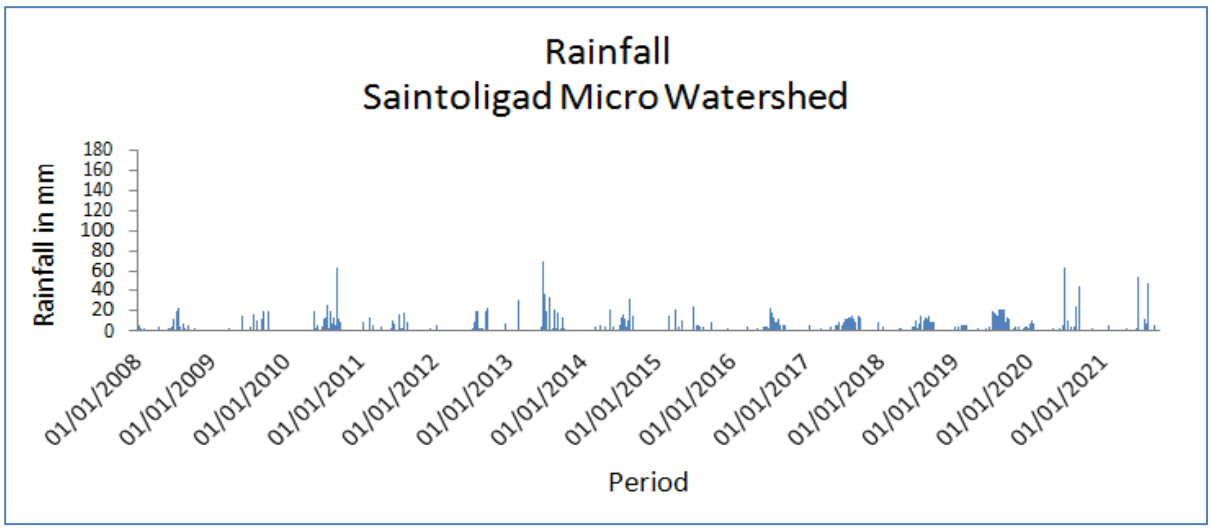

Relative Humidity
Paligad Micro Watershed
Relative Humidity in mj/sqm
1.50
1.00
0.50
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

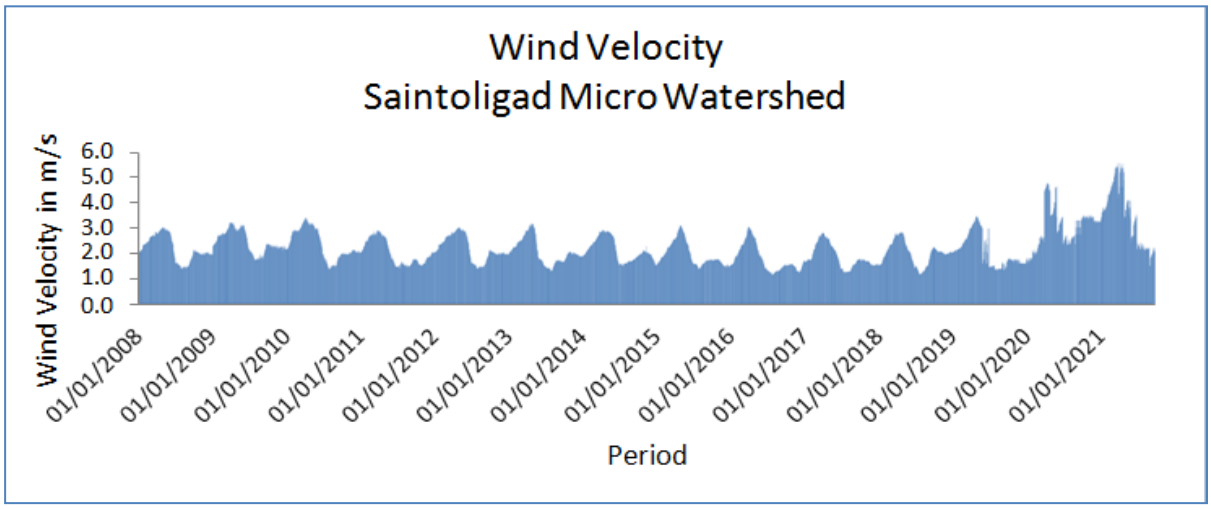

Solar Irradiance
Paligad Micro Watershed
Solar Irradiance mj/sqm
20.0
15.0
10.0
5.0
0.0
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

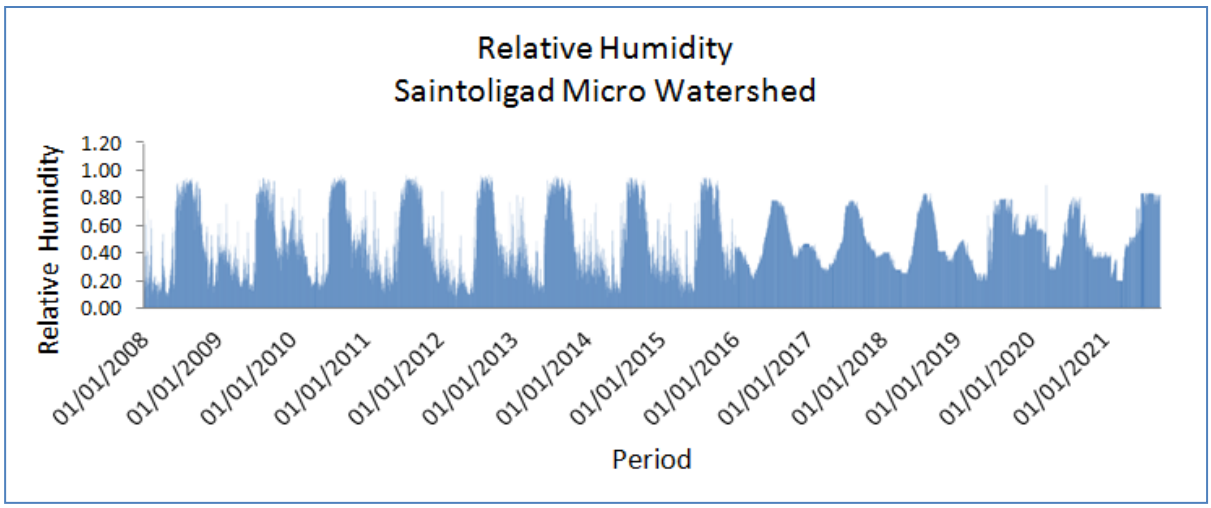
Weather data of Saintoligad Micro watershed

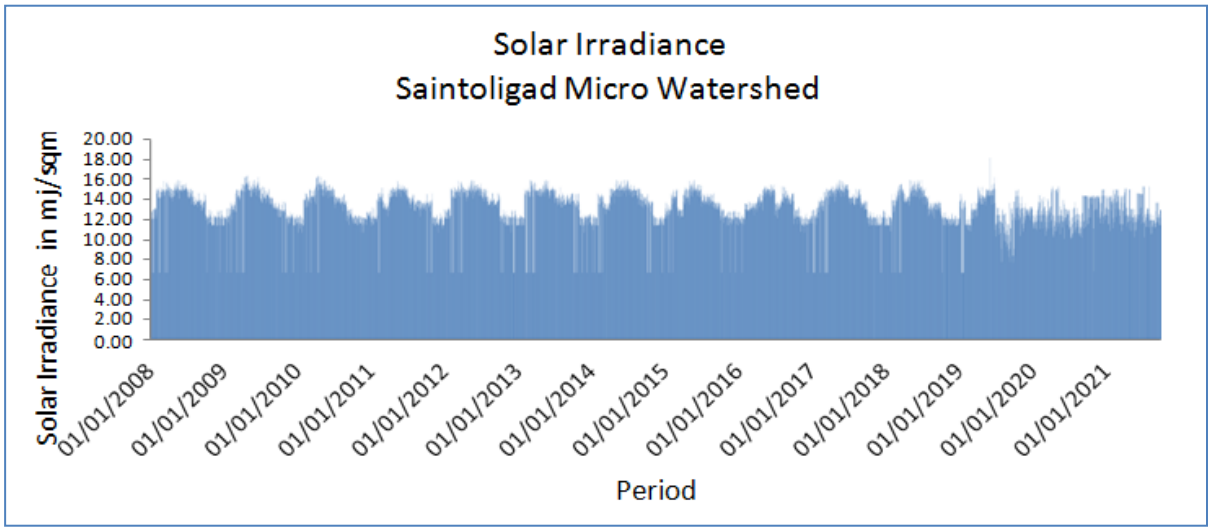




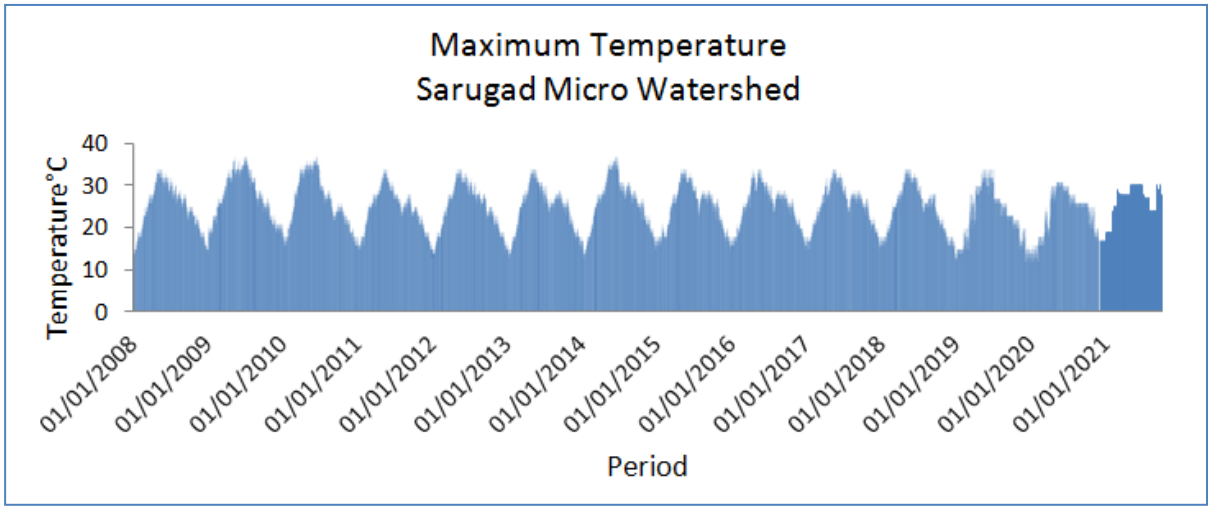


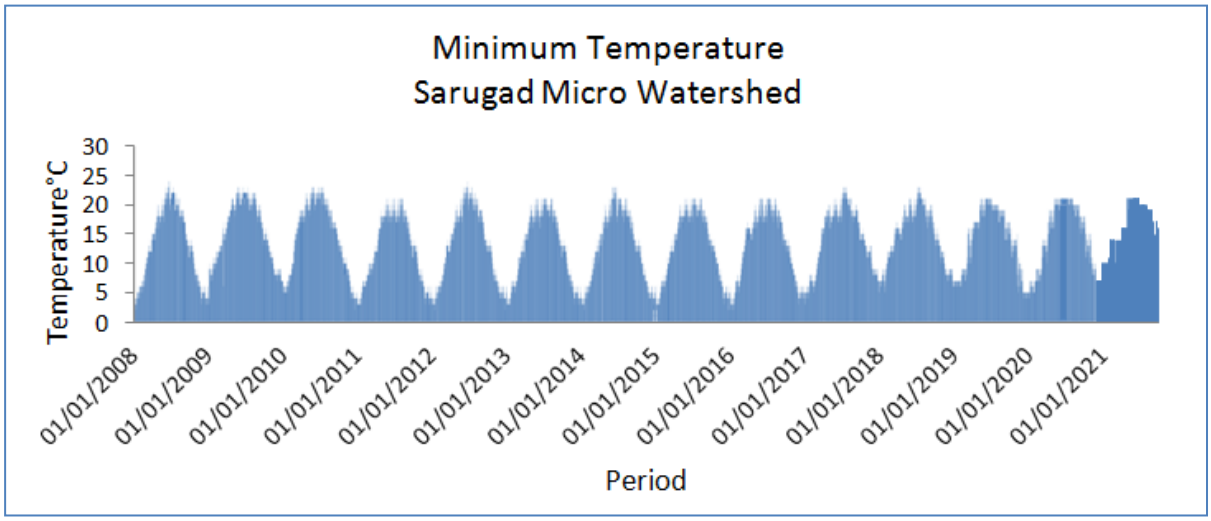

Wind Velocity
Saintoligad Micro Watershed
Wind Velocity in m/s
6.0
5.0
4.0
3.0
2.0
1.0
0.0
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

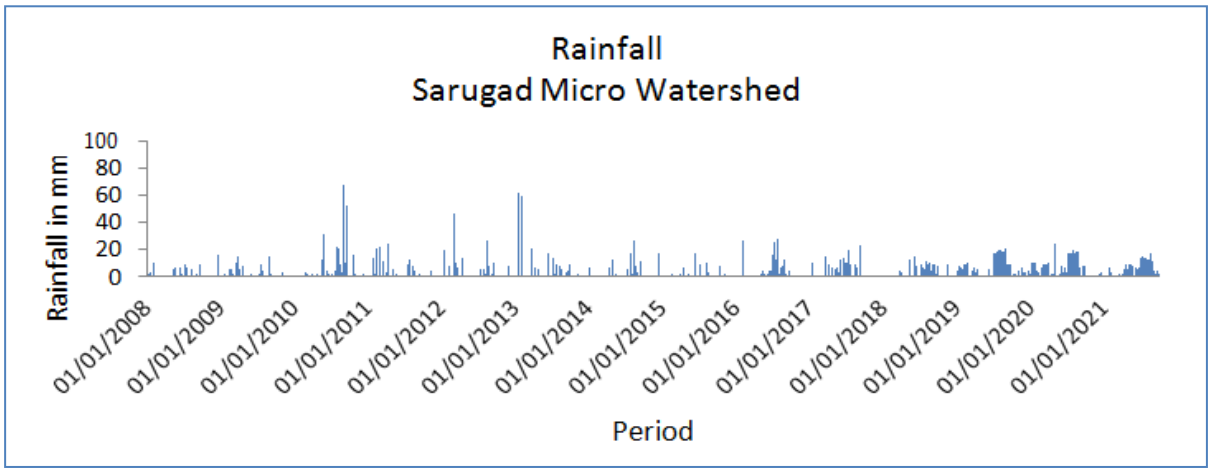

Relative Humidity
Saintoligad Micro Watershed
Relative Humidity
1.20
1.00
0.80
0.60
0.40
0.20
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

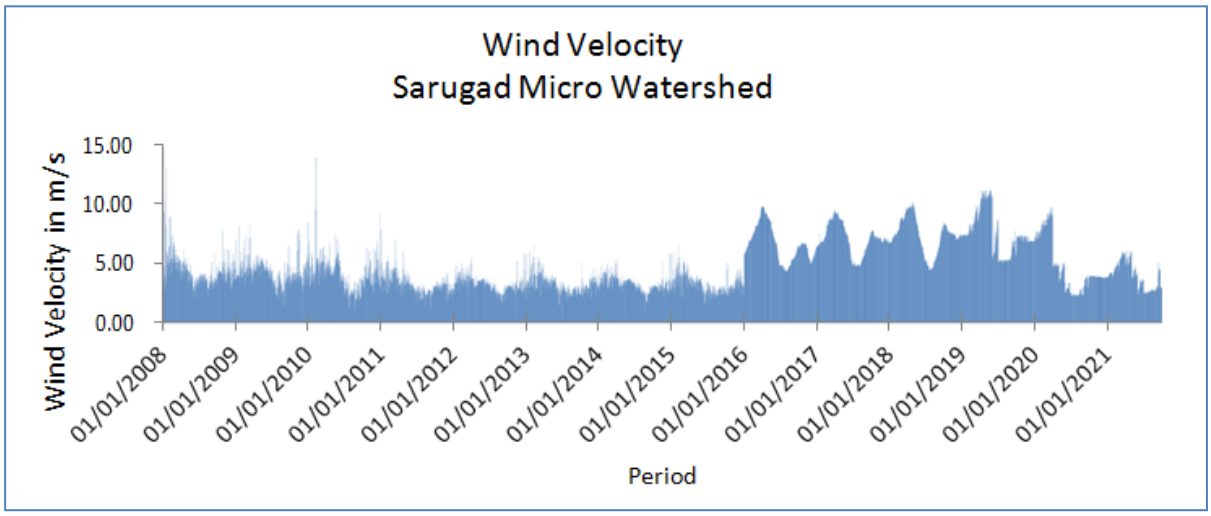

Solar Irradiance
Saintoligad Micro Watershed
Solar Irradiance in mj/sqm
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

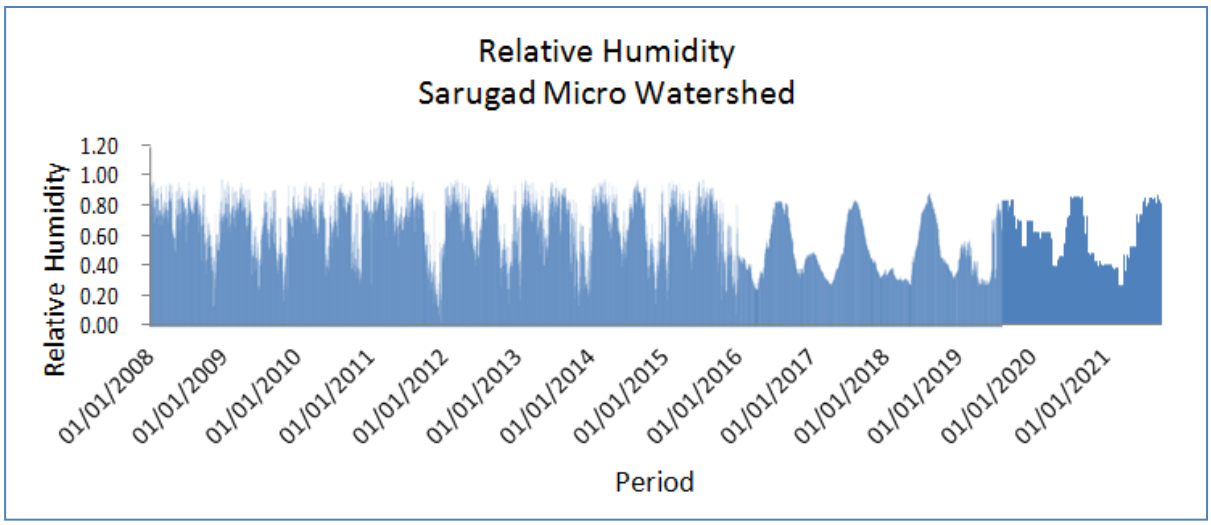
Weather data of Sarugad Micro watershed

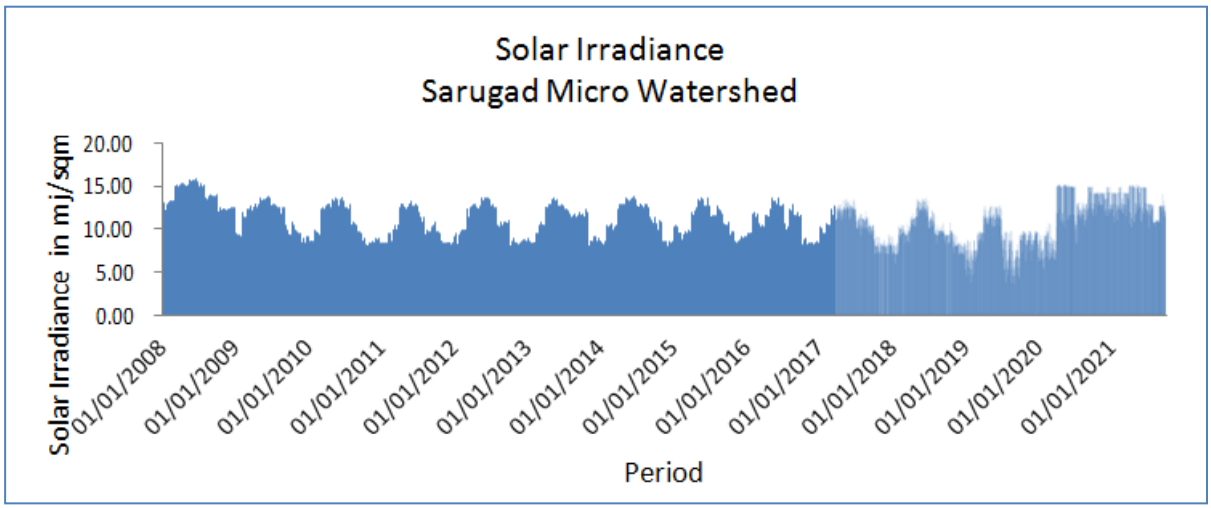




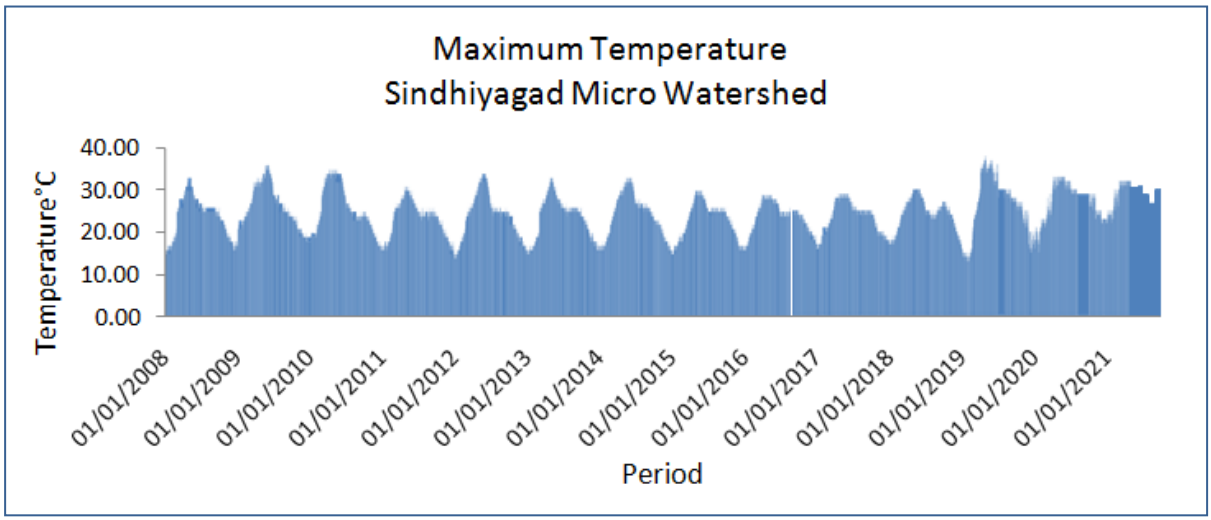


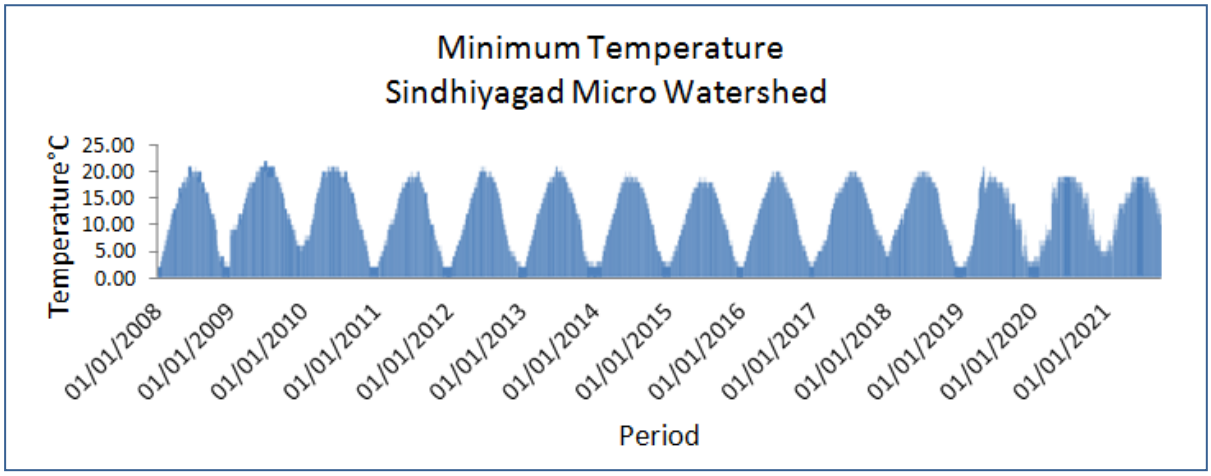

Wind Velocity
Sarugad Micro Watershed
Wind Velocity in m/s
15.00
10.00
5.00
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

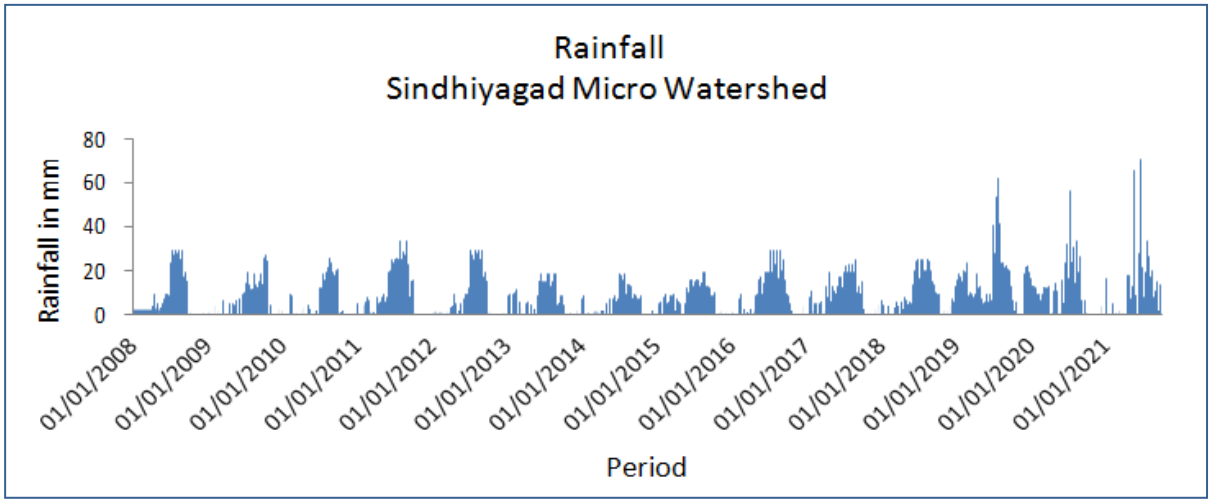

Relative Humidity
Sarugad Micro Watershed
Relative Humidity
1.20
1.00
0.80
0.60
0.40
0.20
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

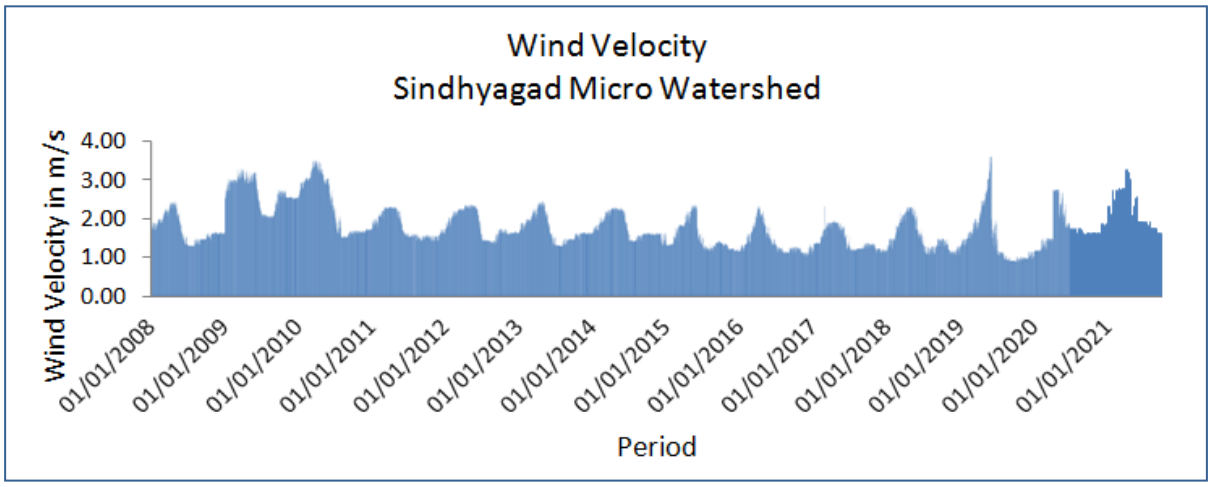

Solar Irradiance
Sarugad Micro Watershed
Solar Irradiance in mj/sqm
20.00
15.00
10.00
5.00
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

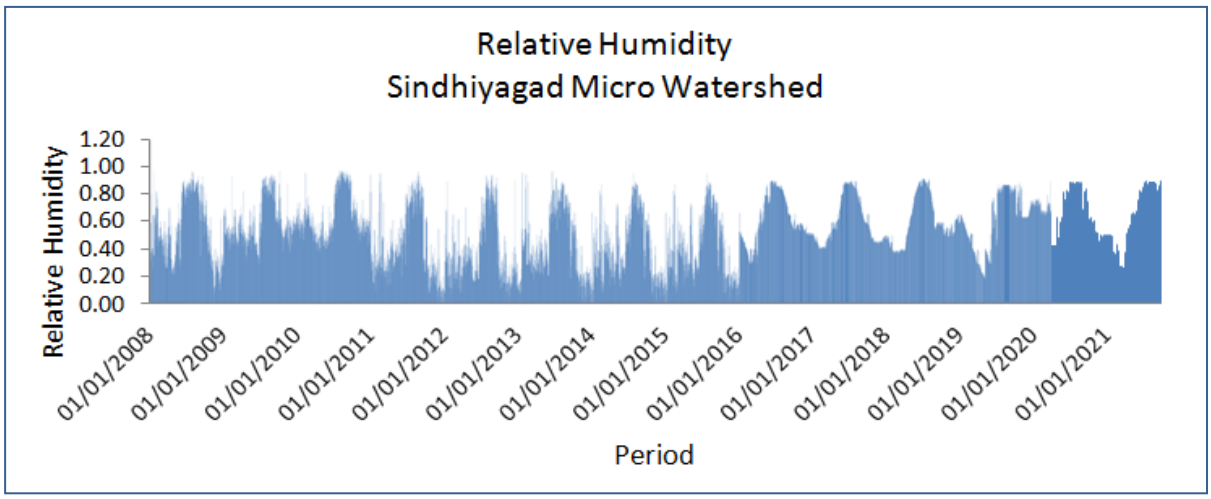
Weather data of Sindhiyagad Micro watershed

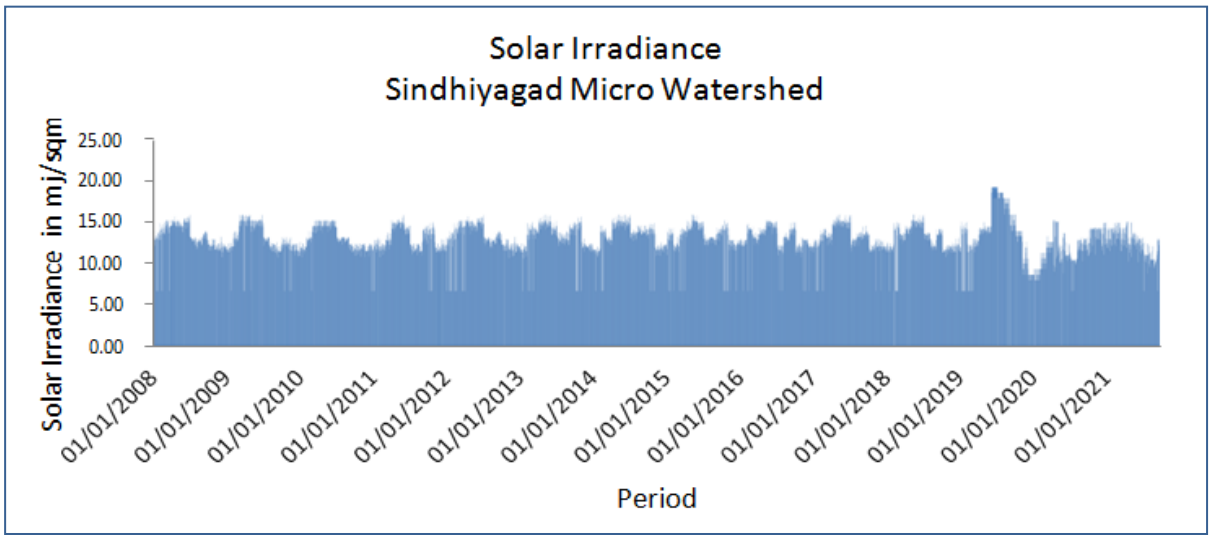




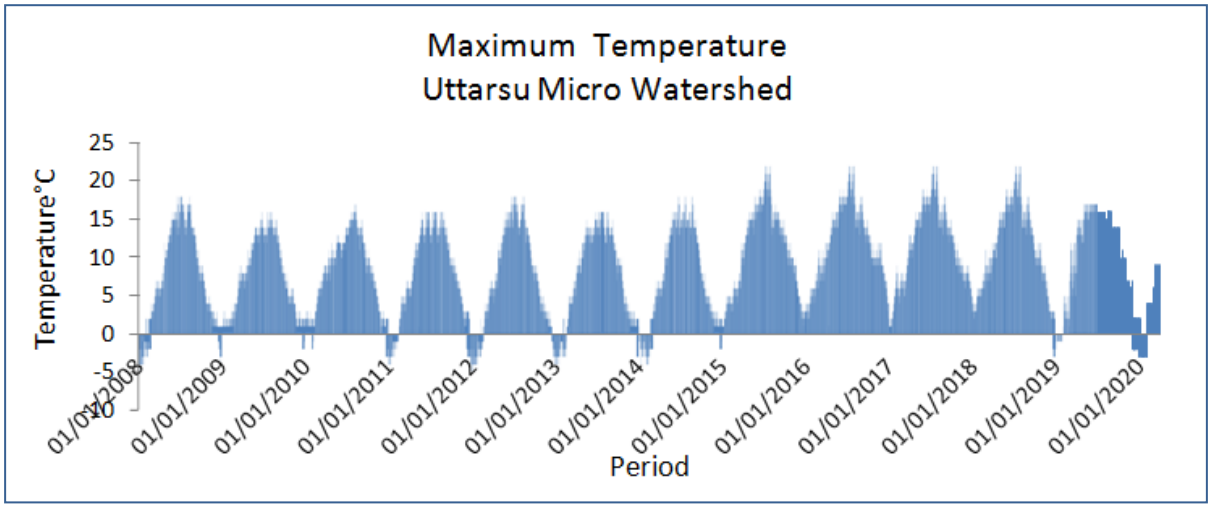


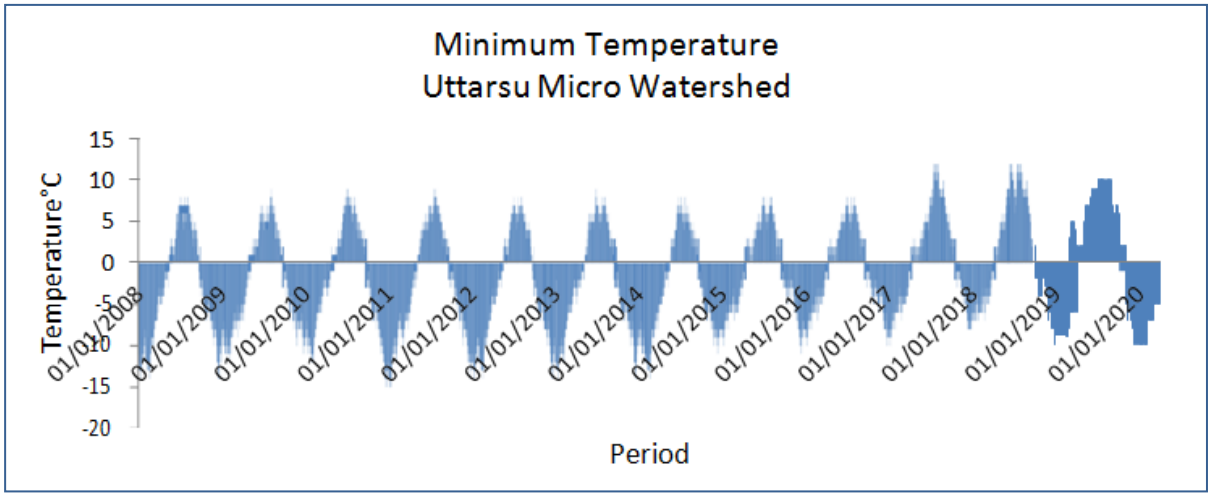

Wind Velocity
Sindhyagad Micro Watershed
Wind Velocity in m/s
4.00
3.00
2.00
1.00
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

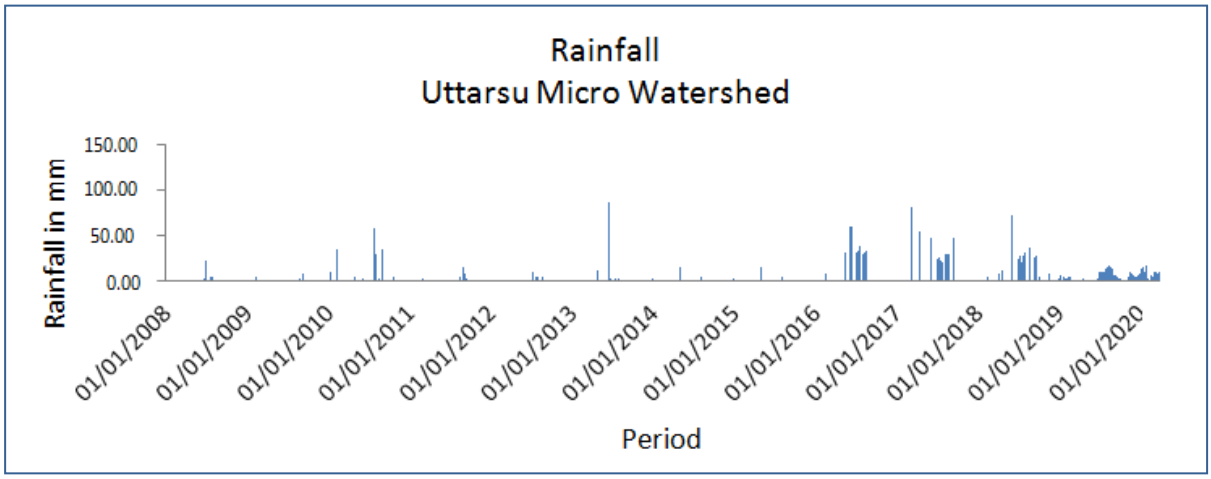

Relative Humidity
Sindhiyagad Micro Watershed
Relative Humidity
1.20
1.00
0.80
0.60
0.40
0.20
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

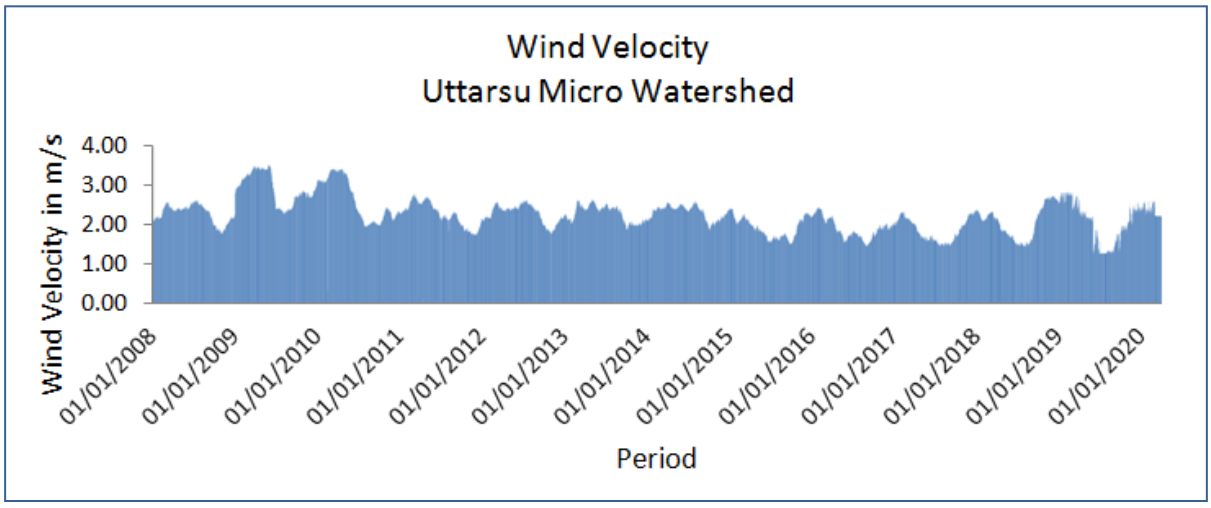

Solar Irradiance
Sindhiyagad Micro Watershed
Solar Irradiance in mj/sqm
25.00
20.00
15.00
10.00
5.00
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
01/01/2021
Period

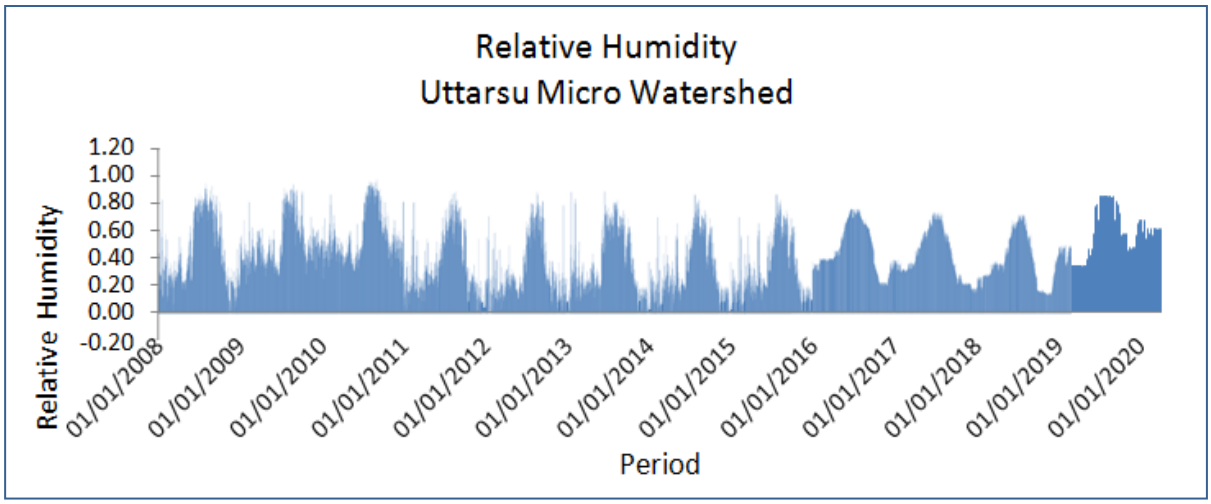
Weather data of Uttarsu Micro watershed

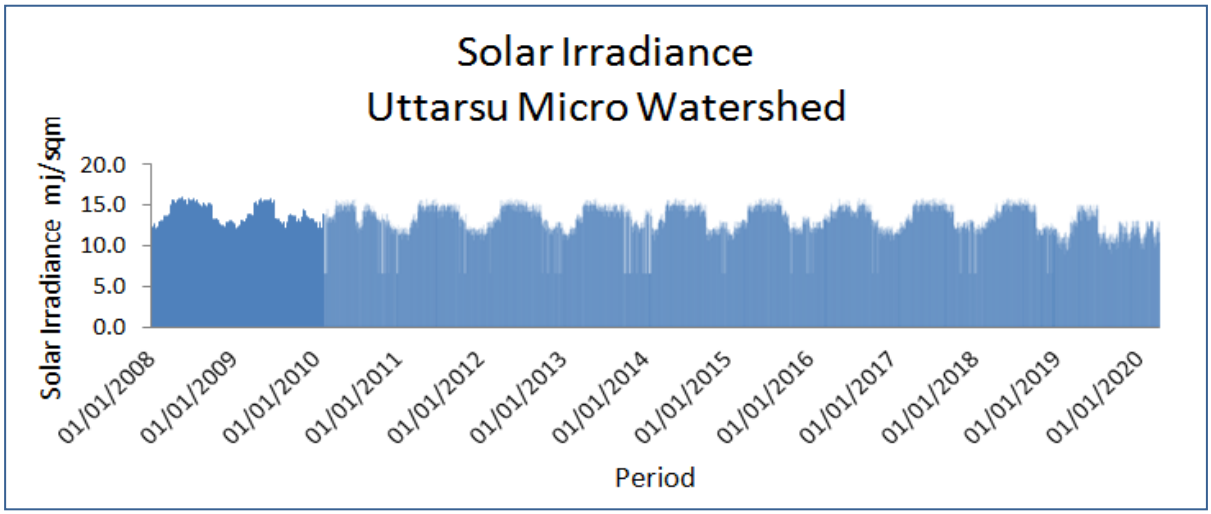






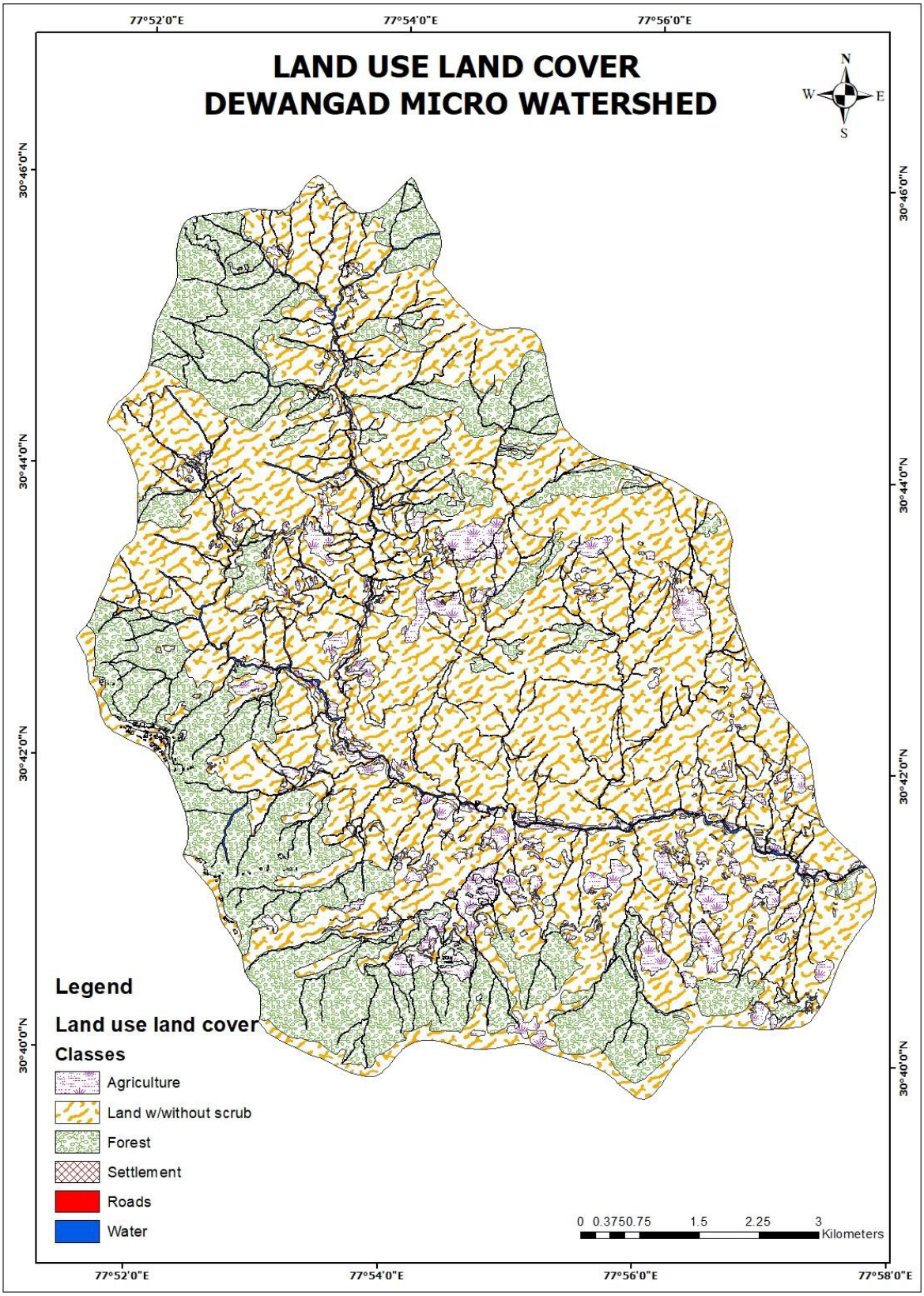

Wind Velocity
Uttarsu Micro Watershed
Wind Velocity in m/s
4.00
3.00
2.00
1.00
0.00
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Period


Relative Humidity
Uttarsu Micro Watershed
Relative Humidity
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Period

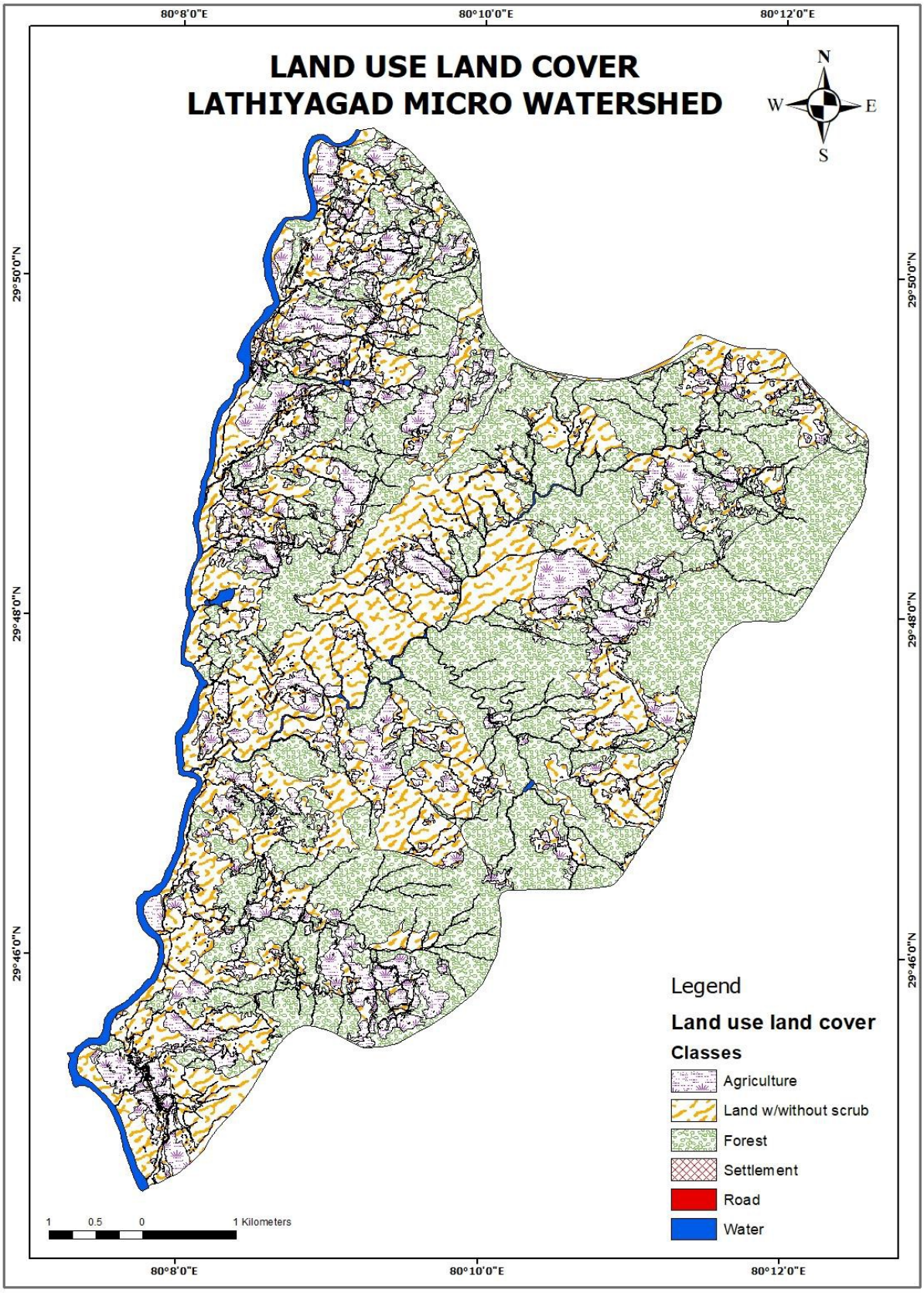

Solar Irradiance
Uttarsu Micro Watershed
Solar Irradiance mj/sqm
20.0
15.0
10.0
5.0
0.0
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Period

Map plate: 2.3.1 Land use land cover maps of 8 representative micro watersheds

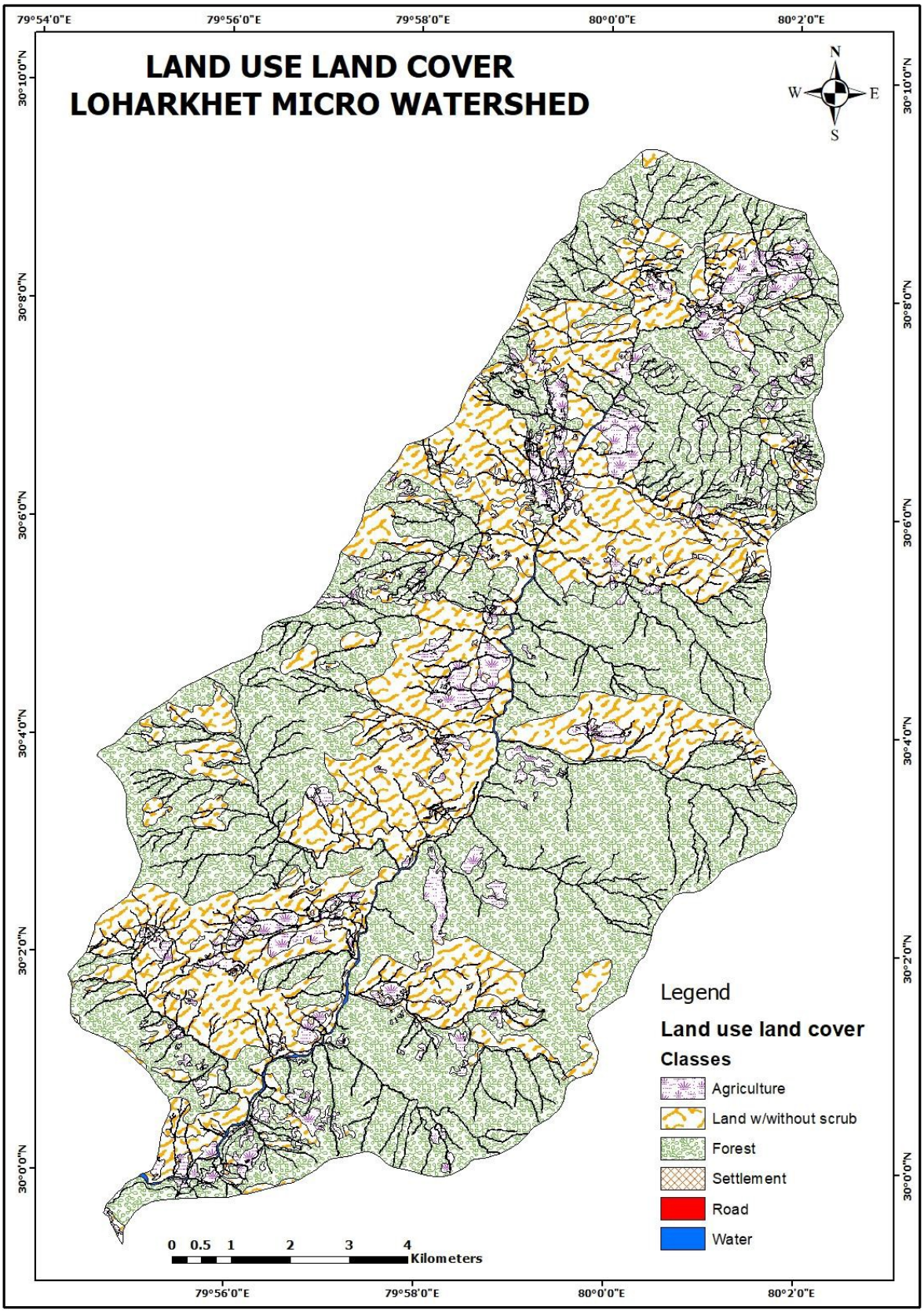
Dewangad micro watershed



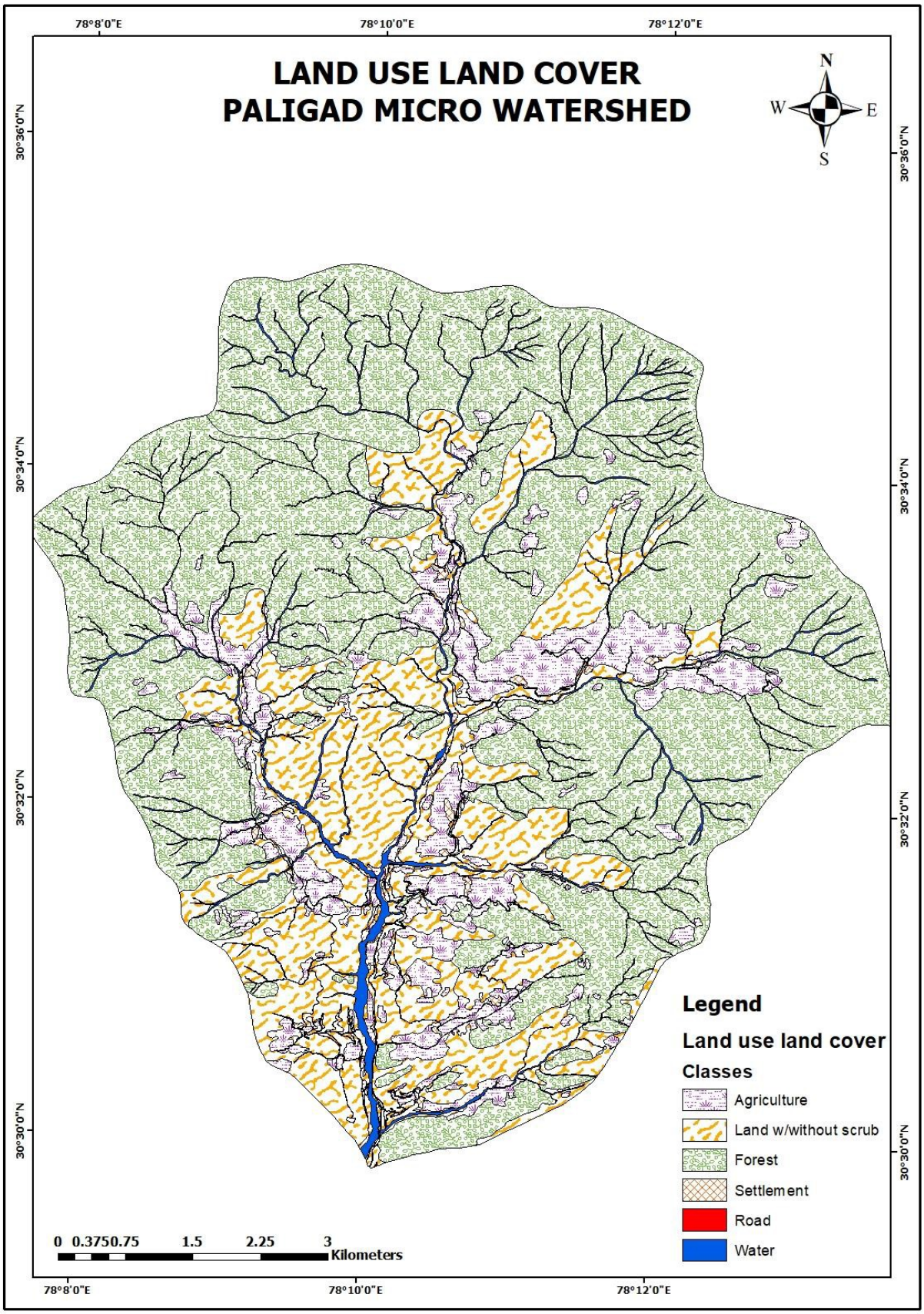
Lathiyagad micro watershed



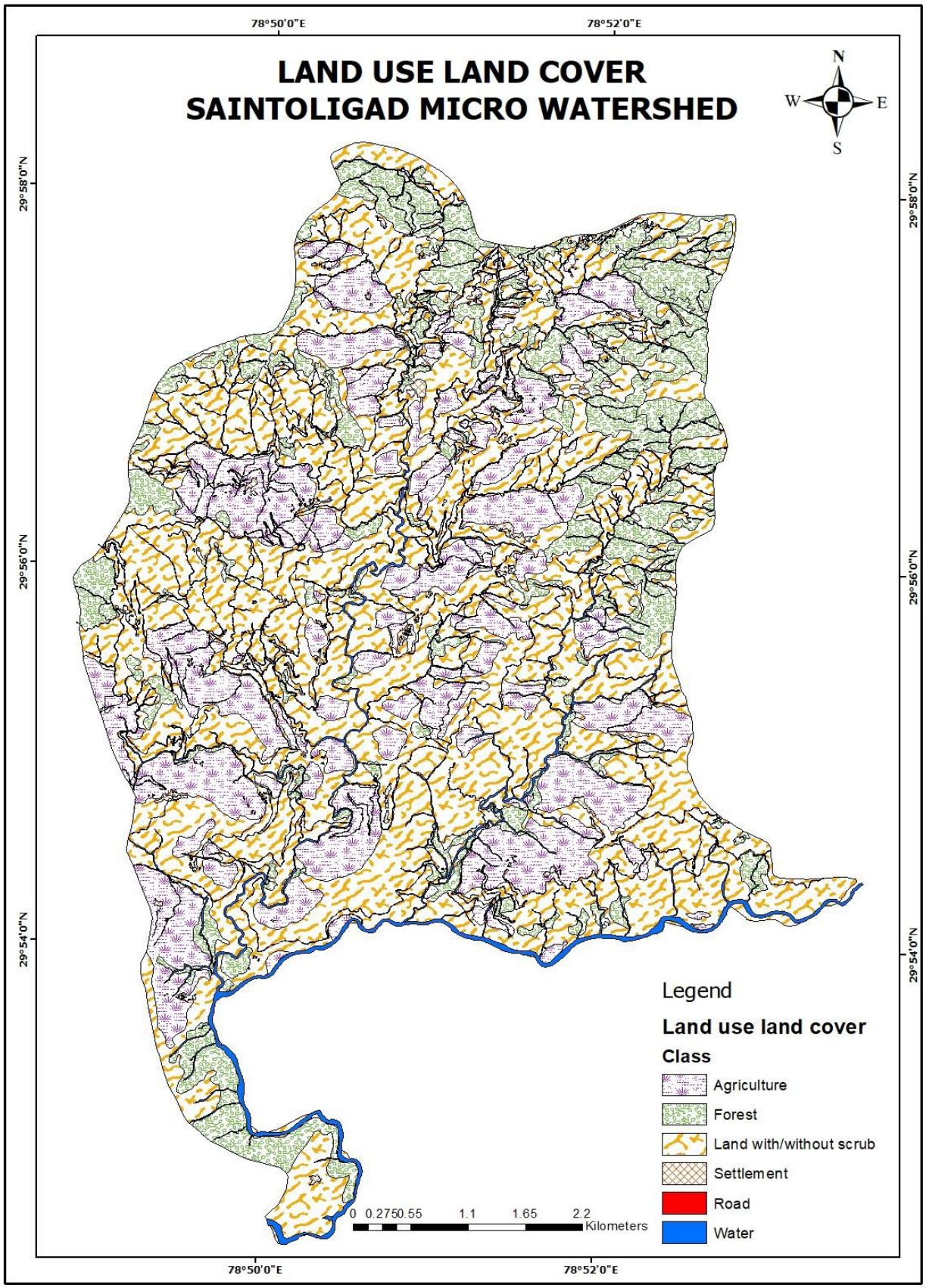
Loharkhet micro watershed



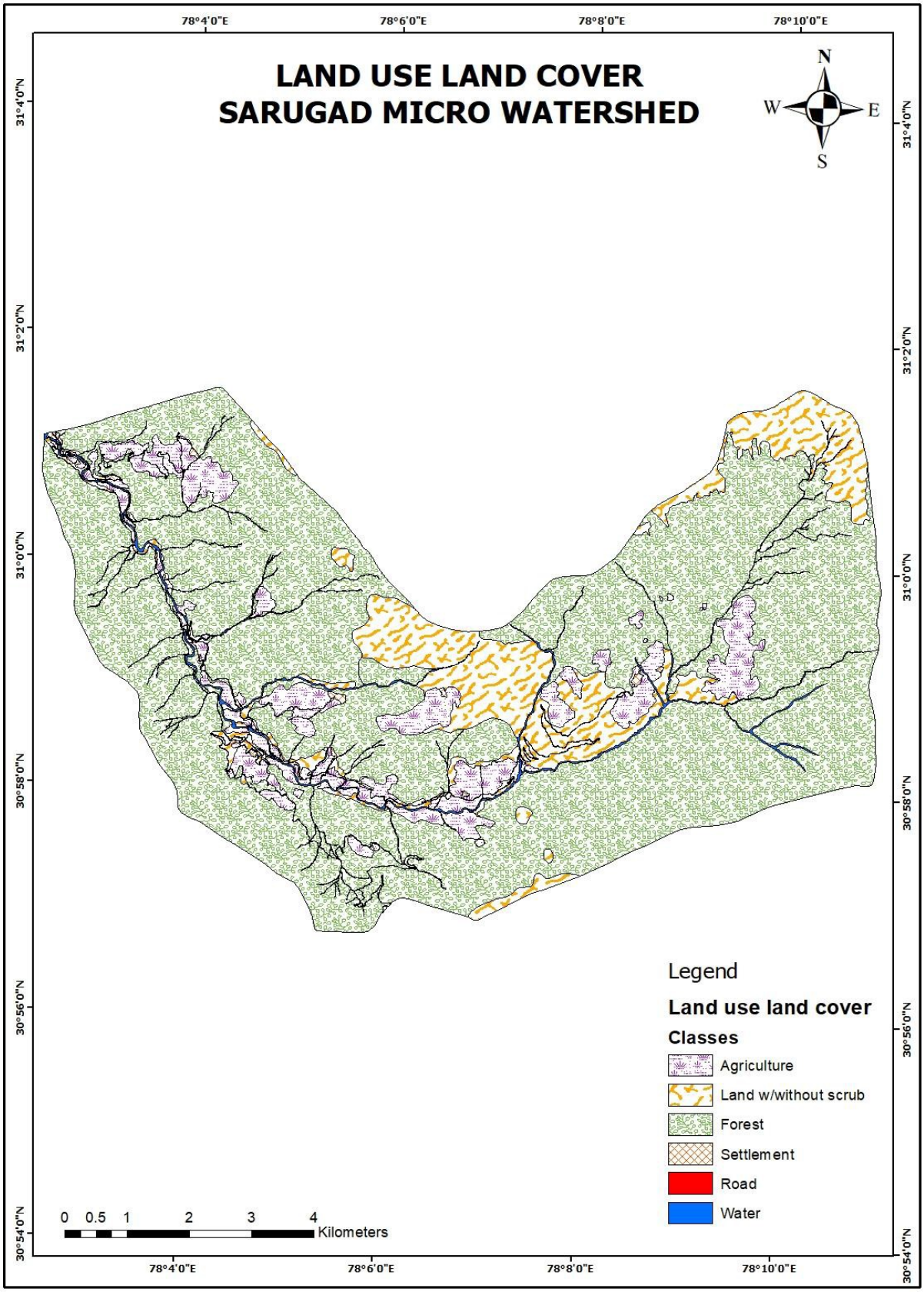
Paligad micro watershed



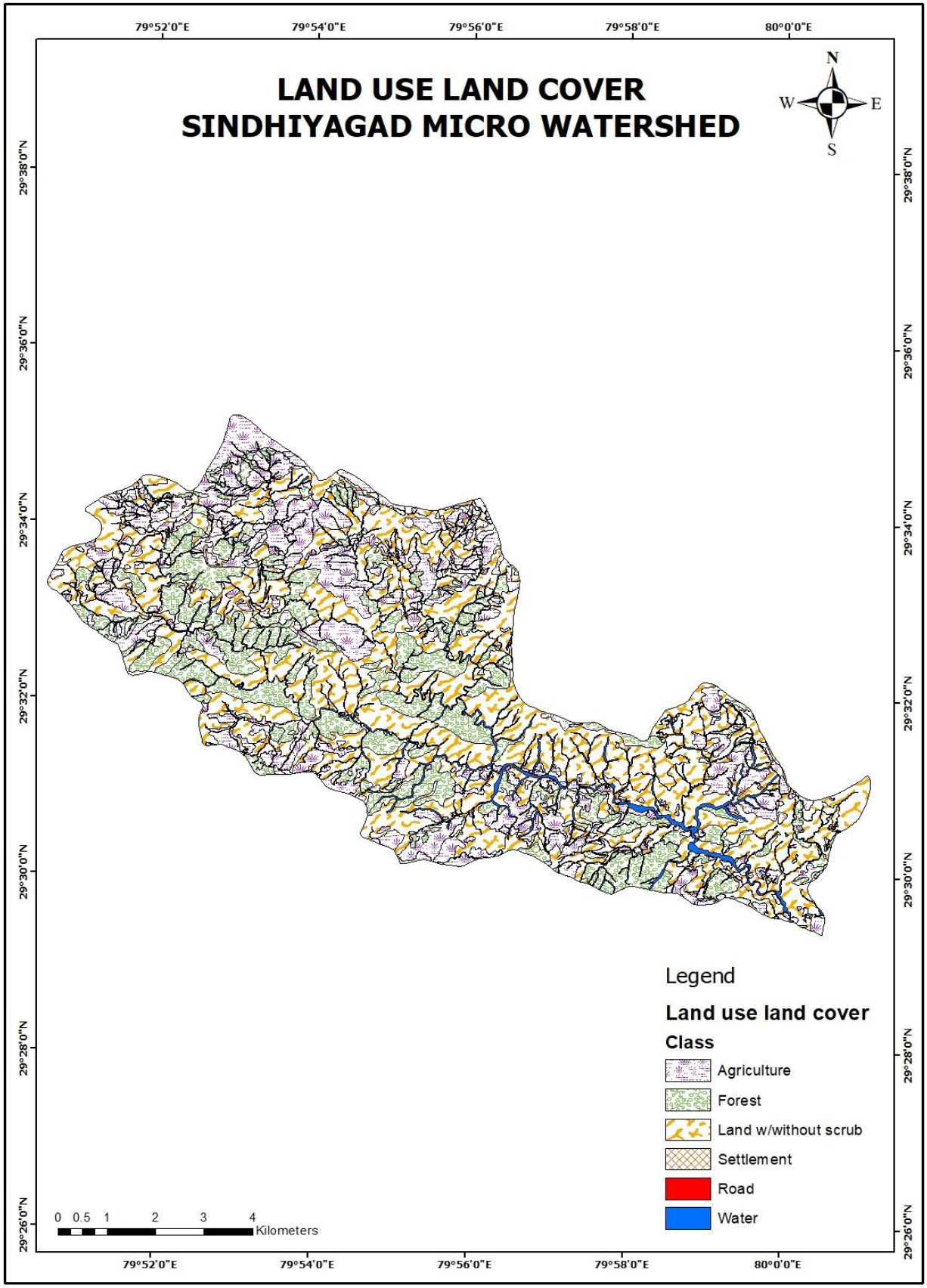
Saintoligad micro watershed



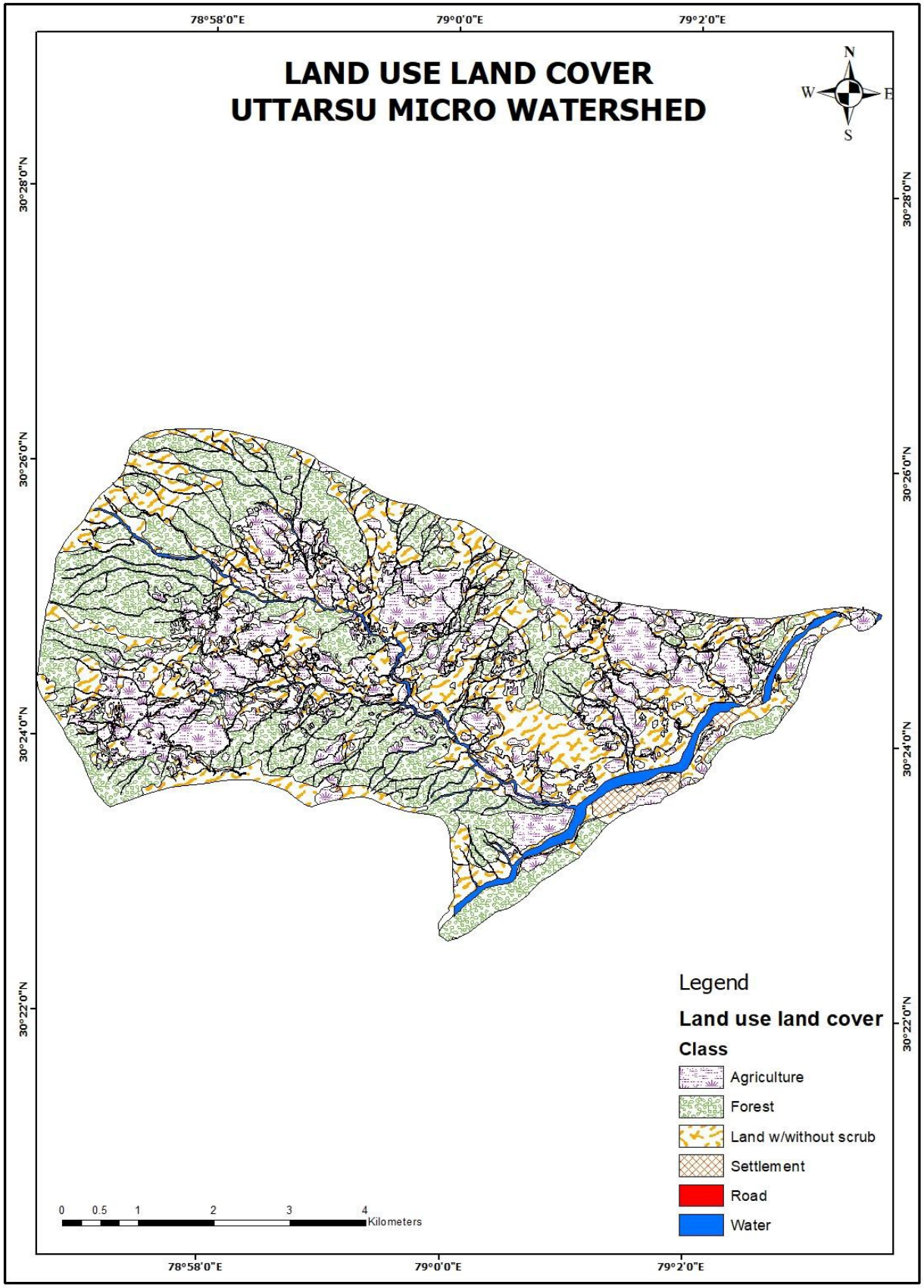
Sarugad micro watershed



Sindhiyagad micro watershed

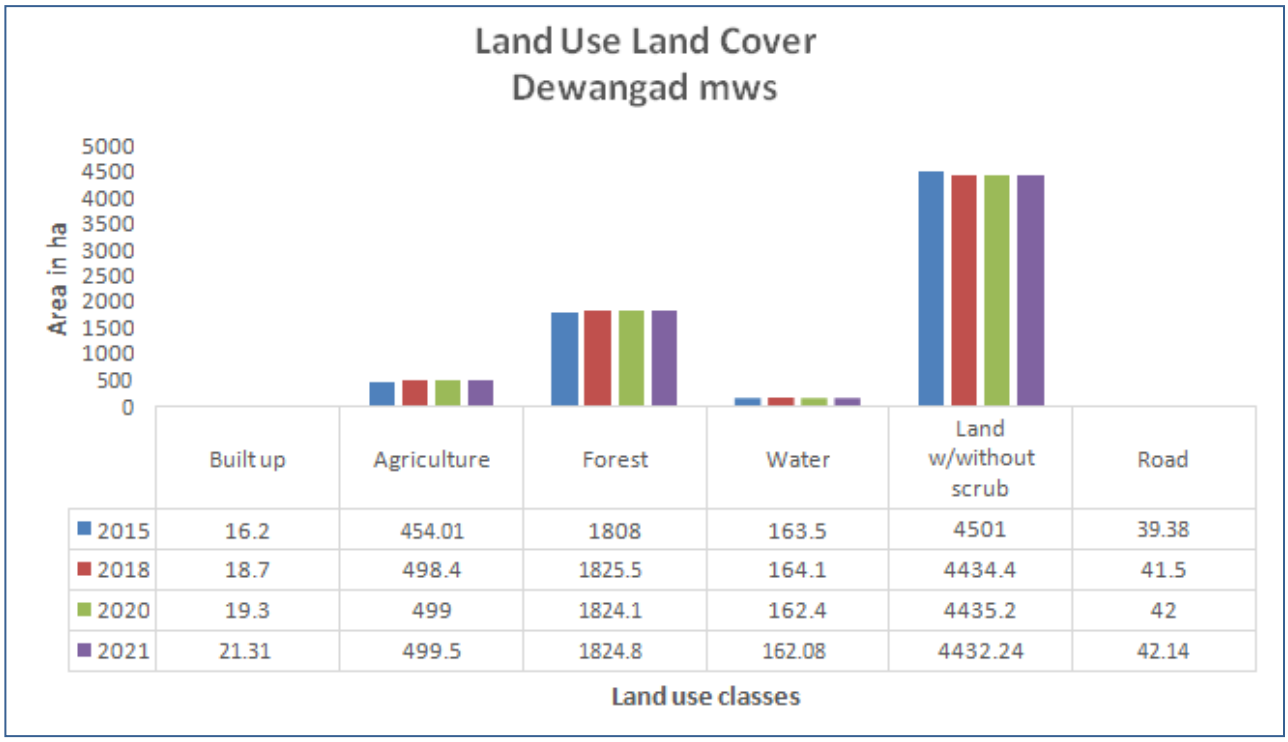


Uttarsu micro watershed



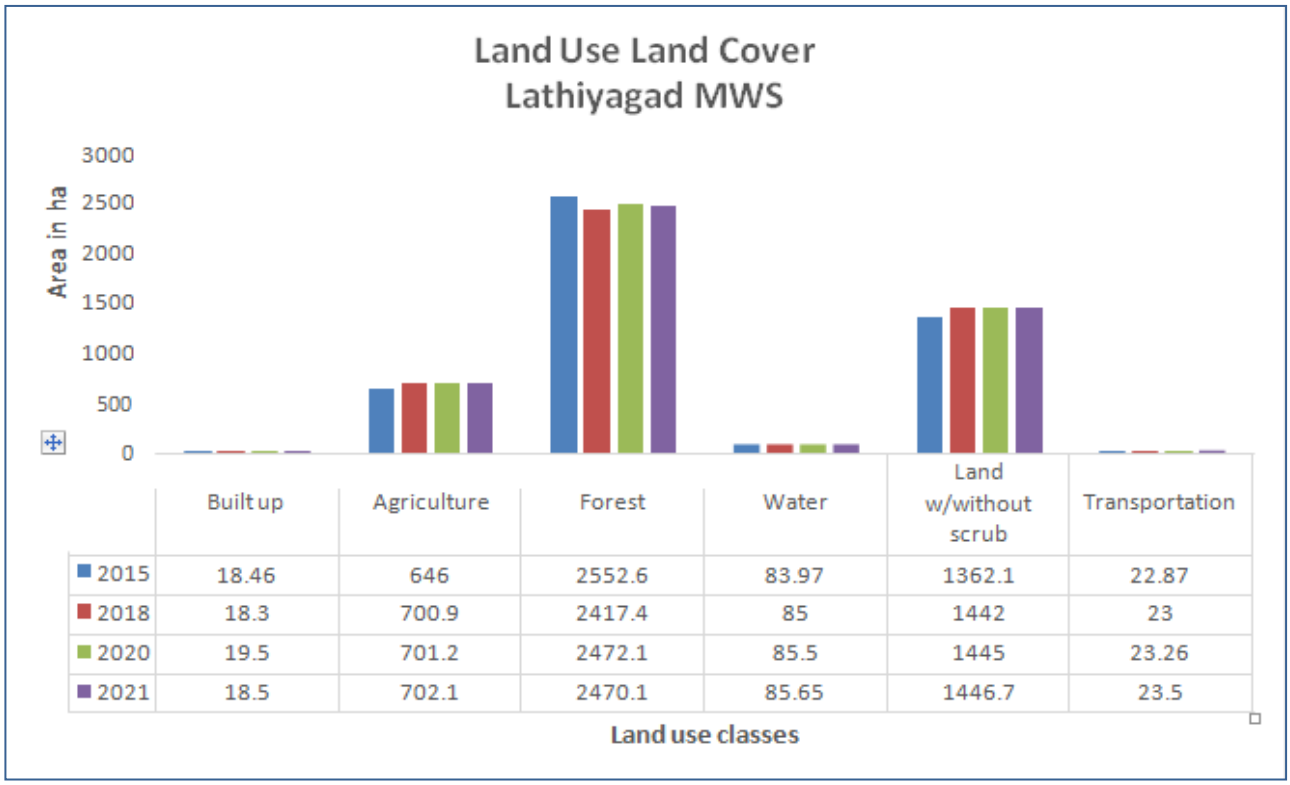
Map plate: 2.3.2 Land use land cover area statistics of 8 representative micro watersheds

Dewangad micro watershed



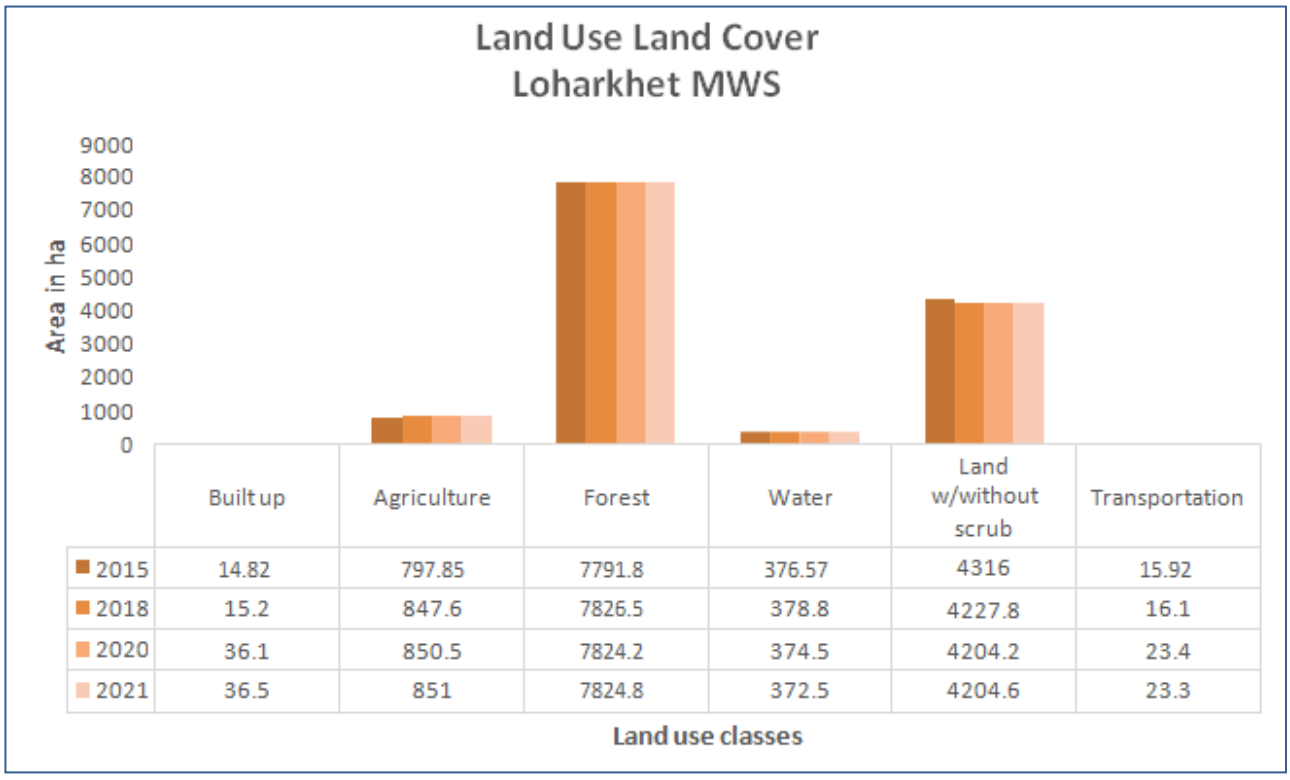
	Built up	Agriculture	Forest	Water	Land w/without scrub	Road
2015	16.2	454.01	1808	163.5	4501	39.38
2018	18.7	498.4	1825.5	164.1	4434.4	41.5
2020	19.3	499	1824.1	162.4	4435.2	42
2021	21.31	499.5	1824.8	162.08	4432.24	42.14

Lathiyagad micro watershed



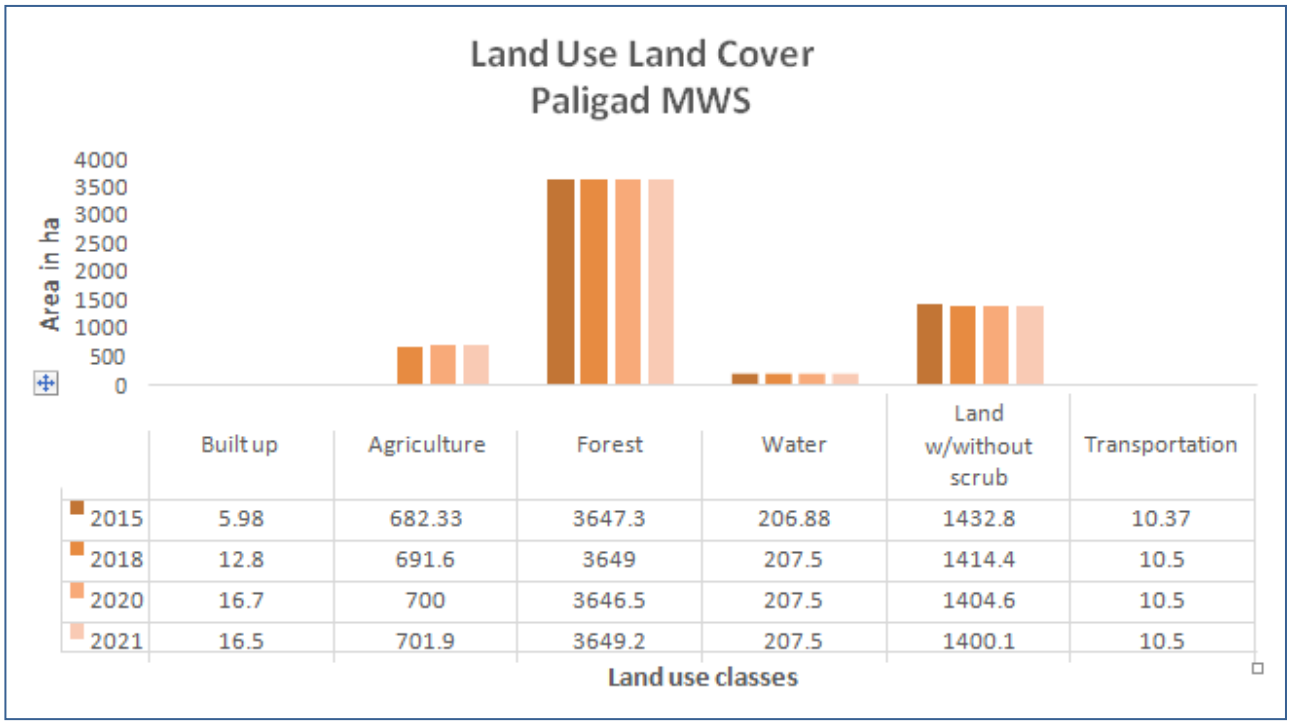
	Built up	Agriculture	Forest	Water	Land w/without scrub	Transportation
2015	18.46	646	2552.6	83.97	1362.1	22.87
2018	18.3	700.9	2417.4	85	1442	23
2020	19.5	701.2	2472.1	85.5	1445	23.26
2021	18.5	702.1	2470.1	85.65	1446.7	23.5

Loharkhet micro watershed



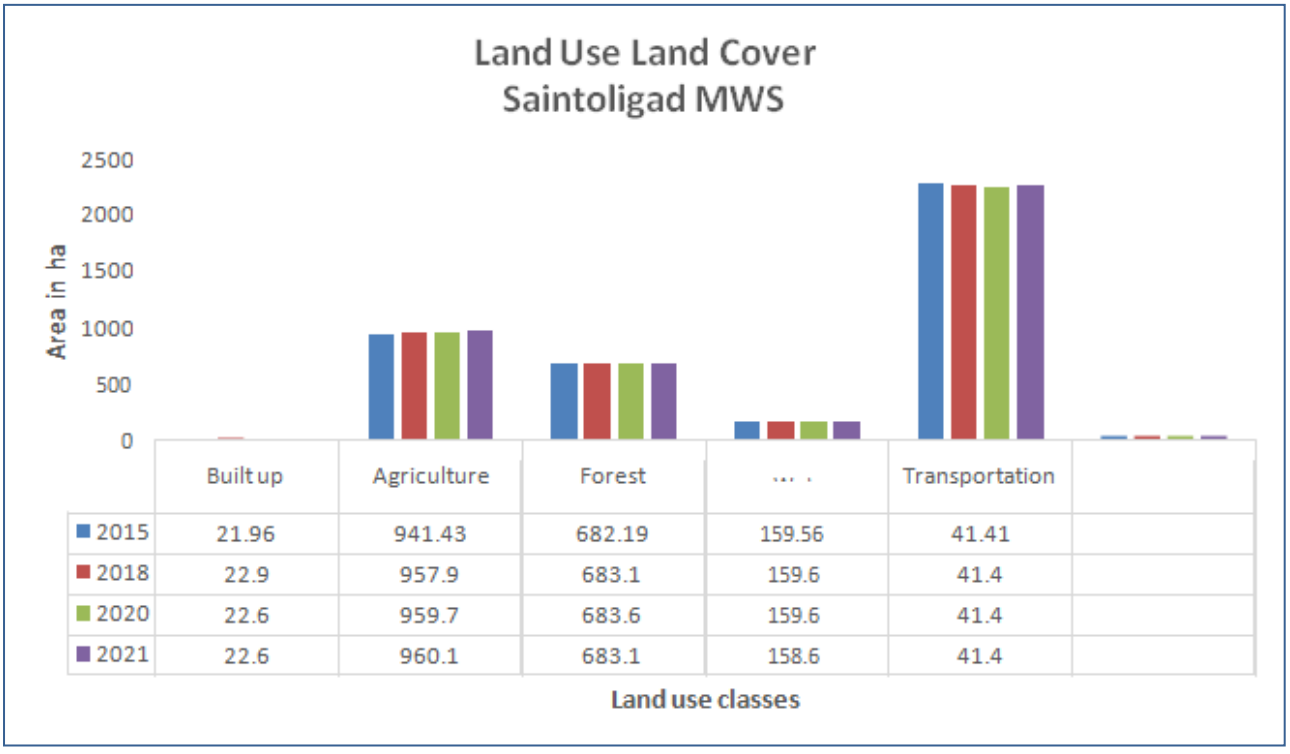
	Built up	Agriculture	Forest	Water	Land w/without scrub	Transportation
2015	14.82	797.85	7791.8	376.57	4316	15.92
2018	15.2	847.6	7826.5	378.8	4227.8	16.1
2020	36.1	850.5	7824.2	374.5	4204.2	23.4
2021	36.5	851	7824.8	372.5	4204.6	23.3

Paligad micro watershed



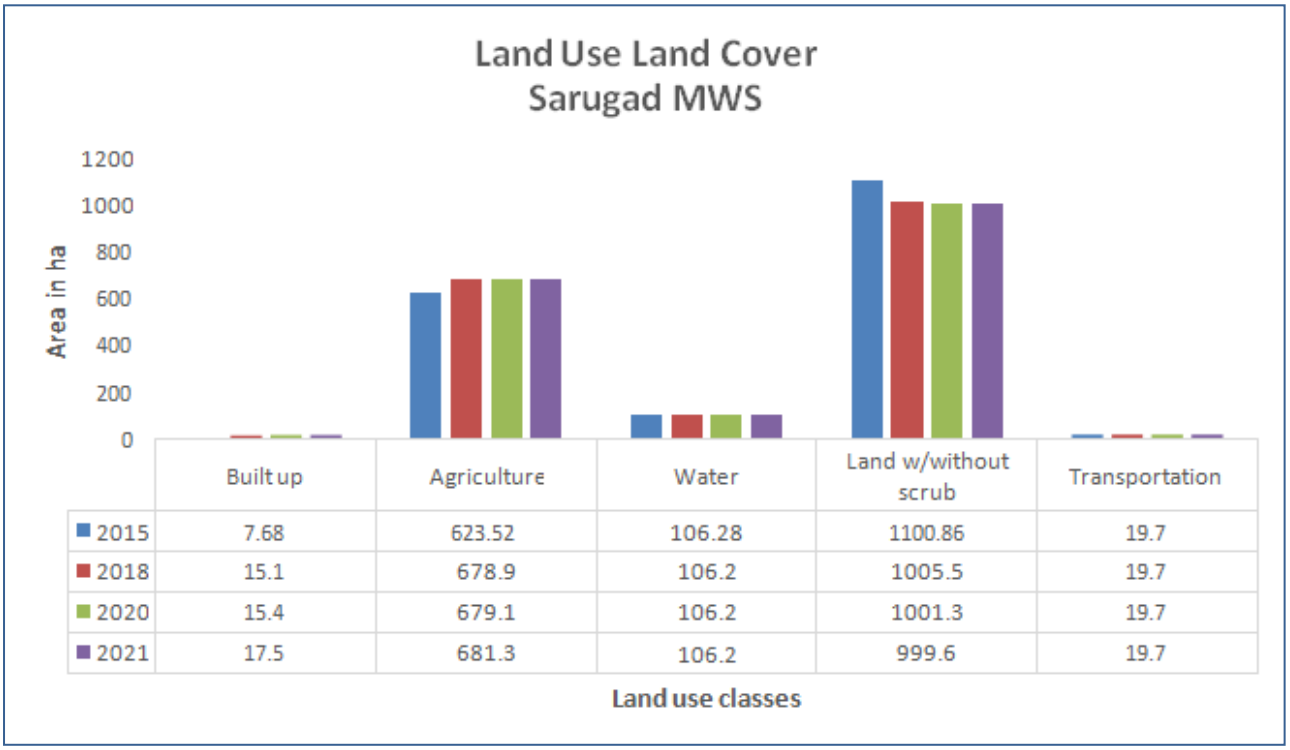
	Built up	Agriculture	Forest	Water	Land w/without scrub	Transportation
2015	5.98	682.33	3647.3	206.88	1432.8	10.37
2018	12.8	691.6	3649	207.5	1414.4	10.5
2020	16.7	700	3646.5	207.5	1404.6	10.5
2021	16.5	701.9	3649.2	207.5	1400.1	10.5

Saintoligad micro watershed



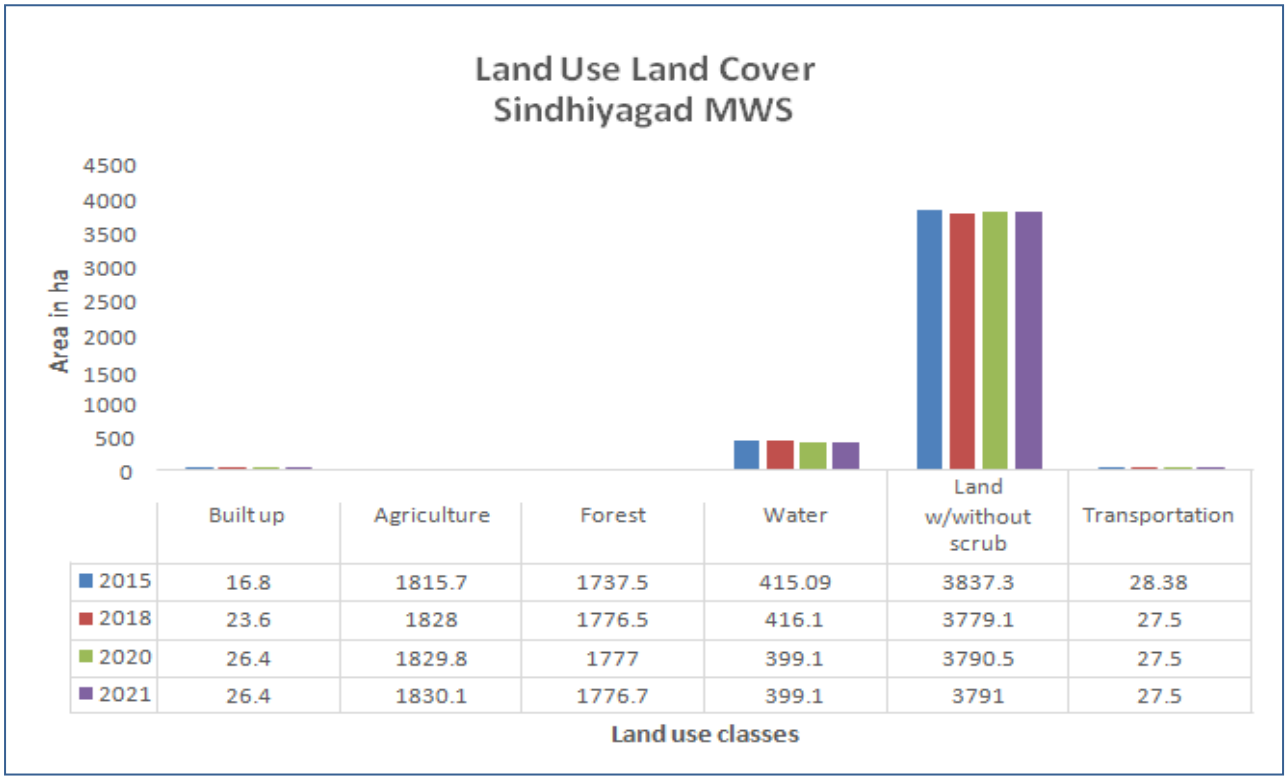
	Built up	Agriculture	Forest	… .	Transportation	
2015	21.96	941.43	682.19	159.56	41.41	
2018	22.9	957.9	683.1	159.6	41.4	
2020	22.6	959.7	683.6	159.6	41.4	
2021	22.6	960.1	683.1	158.6	41.4	

Sarugad micro watershed



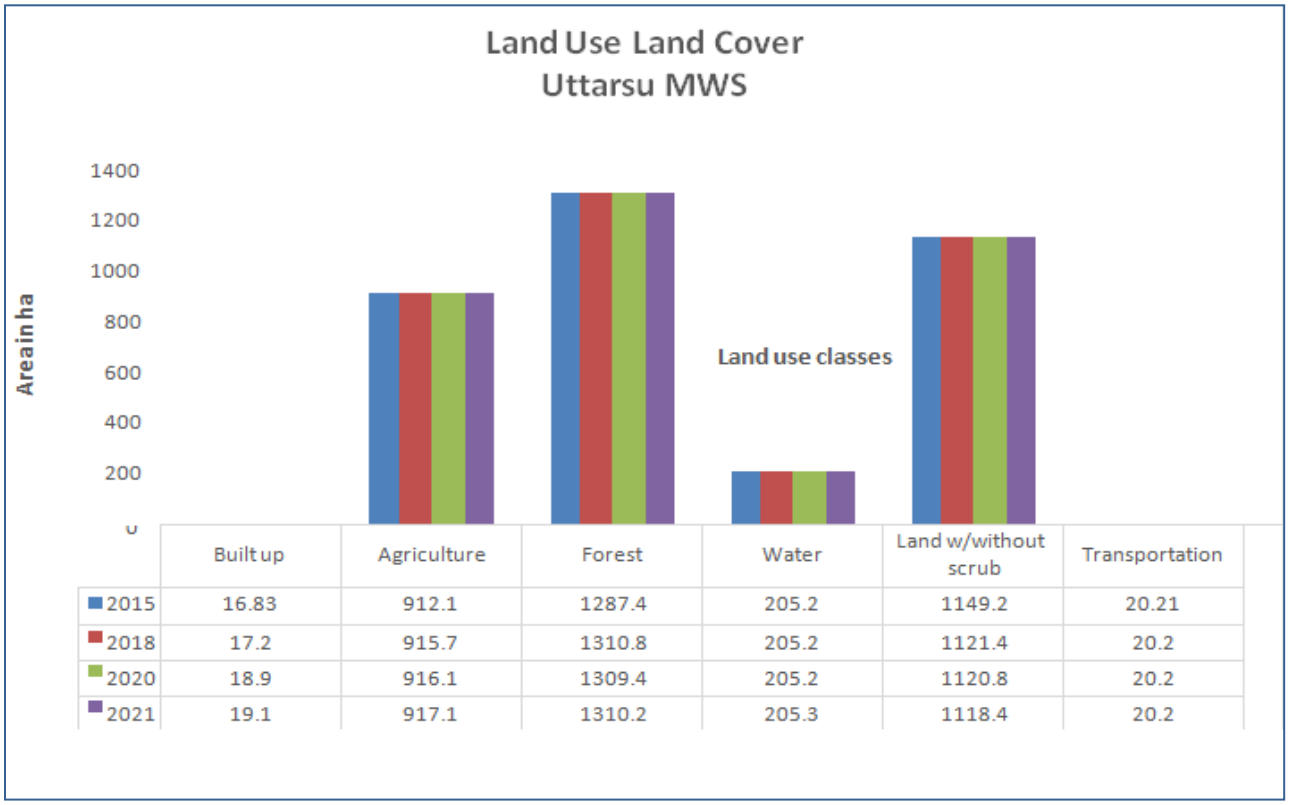
	Built up	Agriculture	Water	Land w/without scrub	Transportation
2015	7.68	623.52	106.28	1100.86	19.7
2018	15.1	678.9	106.2	1005.5	19.7
2020	15.4	679.1	106.2	1001.3	19.7
2021	17.5	681.3	106.2	999.6	19.7

Sindhiyagad micro watershed



	Built up	Agriculture	Forest	Water	Land w/without scrub	Transportation
2015	16.8	1815.7	1737.5	415.09	3837.3	28.38
2018	23.6	1828	1776.5	416.1	3779.1	27.5
2020	26.4	1829.8	1777	399.1	3790.5	27.5
2021	26.4	1830.1	1776.7	399.1	3791	27.5

Uttarsu micro watershed



	Built up	Agriculture	Forest	Water	Land w/without scrub	Transportation
2015	16.83	912.1	1287.4	205.2	1149.2	20.21
2018	17.2	915.7	1310.8	205.2	1121.4	20.2
2020	18.9	916.1	1309.4	205.2	1120.8	20.2
2021	19.1	917.1	1310.2	205.3	1118.4	20.2

Map Plate: Constructed weir structures in eight representative micro watersheds

Lathiyagad micro watershed

Loharkhet micro watershed

Paligad micro watershed

Saintoligad micro watershed

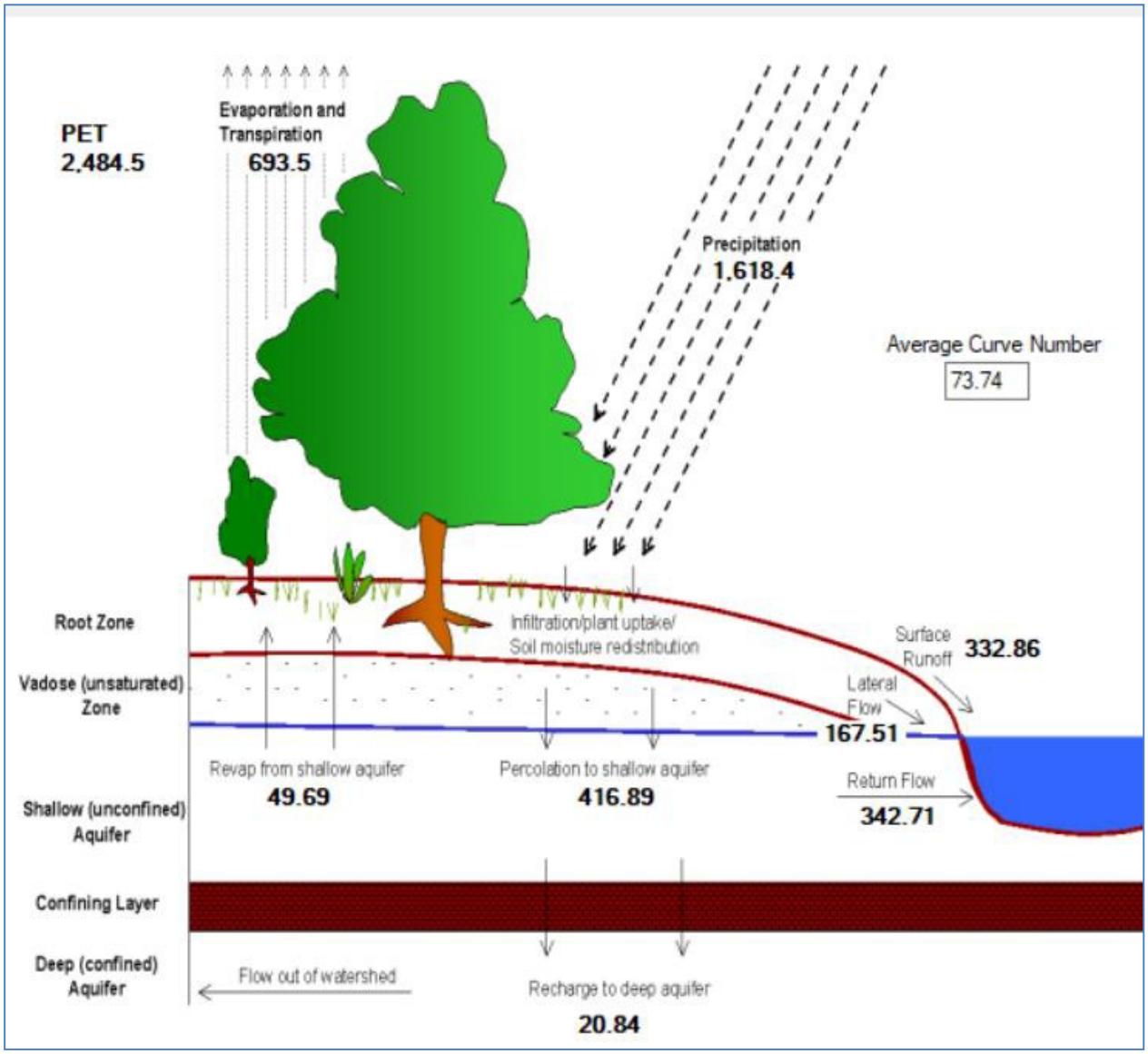
Sarugad micro watershed

Sindhiyagad micro watershed

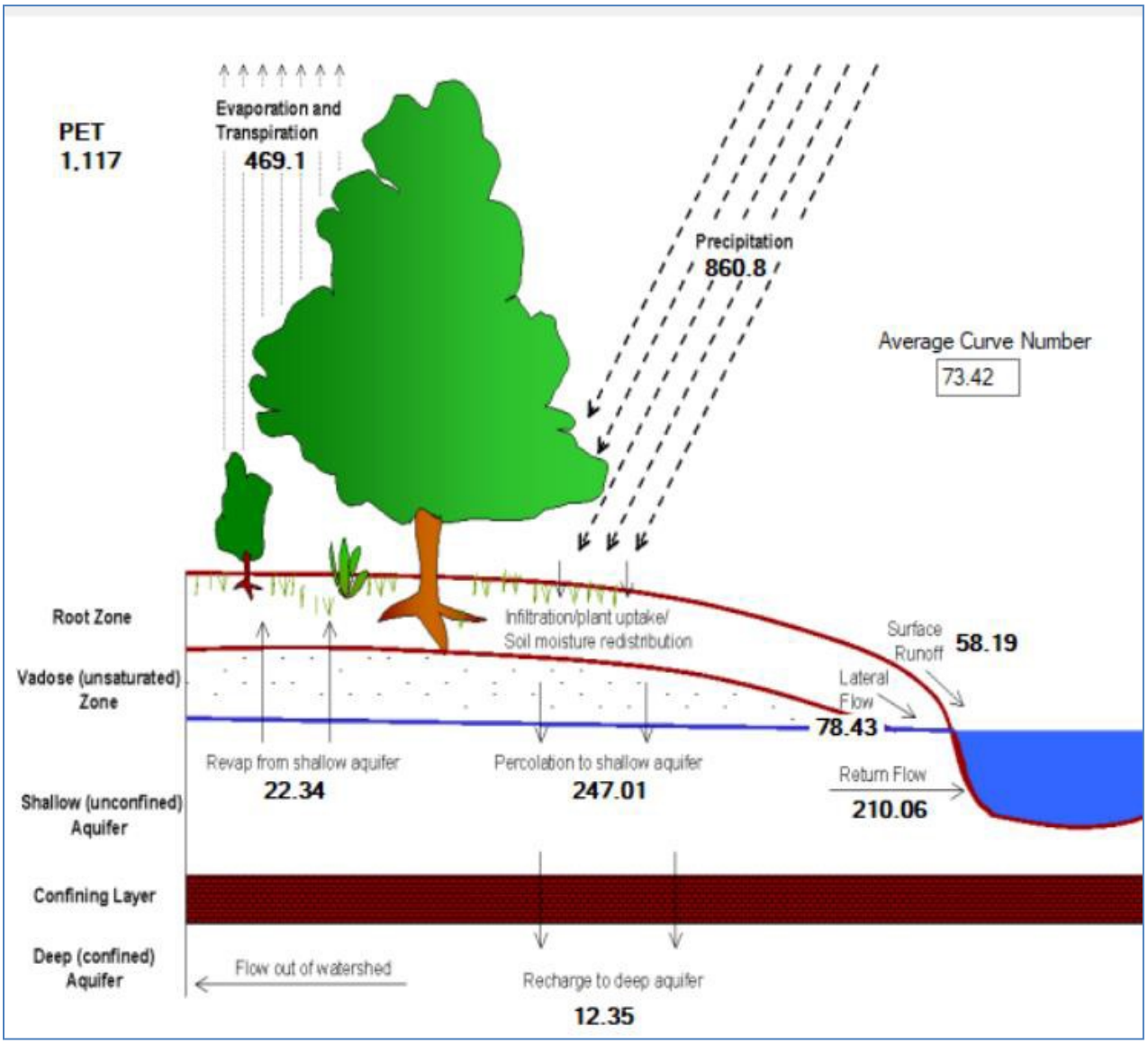
Uttarsu micro watershed

Map Plate: SWAT model

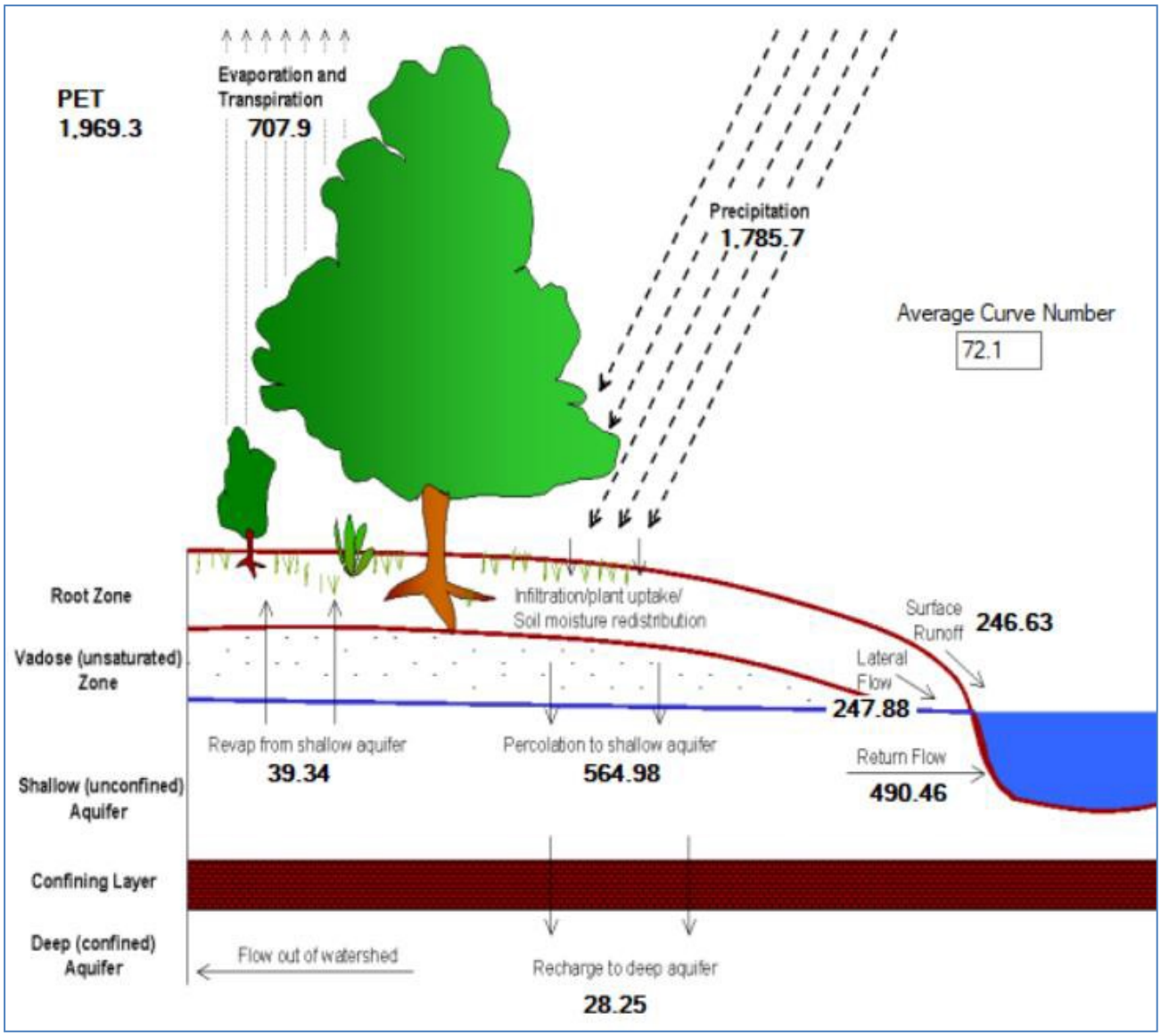
Dewangad



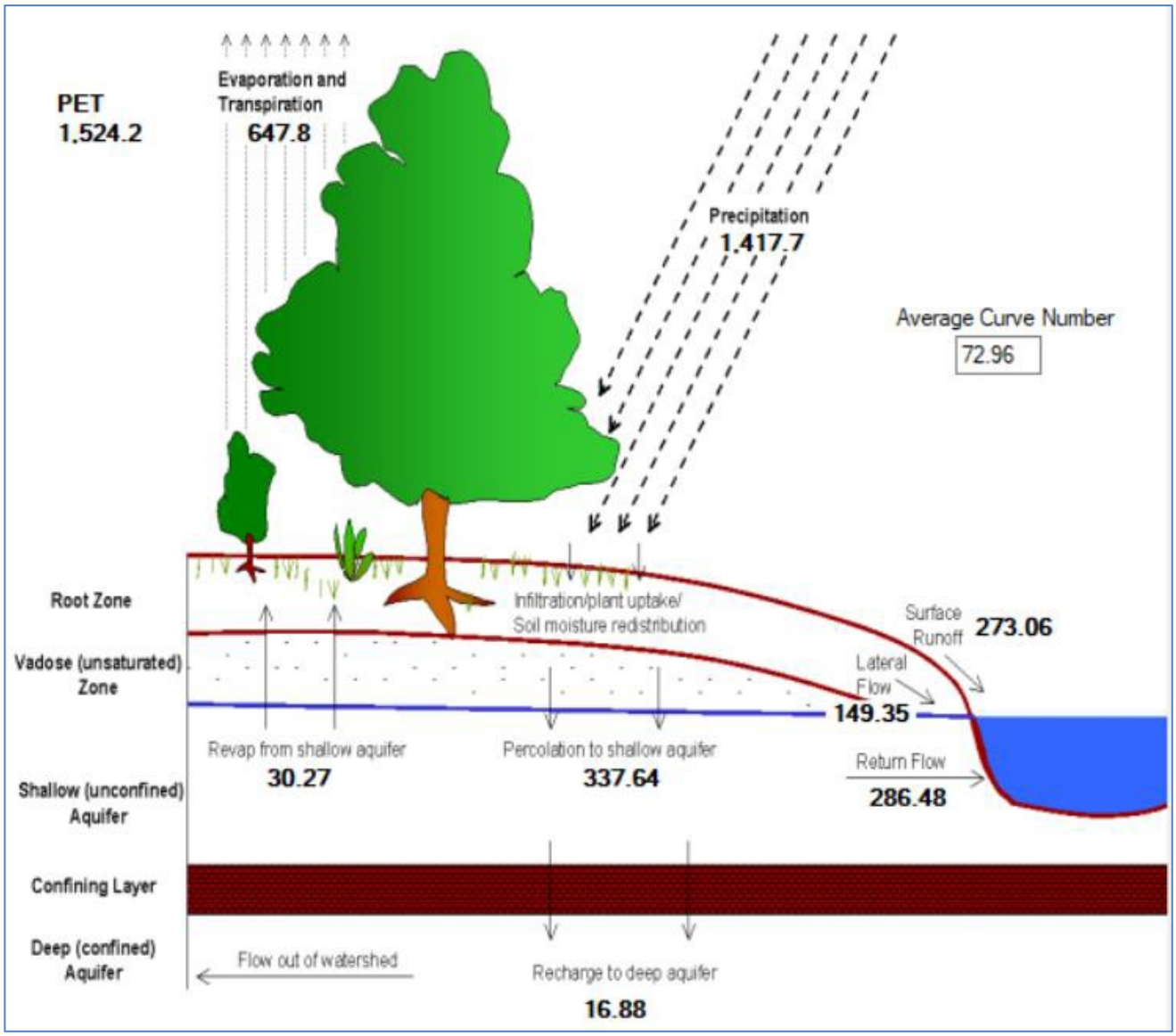
Lathiyagad


PET
1.117
Evaporation and
Transpiration
469.1
Precipitation
860.8
Average Curve Number
73.42
Root Zone
Infiltration/plant uptake/
Soil moisture redistribution
Surface
Runoff
58.19
Vadose (unsaturated)
Zone
Lateral
Flow
78.43
Revap from shallow aquifer
22.34
Percolation to shallow aquifer
247.01
Return Flow
210.06
Shallow (unconfined)
Aquifer
Confining Layer
Deep (confined)
Aquifer
Flow out of watershed
Recharge to deep aquifer
12.35

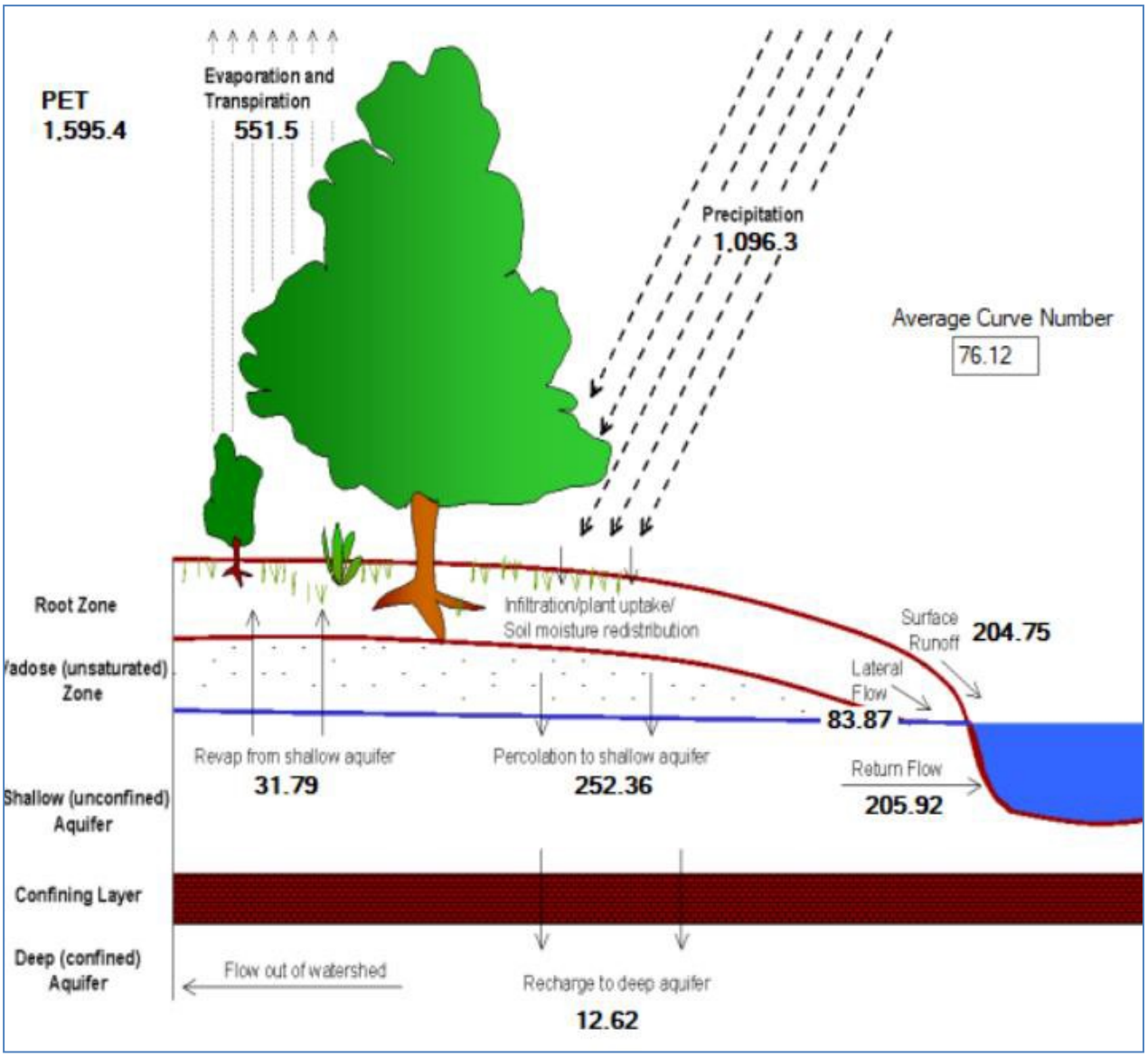
Loharkhet


PET
1,969.3
Evaporation and Transpiration
707.9
Precipitation
1,785.7
Average Curve Number
72.1
Root Zone
Vadose (unsaturated) Zone
Infiltration/plant uptake/ Soil moisture redistribution
Surface Runoff
246.63
Lateral Flow
247.88
Revap from shallow aquifer
39.34
Percolation to shallow aquifer
564.98
Return Flow
490.46
Shallow (unconfined) Aquifer
Confining Layer
Deep (confined) Aquifer
Flow out of watershed
Recharge to deep aquifer
28.25

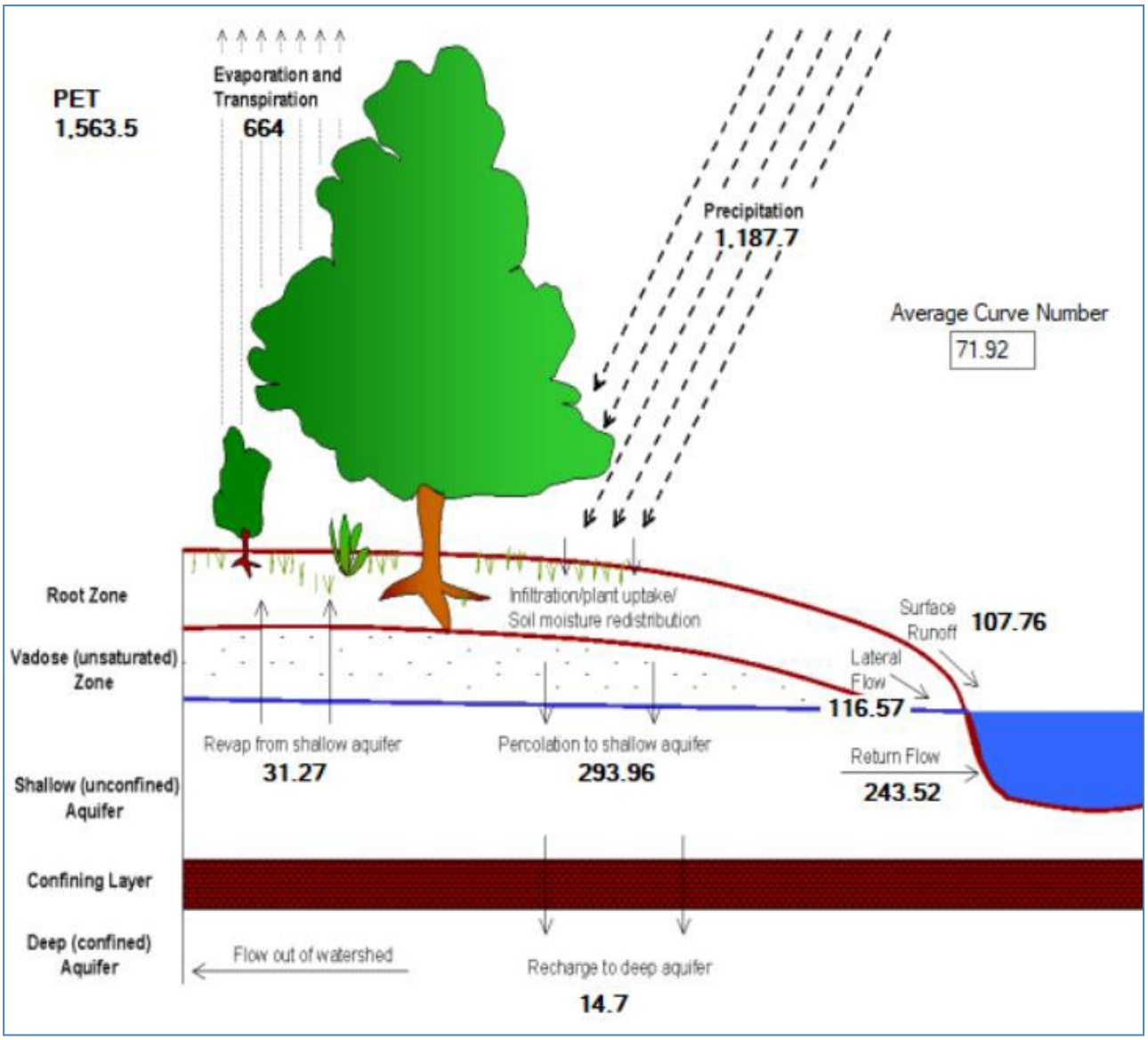
Paligad


PET
1,524.2
Evaporation and Transpiration
647.8
Precipitation
1,417.7
Average Curve Number
72.96
Root Zone
Infiltration/plant uptake/
Soil moisture redistribution
Surface Runoff
273.06
Vadose (unsaturated) Zone
Lateral Flow
149.35
Revap from shallow aquifer
30.27
Percolation to shallow aquifer
337.64
Return Flow
286.48
Shallow (unconfined) Aquifer
Confining Layer
Deep (confined) Aquifer
Flow out of watershed
Recharge to deep aquifer
16.88

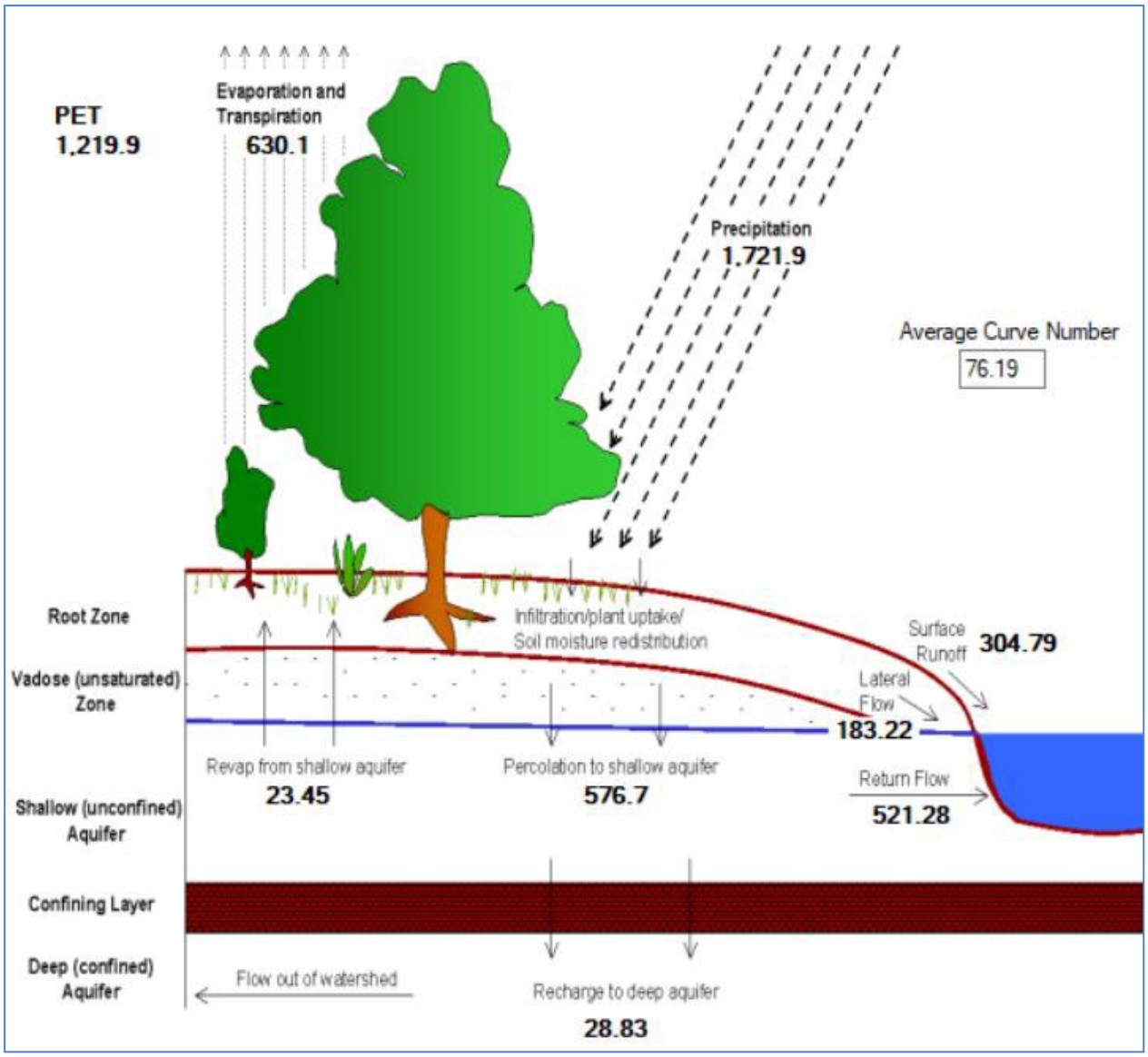
Saintoligad



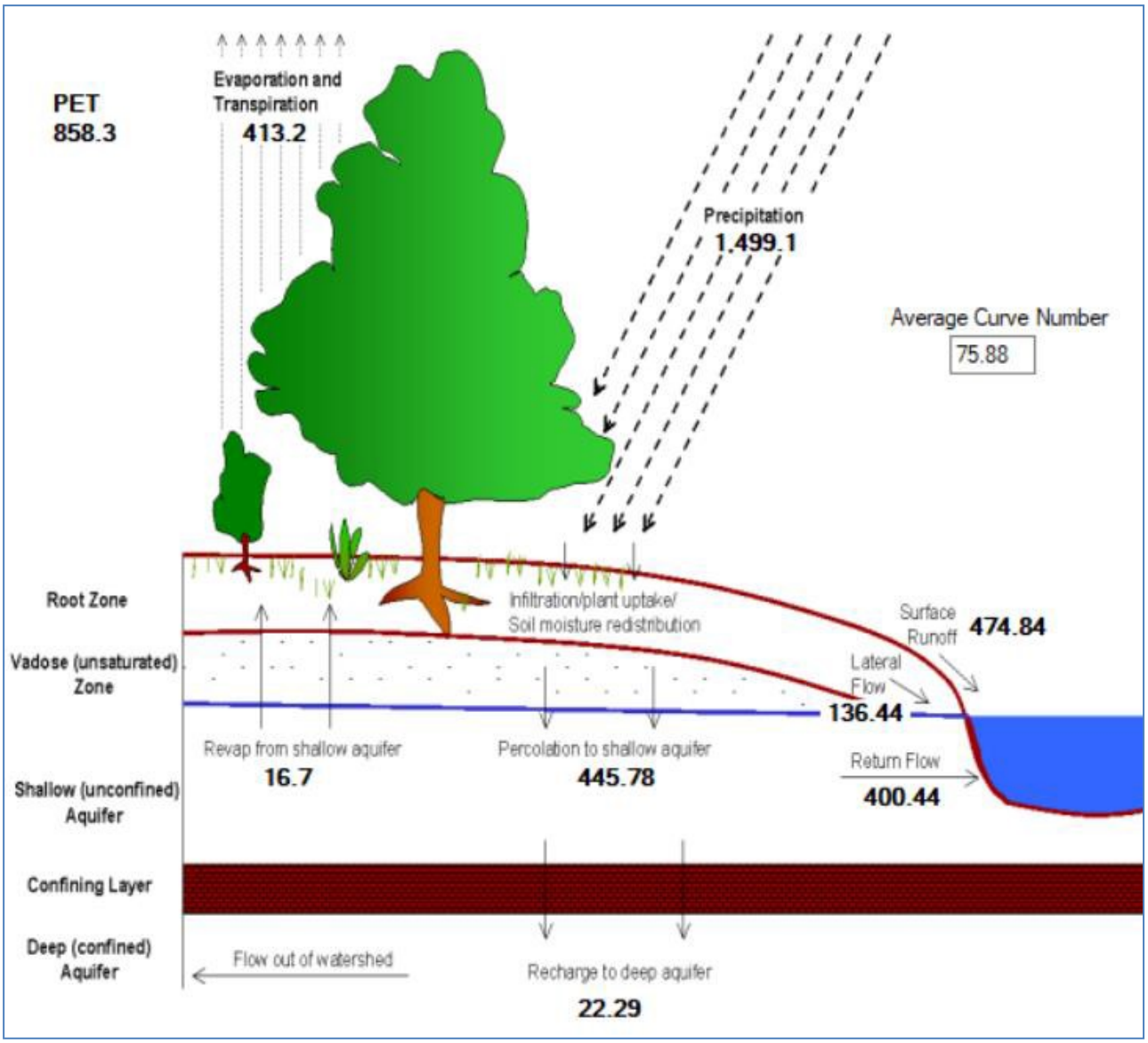
Sarugad


PET
1,563.5
Evaporation and Transpiration
664
Precipitation
1,187.7
Average Curve Number
71.92
Root Zone
Vadose (unsaturated) Zone
Infiltration/plant uptake/ Soil moisture redistribution
Surface Runoff
107.76
Lateral Flow
116.57
Revap from shallow aquifer
31.27
Percolation to shallow aquifer
293.96
Return Flow
243.52
Shallow (unconfined) Aquifer
Confining Layer
Deep (confined) Aquifer
Flow out of watershed
Recharge to deep aquifer
14.7

Sindhiyagad

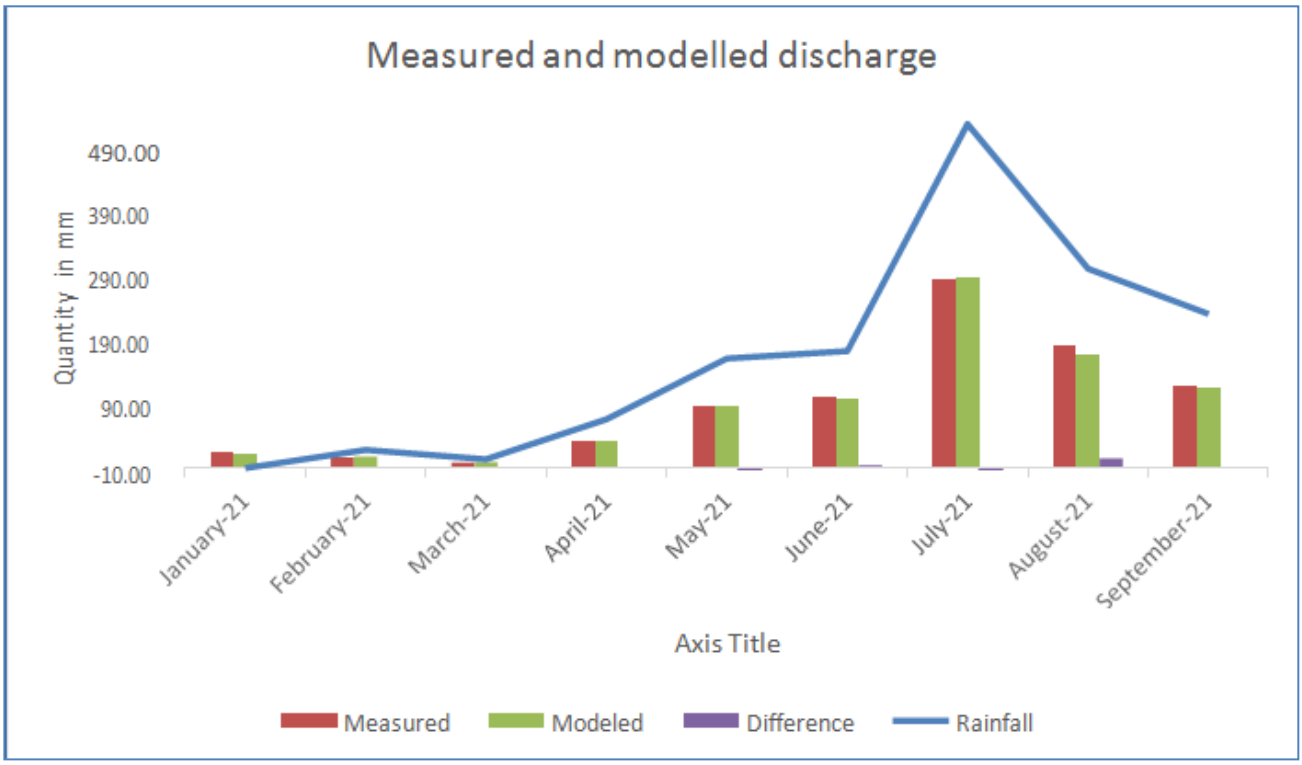


Uttarshu

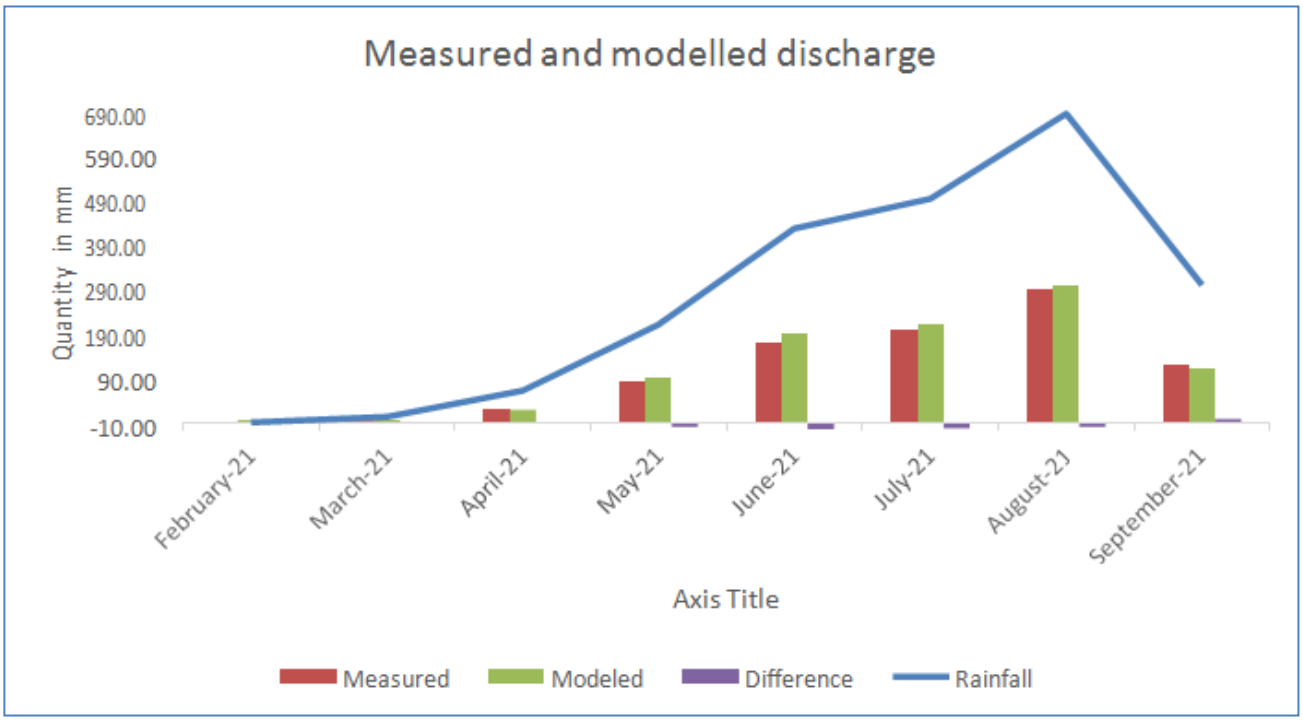

PET
858.3
Evaporation and Transpiration
413.2
Precipitation
1,499.1
Average Curve Number
75.88
Root Zone
Infiltration/plant uptake/
Soil moisture redistribution
Surface Runoff
474.84
Vadose (unsaturated) Zone
Lateral Flow
136.44
Revap from shallow aquifer
16.7
Percolation to shallow aquifer
445.78
Return Flow
400.44
Shallow (unconfined) Aquifer
Confining Layer
Deep (confined) Aquifer
Flow out of watershed
Recharge to deep aquifer
22.29

Map Plate: SWAT model validation

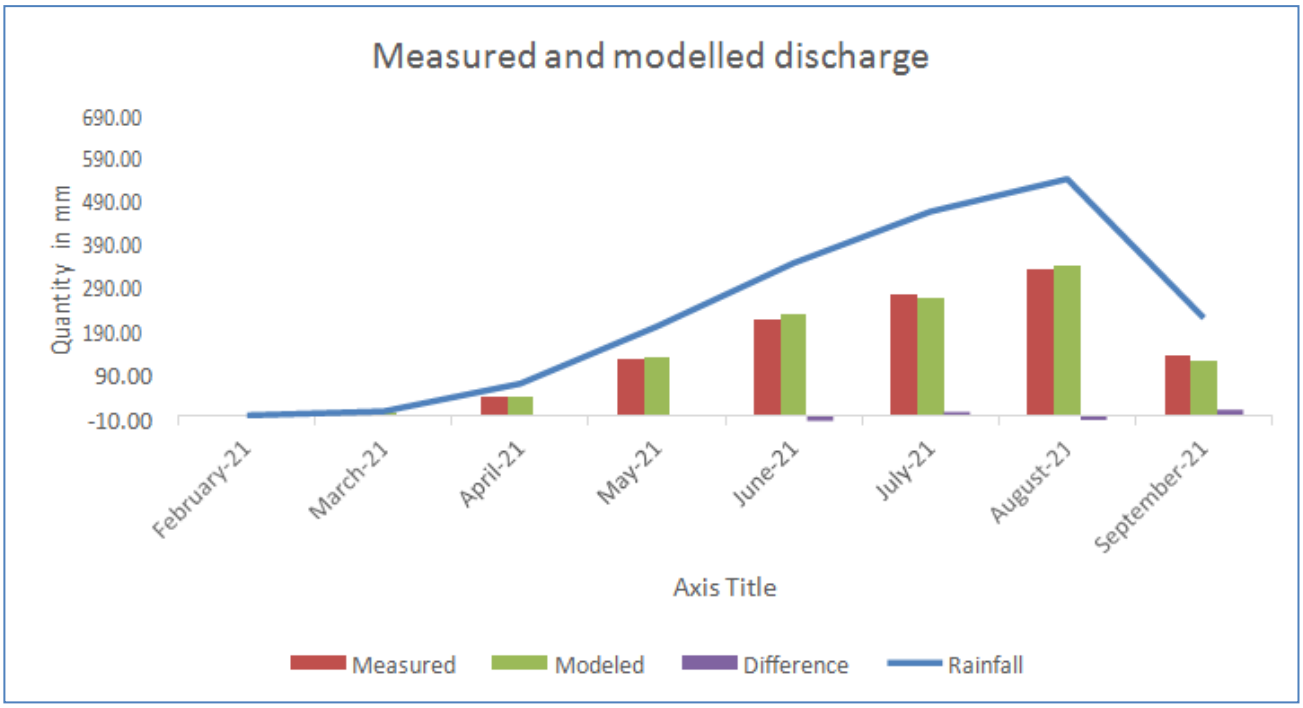
Dewangad



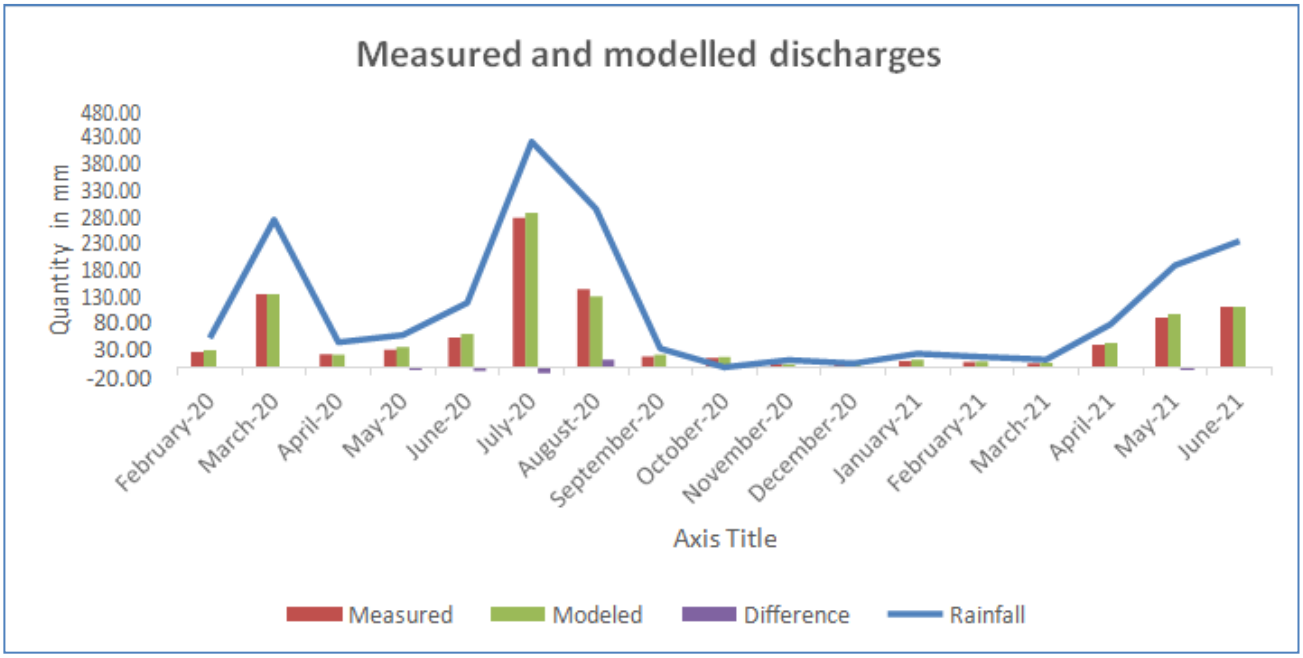
Lathiyagad



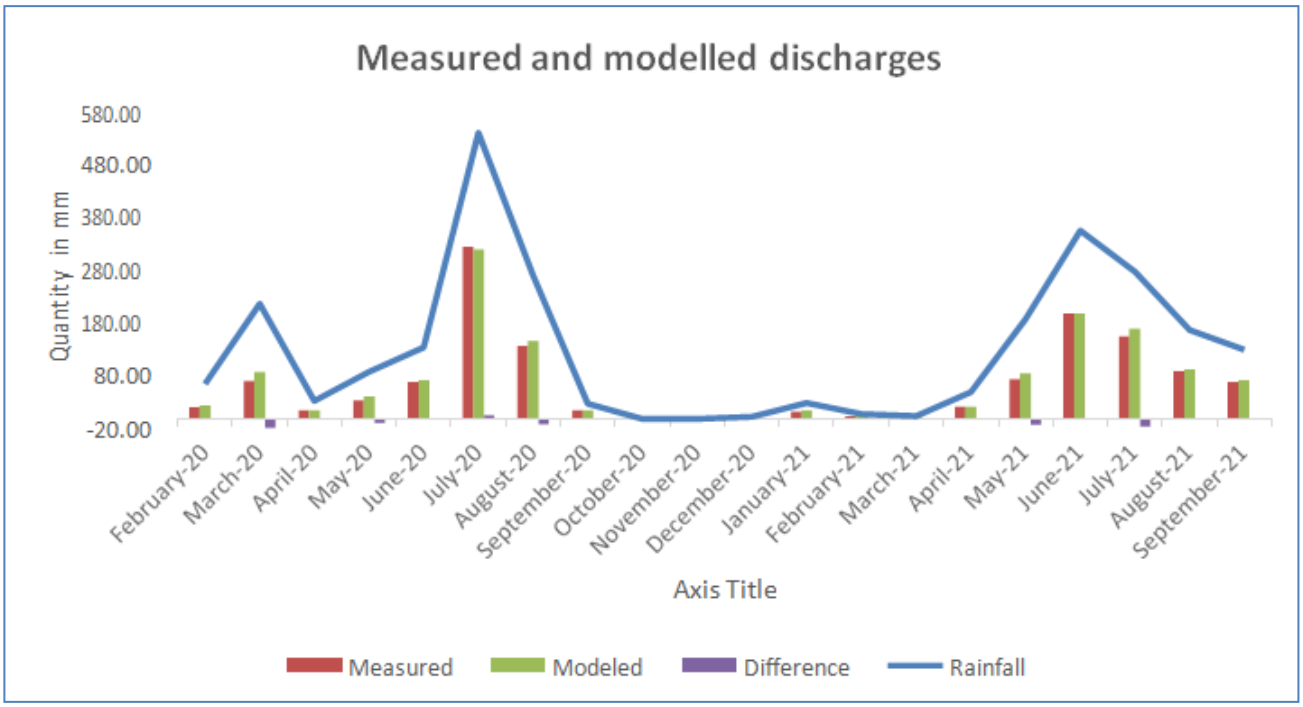
Loharkhet



Paligad

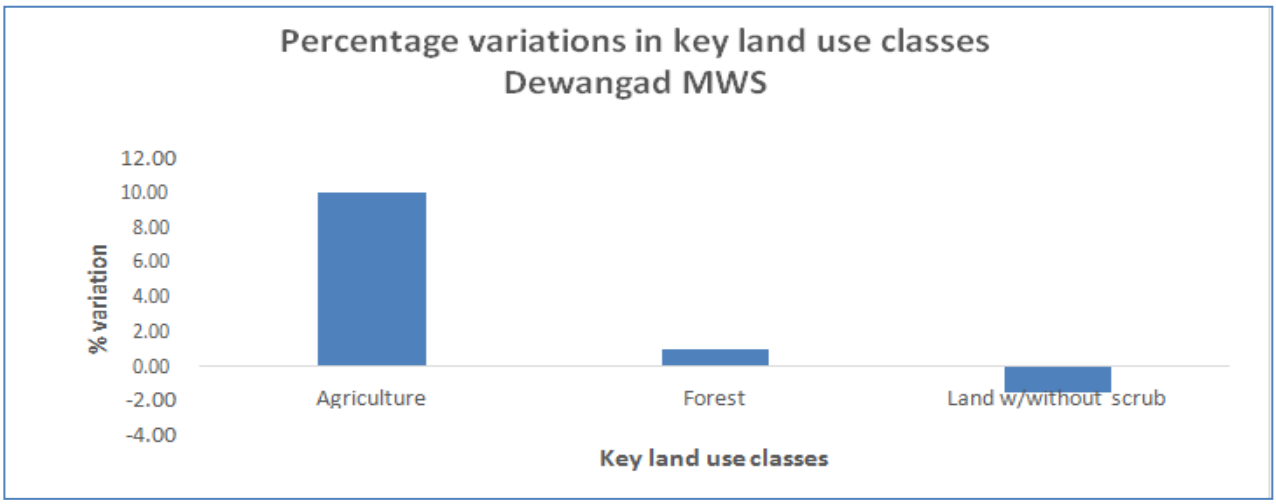


Sindhiyagad

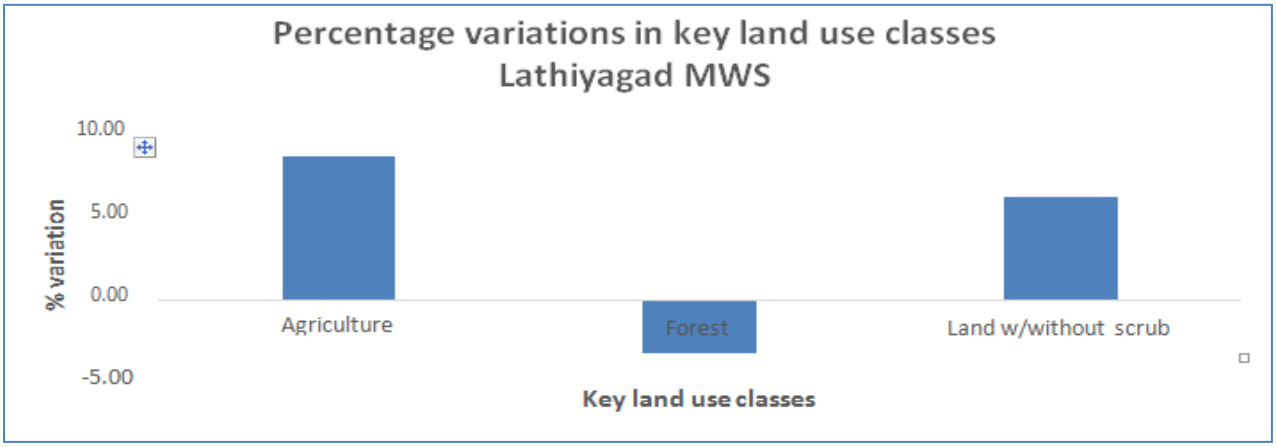


Map Plate: Percentage variations in key land use classes

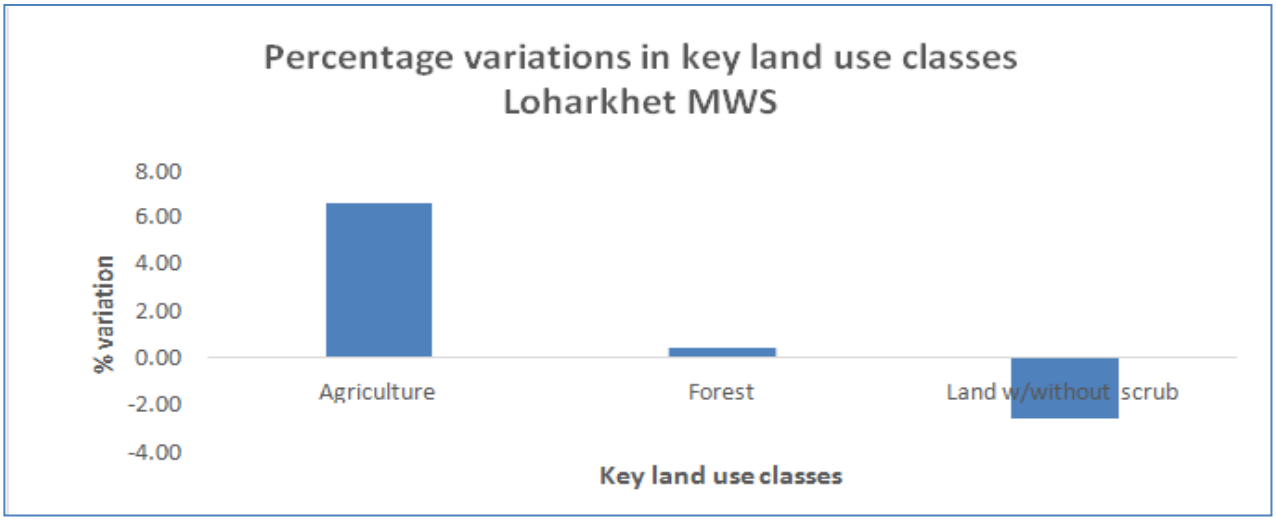
Dewangad.



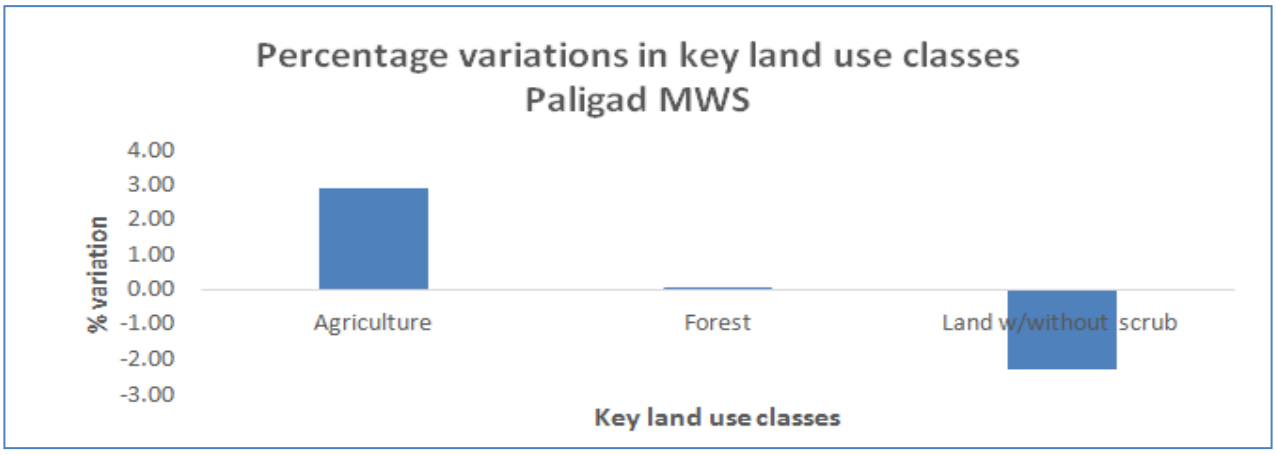
Lathiyagad



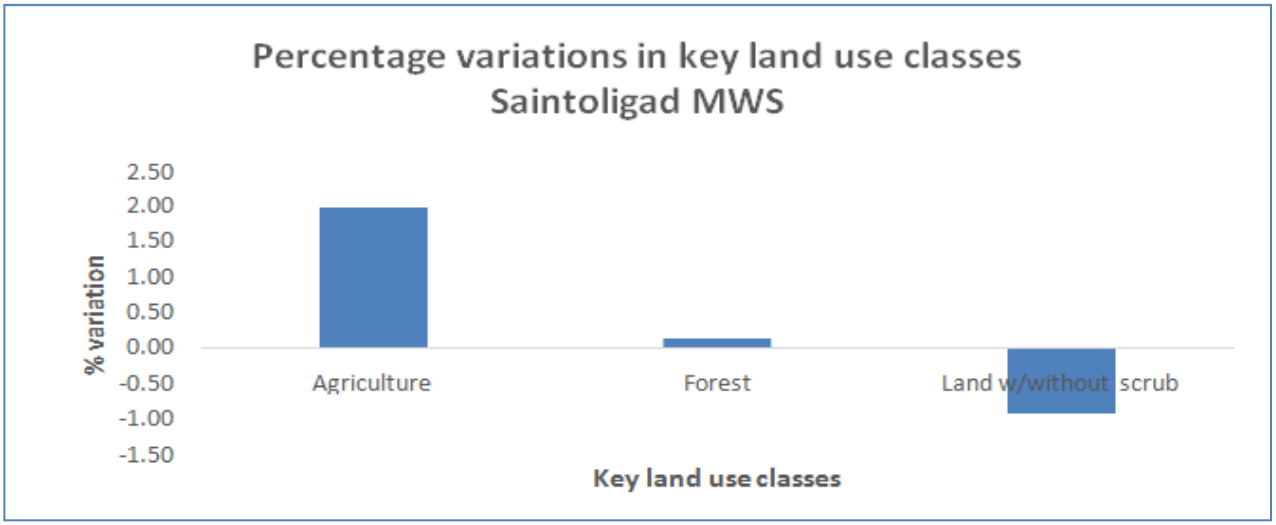
Loharkhet



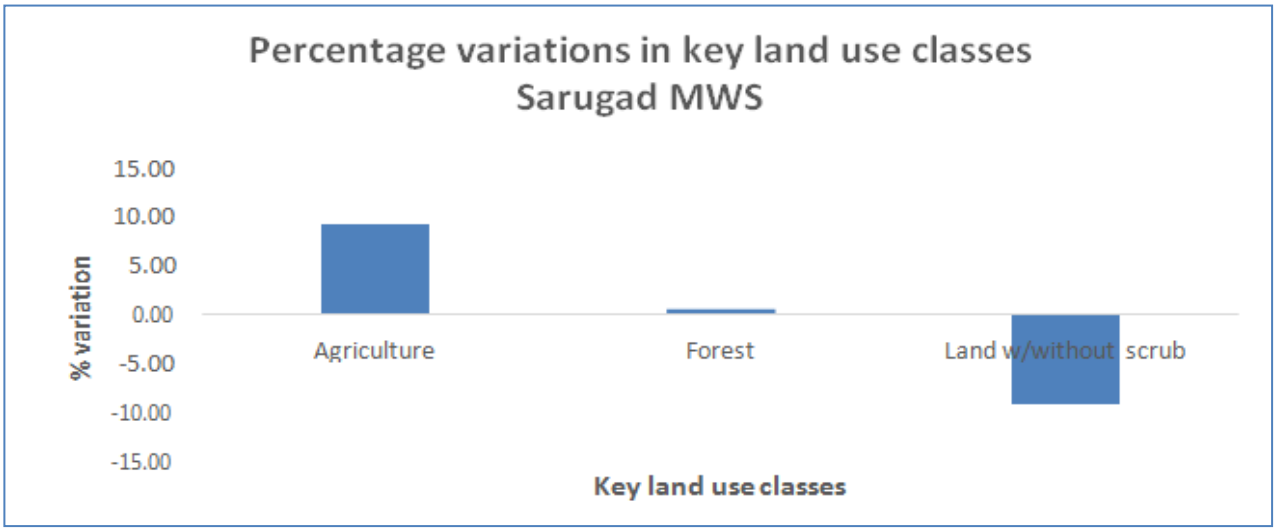
Paligad



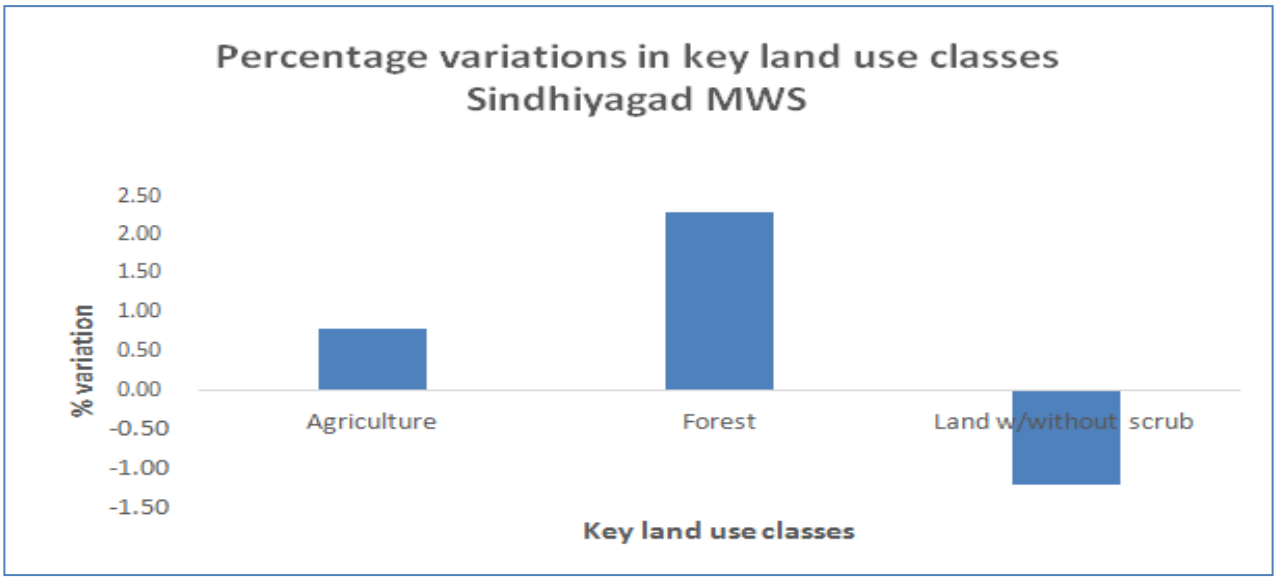
Saintoligad



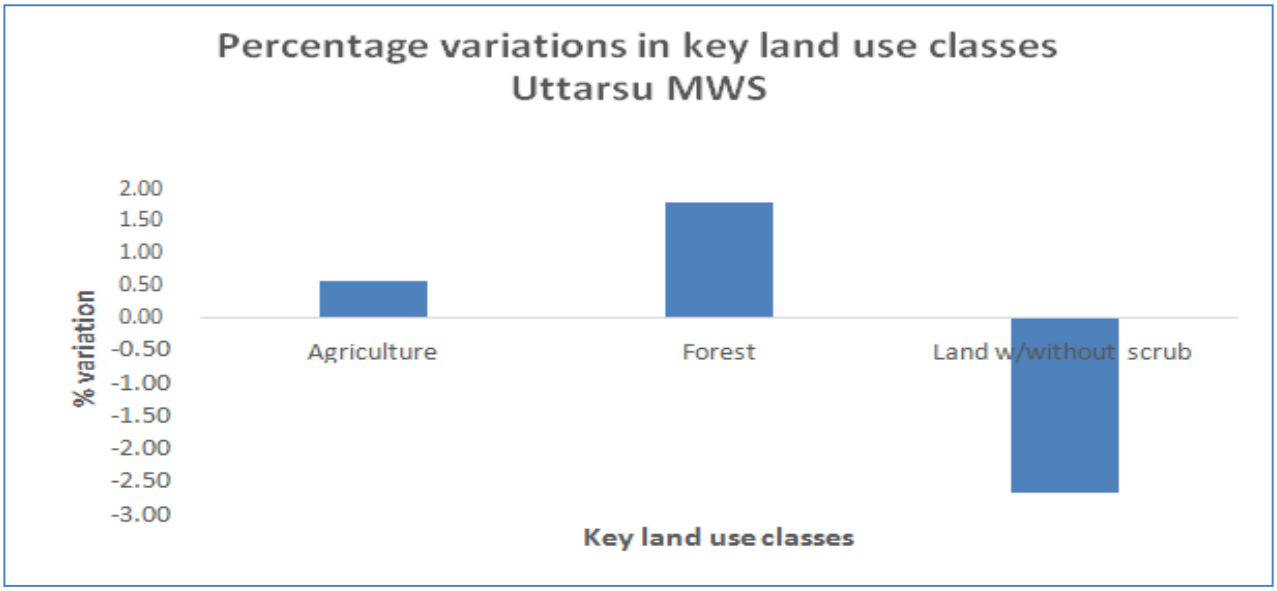
Sarugad



Sindhiyagad



Uttarshu



Annexure: 2.3.1 Land use land cover area statistics

Dewangad micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)
1	Built up	16.2	18.7	19.3	21.31
2	Agriculture	454.01	498.4	499	499.5
3	Forest	1808	1825.5	1824.1	1824.8
4	Water	163.5	164.1	162.4	162.08
5	Land w/without scrub	4501	4434.4	4435.2	4432.24
6	Road	39.38	41.5	42	42.14
Total		**6982.09**	**6982.6**	**6982**	**6982.07**

Lathiyagad micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)
1	Built up	18.46	18.3	19.5	18.5
2	Agriculture	646	700.9	701.2	702.1
3	Forest	2552.6	2417.4	2472.1	2470.1
4	Water	83.97	85	85.5	85.65
5	Land w/without scrub	1362.1	1442	1445	1446.7
6	Transportation	22.87	23	23.26	23.5
Total		**4686**	**4686.6**	**4746.56**	**4746.55**

Loharkhet micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)
1	Built up	14.82	15.2	36.1	36.5
2	Agriculture	797.85	847.6	850.5	851
3	Forest	7791.8	7826.5	7824.2	7824.8
4	Water	376.57	378.8	374.5	372.5
5	Land w/without scrub	4316	4227.8	4204.2	4204.6
6	Transportation	15.92	16.1	23.4	23.3
Total		**13312.96**	**13312**	**13312.9**	**13312.7**

Paligad micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line	Midterm (2018)	CR (2020)	Final (2021)
1	Built up	5.98	12.8	16.7	16.5
2	Agriculture	682.33	691.6	700	701.9
3	Forest	3647.3	3649	3646.5	3649.2
4	Water	206.88	207.5	207.5	207.5
5	Land w/without scrub	1432.8	1414.4	1404.6	1400.1
6	Transportation	10.37	10.5	10.5	10.5
Total		**5985.66**	**5985.8**	**5985.8**	**5985.7**

Saintoligad micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)
1	Built up	21.96	22.9	22.6	22.6
2	Agriculture	941.43	957.9	959.7	960.1
3	Forest	682.19	683.1	683.6	683.1
4	Water	159.56	159.6	159.6	158.6
5	Land w/without scrub	2262.3	2242.3	2240.3	2241.3
6	Transportation	41.41	41.4	41.4	41.4
Total		**4108.85**	**4107.2**	**4107.2**	**4107.1**

Sarugad micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line	Midterm (2018)	CR (2020)	Final (2021)
1	Built up	7.68	15.1	15.4	17.5
2	Agriculture	623.52	678.9	679.1	681.3
3	Forest	5535.43	5568.2	5571.7	5569.1
4	Water	106.28	106.2	106.2	106.2
5	Land w/without scrub	1100.86	1005.5	1001.3	999.6
6	Transportation	19.7	19.7	19.7	19.7
Total		**7393.47**	**7393.6**	**7393.4**	**7393.4**

Sindhiyagad micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line (2015)	**Midterm (2018)**	**CR (2020)**	**Final (2021)**
1	Built up	16.8	23.6	26.4	26.4
2	Agriculture	1815.7	1828	1829.8	1830.1
3	Forest	1737.5	1776.5	1777	1776.7
4	Water	415.09	416.1	399.1	399.1
5	Land w/without scrub	3837.3	3779.1	3790.5	3791
6	Transportation	28.38	27.5	27.5	27.5
Total		**7850.77**	**7850.8**	**7850.3**	**7850.8**

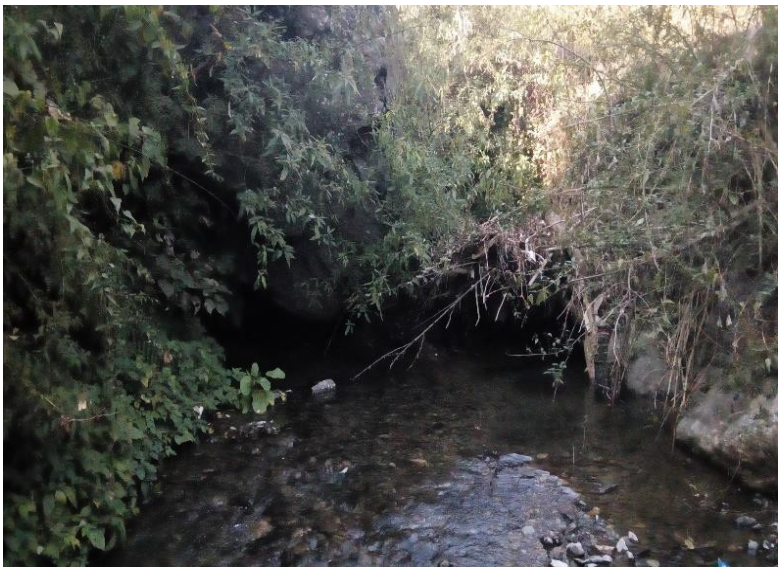
Uttarsu micro watershed

Sl.No.	Land use categories	Area (ha)			
		Base line (2015)	**Midterm (2018)**	**CR (2020)**	**Final (2021)**
1	Built up	16.83	17.2	18.9	19.1
2	Agriculture	912.1	915.7	916.1	917.1
3	Forest	1287.4	1310.8	1309.4	1310.2
4	Water	205.2	205.2	205.2	205.3
5	Land w/without scrub	1149.2	1121.4	1120.8	1118.4
6	Transportation	20.21	20.2	20.2	20.2
Total		**3590.94**	**3590.5**	**3590.6**	**3590.3**

Annexure: 2.4.1 Site selection reports of Weirs for stage discharge measurements

Dewangad Micro Water Shed, Dehradun District Weir location after field verification

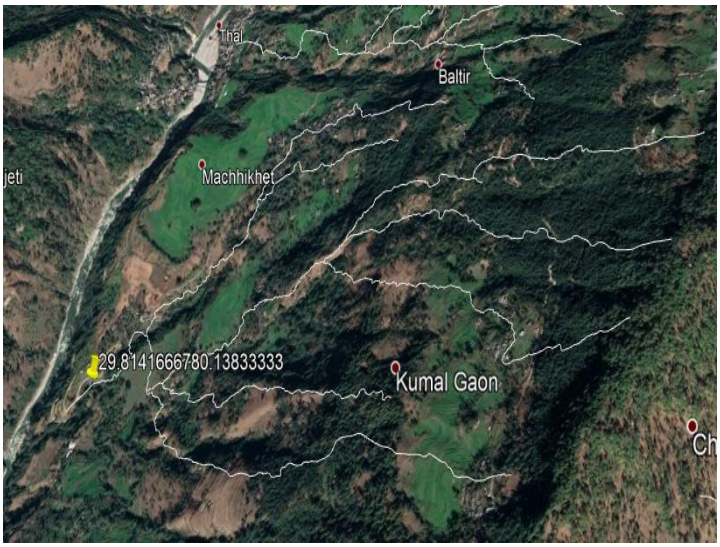
Parameters	Description
Coordinates	30.70997364°N, 77.88028827° E
Name of the stream	Dewangad
Nature of the stream course	Sinuous course
Nature of the stream bed	Boulder, Cobble, Pebble deposits
Stream order at site	3rd order
Width at proposed site	5 m Measured
Altitude of proposed site a msl	1493 m amsl approx
Nearby known village	Near Tigerfall, Khoya Channi village, GP Mona



Proposed weir location

Lathiyagad Micro Water Shed, Pithoragarh District Weir location at Lathiyagad

Parameters	Description
Coordinates	29.81416667°N, 80.13833333°E
Name of the stream	MWS Lathiyagad, Shalkhetigad
Nature of the stream course	Sinuous
Nature of the stream bed	Boulder, Cobble, Pebble deposits
Stream order at site	3rd order
Width at proposed site	5.0 m Measured
Altitude of proposed site a msl	784 m approx
Nearby known village	GP Baltir, RV Baltir, Kumalgaon, Dokhi
Contact Person (WMD)	Mr.Sati, 7500156249
Hydrologist	Mr.Venugopalan Nair, 9074828649



Proposed weir location

Loharkhet Micro Water Shed, Bageshwar District Weir location at Songnala

Parameters	Description
Coordinates	30.03321947°N, 79.95508897°E
Name of the stream	MWS Loharkhet, Songnala
Nature of the stream course	Sinuous
Nature of the stream bed	Boulder, Cobble, Pebble deposits
Stream order at site	2nd order
Width at proposed site	4.2 m Measured
Altitude of proposed site a msl	1342 m approx
Nearby known village	GP Suding, RV Suding
Contact Person (WMD)	Mr.Himanshu Negi, 9012662990
Hydrologist	Mr.Venugopalan Nair, 9074828649

Proposed weir location

Paligad Micro Water Shed, Tehri District Weir location at Butterfly park

Parameters	Description
Coordinates	30.542509°N, 78.176003°E
Name of the stream	Paligad
Nature of the stream course	Moderately straight course
Nature of the stream bed	Boulder, Cobble, Pebble deposits
Stream order at site	4th order
Width at proposed site	5.2 m Measured
Altitude of proposed site a msl	1433 m approx
Nearby known village	GP Tewa, RV Tewa
Discharge (15-6-2019)	7258 m3/day (base flow)

Proposed weir location

Saintoligad Micro Water Shed, Uttarkashi District Weir location details

Parameters	Description
Coordinates	29.90580573°N, 78.83235587°E
Name of the stream	Saintoligad
Nature of the stream course	Stream is having sinuous course with moderate gradient
Nature of the stream bed	Boulder, Cobble, Pebble deposits
Stream order at site	4th order
Width at proposed site	5.3 m Measured
Altitude of proposed site a msl	994 m approx
Nearby known village	GP Kandai, RV Ghandoli
Contact persons	Vinod Chouhan, 8979699385, Amit Panwar, 952880902
Hydrologist	Venugopalan Nair, 9074828649
Site description	Site is near to a farm which is converted to farm from a barren land

Proposed weir location

Sarugad Micro Water Shed, Uttarkashi District Weir location after field verification

Parameters	Description
Coordinates	30.9786995°N, 78.07507918° E
Name of the stream	Sarugad
Nature of the stream course	Moderately straight course
Nature of the stream bed	Boulder, Cobble, Pebble deposits
Stream order at site	2nd order
Width at proposed site	6 m Measured
Altitude of proposed site a msl	1422 m amsl approx
Nearby known village	GP Dhobalgaon, RV Kaflikhan

Proposed weir location

Sidhiyagad Micro Water Shed, Almora District Weir location at kali Baisali

Parameters	Description
Coordinates	29.521339°N, 79.937274°E
Name of the stream	Sidhiyagad MWS, Kali Baisali
Nature of the stream course	Coarsely sinuous
Nature of the stream bed	Valley deposits of cobbles, pebbles etc
Stream order at site	4th order
Width at proposed site	6.5 m Measured
Altitude of proposed site a msl	844 m approx
Nearby known village	Chandungri GP, Sindhyakhet village, Nala from Dhanya side
Land use in the vicinity	Agriculture, land with or without scrub
Details	Site is at a Nala reaching from Danya RV side. This is a perennial stream. About 3km distance from nearest transport location. Site is having rocks available for construction, stream is bringing necessary sand, this can be sieved for the construction purpose. Only cement need to transport. Local people can help in arranging ponys (mules/donkeys) for transporting material for construction. Requested to take necessary help from Gramya Chandungri area unit office during construction.

Proposed weir location

Uttarsu Micro Water Shed, Rudra Prayag District Weir location near a bridge

Parameters	Description
Coordinates	29.521339°N, 79.937274°E
Name of the stream	Uttarsu
Nature of the stream course	Moderately straight course with relatively high gradient
Nature of the stream bed	Boulder, Cobble, Pebble deposits
Stream order at site	4th order
Width at proposed site	5.3 m Measured
Altitude of proposed site a msl	985 m approx
Nearby known village	GP Samkoti, RV Koti
Contact persons	Kailash Joshi, 9012958429, Digambar Negi, 8006913620
Hydrologist	Venugopalan Nair, 9074828649
Site description	Site is near to a bridge in Koti village, 50m from road and bridge.

Proposed weir location

Annexure: 2.4.2 Stage discharge data

Dewangad micro watershed

Sr N0	Date	Depth (m)	Discharge (cum/day)	Sr N0	Date	Depth (m)	Discharge (cum/day)
1	11.01.2021	0.165	5988	148	07.06.2021	0.125	2786
2	12.01.2021	0.165	5988	149	08.06.2021	0.138	3333
3	13.01.2021	0.168	5792	150	09.06.2021	0.137	3308
4	14.01.2021	0.135	3429	151	10.06.2021	0.125	2786
5	15.01.2021	0.141	3837	152	11.06.2021	0.125	2786
6	16.01.2021	0.142	3865	153	12.06.2021	0.136	3284
7	17.01.2021	0.139	3279	154	13.06.2021	0.135	3260
8	18.01.2021	0.135	3429	155	14.06.2021	0.125	2786
9	19.01.2021	0.143	3892	156	15.06.2021	0.125	2786
10	20.01.2021	0.135	3429	157	16.06.2021	0.134	3236
11	21.01.2021	0.138	3255	158	17.06.2021	0.133	3212
12	22.01.2021	0.125	2722	159	18.06.2021	0.135	3511
13	23.01.2021	0.125	2722	160	19.06.2021	0.135	3511
14	24.01.2021	0.122	2435	161	20.06.2021	0.132	3188
15	25.01.2021	0.115	2087	162	21.06.2021	0.134	3236
16	26.01.2021	0.125	2722	163	22.06.2021	0.135	3511
17	27.01.2021	0.125	2722	164	23.06.2021	0.135	3511
18	28.01.2021	0.125	2722	165	24.06.2021	0.138	3333
19	29.01.2021	0.123	2455	166	25.06.2021	0.137	3308
20	30.01.2021	0.137	3231	167	26.06.2021	0.125	2786
21	31.01.2021	0.115	2087	168	27.06.2021	0.136	3284
22	01.02.2021	0.135	3429	169	28.06.2021	0.125	2786
23	02.02.2021	0.136	3208	170	29.06.2021	0.125	2786
24	03.02.2021	0.135	3184	171	30.06.2021	0.135	3260
25	04.02.2021	0.144	3919	172	01.07.2021	0.134	3236
26	05.02.2021	0.145	3946	173	02.07.2021	0.125	2786
27	06.02.2021	0.145	4209	174	03.07.2021	0.133	3212
28	07.02.2021	0.167	5757	175	04.07.2021	0.135	3511
29	08.02.2021	0.166	5723	176	05.07.2021	0.135	3511
30	09.02.2021	0.165	5688	177	06.07.2021	0.148	4124
31	10.02.2021	0.165	5988	178	07.07.2021	0.146	4068
32	11.02.2021	0.155	5062	179	08.07.2021	0.156	4926
33	12.02.2021	0.164	5654	180	09.07.2021	0.154	4863
34	13.02.2021	0.165	5988	181	10.07.2021	0.155	5183
35	14.02.2021	0.172	6554	182	11.07.2021	0.155	5183
36	15.02.2021	0.175	6985	183	12.07.2021	0.465	69103
37	16.02.2021	0.176	6706	184	13.07.2021	0.496	78316
38	17.02.2021	0.165	5988	185	14.07.2021	0.468	68679
39	18.02.2021	0.165	5988	186	15.07.2021	0.455	65926

40	19.02.2021	0.178	6782	187	16.07.2021	0.448	62415
41	20.02.2021	0.175	6985	188	17.07.2021	0.446	62137
42	21.02.2021	0.165	5988	189	18.07.2021	0.426	56185
43	22.02.2021	0.163	5619	190	19.07.2021	0.417	53449
44	23.02.2021	0.162	5585	191	20.07.2021	0.397	47935
45	24.02.2021	0.155	5062	192	21.07.2021	0.378	42833
46	25.02.2021	0.161	5550	193	22.07.2021	0.315	29257
47	26.02.2021	0.155	5062	194	23.07.2021	0.315	29257
48	27.02.2021	0.152	4688	195	24.07.2021	0.485	75679
49	28.02.2021	0.153	4719	196	25.07.2021	0.505	82552
50	01.03.2021	0.145	4310	197	26.07.2021	0.514	84978
51	02.03.2021	0.145	4310	198	27.07.2021	0.497	78474
52	03.03.2021	0.146	4068	199	28.07.2021	0.485	75679
53	04.03.2021	0.147	4096	200	29.07.2021	0.476	71622
54	05.03.2021	0.148	4124	201	30.07.2021	0.415	53963
55	06.03.2021	0.145	4310	202	31.07.2021	0.425	56843
56	07.03.2021	0.145	4310	203	01.08.2021	0.447	62276
57	08.03.2021	0.149	4152	204	02.08.2021	0.365	40681
58	09.03.2021	0.148	4124	205	03.08.2021	0.398	48056
59	10.03.2021	0.147	4096	206	04.08.2021	0.328	31074
60	11.03.2021	0.135	3511	207	05.08.2021	0.326	30884
61	12.03.2021	0.135	3511	208	06.08.2021	0.315	29257
62	13.03.2021	0.146	4068	209	07.08.2021	0.305	27195
63	14.03.2021	0.145	4040	210	08.08.2021	0.295	25208
64	15.03.2021	0.135	3511	211	09.08.2021	0.265	19691
65	16.03.2021	0.134	3236	212	10.08.2021	0.225	13375
66	17.03.2021	0.133	3212	213	11.08.2021	0.245	16384
67	18.03.2021	0.135	3511	214	12.08.2021	0.242	15734
68	19.03.2021	0.135	3511	215	13.08.2021	0.236	14467
69	20.03.2021	0.132	3188	216	14.08.2021	0.243	15799
70	21.03.2021	0.135	3511	217	15.08.2021	0.235	14842
71	22.03.2021	0.144	4012	218	16.08.2021	0.235	14842
72	23.03.2021	0.138	3333	219	17.08.2021	0.235	14842
73	24.03.2021	0.137	3308	220	18.08.2021	0.237	14528
74	25.03.2021	0.135	3511	221	19.08.2021	0.225	13375
75	26.03.2021	0.143	3985	222	20.08.2021	0.238	14590
76	27.03.2021	0.139	3357	223	21.08.2021	0.235	14842
77	28.03.2021	0.136	3284	224	22.08.2021	0.235	14842
78	29.03.2021	0.125	2786	225	23.08.2021	0.239	14651
79	30.03.2021	0.125	2786	226	24.08.2021	0.235	14842
80	31.03.2021	0.125	2786	227	25.08.2021	0.235	14842
81	01.04.2021	0.125	2786	228	26.08.2021	0.235	14842
82	02.04.2021	0.135	3511	229	27.08.2021	0.235	14406
83	03.04.2021	0.135	3260	230	28.08.2021	0.225	13375
84	04.04.2021	0.134	3236	231	29.08.2021	0.225	13375

85	05.04.2021	0.135	3511	232	30.08.2021	0.215	11982
86	06.04.2021	0.135	3511	233	31.08.2021	0.215	11982
87	07.04.2021	0.133	3212	234	01.09.2021	0.226	13014
88	08.04.2021	0.132	3188	235	02.09.2021	0.229	13187
89	09.04.2021	0.135	3511	236	03.09.2021	0.215	11982
90	10.04.2021	0.135	3511	237	04.09.2021	0.215	11982
91	11.04.2021	0.125	2786	238	05.09.2021	0.228	13130
92	12.04.2021	0.125	2786	239	06.09.2021	0.215	11982
93	13.04.2021	0.131	3163	240	07.09.2021	0.215	11982
94	14.04.2021	0.125	2786	241	08.09.2021	0.216	11636
95	15.04.2021	0.125	2786	242	09.09.2021	0.205	10663
96	16.04.2021	0.135	3260	243	10.09.2021	0.219	11798
97	17.04.2021	0.125	2786	244	11.09.2021	0.205	10663
98	18.04.2021	0.136	3284	245	12.09.2021	0.405	51158
99	19.04.2021	0.135	3511	246	13.09.2021	0.385	45771
100	20.04.2021	0.135	3511	247	14.09.2021	0.396	47815
101	21.04.2021	0.145	4310	248	15.09.2021	0.402	50033
102	22.04.2021	0.145	4310	249	16.09.2021	0.365	40681
103	23.04.2021	0.142	3957	250	17.09.2021	0.419	53705
104	24.04.2021	0.135	3511	251	18.09.2021	0.365	40681
105	25.04.2021	0.135	3511	252	19.09.2021	0.368	40332
106	26.04.2021	0.137	3308	253	20.09.2021	0.345	35889
107	27.04.2021	0.135	3511	254	21.09.2021	0.325	31393
108	28.04.2021	0.136	3284	255	22.09.2021	0.315	29257
109	29.04.2021	0.138	3333	256	23.09.2021	0.485	75679
110	30.04.2021	0.139	3357	257	24.09.2021	0.486	74932
111	01.05.2021	0.135	3511	258	25.09.2021	0.485	75679
112	02.05.2021	0.135	3511	259	26.09.2021	0.479	72073
113	03.05.2021	0.141	3929	260	27.09.2021	0.465	69103
114	04.05.2021	0.144	4012	261	28.09.2021	0.435	59796
115	05.05.2021	0.145	4310	262	29.09.2021	0.443	61719
116	06.05.2021	0.145	4310	263	30.09.2021	0.438	59395
117	07.05.2021	0.155	5183	264	1.10.2021	0.428	56449
118	08.05.2021	0.154	4863	265	2.10.2021	0.405	51158
119	09.05.2021	0.155	4895	266	3.10.2021	0.385	45771
120	10.05.2021	0.145	4310	267	4.10.2021	0.365	40681
121	11.05.2021	0.145	4310	268	5.10.2021	0.348	35554
122	12.05.2021	0.156	4926	269	6.10.2021	0.343	35044
123	13.05.2021	0.157	4958	270	7.10.2021	0.325	31393
124	14.05.2021	0.145	4310	271	8.10.2021	0.313	28490
125	15.05.2021	0.145	4310	272	9.10.2021	0.304	26541
126	16.05.2021	0.155	5183	273	10.10.2021	0.295	25208
127	17.05.2021	0.155	5183	274	11.10.2021	0.297	24827
128	18.05.2021	0.168	5929	275	12.10.2021	0.288	23005
129	19.05.2021	0.167	5894	276	13.10.2021	0.275	21455

130	20.05.2021	0.155	5183	277	14.10.2021	0.265	19691
131	21.05.2021	0.158	4990	278	15.10.2021	0.255	18000
132	22.05.2021	0.159	5021	279	16.10.2021	0.244	15864
133	23.05.2021	0.145	4310	280	17.10.2021	0.234	14344
134	25.05.2021	0.145	4040	281	18.10.2021	0.215	11982
135	25.05.2021	0.137	3308	282	19.10.2021	0.205	10663
136	26.05.2021	0.135	3260	283	20.10.2021	0.205	10663
137	27.05.2021	0.125	2786	284	21.10.2021	0.206	10332
138	28.05.2021	0.134	3236	285	22.10.2021	0.208	10432
139	29.05.2021	0.133	3212	286	23.10.2021	0.195	9418
140	30.05.2021	0.135	3511	287	24.10.2021	0.194	9009
141	31.05.2021	0.135	3511	288	25.10.2021	0.209	10482
142	01.06.2021	0.147	4096	289	26.10.2021	0.185	8248
143	02.06.2021	0.135	3511	290	27.10.2021	0.185	8248
144	03.06.2021	0.135	3511	291	28.10.2021	0.175	7152
145	04.06.2021	0.132	3188	292	29.10.2021	0.175	7152
146	05.06.2021	0.139	3357	293	30.10.2021	0.183	7819
147	06.06.2021	0.125	2786	294	31.10.2021	0.189	8075

Lathiyagad micro watershed

Sr No	Date	Depth (m)	Discharge (cum/day)	Sr No	Date	Depth (m)	Discharge (cum/day)
1	20.02.2021	0.08	597	113	12.06.2021	0.07	429
2	21.02.2021	0.06	331	114	13.06.2021	0.08	597
3	22.02.2021	0.07	429	115	14.06.2021	0.07	429
4	23.02.2021	0.07	479	116	15.06.2021	0.07	429
5	24.02.2021	0.08	638	117	16.06.2021	0.07	479
6	25.02.2021	0.07	472	118	17.06.2021	0.08	647
7	26.02.2021	0.06	336	119	18.06.2021	0.07	479
8	27.02.2021	0.08	597	120	19.06.2021	0.07	479
9	28.02.2021	0.07	472	121	20.06.2021	0.07	479
10	01.03.2021	0.08	638	122	21.06.2021	0.07	479
11	02.03.2021	0.07	429	123	22.06.2021	0.07	479
12	03.03.2021	0.06	336	124	23.06.2021	0.07	479
13	04.03.2021	0.08	638	125	24.06.2021	0.07	479
14	05.03.2021	0.06	331	126	25.06.2021	0.06	313
15	06.03.2021	0.06	331	127	26.06.2021	0.08	658
16	07.03.2021	0.07	472	128	27.06.2021	0.06	317
17	08.03.2021	0.08	638	129	28.06.2021	0.06	317
18	09.03.2021	0.06	336	130	29.06.2021	0.05	235
19	10.03.2021	0.07	429	131	30.06.2021	0.07	411
20	11.03.2021	0.07	472	132	01.07.2021	0.06	327
21	12.03.2021	0.07	429	133	02.07.2021	0.06	331
22	13.03.2021	0.07	472	134	03.07.2021	0.06	327
23	14.03.2021	0.06	331	135	04.07.2021	0.06	336

24	15.03.2021	0.07	429	136	05.07.2021	0.05	215
25	16.03.2021	0.07	429	137	06.07.2021	0.06	341
26	17.03.2021	0.07	429	138	07.07.2021	0.06	327
27	18.03.2021	0.07	472	139	08.07.2021	0.06	331
28	19.03.2021	0.07	429	140	09.07.2021	0.05	215
29	20.03.2021	0.07	472	141	10.07.2021	0.06	331
30	21.03.2021	0.07	429	142	11.07.2021	0.05	215
31	22.03.2021	0.07	472	143	12.07.2021	0.06	327
32	23.03.2021	0.07	429	144	13.07.2021	0.05	221
33	24.03.2021	0.07	472	145	14.07.2021	0.06	327
34	25.03.2021	0.06	336	146	15.07.2021	0.06	331
35	26.03.2021	0.07	472	147	16.07.2021	0.07	411
36	27.03.2021	0.07	429	148	17.07.2021	0.06	331
37	28.03.2021	0.07	472	149	18.07.2021	0.05	215
38	29.03.2021	0.06	336	150	19.07.2021	0.06	331
39	30.03.2021	0.06	331	151	20.07.2021	0.05	215
40	31.03.2021	0.06	331	152	21.07.2021	0.06	327
41	01.04.2021	0.06	331	153	22.07.2021	0.05	221
42	02.04.2021	0.06	331	154	23.07.2021	0.07	411
43	03.04.2021	0.07	429	155	24.07.2021	0.06	327
44	04.04.2021	0.07	472	156	25.07.2021	0.06	331
45	05.04.2021	0.07	429	157	26.07.2021	0.06	327
46	06.04.2021	0.07	472	158	27.07.2021	0.06	336
47	07.04.2021	0.07	472	159	28.07.2021	0.05	215
48	08.04.2021	0.07	472	160	29.07.2021	0.06	341
49	09.04.2021	0.06	336	161	30.07.2021	0.06	327
50	10.04.2021	0.06	331	162	31.07.2021	0.06	331
51	11.04.2021	0.07	429	163	01.08.2021	0.06	327
52	12.04.2021	0.07	472	164	02.08.2021	0.06	327
53	13.04.2021	0.07	472	165	03.08.2021	0.07	442
54	14.04.2021	0.07	472	166	04.08.2021	0.07	479
55	15.04.2021	0.06	331	167	05.08.2021	0.08	597
56	16.04.2021	0.06	331	168	06.08.2021	0.08	638
57	17.04.2021	0.07	435	169	07.08.2021	0.06	331
58	18.04.2021	0.07	435	170	08.08.2021	0.08	656
59	19.04.2021	0.07	472	171	09.08.2021	0.09	896
60	20.04.2021	0.07	472	172	10.08.2021	0.08	638
61	21.04.2021	0.06	331	173	11.08.2021	0.08	597
62	22.04.2021	0.07	429	174	12.08.2021	0.06	341
63	23.04.2021	0.06	331	175	13.08.2021	0.06	327
64	24.04.2021	0.08	638	176	14.08.2021	0.07	466
65	25.04.2021	0.07	479	177	15.08.2021	0.07	479
66	26.04.2021	0.07	435	178	16.08.2021	0.05	232
67	27.04.2021	0.08	647	179	17.08.2021	0.06	317
68	28.04.2021	0.08	647	180	18.08.2021	0.07	446

69	29.04.2021	0.07	479	181	19.08.2021	0.08	658
70	30.04.2021	0.07	479	182	20.08.2021	0.05	235
71	01.05.2021	0.07	472	183	21.08.2021	0.07	459
72	02.05.2021	0.07	429	184	22.08.2021	0.06	322
73	03.05.2021	0.06	331	185	23.08.2021	0.06	327
74	04.05.2021	0.06	331	186	24.08.2021	0.07	466
75	05.05.2021	0.06	331	187	25.08.2021	0.06	331
76	06.05.2021	0.06	358	188	26.08.2021	0.07	466
77	07.05.2021	0.07	479	189	27.08.2021	0.07	479
78	08.05.2021	0.07	429	190	28.08.2021	0.07	472
79	09.05.2021	0.07	429	191	29.08.2021	0.05	221
80	10.05.2021	0.06	327	192	30.08.2021	0.06	331
81	11.05.2021	0.07	442	193	31.08.2021	0.06	331
82	12.05.2021	0.08	638	194	01.09.2021	0.06	327
83	13.05.2021	0.08	647	195	02.09.2021	0.06	327
84	14.05.2021	0.07	429	196	03.09.2021	0.07	472
85	15.05.2021	0.07	479	197	04.09.2021	0.08	638
86	16.05.2021	0.08	638	198	05.09.2021	0.06	327
87	17.05.2021	0.08	600	199	06.09.2021	0.03	123
88	18.05.2021	0.07	479	200	07.09.2021	0.05	212
89	19.05.2021	0.07	479	201	08.09.2021	0.05	212
90	20.05.2021	0.06	331	202	09.09.2021	0.06	317
91	21.05.2021	0.06	341	203	10.09.2021	0.06	317
92	22.05.2021	0.07	429	204	11.09.2021	0.07	435
93	23.05.2021	0.08	677	205	12.09.2021	0.08	620
94	25.05.2021	0.07	429	206	13.09.2021	0.08	668
95	25.05.2021	0.07	479	207	14.09.2021	0.08	629
96	26.05.2021	0.06	327	208	15.09.2021	0.08	581
97	27.05.2021	0.07	429	209	16.09.2021	0.07	472
98	28.05.2021	0.07	429	210	17.09.2021	0.07	472
99	29.05.2021	0.08	647	211	18.09.2021	0.07	472
100	30.05.2021	0.08	647	212	19.09.2021	0.08	647
101	31.05.2021	0.08	638	213	20.09.2021	0.08	638
102	01.06.2021	0.07	429	214	21.09.2021	0.09	851
103	02.06.2021	0.08	647	215	22.09.2021	0.09	851
104	03.06.2021	0.07	429	216	23.09.2021	0.09	806
105	04.06.2021	0.08	597	217	24.09.2021	0.09	806
106	05.06.2021	0.07	429	218	25.09.2021	0.06	331
107	06.06.2021	0.07	429	219	26.09.2021	0.06	345
108	07.06.2021	0.08	647	220	27.09.2021	0.07	479
109	08.06.2021	0.08	597	221	28.09.2021	0.07	472
110	09.06.2021	0.06	336	222	29.09.2021	0.06	336
111	10.06.2021	0.08	656	223	30.09.2021	0.06	336
112	11.06.2021	0.07	466	224			

Loharkhet micro watershed

Sr No	Date	Depth (m)	Discharge (cum/day)	Sr No	Date	Depth (m)	Discharge (cum/day)
1	19.02.2021	0.1	480	128	26.06.2021	0.31	2799
2	20.02.2021	0.1	511	129	27.06.2021	0.31	2544
3	21.02.2021	0.1	511	130	28.06.2021	0.26	2224
4	22.02.2021	0.09	392	131	29.06.2021	0.26	2224
5	23.02.2021	0.09	420	132	30.06.2021	0.21	1851
6	24.02.2021	0.08	314	133	01.07.2021	0.21	1851
7	25.02.2021	0.08	314	134	02.07.2021	0.21	1851
8	26.02.2021	0.08	306	135	03.07.2021	0.2	1742
9	27.02.2021	0.08	306	136	04.07.2021	0.2	1742
10	28.02.2021	0.08	306	137	05.07.2021	0.18	1530
11	01.03.2021	0.08	306	138	06.07.2021	0.18	1530
12	02.03.2021	0.08	329	139	07.07.2021	0.19	1635
13	03.03.2021	0.09	420	140	08.07.2021	0.19	1635
14	04.03.2021	0.09	392	141	09.07.2021	0.2	1742
15	05.03.2021	0.09	420	142	10.07.2021	0.34	2879
16	06.03.2021	0.08	314	143	11.07.2021	0.34	3455
17	07.03.2021	0.08	314	144	12.07.2021	0.33	3042
18	08.03.2021	0.08	314	145	13.07.2021	0.33	2766
19	09.03.2021	0.09	420	146	14.07.2021	0.31	3053
20	10.03.2021	0.09	420	147	15.07.2021	0.31	2799
21	11.03.2021	0.1	525	148	16.07.2021	0.3	2680
22	12.03.2021	0.1	498	149	17.07.2021	0.3	2680
23	13.03.2021	0.1	498	150	18.07.2021	0.35	3293
24	14.03.2021	0.1	492	151	19.07.2021	0.35	3593
25	15.03.2021	0.1	518	152	20.07.2021	0.35	3593
26	16.03.2021	0.1	492	153	21.07.2021	0.34	2879
27	17.03.2021	0.1	518	154	22.07.2021	0.28	2419
28	18.03.2021	0.1	492	155	23.07.2021	0.28	2419
29	19.03.2021	0.09	410	156	24.07.2021	0.27	2321
30	20.03.2021	0.09	410	157	25.07.2021	0.27	2321
31	21.03.2021	0.09	386	158	26.07.2021	0.26	2224
32	22.03.2021	0.09	410	159	27.07.2021	0.28	2419
33	23.03.2021	0.08	311	160	28.07.2021	0.28	2419
34	24.03.2021	0.08	311	161	29.07.2021	0.26	2224
35	25.03.2021	0.08	311	162	30.07.2021	0.26	2224
36	26.03.2021	0.08	290	163	31.07.2021	0.28	2419
37	27.03.2021	0.07	237	164	01.08.2021	0.27	2321
38	28.03.2021	0.07	254	165	02.08.2021	0.27	2321
39	29.03.2021	0.07	237	166	03.08.2021	0.26	2224
40	30.03.2021	0.07	254	167	04.08.2021	0.26	2224
41	31.03.2021	0.06	224	168	05.08.2021	0.24	2032

42	01.04.2021	0.06	224	169	06.08.2021	0.24	2032
43	02.04.2021	0.06	210	170	07.08.2021	0.28	2419
44	03.04.2021	0.06	224	171	08.08.2021	0.28	2419
45	04.04.2021	0.06	196	172	09.08.2021	0.28	2419
46	05.04.2021	0.06	210	173	10.08.2021	0.26	2224
47	06.04.2021	0.06	196	174	11.08.2021	0.3	2618
48	07.04.2021	0.05	157	175	12.08.2021	0.3	2618
49	08.04.2021	0.05	157	176	13.08.2021	0.26	2224
50	09.04.2021	0.05	168	177	14.08.2021	0.24	2032
51	10.04.2021	0.05	157	178	15.08.2021	0.23	1938
52	11.04.2021	0.05	168	179	16.08.2021	0.18	1477
53	12.04.2021	0.05	162	180	17.08.2021	0.16	1299
54	13.04.2021	0.05	151	181	18.08.2021	0.15	969
55	14.04.2021	0.05	151	182	19.08.2021	0.13	831
56	15.04.2021	0.05	162	183	20.08.2021	0.13	831
57	16.04.2021	0.05	151	184	21.08.2021	0.12	763
58	17.04.2021	0.05	162	185	22.08.2021	0.12	763
59	18.04.2021	0.05	151	186	23.08.2021	0.12	763
60	19.04.2021	0.05	151	187	24.08.2021	0.11	522
61	20.04.2021	0.05	146	188	25.08.2021	0.11	522
62	21.04.2021	0.06	210	189	26.08.2021	0.1	472
63	22.04.2021	0.07	254	190	27.08.2021	0.1	472
64	23.04.2021	0.08	321	191	28.08.2021	0.28	2419
65	24.04.2021	0.09	397	192	29.08.2021	0.29	2518
66	25.04.2021	0.09	420	193	30.08.2021	0.29	2518
67	26.04.2021	0.09	373	194	31.08.2021	0.27	2321
68	27.04.2021	0.09	397	195	01.09.2021	0.27	2321
69	28.04.2021	0.09	397	196	02.09.2021	0.26	2224
70	29.04.2021	0.1	482	197	03.09.2021	0.26	2224
71	30.04.2021	0.1	509	198	04.09.2021	0.25	2128
72	01.05.2021	0.1	482	199	05.09.2021	0.25	2128
73	02.05.2021	0.1	482	200	06.09.2021	0.23	1938
74	03.05.2021	0.11	608	201	07.09.2021	0.22	1844
75	04.05.2021	0.11	578	202	08.09.2021	0.22	1844
76	05.05.2021	0.11	608	203	09.09.2021	0.21	1751
77	06.05.2021	0.11	596	204	10.09.2021	0.21	1401
78	07.05.2021	0.12	719	205	11.09.2021	0.21	1751
79	08.05.2021	0.11	578	206	12.09.2021	0.2	1659
80	09.05.2021	0.11	608	207	13.09.2021	0.2	1659
81	10.05.2021	0.11	578	208	14.09.2021	0.19	1568
82	11.05.2021	0.11	608	209	15.09.2021	0.18	1477
83	12.05.2021	0.1	482	210	16.09.2021	0.18	1477
84	13.05.2021	0.1	509	211	17.09.2021	0.17	1388
85	14.05.2021	0.1	482	212	18.09.2021	0.17	1110
86	15.05.2021	0.1	509	213	19.09.2021	0.15	969

87	16.05.2021	0.1	509	214	20.09.2021	0.15	969
88	17.05.2021	0.09	397	215	21.09.2021	0.14	900
89	18.05.2021	0.09	420	216	22.09.2021	0.14	900
90	19.05.2021	0.09	397	217	23.09.2021	0.13	623
91	20.05.2021	0.09	420	218	24.09.2021	0.13	831
92	21.05.2021	0.09	397	219	25.09.2021	0.12	763
93	22.05.2021	0.09	397	220	26.09.2021	0.18	1477
94	23.05.2021	0.08	321	221	27.09.2021	0.19	1568
95	25.05.2021	0.08	321	222	28.09.2021	0.19	1568
96	25.05.2021	0.11	608	223	29.09.2021	0.18	1477
97	26.05.2021	0.17	1395	224	30.09.2021	0.17	1388
98	27.05.2021	0.17	1395	225	1.10.2021	0.16	1293
99	28.05.2021	0.15	1026	226	2.10.2021	0.14	895
100	29.05.2021	0.15	1026	227	3.10.2021	0.13	827
101	30.05.2021	0.14	889	228	4.10.2021	0.11	519
102	31.05.2021	0.14	931	229	5.10.2021	0.1	469
103	01.06.2021	0.13	802	230	6.10.2021	0.09	420
104	02.06.2021	0.13	802	231	7.10.2021	0.08	247
105	03.06.2021	0.11	608	232	8.10.2021	0.07	215
106	04.06.2021	0.11	578	233	9.10.2021	0.07	213
107	05.06.2021	0.11	608	234	10.10.2021	0.07	212
108	06.06.2021	0.11	608	235	11.10.2021	0.06	180
109	07.06.2021	0.11	578	236	12.10.2021	0.06	179
110	08.06.2021	0.1	509	237	13.10.2021	0.06	178
111	09.06.2021	0.1	482	238	14.10.2021	0.06	176
112	10.06.2021	0.1	509	239	15.10.2021	0.06	176
113	11.06.2021	0.1	509	240	16.10.2021	0.06	175
114	12.06.2021	0.1	509	241	17.10.2021	0.27	2321
115	13.06.2021	0.1	492	242	18.10.2021	0.28	2431
116	14.06.2021	0.09	397	243	19.10.2021	0.29	2531
117	15.06.2021	0.09	420	244	20.10.2021	0.27	2321
118	16.06.2021	0.14	925	245	21.10.2021	0.25	2128
119	17.06.2021	0.3	2696	246	22.10.2021	0.25	2128
120	18.06.2021	0.45	5599	247	23.10.2021	0.24	2032
121	19.06.2021	0.48	6739	248	24.10.2021	0.22	1844
122	20.06.2021	0.45	6065	249	25.10.2021	0.2	1659
123	21.06.2021	0.45	5132	250	26.10.2021	0.28	2298
124	22.06.2021	0.36	3732	251	27.10.2021	0.28	2298
125	23.06.2021	0.36	3421	252	28.10.2021	0.26	2112
126	24.06.2021	0.36	3732	253	29.10.2021	0.24	1928
127	25.06.2021	0.34	3167	254	30.10.2021	0.23	1838
				255	31.10.2021	0.23	1838

`Paligad micro watershed

Sr No	Date	Depth (m)	Discharge (cum/day)	Sr No	Date	Depth (m)	Discharge (cum/day)
1	2/10/2020	0.067	4052	254	10/20/2020	0.1	5184
2	2/11/2020	0.067	4052	255	10/21/2020	0.1	5616
3	2/12/2020	0.14	7620	256	10/22/2020	0.09	4666
4	2/13/2020	0.14	7258	257	10/23/2020	0.09	4666
5	2/14/2020	0.14	7620	258	10/24/2020	0.08	4493
6	2/15/2020	0.07	4173	259	10/25/2020	0.08	4493
7	2/16/2020	0.13	7076	260	10/26/2020	0.08	4838
8	2/17/2020	0.13	7076	261	10/27/2020	0.08	4493
9	2/18/2020	0.13	6739	262	10/28/2020	0.08	4493
10	2/19/2020	0.13	7076	263	10/29/2020	0.07	3931
11	2/20/2020	0.13	6739	264	10/30/2020	0.07	4234
12	2/21/2020	0.13	6739	265	10/31/2020	0.08	4838
13	2/22/2020	0.073	3784	266	11/1/2020	0.08	4493
14	2/23/2020	0.073	4100	267	11/2/2020	0.07	4234
15	2/24/2020	0.073	4100	268	11/3/2020	0.07	3931
16	2/25/2020	0.073	3784	269	11/4/2020	0.07	3931
17	2/26/2020	0.073	4100	270	11/5/2020	0.07	4234
18	2/27/2020	0.073	4100	271	11/6/2020	0.07	4234
19	2/28/2020	0.073	3784	272	11/7/2020	0.07	3931
20	2/29/2020	0.073	4100	273	11/8/2020	0.07	4234
21	3/1/2020	0.073	3784	274	11/9/2020	0.07	3931
22	3/2/2020	0.083	4661	275	11/10/2020	0.06	3370
23	3/3/2020	0.083	4661	276	11/11/2020	0.06	3370
24	3/4/2020	0.083	4303	277	11/12/2020	0.06	3629
25	3/5/2020	0.083	4303	278	11/13/2020	0.06	3370
26	3/6/2020	0.085	5141	279	11/14/2020	0.06	3629
27	3/7/2020	0.085	5141	280	11/15/2020	0.06	3370
28	3/8/2020	0.1	5616	281	11/16/2020	0.06	3370
29	3/9/2020	0.095	5746	282	11/17/2020	0.06	3629
30	3/10/2020	0.1	5616	283	11/18/2020	0.06	3370
31	3/11/2020	0.12	6739	284	11/19/2020	0.65	22464
32	3/12/2020	0.15	8424	285	11/20/2020	0.06	3629
33	3/13/2020	0.17	8813	286	11/21/2020	0.05	3024
34	3/14/2020	0.2	10368	287	11/22/2020	0.05	3024
35	3/15/2020	0.2	10368	288	11/23/2020	0.05	2808
36	3/16/2020	0.2	9504	289	11/24/2020	0.05	3240
37	3/17/2020	0.25	12960	290	11/25/2020	0.55	21384
38	3/18/2020	0.25	12960	291	11/26/2020	0.05	3024
39	3/19/2020	0.2	10368	292	11/27/2020	0.05	3024
40	3/20/2020	0.15	8424	293	11/28/2020	0.05	3240
41	3/21/2020	0.15	7776	294	11/29/2020	0.05	3024
42	3/22/2020	0.15	8424	295	11/30/2020	0.05	2808
43	3/23/2020	0.15	8424	296	12/1/2020	0.05	3024

44	3/24/2020	0.15	7776	297	12/2/2020	0.05	2808
45	3/25/2020	0.15	7776	298	12/3/2020	0.05	3024
46	3/26/2020	0.2	10368	299	12/4/2020	0.05	3024
47	3/27/2020	0.2	9504	300	12/5/2020	0.05	2808
48	3/28/2020	0.2	10368	301	12/6/2020	0.05	3024
49	3/29/2020	0.2	9504	302	12/7/2020	0.05	3024
50	3/30/2020	0.14	7862	303	12/8/2020	0.05	2808
51	3/31/2020	0.14	7862	304	12/9/2020	0.05	3024
52	4/1/2020	0.12	6221	305	12/10/2020	0.05	3240
53	4/2/2020	0.12	6739	306	12/11/2020	0.05	3024
54	4/3/2020	0.12	6221	307	12/12/2020	0.05	2808
55	4/4/2020	0.12	6221	308	12/13/2020	0.05	3024
56	4/5/2020	0.12	6739	309	12/14/2020	0.05	3024
57	4/6/2020	0.12	6739	310	12/15/2020	0.04	2419
58	4/7/2020	0.12	6739	311	12/16/2020	0.04	2592
59	4/8/2020	0.1	5616	312	12/17/2020	0.04	2419
60	4/9/2020	0.1	5184	313	12/18/2020	0.04	2592
61	4/10/2020	0.1	5184	314	12/19/2020	0.04	2592
62	4/11/2020	0.1	5184	315	12/20/2020	0.04	2592
63	4/12/2020	0.1	5616	316	12/21/2020	0.13	7076
64	4/13/2020	0.095	5335	317	12/22/2020	0.13	7076
65	4/14/2020	0.095	4925	318	12/23/2020	0.12	6532
66	4/15/2020	0.095	4925	319	12/24/2020	0.12	6221
67	4/16/2020	0.09	5054	320	12/25/2020	0.12	6532
68	4/17/2020	0.09	5054	321	12/26/2020	0.12	6532
69	4/18/2020	0.09	5054	322	12/27/2020	0.12	6221
70	4/19/2020	0.09	5443	323	12/28/2020	0.12	6532
71	4/20/2020	0.09	5054	324	12/29/2020	0.12	6532
72	4/21/2020	0.09	5054	325	12/30/2020	0.12	6221
73	4/22/2020	0.09	5443	326	12/31/2020	0.11	6273
74	4/23/2020	0.085	5141	327	1/1/2021	0.11	5988
75	4/24/2020	0.085	5141	328	1/2/2021	0.11	6273
76	4/25/2020	0.085	4406	329	1/3/2021	0.11	5988
77	4/26/2020	0.1	5616	330	1/4/2021	0.18	9798
78	4/27/2020	0.1	5616	331	1/5/2021	0.18	9798
79	4/28/2020	0.1	5184	332	1/6/2021	0.17	8813
80	4/29/2020	0.1	5616	333	1/7/2021	0.15	8165
81	4/30/2020	0.1	5616	334	1/8/2021	0.15	8165
82	5/1/2020	0.1	5184	335	1/9/2021	0.15	8554
83	5/2/2020	0.1	5184	336	1/10/2021	0.15	8165
84	5/3/2020	0.1	5616	337	1/11/2021	0.12	6221
85	5/4/2020	0.18	9798	338	1/12/2021	0.12	6532
86	5/5/2020	0.2	10886	339	1/13/2021	0.12	6532
87	5/6/2020	0.2	10886	340	1/14/2021	0.12	6221
88	5/7/2020	0.2	10886	341	1/15/2021	0.12	6532

89	5/8/2020	0.18	9798	342	1/16/2021	0.12	6221
90	5/9/2020	0.18	9331	343	1/17/2021	0.12	6532
91	5/10/2020	0.18	9798	344	1/18/2021	0.14	7620
92	5/11/2020	0.18	9798	345	1/19/2021	0.14	7620
93	5/12/2020	0.15	8165	346	1/20/2021	0.14	7983
94	5/13/2020	0.15	8554	347	1/21/2021	0.13	6739
95	5/14/2020	0.15	8165	348	1/22/2021	0.13	7076
96	5/15/2020	0.15	8165	349	1/23/2021	0.13	7076
97	5/16/2020	0.15	7776	350	1/24/2021	0.13	6739
98	5/17/2020	0.12	6532	351	1/25/2021	0.13	6739
99	5/18/2020	0.33	17107	352	1/26/2021	0.13	7076
100	5/19/2020	0.13	7076	353	1/27/2021	0.13	7413
101	5/20/2020	0.17	9089	354	1/28/2021	0.13	7076
102	5/21/2020	0.15	8165	355	1/29/2021	0.13	7413
103	5/22/2020	0.18	9580	356	1/30/2021	0.13	7076
104	5/23/2020	0.18	9580	357	1/31/2021	0.13	7413
105	5/24/2020	0.14	7737	358	2/1/2021	0.1	5443
106	5/25/2020	0.06	3546	359	2/2/2021	0.1	5443
107	5/26/2020	0.17	9048	360	2/3/2021	0.1	5702
108	5/27/2020	0.16	8528	361	2/4/2021	0.12	6221
109	5/28/2020	0.5	21384	362	2/5/2021	0.14	7620
110	5/29/2020	0.11	6121	363	2/6/2021	0.16	8294
111	5/30/2020	0.5	22118	364	2/7/2021	0.14	7620
112	5/31/2020	0.34	17449	365	2/8/2021	0.14	7620
113	6/1/2020	0.34	16921	366	2/9/2021	0.14	7258
114	6/2/2020	0.07	3931	367	2/10/2021	0.14	7620
115	6/3/2020	0.07	3931	368	2/11/2021	0.14	7620
116	6/4/2020	0.07	4234	369	2/12/2021	0.14	7620
117	6/5/2020	0.07	3931	370	2/13/2021	0.14	7258
118	6/6/2020	0.065	4212	371	2/14/2021	0.14	7258
119	6/7/2020	0.065	3931	372	2/15/2021	0.14	7620
120	6/8/2020	0.065	3931	373	2/16/2021	0.13	7076
121	6/9/2020	0.065	4212	374	2/17/2021	0.13	6739
122	6/10/2020	0.6	23328	375	2/18/2021	0.13	7076
123	6/11/2020	0.055	3564	376	2/19/2021	0.13	6739
124	6/12/2020	0.055	3326	377	2/20/2021	0.13	7076
125	6/13/2020	0.065	3931	378	2/21/2021	0.13	7076
126	6/14/2020	0.065	3931	379	2/22/2021	0.13	6739
127	6/15/2020	0.6	23328	380	2/23/2021	0.13	7076
128	6/16/2020	0.6	23328	381	2/24/2021	0.14	7620
129	6/17/2020	0.6	23328	382	2/25/2021	0.14	7258
130	6/18/2020	0.09	5054	383	2/26/2021	0.13	6739
131	6/19/2020	0.14	7862	384	2/27/2021	0.13	7076
132	6/20/2020	0.14	7862	385	2/28/2021	0.13	7076
133	6/21/2020	0.12	6221	386	3/1/2021	0.13	6739

134	6/22/2020	0.1	5616	387	3/2/2021	0.13	6739
135	6/23/2020	0.1	5616	388	3/3/2021	0.13	7076
136	6/24/2020	0.1	5184	389	3/4/2021	0.13	7076
137	6/25/2020	0.09	5054	390	3/5/2021	0.13	6739
138	6/26/2020	0.09	5443	391	3/6/2021	0.2	10886
139	6/27/2020	0.09	5054	392	3/7/2021	0.2	10886
140	6/28/2020	0.09	5054	393	3/8/2021	0.12	6532
141	6/29/2020	0.09	4666	394	3/9/2021	0.12	6532
142	6/30/2020	0.09	5054	395	3/10/2021	0.12	6221
143	7/1/2020	0.5	19440	396	3/11/2021	0.12	6532
144	7/2/2020	0.5	21600	397	3/12/2021	0.12	6221
145	7/3/2020	0.5	19440	398	3/13/2021	0.12	6221
146	7/4/2020	0.5	19440	399	3/14/2021	0.12	6532
147	7/5/2020	0.76	23409	400	3/15/2021	0.1	5443
148	7/6/2020	0.6	22810	401	3/16/2021	0.1	5702
149	7/7/2020	0.07	4058	402	3/17/2021	0.1	5443
150	7/8/2020	0.09	5097	403	3/18/2021	0.12	6221
151	7/9/2020	0.12	6480	404	3/19/2021	0.12	6532
152	7/10/2020	0.57	21669	405	3/20/2021	0.12	6532
153	7/11/2020	0.11	5994	406	3/21/2021	0.12	6221
154	7/12/2020	0.76	23639	407	3/22/2021	0.1	5443
155	7/13/2020	0.09	5054	408	3/23/2021	0.1	5702
156	7/14/2020	0.09	5443	409	3/24/2021	0.1	5443
157	7/15/2020	0.09	5054	410	3/25/2021	0.1	5702
158	7/16/2020	0.09	5054	411	3/26/2021	0.1	5443
159	7/17/2020	0.09	4666	412	3/27/2021	0.1	5702
160	7/18/2020	0.095	5335	413	3/28/2021	0.1	5443
161	7/19/2020	0.1	5616	414	3/29/2021	0.1	5702
162	7/20/2020	0.1	5616	415	3/30/2021	0.1	5443
163	7/21/2020	0.105	6350	416	3/31/2021	0.1	5443
164	7/22/2020	0.12	6221	417	4/1/2021	0.09	5132
165	7/23/2020	0.12	6739	418	4/2/2021	0.09	5132
166	7/24/2020	0.13	6739	419	4/3/2021	0.1	5702
167	7/25/2020	0.13	6739	420	4/4/2021	0.1	5443
168	7/26/2020	0.13	7301	421	4/5/2021	0.1	5530
169	7/27/2020	0.13	6739	422	4/6/2021	0.1	5357
170	7/28/2020	0.14	7258	423	4/7/2021	0.08	4424
171	7/29/2020	0.14	7258	424	4/8/2021	0.08	4562
172	7/30/2020	0.15	7776	425	4/9/2021	0.08	4562
173	7/31/2020	0.2	10368	426	4/10/2021	0.08	4424
174	8/1/2020	0.3	15552	427	4/11/2021	0.08	4424
175	8/2/2020	0.3	14256	428	4/12/2021	0.08	4562
176	8/3/2020	0.28	14515	429	4/13/2021	0.08	4424
177	8/4/2020	0.28	14515	430	4/14/2021	0.08	4424
178	8/5/2020	0.25	14040	431	4/15/2021	0.08	4562

179	8/6/2020	0.25	12960	432	4/16/2021	0.08	4424
180	8/7/2020	0.25	14040	433	4/17/2021	0.08	4562
181	8/8/2020	0.25	14040	434	4/18/2021	0.08	4424
182	8/9/2020	0.25	12960	435	4/19/2021	0.08	4562
183	8/10/2020	0.3	15552	436	4/20/2021	0.08	4424
184	8/11/2020	0.3	15552	437	4/21/2021	0.1	5530
185	8/12/2020	0.3	14256	438	4/22/2021	0.11	6083
186	8/13/2020	0.3	15552	439	4/23/2021	0.12	6636
187	8/14/2020	0.35	18144	440	4/24/2021	0.1	5357
188	8/15/2020	0.33	17107	441	4/25/2021	0.1	5530
189	8/16/2020	0.33	17107	442	4/26/2021	0.1	5357
190	8/17/2020	0.35	18144	443	4/27/2021	0.09	4977
191	8/18/2020	0.35	19656	444	4/28/2021	0.1	5357
192	8/19/2020	0.33	17107	445	4/29/2021	0.11	6083
193	8/20/2020	0.4	20736	446	4/30/2021	0.11	5892
194	8/21/2020	0.35	18144	447	5/1/2021	0.11	6083
195	8/22/2020	0.3	15552	448	5/2/2021	0.11	6083
196	8/23/2020	0.3	16848	449	5/3/2021	0.18	9798
197	8/24/2020	0.28	14515	450	5/4/2021	0.18	9331
198	8/25/2020	0.28	14515	451	5/5/2021	0.22	11975
199	8/26/2020	0.28	13306	452	5/6/2021	0.21	10886
200	8/27/2020	0.26	13478	453	5/7/2021	0.21	11431
201	8/28/2020	0.26	13478	454	5/8/2021	0.19	10342
202	8/29/2020	0.3	15552	455	5/9/2021	0.17	8813
203	8/30/2020	0.35	18144	456	5/10/2021	0.18	9798
204	8/31/2020	0.3	14256	457	5/11/2021	0.18	9798
205	9/1/2020	0.35	19656	458	5/12/2021	0.22	11975
206	9/2/2020	0.35	18144	459	5/13/2021	0.21	11431
207	9/3/2020	0.35	18144	460	5/14/2021	0.21	10886
208	9/4/2020	0.3	15552	461	5/15/2021	0.19	10835
209	9/5/2020	0.3	15552	462	5/16/2021	0.17	9253
210	9/6/2020	0.32	16589	463	5/17/2021	0.2	10368
211	9/7/2020	0.28	14515	464	5/18/2021	0.22	11405
212	9/8/2020	0.28	14515	465	5/19/2021	0.18	9331
213	9/9/2020	0.24	12442	466	5/20/2021	0.18	9331
214	9/10/2020	0.24	12442	467	5/21/2021	0.18	9331
215	9/11/2020	0.25	14040	468	5/22/2021	0.15	7776
216	9/12/2020	0.25	12960	469	5/23/2021	0.15	7776
217	9/13/2020	0.24	12442	470	5/24/2021	0.15	8424
218	9/14/2020	0.22	11405	471	5/25/2021	0.12	6221
219	9/15/2020	0.22	11405	472	5/26/2021	0.12	6739
220	9/16/2020	0.2	10368	473	5/27/2021	0.1	5616
221	9/17/2020	0.2	9504	474	5/28/2021	0.1	5184
222	9/18/2020	0.15	8424	475	5/29/2021	0.1	5616
223	9/19/2020	0.15	8424	476	5/30/2021	0.12	6221

224	9/20/2020	0.14	7862	477	5/31/2021	0.12	6739
225	9/21/2020	0.14	7258	478	6/1/2021	0.1	5616
226	9/22/2020	0.14	7862	479	6/2/2021	0.1	5184
227	9/23/2020	0.14	7258	480	6/3/2021	0.1	5616
228	9/24/2020	0.14	7862	481	6/4/2021	0.1	5616
229	9/25/2020	0.15	7776	482	6/5/2021	0.1	5184
230	9/26/2020	0.15	7776	483	6/6/2021	0.1	5616
231	9/27/2020	0.13	7301	484	6/7/2021	0.18	9798
232	9/28/2020	0.13	7301	485	6/8/2021	0.18	9331
233	9/29/2020	0.12	6221	486	6/9/2021	0.18	9798
234	9/30/2020	0.12	6739	487	6/10/2021	0.18	9798
235	10/1/2020	0.12	6739	488	6/11/2021	0.18	9331
236	10/2/2020	0.12	6221	489	6/12/2021	0.2	10886
237	10/3/2020	0.11	6178	490	6/13/2021	0.2	10886
238	10/4/2020	0.12	6739	491	6/14/2021	0.09	5054
239	10/5/2020	0.12	6221	492	6/15/2021	0.11	6178
240	10/6/2020	0.12	6221	493	6/16/2021	0.14	7258
241	10/7/2020	0.12	6221	494	6/17/2021	0.09	5054
242	10/8/2020	0.11	6178	495	6/18/2021	0.09	5054
243	10/9/2020	0.11	6178	496	6/19/2021	0.14	7258
244	10/10/2020	0.11	6653	497	6/20/2021	0.14	7862
245	10/11/2020	0.11	6178	498	6/21/2021	0.12	6221
246	10/12/2020	0.11	5702	499	6/22/2021	0.1	5184
247	10/13/2020	0.1	5184	500	6/23/2021	0.1	5616
248	10/14/2020	0.1	5616	501	6/24/2021	0.1	5184
249	10/15/2020	0.09	5054	502	6/25/2021	0.09	5054
250	10/16/2020	0.12	6221	503	6/26/2021	0.09	5054
251	10/17/2020	0.12	6739	504	6/27/2021	0.09	4666
252	10/18/2020	0.11	6178	505	6/28/2021	0.09	5054
253	10/19/2020	0.1	5616	506	6/29/2021	0.09	4666
				507	6/30/2021	0.09	5054

Sindhiyagad micro watershed

Sr No	Date	Depth (m)	Discharge (cum/day)	Sr No	Date	Depth (m)	Discharge (cum/day)
1	2/5/2020	0.11	6843	311	12/11/2020	0.06	2074
2	2/6/2020	0.1	4994	312	12/12/2020	0.06	2053
3	2/7/2020	0.1	5141	313	12/13/2020	0.07	2540
4	2/8/2020	0.09	4619	314	12/14/2020	0.07	2480

5	2/9/2020	0.08	3048	315	12/15/2020	0.05	1555
6	2/10/2020	0.09	4409	316	12/16/2020	0.07	2528
7	2/11/2020	0.1	4994	317	12/17/2020	0.07	2540
8	2/12/2020	0.09	4306	318	12/18/2020	0.06	2053
9	2/13/2020	0.07	2506	319	12/19/2020	0.06	2022
10	2/14/2020	0.08	2986	320	12/20/2020	0.05	1469
11	2/15/2020	0.1	5122	321	12/21/2020	0.07	2528
12	2/16/2020	0.1	5165	322	12/22/2020	0.07	2540
13	2/17/2020	0.09	4546	323	12/23/2020	0.07	2540
14	2/18/2020	0.1	4901	324	12/24/2020	0.05	1521
15	2/19/2020	0.08	3055	325	12/25/2020	0.07	2540
16	2/20/2020	0.09	4572	326	12/26/2020	0.09	4510
17	2/21/2020	0.09	4444	327	12/27/2020	0.07	2528
18	2/22/2020	0.09	4554	328	12/28/2020	0.09	4572
19	2/23/2020	0.12	7407	329	12/29/2020	0.09	4479
20	2/24/2020	0.07	2616	330	12/30/2020	0.08	2765
21	2/25/2020	0.07	2490	331	12/31/2020	0.08	3110
22	2/26/2020	0.06	1894	332	1/1/2021	0.09	4510
23	2/27/2020	0.07	2368	333	1/2/2021	0.09	4533
24	2/28/2020	0.07	2563	334	1/3/2021	0.09	4572
25	2/29/2020	0.08	3086	335	1/4/2021	0.08	3069
26	3/1/2020	0.15	10109	336	1/5/2021	0.08	2903
27	3/2/2020	0.06	1655	337	1/6/2021	0.09	4572
28	3/3/2020	0.06	1763	338	1/7/2021	0.07	2528
29	3/4/2020	0.07	2359	339	1/8/2021	0.08	2903
30	3/5/2020	0.07	3726	340	1/9/2021	0.07	2528
31	3/6/2020	0.1	5115	341	1/10/2021	0.07	2480
32	3/7/2020	0.09	4432	342	1/11/2021	0.08	3180
33	3/8/2020	0.1	5141	343	1/12/2021	0.08	2903
34	3/9/2020	0.08	3000	344	1/13/2021	0.08	2972
35	3/10/2020	0.1	5011	345	1/14/2021	0.07	2540
36	3/11/2020	0.09	4510	346	1/15/2021	0.07	2528
37	3/12/2020	0.08	3124	347	1/16/2021	0.06	2074
38	3/13/2020	0.15	10368	348	1/17/2021	0.08	2972
39	3/14/2020	0.15	10109	349	1/18/2021	0.07	2540
40	3/15/2020	0.15	10368	350	1/19/2021	0.08	2903
41	3/16/2020	0.13	8649	351	1/20/2021	0.08	3041
42	3/17/2020	0.08	3110	352	1/21/2021	0.07	2528
43	3/18/2020	0.11	7366	353	1/22/2021	0.07	2540
44	3/19/2020	0.13	8491	354	1/23/2021	0.09	4510
45	3/20/2020	0.09	4763	355	1/24/2021	0.07	2540
46	3/21/2020	0.11	7185	356	1/25/2021	0.07	2540
47	3/22/2020	0.1	5167	357	1/26/2021	0.08	3041
48	3/23/2020	0.09	4339	358	1/27/2021	0.08	3193

49	3/24/2020	0.1	5141	359	1/28/2021	0.09	4510
50	3/25/2020	0.08	2986	360	1/29/2021	0.07	2540
51	3/26/2020	0.11	6890	361	1/30/2021	0.08	3110
52	3/27/2020	0.1	5132	362	1/31/2021	0.08	2986
53	3/28/2020	0.1	4942	363	2/1/2021	0.08	3007
54	3/29/2020	0.11	7269	364	2/2/2021	0.08	3021
55	3/30/2020	0.09	4666	365	2/3/2021	0.08	3117
56	3/31/2020	0.08	3007	366	2/4/2021	0.08	2903
57	4/1/2020	0.07	2540	367	2/5/2021	0.08	3117
58	4/2/2020	0.06	2027	368	2/6/2021	0.08	2903
59	4/3/2020	0.07	2540	369	2/7/2021	0.07	2540
60	4/4/2020	0.06	2022	370	2/8/2021	0.08	3097
61	4/5/2020	0.05	1490	371	2/9/2021	0.08	3152
62	4/6/2020	0.05	1469	372	2/10/2021	0.08	3117
63	4/7/2020	0.07	2555	373	2/11/2021	0.08	3193
64	4/8/2020	0.05	1469	374	2/12/2021	0.08	3041
65	4/9/2020	0.06	2053	375	2/13/2021	0.09	4572
66	4/10/2020	0.06	2073	376	2/14/2021	0.08	3048
67	4/11/2020	0.05	1469	377	2/15/2021	0.08	3000
68	4/12/2020	0.05	1555	378	2/16/2021	0.08	3048
69	4/13/2020	0.06	2074	379	2/17/2021	0.07	2462
70	4/14/2020	0.06	1999	380	2/18/2021	0.09	4572
71	4/15/2020	0.06	2074	381	2/19/2021	0.09	4580
72	4/16/2020	0.06	1945	382	2/20/2021	0.07	2540
73	4/17/2020	0.07	2515	383	2/21/2021	0.11	5930
74	4/18/2020	0.05	1555	384	2/22/2021	0.11	6083
75	4/19/2020	0.07	2468	385	2/23/2021	0.09	4572
76	4/20/2020	0.06	2074	386	2/24/2021	0.08	3290
77	4/21/2020	0.04	1060	387	2/25/2021	0.08	3121
78	4/22/2020	0.06	1992	388	2/26/2021	0.08	3117
79	4/23/2020	0.06	2074	389	2/27/2021	0.09	4572
80	4/24/2020	0.05	1555	390	2/28/2021	0.09	4549
81	4/25/2020	0.07	2480	391	3/1/2021	0.13	8452
82	4/26/2020	0.06	1974	392	3/2/2021	0.13	8694
83	4/27/2020	0.06	1970	393	3/3/2021	0.13	8452
84	4/28/2020	0.06	2022	394	3/4/2021	0.13	8694
85	4/29/2020	0.07	2480	395	3/5/2021	0.13	8452
86	4/30/2020	0.08	3021	396	3/6/2021	0.13	8694
87	5/1/2020	0.06	1908	397	3/7/2021	0.13	8452
88	5/2/2020	0.06	2022	398	3/8/2021	0.13	8694
89	5/3/2020	0.08	3041	399	3/9/2021	0.13	8452
90	5/4/2020	0.09	4479	400	3/10/2021	0.13	8694
91	5/5/2020	0.12	7465	401	3/11/2021	0.13	8694
92	5/6/2020	0.12	7527	402	3/12/2021	0.13	8452

93	5/7/2020	0.1	5037	403	3/13/2021	0.13	8452
94	5/8/2020	0.1	4977	404	3/14/2021	0.13	8694
95	5/9/2020	0.08	3048	405	3/15/2021	0.13	8452
96	5/10/2020	0.07	2595	406	3/16/2021	0.13	8452
97	5/11/2020	0.07	2462	407	3/17/2021	0.13	8694
98	5/12/2020	0.06	1944	408	3/18/2021	0.13	8452
99	5/13/2020	0.09	4448	409	3/19/2021	0.13	8452
100	5/14/2020	0.13	8649	410	3/20/2021	0.13	8694
101	5/15/2020	0.12	7465	411	3/21/2021	0.13	8452
102	5/16/2020	0.07	2528	412	3/22/2021	0.13	8694
103	5/17/2020	0.09	4572	413	3/23/2021	0.13	8452
104	5/18/2020	0.07	2528	414	3/24/2021	0.13	8452
105	5/19/2020	0.08	3069	415	3/25/2021	0.13	8694
106	5/20/2020	0.12	7465	416	3/26/2021	0.13	8694
107	5/21/2020	0.16	10949	417	3/27/2021	0.13	8452
108	5/22/2020	0.09	4495	418	3/28/2021	0.13	8452
109	5/23/2020	0.16	11032	419	3/29/2021	0.13	8694
110	5/24/2020	0.15	10161	420	3/30/2021	0.13	8452
111	5/25/2020	0.15	10109	421	3/31/2021	0.08	3193
112	5/26/2020	0.09	4495	422	4/1/2021	0.08	3069
113	5/27/2020	0.13	8626	423	4/2/2021	0.08	3152
114	5/28/2020	0.12	7465	424	4/3/2021	0.06	2053
115	5/29/2020	0.18	13344	425	4/4/2021	0.08	3021
116	5/30/2020	0.11	7537	426	4/5/2021	0.05	1521
117	5/31/2020	0.08	3193	427	4/6/2021	0.08	2986
118	6/1/2020	0.12	8211	428	4/7/2021	0.06	2053
119	6/2/2020	0.09	4448	429	4/8/2021	0.08	3097
120	6/3/2020	0.12	7392	430	4/9/2021	0.06	2053
121	6/4/2020	0.2	15241	431	4/10/2021	0.06	2022
122	6/5/2020	0.13	8402	432	4/11/2021	0.06	2022
123	6/6/2020	0.11	7318	433	4/12/2021	0.08	2986
124	6/7/2020	0.14	9798	434	4/13/2021	0.07	2528
125	6/8/2020	0.13	8649	435	4/14/2021	0.06	2022
126	6/9/2020	0.13	8491	436	4/15/2021	0.08	3055
127	6/10/2020	0.15	10264	437	4/16/2021	0.07	2129
128	6/11/2020	0.14	9580	438	4/17/2021	0.08	3048
129	6/12/2020	0.13	8402	439	4/18/2021	0.08	2972
130	6/13/2020	0.14	9677	440	4/19/2021	0.08	2941
131	6/14/2020	0.12	7403	441	4/20/2021	0.08	3121
132	6/15/2020	0.08	3069	442	4/21/2021	0.07	2062
133	6/16/2020	0.12	7403	443	4/22/2021	0.07	2262
134	6/17/2020	0.1	5132	444	4/23/2021	0.06	2203
135	6/18/2020	0.18	13001	445	4/24/2021	0.06	2017
136	6/19/2020	0.1	5288	446	4/25/2021	0.07	2413

137	6/20/2020	0.16	11032	447	4/26/2021	0.07	2322
138	6/21/2020	0.13	8402	448	4/27/2021	0.07	2044
139	6/22/2020	0.12	7620	449	4/28/2021	0.06	2504
140	6/23/2020	0.11	7660	450	4/29/2021	0.07	2322
141	6/24/2020	0.08	3000	451	4/30/2021	0.07	2226
142	6/25/2020	0.14	9399	452	5/1/2021	0.06	2053
143	6/26/2020	0.21	16112	453	5/2/2021	0.03	513
144	6/27/2020	0.14	9459	454	5/3/2021	0.03	477
145	6/28/2020	0.1	4847	455	5/4/2021	0.12	7646
146	6/29/2020	0.09	4463	456	5/5/2021	0.07	2661
147	6/30/2020	0.18	13173	457	5/6/2021	0.11	5988
148	7/1/2020	0.11	7223	458	5/7/2021	0.07	2044
149	7/2/2020	0.11	7356	459	5/8/2021	0.06	2028
150	7/3/2020	0.09	4743	460	5/9/2021	0.07	2206
151	7/4/2020	0.1	5184	461	5/10/2021	0.07	2498
152	7/5/2020	0.1	5184	462	5/11/2021	0.08	3021
153	7/6/2020	0.08	3117	463	5/12/2021	0.07	2413
154	7/7/2020	0.11	7128	464	5/13/2021	0.06	2074
155	7/8/2020	0.12	7672	465	5/14/2021	0.06	2014
156	7/9/2020	0.11	7185	466	5/15/2021	0.05	1555
157	7/10/2020	0.09	4510	467	5/16/2021	0.07	2413
158	7/11/2020	0.07	2419	468	5/17/2021	0.12	7154
159	7/12/2020	0.08	3000	469	5/18/2021	0.06	2053
160	7/13/2020	0.09	4603	470	5/19/2021	0.07	2117
161	7/14/2020	0.09	4409	471	5/20/2021	0.07	2540
162	7/15/2020	0.09	4666	472	5/21/2021	0.15	10070
163	7/16/2020	0.09	4409	473	5/22/2021	0.15	10161
164	7/17/2020	0.12	7465	474	5/23/2021	0.18	13001
165	7/18/2020	0.11	7128	475	5/24/2021	0.14	9435
166	7/19/2020	0.08	3193	476	5/25/2021	0.15	10096
167	7/20/2020	0.1	5089	477	5/26/2021	0.17	12602
168	7/21/2020	0.14	9749	478	5/27/2021	0.16	11279
169	7/22/2020	0.08	3041	479	5/28/2021	0.05	1555
170	7/23/2020	0.12	7548	480	5/29/2021	0.08	3100
171	7/24/2020	0.13	8649	481	5/30/2021	0.05	1521
172	7/25/2020	0.14	9253	482	5/31/2021	0.06	2053
173	7/26/2020	0.11	7109	483	6/1/2021	0.03	446
174	7/27/2020	0.1	5184	484	6/2/2021	0.12	7465
175	7/28/2020	0.14	9290	485	6/3/2021	0.17	12558
176	7/29/2020	0.12	7652	486	6/4/2021	0.18	12877
177	7/30/2020	0.11	7527	487	6/5/2021	0.17	12499
178	7/31/2020	0.14	9374	488	6/6/2021	0.17	12660
179	8/1/2020	0.11	7223	489	6/7/2021	0.15	10070
180	8/2/2020	0.11	6947	490	6/8/2021	0.16	11999

181	8/3/2020	0.1	5270	491	6/9/2021	0.18	13001
182	8/4/2020	0.1	4925	492	6/10/2021	0.04	1037
183	8/5/2020	0.1	5184	493	6/11/2021	0.08	3180
184	8/6/2020	0.08	3117	494	6/12/2021	0.18	13219
185	8/7/2020	0.11	7128	495	6/13/2021	0.2	15500
186	8/8/2020	0.12	7672	496	6/14/2021	0.18	13064
187	8/9/2020	0.11	7185	497	6/15/2021	0.17	12485
188	8/10/2020	0.16	12165	498	6/16/2021	0.13	8592
189	8/11/2020	0.09	2994	499	6/17/2021	0.19	14758
190	8/12/2020	0.18	12333	500	6/18/2021	0.26	21206
191	8/13/2020	0.11	6928	501	6/19/2021	0.35	27936
192	8/14/2020	0.14	9870	502	6/20/2021	0.38	31059
193	8/15/2020	0.09	4417	503	6/21/2021	0.41	32849
194	8/16/2020	0.1	5089	504	6/22/2021	0.49	40685
195	8/17/2020	0.09	4666	505	6/23/2021	0.52	42142
196	8/18/2020	0.13	8222	506	6/24/2021	0.12	7465
197	8/19/2020	0.11	7318	507	6/25/2021	0.17	12558
198	8/20/2020	0.11	6928	508	6/26/2021	0.18	13157
199	8/21/2020	0.16	11750	509	6/27/2021	0.18	13064
200	8/22/2020	0.12	7714	510	6/28/2021	0.33	25661
201	8/23/2020	0.11	7404	511	6/29/2021	0.17	12660
202	8/24/2020	0.13	8402	512	6/30/2021	0.08	3021
203	8/25/2020	0.1	5227	513	7/1/2021	0.37	30881
204	8/26/2020	0.14	9447	514	7/2/2021	0.37	30162
205	8/27/2020	0.08	2965	515	7/3/2021	0.13	8649
206	8/28/2020	0.09	4666	516	7/4/2021	0.15	10342
207	8/29/2020	0.11	7318	517	7/5/2021	0.76	61166
208	8/30/2020	0.09	4666	518	7/6/2021	0.6	53603
209	8/31/2020	0.08	3110	519	7/7/2021	0.43	33511
210	9/1/2020	0.07	2661	520	7/8/2021	0.33	25247
211	9/2/2020	0.07	2419	521	7/9/2021	0.12	7646
212	9/3/2020	0.16	11032	522	7/10/2021	0.06	2053
213	9/4/2020	0.13	8402	523	7/11/2021	0.11	5994
214	9/5/2020	0.08	2951	524	7/12/2021	0.08	3180
215	9/6/2020	0.11	7318	525	7/13/2021	0.12	7216
216	9/7/2020	0.11	7004	526	7/14/2021	0.17	12668
217	9/8/2020	0.08	3110	527	7/15/2021	0.17	12652
218	9/9/2020	0.1	4908	528	7/16/2021	0.08	3100
219	9/10/2020	0.07	2431	529	7/17/2021	0.04	1161
220	9/11/2020	0.11	7128	530	7/18/2021	0.05	1521
221	9/12/2020	0.09	4463	531	7/19/2021	0.13	8452
222	9/13/2020	0.11	6900	532	7/20/2021	0.17	12660
223	9/14/2020	0.13	8424	533	7/21/2021	0.28	23031
224	9/15/2020	0.1	4959	534	7/22/2021	0.34	26864

225	9/16/2020	0.13	8357	535	7/23/2021	0.45	36158
226	9/17/2020	0.13	8424	536	7/24/2021	0.46	36882
227	9/18/2020	0.09	4782	537	7/25/2021	0.46	38194
228	9/19/2020	0.08	3110	538	7/26/2021	0.44	35013
229	9/20/2020	0.11	6178	539	7/27/2021	0.49	40516
230	9/21/2020	0.09	4510	540	7/28/2021	0.52	42457
231	9/22/2020	0.08	3041	541	7/29/2021	0.36	28865
232	9/23/2020	0.08	3110	542	7/30/2021	0.23	18382
233	9/24/2020	0.11	6273	543	7/31/2021	0.17	12602
234	9/25/2020	0.09	4432	544	8/1/2021	0.37	30497
235	9/26/2020	0.08	2903	545	8/2/2021	0.08	3181
236	9/27/2020	0.07	2540	546	8/3/2021	0.08	3021
237	9/28/2020	0.09	4899	547	8/4/2021	0.05	1521
238	9/29/2020	0.1	4838	548	8/5/2021	0.13	8649
239	9/30/2020	0.09	4666	549	8/6/2021	0.15	10025
240	10/1/2020	0.08	2903	550	8/7/2021	0.12	7216
241	10/2/2020	0.09	4666	551	8/8/2021	0.17	12558
242	10/3/2020	0.13	8424	552	8/9/2021	0.12	7216
243	10/4/2020	0.08	2903	553	8/10/2021	0.17	12558
244	10/5/2020	0.1	4908	554	8/11/2021	0.18	13157
245	10/6/2020	0.11	6049	555	8/12/2021	0.17	12499
246	10/7/2020	0.08	3041	556	8/13/2021	0.17	12984
247	10/8/2020	0.08	3041	557	8/14/2021	0.16	11032
248	10/9/2020	0.07	2976	558	8/15/2021	0.16	11225
249	10/10/2020	0.07	2528	559	8/16/2021	0.38	31059
250	10/11/2020	0.07	2595	560	8/17/2021	0.38	31781
251	10/12/2020	0.07	2528	561	8/18/2021	0.12	7216
252	10/13/2020	0.08	2965	562	8/19/2021	0.17	12558
253	10/14/2020	0.07	2582	563	8/20/2021	0.18	13157
254	10/15/2020	0.06	2177	564	8/21/2021	0.17	12771
255	10/16/2020	0.08	2965	565	8/22/2021	0.17	12660
256	10/17/2020	0.07	2468	566	8/23/2021	0.16	11032
257	10/18/2020	0.08	2834	567	8/24/2021	0.16	11225
258	10/19/2020	0.08	3055	568	8/25/2021	0.38	32504
259	10/20/2020	0.07	2528	569	8/26/2021	0.38	31059
260	10/21/2020	0.07	2528	570	8/27/2021	0.12	7216
261	10/22/2020	0.08	3041	571	8/28/2021	0.17	12558
262	10/23/2020	0.07	2516	572	8/29/2021	0.08	2941
263	10/24/2020	0.07	2528	573	8/30/2021	0.37	30881
264	10/25/2020	0.08	2972	574	8/31/2021	0.53	43228
265	10/26/2020	0.07	2516	575	9/1/2021	0.13	8452
266	10/27/2020	0.07	2528	576	9/2/2021	0.17	12558
267	10/28/2020	0.07	2516	577	9/3/2021	0.28	22353
268	10/29/2020	0.07	2540	578	9/4/2021	0.34	25131

269	10/30/2020	0.08	3055	579	9/5/2021	0.45	37325
270	10/31/2020	0.08	2986	580	9/6/2021	0.46	38154
271	11/1/2020	0.07	2528	581	9/7/2021	0.46	36962
272	11/2/2020	0.07	2437	582	9/8/2021	0.44	34100
273	11/3/2020	0.07	2528	583	9/9/2021	0.08	3007
274	11/4/2020	0.07	2437	584	9/10/2021	0.08	3193
275	11/5/2020	0.07	2540	585	9/11/2021	0.06	2074
276	11/6/2020	0.06	2053	586	9/12/2021	0.08	3193
277	11/7/2020	0.06	2053	587	9/13/2021	0.37	30306
278	11/8/2020	0.05	1542	588	9/14/2021	0.06	2115
279	11/9/2020	0.07	2528	589	9/15/2021	0.27	21042
280	11/10/2020	0.05	1512	590	9/16/2021	0.08	3021
281	11/11/2020	0.07	2480	591	9/17/2021	0.37	30945
282	11/12/2020	0.07	2528	592	9/18/2021	0.12	7216
283	11/13/2020	0.07	2540	593	9/19/2021	0.17	12558
284	11/14/2020	0.07	2540	594	9/20/2021	0.18	13157
285	11/15/2020	0.06	2053	595	9/21/2021	0.37	30162
286	11/16/2020	0.06	2074	596	9/22/2021	0.17	12335
287	11/17/2020	0.07	2540	597	9/23/2021	0.2	15500
288	11/18/2020	0.07	2462	598	9/24/2021	0.17	12338
289	11/19/2020	0.07	2528	599	9/25/2021	0.15	10044
290	11/20/2020	0.06	2053	600	9/26/2021	0.17	12558
291	11/21/2020	0.07	2528	601	9/27/2021	0.22	17088
292	11/22/2020	0.07	2528	602	9/28/2021	0.33	26074
293	11/23/2020	0.05	1555	603	9/29/2021	0.36	27807
294	11/24/2020	0.05	1555	604	9/30/2021	0.04	1140
295	11/25/2020	0.07	2540	605	10/1/2021	0.12	7216
296	11/26/2020	0.07	2528	606	10/2/2021	0.17	12558
297	11/27/2020	0.07	2540	607	10/3/2021	0.12	7646
298	11/28/2020	0.07	2540	608	10/4/2021	0.18	13157
299	11/29/2020	0.05	1555	609	10/5/2021	0.37	30753
300	11/30/2020	0.06	2053	610	10/6/2021	0.17	12660
301	12/1/2020	0.06	2074	611	10/7/2021	0.16	11032
302	12/2/2020	0.07	2540	612	10/8/2021	0.16	11999
303	12/3/2020	0.05	1555	613	10/9/2021	0.16	11612
304	12/4/2020	0.06	2074	614	10/10/2021	0.13	8491
305	12/5/2020	0.07	2528	615	10/11/2021	0.19	15267
306	12/6/2020	0.07	2540	616	10/12/2021	0.08	2941
307	12/7/2020	0.07	2540	617	10/13/2021	0.37	30929
308	12/8/2020	0.06	2074	618	10/14/2021	0.54	46283
309	12/9/2020	0.07	2528	619	10/15/2021	0.14	9526
310	12/10/2020	0.05	1555	620	10/16/2021	0.19	14774

Annexure: 3.3.1 Validation of modeled yield of the micro watersheds against the discharges measured in micro watersheds

Dewangad micro watershed

Month	Discharge in (mm)				% Of Rainfall	
	Rainfall (mm)	Measured	Modelled	Difference	Measured	Modelled
January-21	0	25.03	22.87	2.16		

February-21	28.21	16.51	17.18	-0.67	58.5	60.9
March-21	13.5	8.53	9.16	-0.62	63.2	67.8
April-21	76.11	41.04	42.26	-1.22	53.9	55.5
May-21	169.7	94.77	97.36	-2.59	55.8	57.4
June-21	181.28	110.57	106.53	4.04	61.0	58.8
July-21	534.04	292.00	295.62	-3.63	54.7	55.4
August-21	309.19	189.47	175.00	14.47	61.3	56.6
September-21	238.81	126.28	124.74	1.54	52.9	52.2

Lathiyagad micro watershed

Month	Discharge in (mm)				% Of Rainfall	
	Rainfall (mm)	Measured	Modelled	Difference	Measured	Modelled
February-21	0.71	3.31	4.41	-1.10	466.2	621.3
March-21	13.26	5.24	6.01	-0.77	39.5	45.3
April-21	72.35	30.25	29.08	1.17	41.8	40.2
May-21	221.27	91.37	100.08	-8.71	41.3	45.2
June-21	437.28	181.35	200.14	-18.79	41.5	45.8
July-21	504.01	208.89	220.90	-12.01	41.4	43.8
August-21	695.81	301.28	310.34	-9.05	43.3	44.6
September-21	309.94	131.37	123.33	8.03	42.4	39.8

Loharkhet micro watershed

Month	Discharge in (mm)				% Of Rainfall	
	Rainfall (mm)	Measured	Modelled	Difference	Measured	Modelled
February-21	0.63	0.33	0.6	-0.30	52.0	100.0
March-21	10.53	6.99	7.5	-0.54	66.4	71.5
April-21	74.25	45.59	44.3	1.34	61.4	59.6
May-21	207.02	131.55	135.0	-3.47	63.5	65.2
June-21	353.08	221.10	233.1	-	62.6	66.0
July-21	471.65	280.32	271.7	8.67	59.4	57.6
August-21	547.14	337.81	347.1	-9.33	61.7	63.4
September-21	225.54	139.67	125.5	14.13	61.9	55.7

Paligad micro watershed

Month	Discharge in (mm)				% Of Rainfall	
	Rainfall (mm)	Measured	Modelled	Difference	Measured	Modelled
February-20	54.9	27.35	31.31	-3.96	49.8	57.0
March-20	277.05	135.30	137.07	-1.77	48.8	49.5

April-20	46.7	24.79	23.06	1.74	53.1	49.4
May-20	60.57	32.95	38.02	-5.07	54.4	62.8
June-20	120.75	56.14	62.96	-6.83	46.5	52.1
July-20	423.38	280.16	290.39	-10.23	66.2	68.6
August-20	297.02	146.93	132.46	14.47	49.5	44.6
September-20	35.21	19.45	23.07	-3.62	55.2	65.5
October-20	0	16.72	18.65	-1.92		
November-20	13.7	6.40	5.55	0.85	46.7	40.5
December-20	7.37	3.54	3.02	0.53	48.1	40.9
January-21	25.23	11.93	13.56	-1.63	47.3	53.7
February-21	19.48	9.69	10.37	-0.67	49.8	53.2
March-21	14.17	7.05	8.32	-1.27	49.8	58.7
April-21	80.72	42.08	45.55	-3.46	52.1	56.4
May-21	190.93	93.59	98.46	-4.87	49.0	51.6
June-21	236.7	113.68	112.22	1.47	48.0	47.4

Sindhiyagad micro watershed

Month	Discharge in (mm)				% Of Rainfall	
	Rainfall (mm)	Measured	Modelled	Difference	Measured	Modelled
February-20	66	22.12	25.79	-3.67	33.5	39.1
March-20	219.1	72.16	89.02	-16.86	32.9	40.6
April-20	34.2	15.43	16.26	-0.83	45.1	47.5
May-20	89.14	35.17	42.57	-7.40	39.5	47.8
June-20	136.1	70.13	74.21	-4.08	51.5	54.5
July-20	544.7	327.63	322.0	5.55	60.1	59.1
August-20	273.1	138.36	148.6	-	50.7	54.4
September-20	28.5	16.27	15.99	0.28	57.1	56.1
October-20	0	3.93	4.41	-0.48		
November-20	0	2.72	1.7	1.02		
December-20	3.9	1.09	2.02	-0.93	27.9	51.8
January-21	29.8	13.86	15.88	-2.02	46.5	53.3
February-21	8.99	3.98	4.73	-0.75	44.3	52.6
March-21	5.03	2.43	2.31	0.12	48.3	45.9
April-21	51.5	23.11	22.92	0.19	44.9	44.5
May-21	189.8	75.63	86.81	-	39.8	45.7
June-21	358.6	198.41	200.2	-1.86	55.3	55.8

July-21	280.0	156.92	171.8	-	56.0	61.4
August-21	168.8	91.51	93.17	-1.66	54.2	55.2
September-21	131.1	70.54	74.73	-4.19	53.8	57.0

Annexure:3.5.1 Crop coefficient

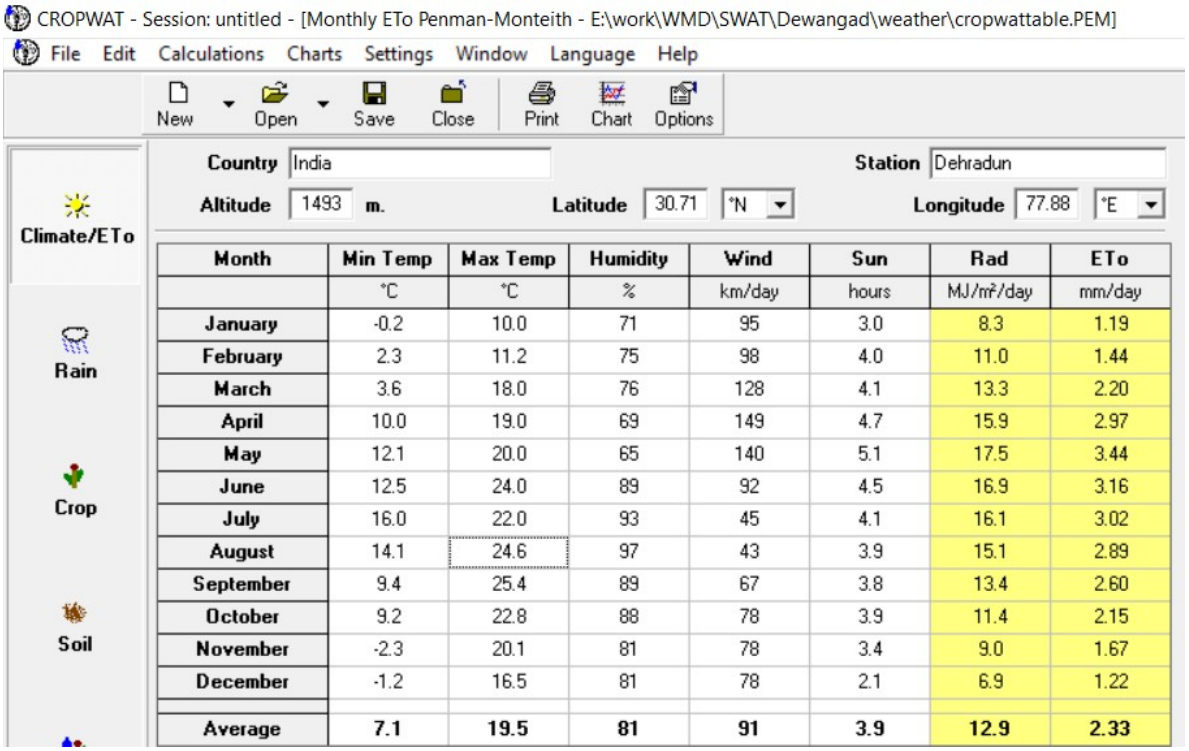
Sl.No.	Crop name	Kc Value	Source
1	Amaranths	0.6	
2	Barnyard millet	**0.65**	
3	Barseem	0.65	
4	Bitter gourd	0.8	
5	Blackgram	0.75	

6	Bottelgourd	0.8	FAO, Chapter 6, Single crop Coefficient, Table 12 (average values of different growth stages were considered, certain amount of generalisation done for same category of crops for example different kinds of millet same Kc value considered)
7	Brinjal	0.97	
8	Cabbage	1	
9	Capsicum	0.9	
10	Cauliflower	1	
11	Chari (sorghum)	0.8	
12	ChIlli	0.7	
13	Coriander	0.97	
14	Cucumber	0.71	
15	fenugreek	0.9	
16	Fingermillet	0.65	
17	Frenchbean	0.88	
18	Garlic	0.81	
19	Ginger	0.8	
20	Gram	0.633	
21	Lady's Finger	0.71	
22	Lentil	0.97	
23	Maize	1.1	
24	Mustard	0.7	
25	Oat	0.7	
26	Onion	0.8	
27	spinach	0.97	
28	Pea	0.67	
29	Pumpkin	0.9	
30	Radish	0.87	
31	Rice	1	
32	Ridge Gourd	0.8	
33	soybean	0.82	
34	Tomato	0.9	
35	Turmeric	0.8	
36	Wheat	0.73	
37	Rajma	0.633	
38	Horsegram	0.633	
39	Potato	0.91	
40	Rayans	0.67	
41	Arhar	0.633	

42	Brokali	1	
43	Urad	0.633	
44	Barley	0.633	

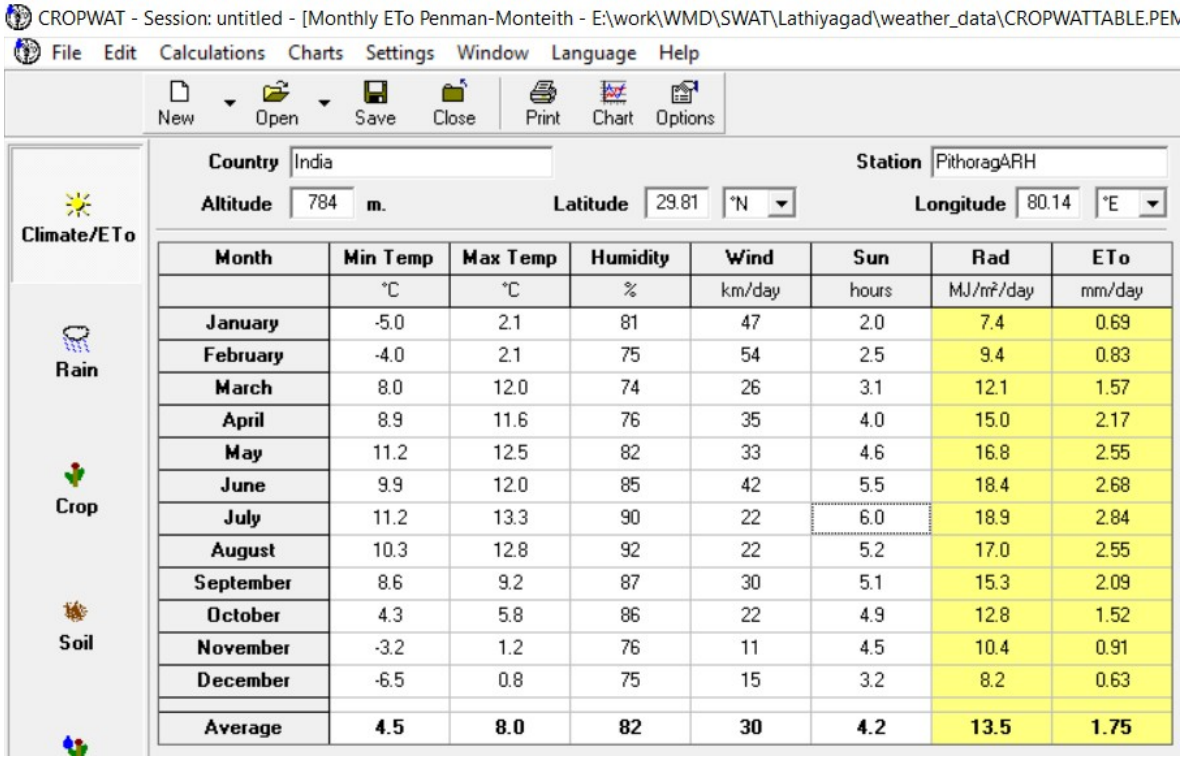
Annexure: 3.5.2 ET_0 values for eight representative micro watersheds

Dewangad



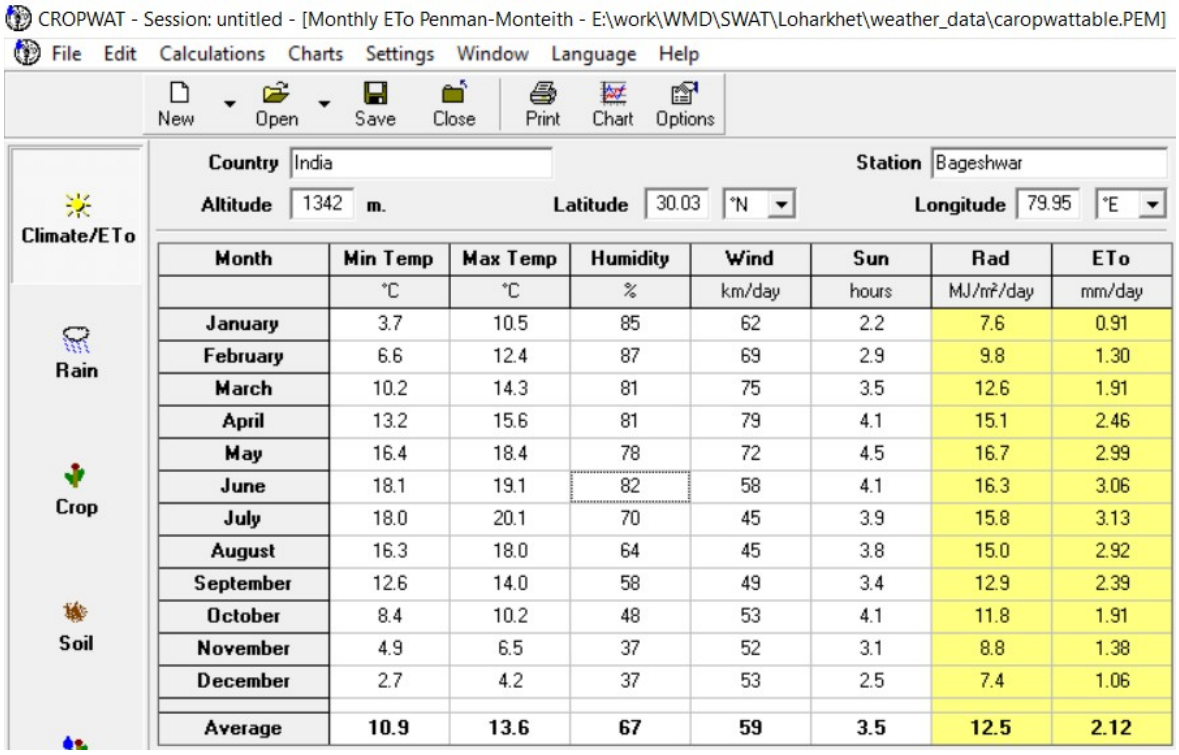
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	-0.2	10.0	71	95	3.0	8.3	1.19
February	2.3	11.2	75	98	4.0	11.0	1.44
March	3.6	18.0	76	128	4.1	13.3	2.20
April	10.0	19.0	69	149	4.7	15.9	2.97
May	12.1	20.0	65	140	5.1	17.5	3.44
June	12.5	24.0	89	92	4.5	16.9	3.16
July	16.0	22.0	93	45	4.1	16.1	3.02
August	14.1	24.6	97	43	3.9	15.1	2.89
September	9.4	25.4	89	67	3.8	13.4	2.60
October	9.2	22.8	88	78	3.9	11.4	2.15
November	-2.3	20.1	81	78	3.4	9.0	1.67
December	-1.2	16.5	81	78	2.1	6.9	1.22
Average	7.1	19.5	81	91	3.9	12.9	2.33

Lathiyagad



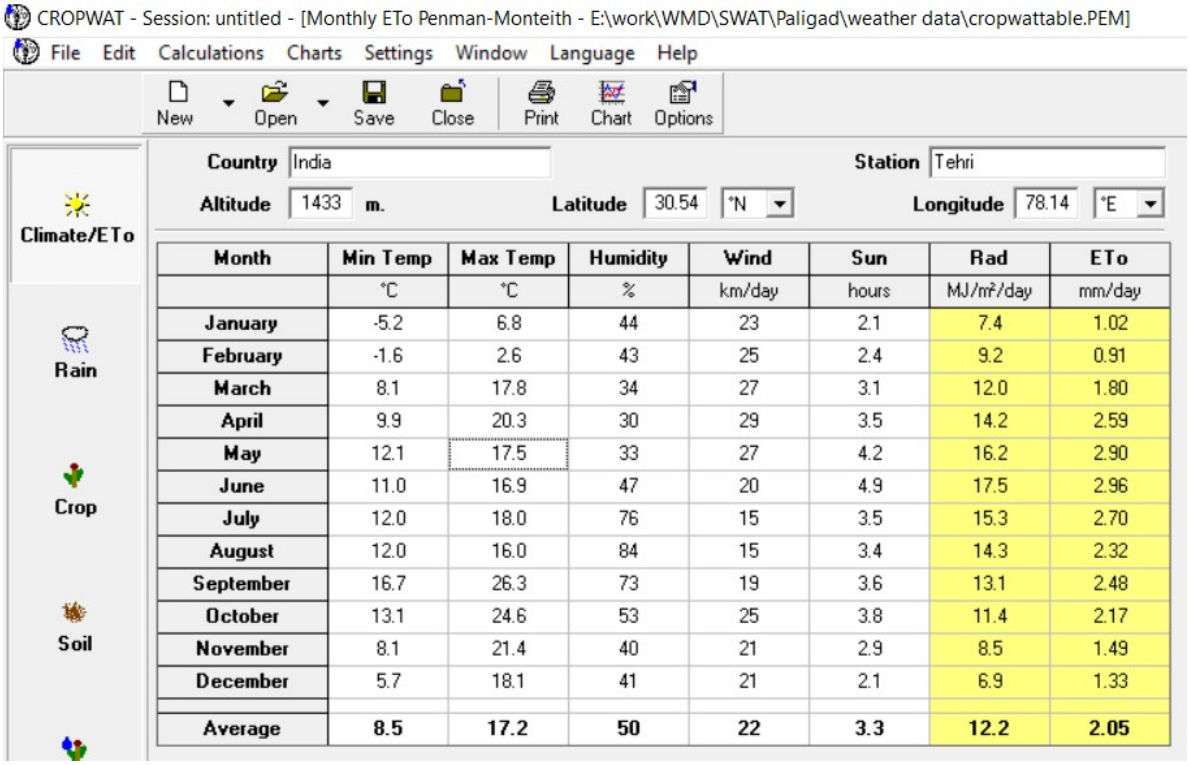
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	-5.0	2.1	81	47	2.0	7.4	0.69
February	-4.0	2.1	75	54	2.5	9.4	0.83
March	8.0	12.0	74	26	3.1	12.1	1.57
April	8.9	11.6	76	35	4.0	15.0	2.17
May	11.2	12.5	82	33	4.6	16.8	2.55
June	9.9	12.0	85	42	5.5	18.4	2.68
July	11.2	13.3	90	22	6.0	18.9	2.84
August	10.3	12.8	92	22	5.2	17.0	2.55
September	8.6	9.2	87	30	5.1	15.3	2.09
October	4.3	5.8	86	22	4.9	12.8	1.52
November	-3.2	1.2	76	11	4.5	10.4	0.91
December	-6.5	0.8	75	15	3.2	8.2	0.63
Average	4.5	8.0	82	30	4.2	13.5	1.75

Loharkhet



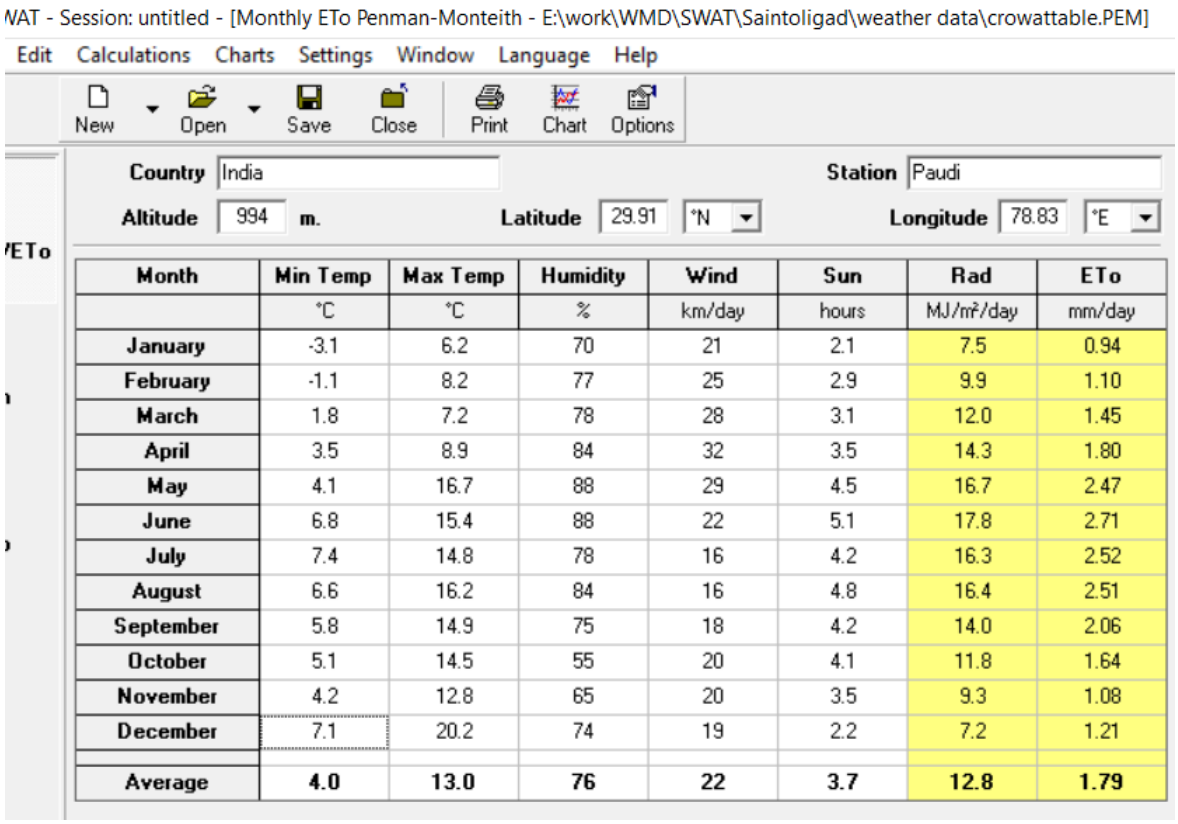
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	3.7	10.5	85	62	2.2	7.6	0.91
February	6.6	12.4	87	69	2.9	9.8	1.30
March	10.2	14.3	81	75	3.5	12.6	1.91
April	13.2	15.6	81	79	4.1	15.1	2.46
May	16.4	18.4	78	72	4.5	16.7	2.99
June	18.1	19.1	82	58	4.1	16.3	3.06
July	18.0	20.1	70	45	3.9	15.8	3.13
August	16.3	18.0	64	45	3.8	15.0	2.92
September	12.6	14.0	58	49	3.4	12.9	2.39
October	8.4	10.2	48	53	4.1	11.8	1.91
November	4.9	6.5	37	52	3.1	8.8	1.38
December	2.7	4.2	37	53	2.5	7.4	1.06
Average	10.9	13.6	67	59	3.5	12.5	2.12

Paligad



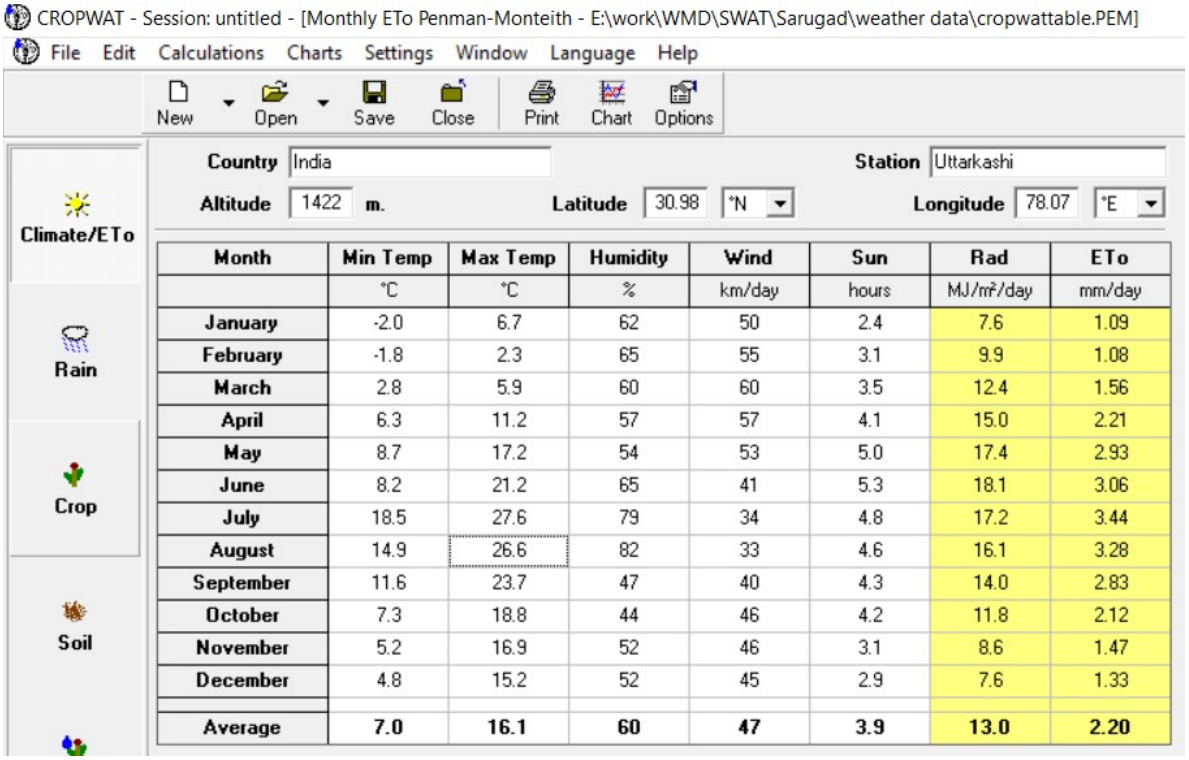
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	-5.2	6.8	44	23	2.1	7.4	1.02
February	-1.6	2.6	43	25	2.4	9.2	0.91
March	8.1	17.8	34	27	3.1	12.0	1.80
April	9.9	20.3	30	29	3.5	14.2	2.59
May	12.1	17.5	33	27	4.2	16.2	2.90
June	11.0	16.9	47	20	4.9	17.5	2.96
July	12.0	18.0	76	15	3.5	15.3	2.70
August	12.0	16.0	84	15	3.4	14.3	2.32
September	16.7	26.3	73	19	3.6	13.1	2.48
October	13.1	24.6	53	25	3.8	11.4	2.17
November	8.1	21.4	40	21	2.9	8.5	1.49
December	5.7	18.1	41	21	2.1	6.9	1.33
Average	8.5	17.2	50	22	3.3	12.2	2.05

Saintoligad



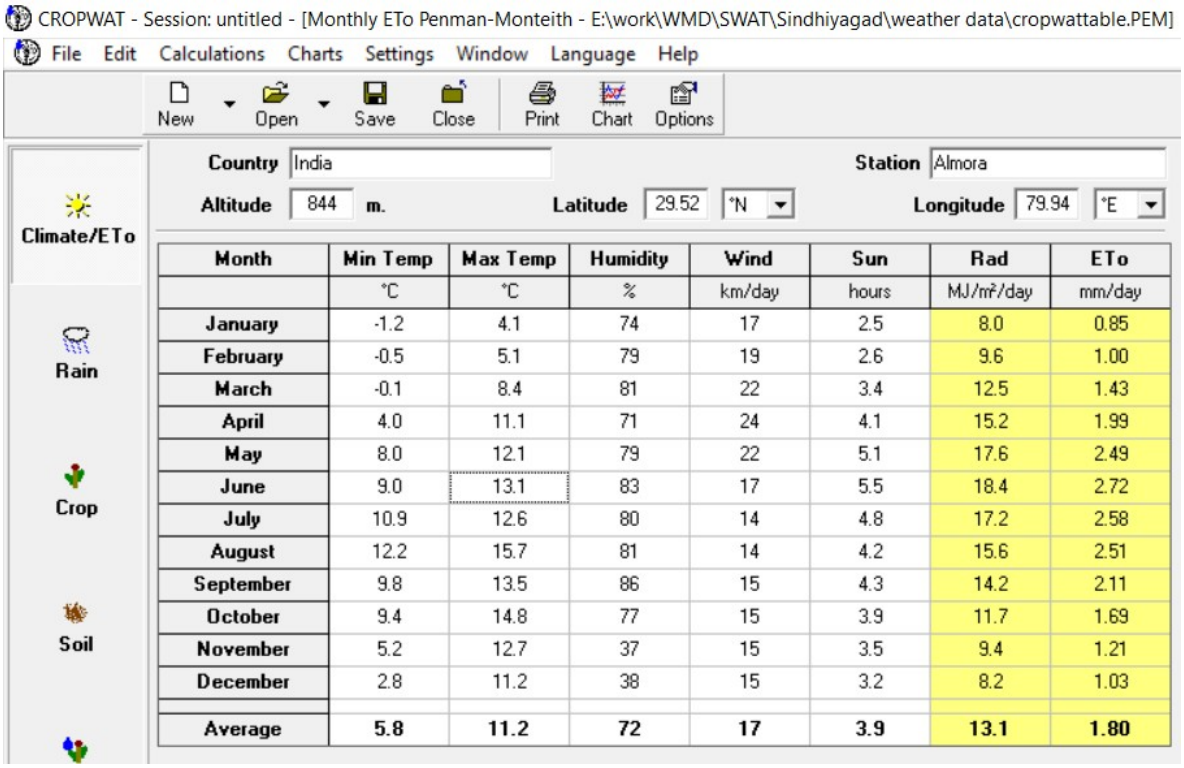
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	-3.1	6.2	70	21	2.1	7.5	0.94
February	-1.1	8.2	77	25	2.9	9.9	1.10
March	1.8	7.2	78	28	3.1	12.0	1.45
April	3.5	8.9	84	32	3.5	14.3	1.80
May	4.1	16.7	88	29	4.5	16.7	2.47
June	6.8	15.4	88	22	5.1	17.8	2.71
July	7.4	14.8	78	16	4.2	16.3	2.52
August	6.6	16.2	84	16	4.8	16.4	2.51
September	5.8	14.9	75	18	4.2	14.0	2.06
October	5.1	14.5	55	20	4.1	11.8	1.64
November	4.2	12.8	65	20	3.5	9.3	1.08
December	7.1	20.2	74	19	2.2	7.2	1.21
Average	**4.0**	**13.0**	**76**	**22**	**3.7**	**12.8**	**1.79**

Sarugad



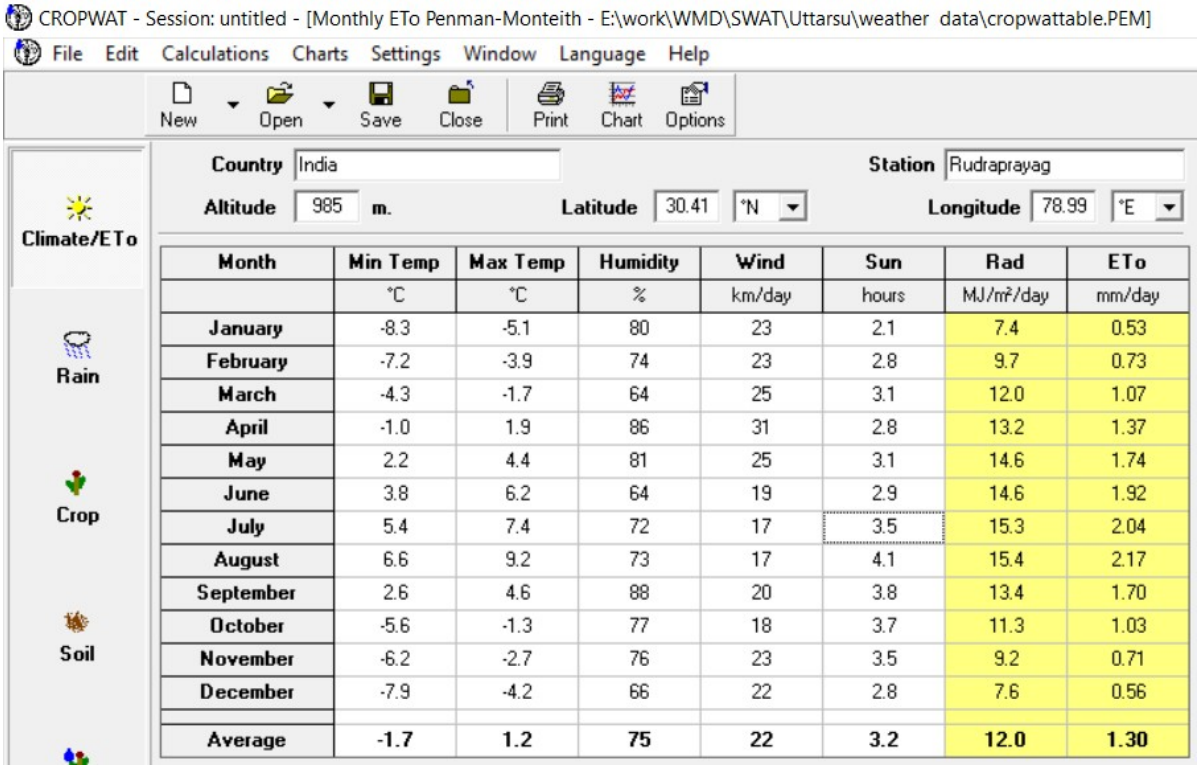
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	-2.0	6.7	62	50	2.4	7.6	1.09
February	-1.8	2.3	65	55	3.1	9.9	1.08
March	2.8	5.9	60	60	3.5	12.4	1.56
April	6.3	11.2	57	57	4.1	15.0	2.21
May	8.7	17.2	54	53	5.0	17.4	2.93
June	8.2	21.2	65	41	5.3	18.1	3.06
July	18.5	27.6	79	34	4.8	17.2	3.44
August	14.9	26.6	82	33	4.6	16.1	3.28
September	11.6	23.7	47	40	4.3	14.0	2.83
October	7.3	18.8	44	46	4.2	11.8	2.12
November	5.2	16.9	52	46	3.1	8.6	1.47
December	4.8	15.2	52	45	2.9	7.6	1.33
Average	**7.0**	**16.1**	**60**	**47**	**3.9**	**13.0**	**2.20**

Sindhiyagad



Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	-1.2	4.1	74	17	2.5	8.0	0.85
February	-0.5	5.1	79	19	2.6	9.6	1.00
March	-0.1	8.4	81	22	3.4	12.5	1.43
April	4.0	11.1	71	24	4.1	15.2	1.99
May	8.0	12.1	79	22	5.1	17.6	2.49
June	9.0	13.1	83	17	5.5	18.4	2.72
July	10.9	12.6	80	14	4.8	17.2	2.58
August	12.2	15.7	81	14	4.2	15.6	2.51
September	9.8	13.5	86	15	4.3	14.2	2.11
October	9.4	14.8	77	15	3.9	11.7	1.69
November	5.2	12.7	37	15	3.5	9.4	1.21
December	2.8	11.2	38	15	3.2	8.2	1.03
Average	**5.8**	**11.2**	**72**	**17**	**3.9**	**13.1**	**1.80**

Uttarsu



Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	-8.3	-5.1	80	23	2.1	7.4	0.53
February	-7.2	-3.9	74	23	2.8	9.7	0.73
March	-4.3	-1.7	64	25	3.1	12.0	1.07
April	-1.0	1.9	86	31	2.8	13.2	1.37
May	2.2	4.4	81	25	3.1	14.6	1.74
June	3.8	6.2	64	19	2.9	14.6	1.92
July	5.4	7.4	72	17	3.5	15.3	2.04
August	6.6	9.2	73	17	4.1	15.4	2.17
September	2.6	4.6	88	20	3.8	13.4	1.70
October	-5.6	-1.3	77	18	3.7	11.3	1.03
November	-6.2	-2.7	76	23	3.5	9.2	0.71
December	-7.9	-4.2	66	22	2.8	7.6	0.56
Average	**-1.7**	**1.2**	**75**	**22**	**3.2**	**12.0**	**1.30**

Annexure: 3.5.3 Estimated ETc values

Dewangad

Estimation of evapotranspiration for Dewangad MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Barnyard millet	0.65	2.33	1.5
Black gram	0.75	2.33	1.7
Lentil	0.97	2.33	2.3
Maize	1.1	2.33	2.6
Rice	1	2.33	2.3
Wheat	0.733	2.33	1.7
Cabbage	1	2.33	2.3
French bean	0.7	2.33	1.6
Ginger	0.88	2.33	2.1
Onion	0.80	2.33	1.9
Pea	0.80	2.33	1.9
Potato	0.67	2.33	1.6
Tomato	0.91	2.33	2.1
Turmeric	0.9	2.33	2.1
Taro root	0.8	2.33	1.9
Amaranth	0.6	2.33	1.4
Pulses	0.75	2.33	1.7
Kidney bean	0.633	2.33	1.5
Yellow pigeon peas	0.633	2.33	1.5
Barley	0.633	2.33	1.5
Capsicum	0.9	2.33	2.1
Mustard	0.7	2.33	1.6
Average			**1.85**

Lathiyagad

Estimation of evapotranspiration for Lathiyagad MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Amaranths	0.6	1.75	1.05
Finger millet	0.65	1.75	1.14
Maize	1.1	1.75	1.93
Rice	1	1.75	1.75
Wheat	0.73	1.75	1.28
Average			**1.43**

Loharkhet

Estimation of evapotranspiration for Loharkhet MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Wheat	0.733	2.21	1.62
Lentil	0.97	2.21	2.14
Rice	1	2.21	2.21
Ginger	0.8	2.21	1.77
Turmeric	0.8	2.21	1.77
Kidney bean	0.633	2.21	1.40
Tomato	0.9	2.21	1.99
Cauli flower	1	2.21	2.21
Green Pea	0.67	2.21	1.48
Mustard	0.7	2.21	1.55
Urad	0.633	2.21	1.40
Maize	1	2.21	2.21
Black bean (Bhatt)	0.633	2.21	1.40
Horse gram (Maduva)	0.633	2.21	1.40
Potato	0.91	2.21	2.01
Chilli	0.7	2.21	1.55
Amaranth	0.6	2.21	1.33
Average			**1.73**

Paligad

Estimation of evapotranspiration for Paligad MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Wheat	0.733	2.05	1.50
Peas	0.67	2.05	1.37
Red Lentil	0.97	2.05	1.99
Paddy	1	2.05	2.05
Barnyard millet	0.65	2.05	1.33
Urad	0.633	2.05	1.30
Suva	0.97	2.05	1.99
Amaranth	0.6	2.05	1.23
Horse gram	0.633	2.05	1.30
Kidney bean	0.633	2.05	1.30
Barley	0.633	2.05	1.30
Mustard	0.7	2.05	1.44

Potato	0.91	2.05	1.87
Turmeric	0.8	2.05	1.64
Tomato	0.9	2.05	1.85
Capsicum	0.9	2.05	1.85
French bean	0.88	2.05	1.80
Brinjal	0.97	2.05	1.99
Average			**1.62**

Saintoligad

Estimation of evapotranspiration for Saintoligad MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Wheat	0.73	1.79	1.31
Lentil	0.97	1.79	1.74
Barley	0.633	1.79	1.13
Rice	1	1.79	1.79
Barnyard millet	0.65	1.79	1.16
Gourd	0.81	1.79	1.45
Bottle gourd	0.8	1.79	1.43
Pumpkin	0.8	1.79	1.43
Average			**1.43**

Sarugad

Estimation of evapotranspiration for lathiyagad MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Rice	1	2.2	2.2
Ragi	0.65	2.2	1.43
Beans	0.88	2.2	1.936
Maize	1.1	2.2	2.42
Wheat	0.733	2.2	1.6126
Mustard	0.7	2.2	1.54
Lentil	0.97	2.2	2.134
Tomato	0.9	2.2	1.98
Average			**1.91**

Sindhiyagad

Estimation of evapotranspiration for lathiyagad MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Rice	1	1.8	1.8
Finger Millet	0.633	1.8	1.1394

Barnyard Millet	0.633	1.8	1.1394
Soybean	0.82	1.8	1.476
Wheat	0.733	1.8	1.3194
Barley	0.633	1.8	1.1394
Lentil	0.97	1.8	1.746
Garlic	0.81	1.8	1.458
Ginger	0.8	1.8	1.44
Turmeric	0.8	1.8	1.44
Green Pea	0.67	1.8	1.206
Cauliflower	1	1.8	1.8
Brinjal	0.97	1.8	1.746
Capsicum	0.9	1.8	1.62
Tomato	0.9	1.8	1.62
Mustard	0.7	1.8	1.26
Amaranth	0.6	1.8	1.08
Horse Gram	0.633	1.8	1.1394
French Bean	0.88	1.8	1.584
Fenugreek	0.9	1.8	1.62
Spinach	0.97	1.8	1.746
Coriander	0.97	1.8	1.746
Onion	0.8	1.8	1.44
Cabbage	1	1.8	1.8
Pumpkin	0.9	1.8	1.62
Bottle Gourd	0.8	1.8	1.44
Bitter Gourd	0.8	1.8	1.44
Sponge Gourd	0.8	1.8	1.44
Average			**1.46**

Uttarsu

Estimation of evapotranspiration for Uttarsu MWS			
Crop	**Crop coefficient (Kc)**	**Average ET o**	**ET c (mm)**
Barnyard millet	0.65	1.3	0.8
Lentil	0.97	1.3	1.3
Finger millet	0.65	1.3	0.8
Mustard	0.7	1.3	0.9
Onion	0.8	1.3	1.0
Pea	0.67	1.3	0.9
Potato	0.91	1.3	1.2
Soybean	0.82	1.3	1.1

Black gram	0.633	1.3	0.8
Wheat	0.733	1.3	1.0
Paddy	1	1.3	1.3
Amaranthus	0.6	1.3	0.8
Average			**0.99**

Annexure: 3.6.1 Water requirement for livestock

Dewangad

Livestock at Dewangad MWS		
Livestock	**Nos.as on 30.09.2021**	**Water requirement (cum /year)**
Cow	490	7154
Buffalo	231	3373
Goat	1146	2091
Poultry	75	27
Mule	7	51
Total		**12697**

Lathiyagad

Livestock at Lathiyagad MWS		
Livestock	**Nos.as on 30.09.2021**	**Water requirement (cum /year)**
Cow	2009	29331
Buffalo	774	11300
Goat	3104	5665
Poultry	329	120
Mule	48	350
Total		**46767**

Loharkhet

Livestock at Loharkhet MWS		
Livestock	**Nos. as on 30.09.2021**	**Water requirement (cum /year)**
Cow	378	5519
Bullock	10	146
Buffalo	141	2059
Goat	749	1367
Poultry	82	30
Horse	1	7
Total		**9128**

Paligad

Livestock at Paligad MWS		
Livestock	**Nos.as on 30.09.2021**	**Water requirement (cum /year)**
Cow	1431	20893
Buffalo	718	10483
Goat	1069	1951
Poultry	170	62
Mule	50	365
Total		**33753**

Saintoligad

Livestock at Saintoligad MWS		
Livestock	**Nos.as on 30.09.2021**	**Water requirement (cum /year)**
Cow	5780	84388
Bullock	210	3066
Goat	5428	9906
Sheep	485	885
Poultry	10368	3784
Mule	683	4986
Total		**107015**

Sarugad

Livestock at Sarugad MWS		
Livestock	**Nos.as on 30.09.2021**	**Water requirement (cum /year)**
Cow	326	4760
Bullock	278	4059
Buffalo	9	131
Goat	130	237
Sheep	26	47
Horse	4	29
Mule	5	37
Total		**9300**

Sindhiyagad

Livestock at Sindhiyagad MWS		
Livestock	**Nos.as on 30.09.2021**	**Water requirement (cum /year)**

Cow	2587	37770
Buffalo	2266	33084
Goat	9205	16799
Total		**87653**

Uttarsu

Livestock at Uttarsu MWS		
Livestock	**Nos.as on 30.09.2021**	**Water requirement (cum /year)**
Cow	183	2672
Bullock	88	1285
Buffalo	133	1942
Goat	210	383
Total		**6282**

Annexure: 3.6.2 Crop water requirement

Dewangad

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year)
Barnyard millet	20.72	450	93240
Black gram	21.25	375	79687.5
Lentil	31.19	500	155950
Maize	112.3	650	729950
Rice	125.55	1100	1381050
Wheat	303.28	550	1668040
Cabbage	9.95	450	44775
French bean	51.35	400	205400
Ginger	67.5	500	337500
Onion	20.35	450	91575
Pea	145.35	425	617737.5
Potato	57.1	600	342600
Tomato	88.92	700	622440
Turmeric	12.15	500	60750
Taro root	38.57	500	192850
Amaranth	11.75	550	64625
Pulses	24	600	144000
Kidney bean	101.08	600	606480
Yellow pigeon peas	23.6	350	82600
Barley	26.9	420	112980
Capsicum	7.9	500	39500
Mustard	44.7	500	223500
Total			**7897230**

Lathiyagad

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year)
Amaranths	3	550	16500
Finger millet	10	400	40000
Maize	5	650	32500
Rice	3	1100	33000
Wheat	15	550	82500
Total			**204500**

Loharkhet

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year)
Wheat	599.1	550	3295050
Red lentil (masoor)	36.7	500	183500
Tomato	10.88	700	76160
Cauliflower	21.4	440	94160
Green pea	30.9	425	131325
Mustard	22	500	110000
Rice	3356	1100	36916000
Ginger	13	500	65000
Turmeric	19.87	500	99350
Urad	50.6	375	189750
Maize (Makka)	161.6	650	1050400
Black bean (Bhatt)	7.4	425	31450
Chilly	13.8	500	69000
Horse gram (Maduva)	22.3	325	72475
Amaranth	16.4	550	90200
Rajma	17.6	600	105600
Potato	4.4	600	26400
herb (jadi buti)	5	500	25000
Total			**42630820**

Paligad

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year
Wheat	231	550	1270500
Peas	22	425	93500
Red Lentil	26	500	130000
Paddy	240	1100	2640000
Barnyard millet	45	450	202500
Urad	28	375	105000
Suva	37	450	166500
Amaranth	31	550	170500
Horse gram	18	3254	585720
Kidney bean	34	600	204000
Barley	26	420	109200
Mustard	21	500	105000

Potato	122	600	732000
Turmeric	56	500	280000
Tomato	18	700	126000
Capsicum	54	500	270000
French bean	29	400	116000
Brinjal	31	440	136400
Total			**7442820**

Saintoligad

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year)
Wheat	28	550	154000
Lentil	4	500	20000
Barley	2	420	8400
Rice	38	1100	418000
Barnyard millet	4	450	18000
Gourd	1	425	4250
Bottle gourd	7	425	29750
Pumpkin	8	425	34000
Total			**686400**

Sarugad

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year)
Rice	280.09	1100	3080990
Lentil	3.84	500	19200
Maize (Makka)	23.38	650	151970
Ragi	109.91	450	494595
Wheat	183.86	550	1011230
Beans	0.04	425	170
Tomato	0.68	700	4760
Mustard	10.89	500	54450
Total			**4817365**

Sindhiyagad

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year)
Rice	442	1100	4862000
Finger Millet	1791.3	375	6717375
Barnyard Millet	965	350	3377500

Soyabean	45	575	258750
Wheat	1897	550	10433500
Barley	19.4	420	81480
Red Lentil (Masoor)	147	500	735000
Garlic	15.4	450	69300
Ginger	103	500	515000
Turmeric	58	500	290000
Green Pea	113	425	480250
Cauliflower	28.1	440	123640
Brinjal	4.5	440	19800
Capsicum	18.5	500	92500
Tomato	19.2	700	134400
Mustard	213	500	1065000
Amaranth	4.8	550	26400
Horse Gram	17.2	325	55900
French Bean	21.3	400	85200
Fenugreek	3.2	450	14400
Spinach	4.6	450	20700
Coriander	17.8	450	80100
Onion	84	450	378000
Cabbage	32.3	440	142120
Pumpkin	9.2	450	41400
Bottle Gourd	10.7	450	48150
Bitter Gourd	7.6	450	34200
Sponge Gourd	5.4	450	24300
Total			**29255495**

Uttarsu

Crop	Area (ha)	Unit CRW (mm)	Total CWR (cum/year)
Paddy	173.64	1100	1910040
Finger millet	184.1	400	736400
Barnyard millet	192.04	450	864180
Soyabean	26.1	575	150075
Black Gram	15.35	375	57562.5
Amaranthus	45.2	550	248600
Wheat	273.25	550	1502875
Mustard	85.1	500	425500
Potato	68.5	600	411000

Pea	19.2	425	81600
Onion	33.5	450	150750
Lentil	5.65	500	28250
Total			**6566832.5**

Annexure: 4.2.1 Percentage variations in key land use classes

Dewangad

Sl.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	454.01	498.4	499	499.5	45.49	10.02
2	Forest	1808	1825.5	1824.1	1824.8	16.8	0.93
3	Land w/without scrub	4501	4434.4	4435.2	4432.24	-68.76	-1.53

Lathiyagad

Sl.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	646	700.9	701.2	702.1	56.1	8.68
2	Forest	2552.6	2417.4	2472.1	2470.1	-82.5	-3.23
3	Land w/without scrub	1362.1	1442	1445	1446.7	84.6	6.21

Loharkhet

Sl.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	797.85	847.6	850.5	851	53.15	6.66
2	Forest	7791.8	7826.5	7824.2	7824.8	33	0.42
3	Land w/without scrub	4316	4227.8	4204.2	4204.6	-111.4	-2.58

Paligad

Sl.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	682.33	691.6	700	701.9	19.57	2.87
2	Forest	3647.3	3649	3646.5	3649.2	1.9	0.05
3	Land w/without scrub	1432.8	1414.4	1404.6	1400.1	-32.7	-2.28

Saintoligad

Sl.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	941.43	957.9	959.7	960.1	18.67	1.98
2	Forest	682.19	683.1	683.6	683.1	0.91	0.13

3	Land w/without scrub	2262.3	2242.3	2240.3	2241.3	-21	-0.93

Sarugad

l.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	623.52	678.9	679.1	681.3	57.78	9.27
2	Forest	5535.43	5568.2	5571.7	5569.1	33.67	0.61
3	Land w/without scrub	1100.86	1005.5	1001.3	999.6	-101.26	-9.20

Sindhiyagad

Sl.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	1815.7	1828	1829.8	1830.1	14.4	0.79
2	Forest	1737.5	1776.5	1777	1776.7	39.2	2.26
3	Land w/without scrub	3837.3	3779.1	3790.5	3791	-46.3	-1.21

Uttarsu

Sl.No.	Land use categories	Area (ha)					
		Base line (2015)	Midterm (2018)	CR (2020)	Final (2021)	Variation	% Variation
1	Agriculture	912.1	915.7	916.1	917.1	5	0.55
2	Forest	1287.4	1310.8	1309.4	1310.2	22.8	1.77
3	Land w/without scrub	1149.2	1121.4	1120.8	1118.4	-30.8	-2.68

Annexure: 4.3.1 Time series analysis of water balance components

Stream flow

Surface runoff as percentage of precipitation					
MWS	**2015**	**2018**	**2020**	**2021**	**Variation**
Dewangad	23.0	21.6	22.5	20.6	-2.4
Lathiyagad	35.8	19.9	7.2	6.7	-29.0
Loharkhet	23.8	11.2	14.9	13.8	-10.0
Paligad	30.6	19.2	20.9	19.3	-11.3
Saintoligad	18.0	15.5	16.8	24.1	6.2
Sarugad	14.5	5.9	7.9	9.1	-5.4
Sindhiyagad	28.9	11.1	17.5	17.7	-11.2
Uttarsu	25.5	30.9	29.2	31.7	6.2

Lateral flow

Variations in lateral flow as percentage of precipitation					
MWS	**2015**	**2018**	**2020**	**2021**	**Variation**
Dewangad	10.1	9.8	10.9	10.3	0.2
Lathiyagad	4.8	8.4	9.9	9.1	4.3
Loharkhet	14.6	14.3	20.9	14.8	0.2
Paligad	7.0	9.2	7.2	10.5	3.5
Saintoligad	7.2	7.3	7.9	7.7	0.4
Sarugad	15.3	15.0	9.3	9.8	-5.4
Sindhiyagad	7.7	30.0	10.7	10.6	3.0
Uttarsu	8.0	8.1	8.5	9.1	1.0

Aquifer recharge

Aquifer recharge as percentage of precipitation					
MWS	**2015**	**2018**	**2020**	**2021**	**Variation**
Dewangad	26.0	25.0	29.7	26.2	0.2
Lathiyagad	11.1	25.6	34.2	28.7	17.6
Loharkhet	20.7	33.3	24.9	31.6	10.9
Paligad	11.9	14.4	9.8	23.8	11.9
Saintoligad	20.5	17.5	23.8	23.0	2.5
Sarugad	21.0	15.2	20.2	24.7	3.8
Sindhiyagad	18.1	26.9	33.6	33.5	15.4
Uttarsu	19.8	18.0	24.3	29.8	9.9

Return flow or base flow

Base flow as percentage of precipitation					
MWS	**2015**	**2018**	**2020**	**2021**	**Variation**
Dewangad	23.0	17.9	26.6	23.4	0.3
Lathiyagad	8.2	22.8	29.9	24.4	16.2
Loharkhet	18.0	25.2	21.2	27.4	9.4
Paligad	8.9	10.8	16.7	20.2	11.3
Saintoligad	15.9	12.4	19.8	18.8	2.8
Sarugad	17.7	9.9	16.2	20.5	2.8
Sindhiyagad	15.0	17.1	30.5	30.3	15.3
Uttarsu	17.3	19.3	20.5	26.7	9.4

Evapotranspiration

ET as percentage of precipitation					
MWS	**2015**	**2018**	**2020**	**2021**	**Variation**
Dewangad	41.5	46.3	36.3	42.8	1.4
Lathiyagad	47.6	44.9	46.5	54.5	6.9
Loharkhet	40.7	41.7	38.6	39.6	-1.1
Paligad	52.0	56.4	48.9	48.2	-3.8
Saintoligad	56.8	59.7	51.6	50.2	-6.6
Sarugad	50.7	64.1	61.7	55.9	5.2
Sindhiyagad	48.3	37.4	36.4	36.6	-11.7
Uttarsu	48.5	38.3	34.4	27.6	-21.0

Yield of the watersheds

Yield of watersheds as percentage of precipitation					
MWS	**2015**	**2018**	**2020**	**2021**	**Variation**
Dewangad	54.1	49.3	59.9	54.3	0.2
Lathiyagad	38.7	51.1	47.0	40.2	1.5
Loharkhet	55.5	50.7	57.0	56.1	0.6
Paligad	46.5	39.1	44.8	49.9	3.4
Saintoligad	41.1	35.1	44.5	50.5	9.4
Sarugad	37.5	30.8	33.5	39.5	2.0
Sindhiyagad	51.5	58.2	58.6	58.6	7.1
Uttarsu	50.9	58.3	58.2	67.4	16.6

Annexure: 4.5.1 Time series analysis of source discharge data

Average Post monsoon Discharge of water sources in lpm												
Sl.No.	**District**	**No of**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Variations**	**% Variations**
			Dec	**Dec**	**Dec**	**Dec**	**Dec**	**Dec**	**Dec**	**Dec**		
1	Dehradun	261	1.1	1.05	1.39	1.4	1.41	1.41	1.42	1.43	0.33	30.00
2	Pithoragarh	279	5.1	5.19	5.5	5.9	5.92	6	5.8	6	0.9	17.65
3	Bageshwar	96	17.5	19.4	19.45	19.5	20.5	20.12	20.2	20.4	2.9	16.57
4	Pauri	196	2.9	2.98	2.9	2.9	3.3	3.3	3.2	3.3	0.4	13.79
5	Tehri	381	10.2	11.01	11.24	11.67	11.9	12	12.2	12.75	2.55	25.00
6	Uttarkashi	144	10.7	10.77	12.59	13.50	14.10	14.15	14.30	14.31	3.61	33.74
7	Almora	550	0.6	0.65	0.65	0.70	0.72	0.72	0.71	0.72	0.12	20.00
8	Rudraprayag	147	7.67	8.2	8.35	8.54	9.165	9.16	9.2	9.21	1.54	20.08
Total		2054	6.97	7.41	7.76	8.01	8.38	8.36	8.38	8.52		

Average Pre monsoon Discharge of water sources in lpm											
Sl.No.	**District**	**No of sources**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Variation**	**% Variation**
1	Dehradun+PMU	261	0.48	0.5	0.505	0.515	0.55	0.56	0.56	0.075	15.63
2	Pithoragarh	279	2.65	2.8	3.05	3.1	3.2	3.2	3.21	0.56	21.13
3	Bageshwar	96	10.1	11.32	11.35	11.38	11.9	12	12.1	2	19.80
4	Pauri	196	1.06	1.09	1.15	1.23	1.27	1.30	1.26	0.2	18.87
5	Tehri	381	3.97	3.98	4.13	4.36	4.54	4.50	4.59	0.62	15.62
6	Uttarkashi	144	6.9	7.32	7.32	7.40	7.80	7.80	7.82	0.92	13.33
7	Almora	550	0.36	0.37	0.36	0.40	0.44	0.44	0.45	0.09	25.00
8	Rudraprayag	147	4.1	4.18	4.28	4.55	4.86	4.90	4.92	0.82	20.00
Total		**2054**	3.70	3.95	4.02	4.12	4.32	4.34	4.36		

Annexure: 5.1.1 Water applied along with rainfall received for wheat crop at Uttarsu micro watershed, Rudraprayag

Water utilisation by farmer for wheat crop at Uttarsu MWS		
Date	**Rainfall (mm)**	**Water applied (mm)**
10/20/2020	0	101.6
10/21/2020	0	0
10/22/2020	0.28	0
10/23/2020	0	0
10/24/2020	0	0
10/25/2020	0	0
10/26/2020	0	0
10/27/2020	0	0
10/28/2020	0	0
10/29/2020	0	0
10/30/2020	0	0
10/31/2020	0	0
11/1/2020	0	0
11/2/2020	0	0
11/3/2020	1.16	0
11/4/2020	0.15	0
11/5/2020	0	0
11/6/2020	0	0
11/7/2020	0	0
11/8/2020	0	0
11/9/2020	0	0
11/10/2020	0	0
11/11/2020	0	0
11/12/2020	0	0
11/13/2020	0	0
11/14/2020	0	0
11/15/2020	0	0
11/16/2020	3.36	0
11/17/2020	6.14	0
11/18/2020	0	0
11/19/2020	0	0
11/20/2020	0	0
11/21/2020	0	0
11/22/2020	0	0

11/23/2020	0	0
11/24/2020	0.92	0
11/25/2020	0	0
11/26/2020	1.78	0
11/27/2020	0	0
11/28/2020	0	0
11/29/2020	0	0
11/30/2020	0	0
12/1/2020	0	101.6
12/2/2020	0	0
12/3/2020	0	0
12/4/2020	0	0
12/5/2020	0	0
12/6/2020	0	0
12/7/2020	0	0
12/8/2020	0	0
12/9/2020	0	0
12/10/2020	0	0
12/11/2020	0	0
12/12/2020	0.24	0
12/13/2020	8.82	0
12/14/2020	0	0
12/15/2020	0	0
12/16/2020	0	0
12/17/2020	0	0
12/18/2020	0	0
12/19/2020	0	0
12/20/2020	0	0
12/21/2020	0	0
12/22/2020	0	0
12/23/2020	0	0
12/24/2020	0	0
12/25/2020	0	0
12/26/2020	0	0
12/27/2020	0	0
12/28/2020	0.1	0
12/29/2020	0	0
12/30/2020	0	0

12/31/2020	0	0
1/1/2021	0	0
1/2/2021	0	0
1/3/2021	0	0
1/4/2021	1.47	0
1/5/2021	0.54	0
1/6/2021	15.34	0
1/7/2021	15.89	0
1/8/2021	0	0
1/9/2021	0	0
1/10/2021	0	0
1/11/2021	0	0
1/12/2021	0	0
1/13/2021	0	0
1/14/2021	0	0
1/15/2021	0	0
1/16/2021	0	0
1/17/2021	0	0
1/18/2021	0	0
1/19/2021	0	0
1/20/2021	0	0
1/21/2021	0	0
1/22/2021	0	0
1/23/2021	0	0
1/24/2021	0	0
1/25/2021	0	0
1/26/2021	0	0
1/27/2021	0	0
1/28/2021	0	0
1/29/2021	0	0
1/30/2021	0	0
1/31/2021	0	0
2/1/2021	0	0
2/2/2021	0	0
2/3/2021	0	0
2/4/2021	0.75	0
2/5/2021	11.2	0
2/6/2021	0.93	0

2/7/2021	0	0
2/8/2021	0	0
2/9/2021	0	0
2/10/2021	0	0
2/11/2021	0	0
2/12/2021	0	0
2/13/2021	0	0
2/14/2021	0	0
2/15/2021	0.73	0
2/16/2021	0.49	0
2/17/2021	0	0
2/18/2021	0	0
2/19/2021	0.46	0
2/20/2021	0	0
2/21/2021	0	0
2/22/2021	0	0
2/23/2021	0	0
2/24/2021	0	0
2/25/2021	0.21	0
2/26/2021	0	0
2/27/2021	3.03	0
2/28/2021	2.12	0
3/1/2021	0	101.6
3/2/2021	0	0
3/3/2021	0	0
3/4/2021	0	0
3/5/2021	0	0
3/6/2021	0	0
3/7/2021	0.4	0
3/8/2021	11.23	0
3/9/2021	1.53	0
3/10/2021	0	0
3/11/2021	1.16	0
3/12/2021	0	0
3/13/2021	0.04	0
3/14/2021	0	0
3/15/2021	0	0
3/16/2021	0	0

3/17/2021	0	0
3/18/2021	0	0
3/19/2021	0	0
3/20/2021	0	0
3/21/2021	0	0
3/22/2021	0	0
3/23/2021	11.35	0
3/24/2021	1.57	0
3/25/2021	0.09	0
3/26/2021	0	0
3/27/2021	0	0
3/28/2021	0	0
3/29/2021	0	0
3/30/2021	0	0
3/31/2021	0	0
4/1/2021	0	0
4/2/2021	0	0
4/3/2021	0	0
4/4/2021	0	0
4/5/2021	0	0
4/6/2021	0.04	0
4/7/2021	2.1	0
4/8/2021	4.5	0
4/9/2021	0.07	0
4/10/2021	0	0
4/11/2021	0	0
4/12/2021	0	0
4/13/2021	0	0
4/14/2021	0	0
4/15/2021	0	0
4/16/2021	0	0
4/17/2021	0.38	0
4/18/2021	8.48	0
4/19/2021	0.45	0
4/20/2021	0	0

Water applied along with rainfall received for tomato crop at Saintoligad micro watershed, Pauri

Water utilisation by farmer for tomato crop at Saintoligad MWS		
Date	**Rainfall (mm)**	**Water applied (mm)**
4/1/2021	0	125
4/2/2021	0	0
4/3/2021	2.52	0
4/4/2021	0	0
4/5/2021	0	0
4/6/2021	0	0
4/7/2021	0	50
4/8/2021	0	0
4/9/2021	0	0
4/10/2021	3.05	0
4/11/2021	0	0
4/12/2021	0	0
4/13/2021	0	10
4/14/2021	2.07	0
4/15/2021	0	0
4/16/2021	0	0
4/17/2021	0	0
4/18/2021	0	0
4/19/2021	3.07	0
4/20/2021	0	0
4/21/2021	0	0
4/22/2021	2.51	0
4/23/2021	3.4	0
4/24/2021	0	0
4/25/2021	2.48	0
4/26/2021	0	0
4/27/2021	0	0
4/28/2021	3.21	0
4/29/2021	0	0
4/30/2021	2.16	0
5/1/2021	9.51	0
5/2/2021	0	0
5/3/2021	7.25	0

5/4/2021	0	0
5/5/2021	7.31	0
5/6/2021	5.69	0
5/7/2021	0	0
5/8/2021	5.49	0
5/9/2021	6.59	0
5/10/2021	8.04	0
5/11/2021	0	0
5/12/2021	28.2	0
5/13/2021	4.8	0
5/14/2021	0	0
5/15/2021	0	0
5/16/2021	0	0
5/17/2021	0	20
5/18/2021	0	0
5/19/2021	0	0
5/20/2021	0	0
5/21/2021	50.7	0
5/22/2021	8.51	0
5/23/2021	0	0
5/24/2021	0	0
5/25/2021	8.48	0
5/26/2021	0	0
5/27/2021	0	0
5/28/2021	10.21	0
5/29/2021	0	0
5/30/2021	8.16	0
5/31/2021	0	0
6/1/2021	11.3	0
6/2/2021	0	0
6/3/2021	0	0
6/4/2021	0	0
6/5/2021	0	15
6/6/2021	0	0
6/7/2021	0	0
6/8/2021	0	0
6/9/2021	0	20
6/10/2021	0	0

6/11/2021	0	0
6/12/2021	3	0
6/13/2021	2.2	0
6/14/2021	1.2	0
6/15/2021	0	0
6/16/2021	0	0
6/17/2021	1.8	0
6/18/2021	10.3	0
6/19/2021	78.2	0
6/20/2021	54	0
6/21/2021	23.7	0
6/22/2021	0	0
6/23/2021	0	0
6/24/2021	0	20
6/25/2021	0	0
6/26/2021	4.2	0
6/27/2021	0	0
6/28/2021	0	0
6/29/2021	0	25
6/30/2021	0	0
7/1/2021	0	0
7/2/2021	0	0
7/3/2021	0	15
7/4/2021	0	0
7/5/2021	0	0
7/6/2021	0	0
7/7/2021	0	0
7/8/2021	0	25
7/9/2021	0	0
7/10/2021	0	0
7/11/2021	17.8	0
7/12/2021	0	0
7/13/2021	2.2	0
7/14/2021	6.4	0
7/15/2021	0	0
7/16/2021	0	0
7/17/2021	0	0
7/18/2021	15.8	0

7/19/2021	22.8	0
7/20/2021	87.6	0
7/21/2021	11.5	0
7/22/2021	20.6	0
7/23/2021	8	0
7/24/2021	0	0
7/25/2021	0	0
7/26/2021	4.2	0
7/27/2021	2.5	0
7/28/2021	19.4	0
7/29/2021	17	0
7/30/2021	3.9	0
7/31/2021	7.5	0
8/1/2021	0	0
8/2/2021	0	0
8/3/2021	0	0
8/4/2021	0	20
8/5/2021	0	0
8/6/2021	0	0
8/7/2021	48	0
8/8/2021	0	0
8/9/2021	0	0
8/10/2021	2.4	0
8/11/2021	0	0
8/12/2021	0	0
8/13/2021	0	0
8/14/2021	0	0
8/15/2021	0	10
8/16/2021	0	0
8/17/2021	0	0
8/18/2021	0	0
8/19/2021	0	0
8/20/2021	8.4	0
8/21/2021	56.4	0
8/22/2021	2.3	0
8/23/2021	0	0
8/24/2021	0	0
8/25/2021	58	0

8/26/2021	0	0
8/27/2021	8.6	0
8/28/2021	59.4	0
8/29/2021	2	0
8/30/2021	0	0
8/31/2021	0	0

Water applied along with rainfall received for rice crop at Sarugad micro watershed, Uttarkashi

Water utilisation by farmer for tomato crop at Saintoligad MWS		
Date	**Rainfall (mm)**	**Water applied (mm)**
5/15/2020	0	6
5/12/2020	0	6
5/17/2020	0	6
5/18/2020	0	6
5/19/2020	1.19	6
5/20/2020	0	6
5/21/2020	0	6
5/22/2020	0	6
5/23/2020	0	6
5/24/2020	2.39	6
51-05-2020	0	6
5/22/2020	1.37	6
5/27/2020	0	6
5/28/2020	2.87	6
5/29/2020	0	6
5/30/2020	3.27	6
5/31/2020	0	6
2/1/2020	8.27	2
2/2/2020	10.37	2
2/3/2020	8.51	2
2/4/2020	0	6
2/5/2020	9.24	2
2/2/2020	0	6
2/7/2020	7.38	2
2/8/2020	0	6
2/9/2020	8.22	2
2/10/2020	0	6

2/11/2020	0	6
2/12/2020	3.39	6
2/13/2020	0	6
2/14/2020	5.31	2
2/15/2020	0	6
2/12/2020	8.29	2
2/17/2020	0	6
2/18/2020	0	6
2/19/2020	2.22	2
2/20/2020	0	6
2/21/2020	0	6
2/22/2020	3.32	6
2/23/2020	0	6
2/24/2020	5.39	2
51-02-2020	0	6
2/22/2020	9.37	2
2/27/2020	0	6
2/28/2020	2.87	6
2/29/2020	0	6
2/30/2020	2.27	20
7/1/2020	12.27	2
7/2/2020	15.37	2
7/3/2020	19.51	2
7/4/2020	18.31	2
7/5/2020	14.58	2
7/2/2020	15.85	2
7/7/2020	17.29	2
7/8/2020	12.55	2
7/9/2020	17.21	2
7/10/2020	12.58	2
7/11/2020	12.39	2
7/12/2020	12.33	2
7/13/2020	11.29	2
7/14/2020	11.58	2
7/15/2020	12.87	2
7/12/2020	18.29	2
7/17/2020	15.21	2
7/18/2020	12.87	2

7/19/2020	12.89	2
7/20/2020	19.57	2
7/21/2020	19.58	2
7/22/2020	17.54	2
7/23/2020	14.52	2
7/24/2020	18.37	2
51-07-2020	11.28	2
7/22/2020	18.59	2
7/27/2020	12.48	2
7/28/2020	13.52	2
7/29/2020	13.89	2
7/30/2020	15.38	2
7/31/2020	19.27	2
8/1/2020	19.71	2
8/2/2020	15.37	2
8/3/2020	19.51	2
8/4/2020	12.31	2
8/5/2020	14.58	2
8/2/2020	15.85	2
8/7/2020	17.29	2
8/8/2020	12.55	2
8/9/2020	17.21	2
8/10/2020	12.58	2
8/11/2020	12.39	2
8/12/2020	12.33	2
8/13/2020	11.29	2
8/14/2020	11.58	2
8/15/2020	12.87	2
8/12/2020	18.29	2
8/17/2020	15.29	2
8/18/2020	12.87	2
8/19/2020	12.89	2
8/20/2020	19.57	2
8/21/2020	19.58	2
8/22/2020	17.29	2
8/23/2020	13.42	2
8/24/2020	18.37	2
51-08-2020	19.58	2

8/22/2020	17.59	2
8/27/2020	12.48	2
8/28/2020	13.52	2
8/29/2020	13.89	2
8/30/2020	15.38	2
8/31/2020	17.27	2
9/1/2020	2.71	2
9/2/2020	0	6
9/3/2020	2.51	2
9/4/2020	5.31	2
9/5/2020	0	6
9/2/2020	7.85	2
9/7/2020	5.29	2
9/8/2020	2.55	2
9/9/2020	0	6
9/10/2020	5.58	2
9/11/2020	0	6
9/12/2020	3.33	6
9/13/2020	5.29	2
9/14/2020	0	6
9/15/2020	2.87	2
9/12/2020	5.29	2
9/17/2020	0	6
9/18/2020	2.87	2
9/19/2020	7.89	2
9/20/2020	0	6
9/21/2020	9.58	2
9/22/2020	7.29	2
9/23/2020	5.43	2
9/24/2020	0	6
51-09-2020	4.58	6
9/22/2020	7.39	2
9/27/2020	0	6
9/28/2020	2.52	2
9/29/2020	7.89	2
9/30/2020	0	6
10/1/2020	0	6
10/2/2020	0	6

10/3/2020	0	6
10/4/2020	0	6
10/5/2020	0	6
10/2/2020	0	6
10/7/2020	0	6
10/8/2020	0	6
10/9/2020	0	6
10/10/2020	0	6
10/11/2020	0	6
10/12/2020	0	6
10/13/2020	0	6
10/14/2020	0	6
10/15/2020	0	6

Annexure: 6.1.1 Water harvesting and conservation structures, their capacities and area brought under irrigation through these structures.

Structures

Structures	Unit	Dewangad	Lathiyagad	Loharkhet	Paligad	Saintoligad	Sarugad	Sindhiyagad	Uttarsu
Contour trenches	Nos	3523	17978	79920	7895	46161	0	135983	43500
Dugout ponds	Nos	23	1008	2089	0	0	0	63	0
Irrigation channels	Kms	18	9	0	1	1	5	44	19
Irrigation pipes	Kms	103	58	17	5	42	4	5	6
Irrigation tanks	Nos	133	65	21	9	17	32	349	25
LDP Tanks	Nos	0	35	153	1	2	0	17	0
Recharge pits	Nos	2629	1323	5117	37	11859	0	0	9018
Roof top RWH	Nos	76	490	295	226	139	3	5042	243
Spring augmentation	Nos	0	75	87	15	1	0	10	0
Village ponds	Nos	19	68	20	0	43	0	40	2

Capacities and area brought under irrigation

Structures	Capacity	Dewangad	Lathiyagad	Loharkhet	Paligad	Saintoligad	Sarugad	Sindhiyagad	Uttarsu
Contour trenches	cum	2642	13484	59940	5921	34621	0	101987	32625
Dugout ponds	cum	207	9072	18801	0	0	0	567	0
Irrigation channels	ha	107	56	1	8	6	33	264	116
Irrigation pipes	ha	412	231	69	19	167	16	21	23
Irrigation tanks	ha	106	52	17	7	14	26	279	20
Irrigation tanks	cum	1995	975	315	135	255	480	5235	375
LDP Tanks	ha	0	35	153	1	2	0	17	0
LDP Tanks	cum	0	700	3060	20	40	0	340	0
Recharge pits	cum	8676	4366	16886	122	39135	0	0	29759
Roof top RWH	cum	190	1225	738	565	348	8	12605	608
Roof top RWH	ha	3	20	12	9	6	0	202	10
Village ponds	cum	2280	8160	2400	0	5160	0	4800	240
Village ponds	ha	19	68	20	0	43	0	40	2
Total capacity	**Cum**	**15990**	**37981**	**102140**	**6763**	**79558**	**488**	**125534**	**63607**
Total area	**ha**	**647**	**462**	**272**	**45**	**237**	**75**	**823**	**171**

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