MTP 2nd stage presentation

UNDERSTANDING GROUNDWATER FLOWS IN HILLY WATERSHEDS OF JAWHAR AND MOKHADA FROM WATER SECURITY PERSPECTIVE

By,

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Under guidance of

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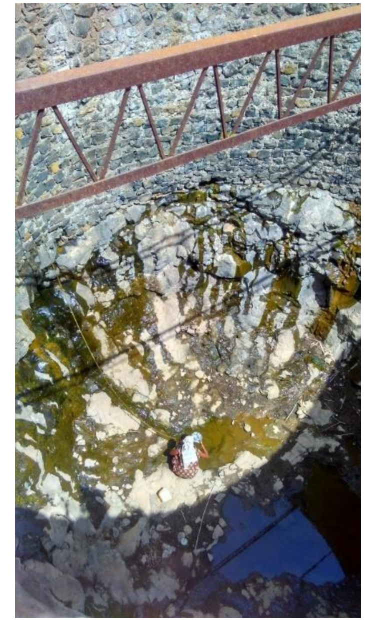
Presentation outline

- Background and motivation
- Empirics/Methodology
- Estimating baseflows, problems with GEC methodology
- Understanding the influence of soil moisture and ET
- Well analysis
- Conclusions and scope for future work

Motivation



- Severe and widespread **drinking water stress,** high number of **tanker fed** habitations in dry season, very **low Rabi** cultivation resulting in **poverty and migration** in Jawhar and Mokhada blocks

- Difficulty in state led programs (like JYS) to address this problem (repeating tanker fed hamlets).

- Problems in groundwater assessment methodology (GEC 97) to capture the water stress situation in the study region.

Source: MRSAC

Objectives of the study

- To measure groundwater and to understand the functioning of watersheds of Mokhada and Jawhar region with different land use and land cover.
- To measure and understand the effect of land use (forest cover, cropping land, grassland etc.,) on the base flows and hydrogeological parameters (specific yield, infiltration etc.,)
- To link well readings with stream flows and to account for discrepancies.
- To verify the suitability of GSDA groundwater assessment methodology in the study area.
- To suggest the parameters that needs to be considered while planning watershed interventions in Mokhada and Jawhar Region.

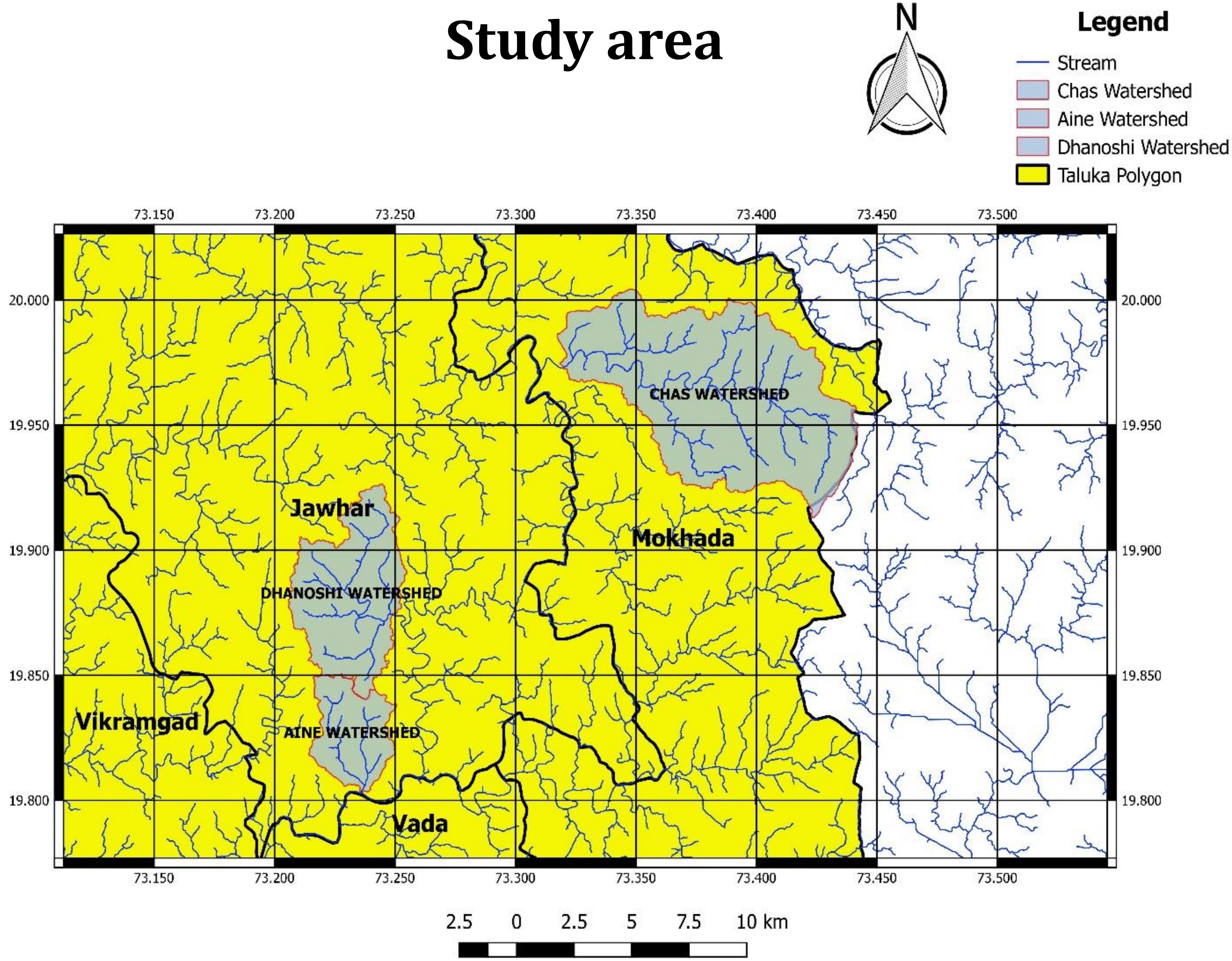
Inferences from past studies

- Significant contribution of base-flows to the post-monsoon streamflow - *Parth study in Mokhada*
- Natural Forests help in more ground water recharge, followed by planted forest (Acacia) and degraded forest (NF>AC>DF). Similarly higher Peak flows are observed in Degraded Forest followed by Acacia and Natural Forest. Which in fact shows the increase in infiltration due to forest cover presumably increasing the specific yield of the soil - *Sharad Lele and team in Western Ghats of Karnataka*
- Evapotranspiration load exceeds infiltration benefit from the forest. , but this is applicable to the annual precipitation of 350-600mm. – *Semi arid region of china*
- Dependence of local community on forest for water and livelihood. – *S Lele*
- More base flows associated with higher forest cover – *K Price*

Methodology/Empirics

- Selection of study area
  - Based on different land use land cover and geomorphologic parameters
- Monitoring important flows and stocks
  - Methodology for flow measurement using pygmy/current meter (ungauged basin)
  - Measuring base-flows at key locations (sixteen locations monitored at twenty one day interval)
  - Measuring groundwater levels at key locations (eighty-three wells monitored at twenty one day interval)
- Analysing important stocks and flows and understanding their determinants
  - Using empirical data and geospatial analysis
- Strengthening the field understanding of hilly watersheds in the study region

Study area

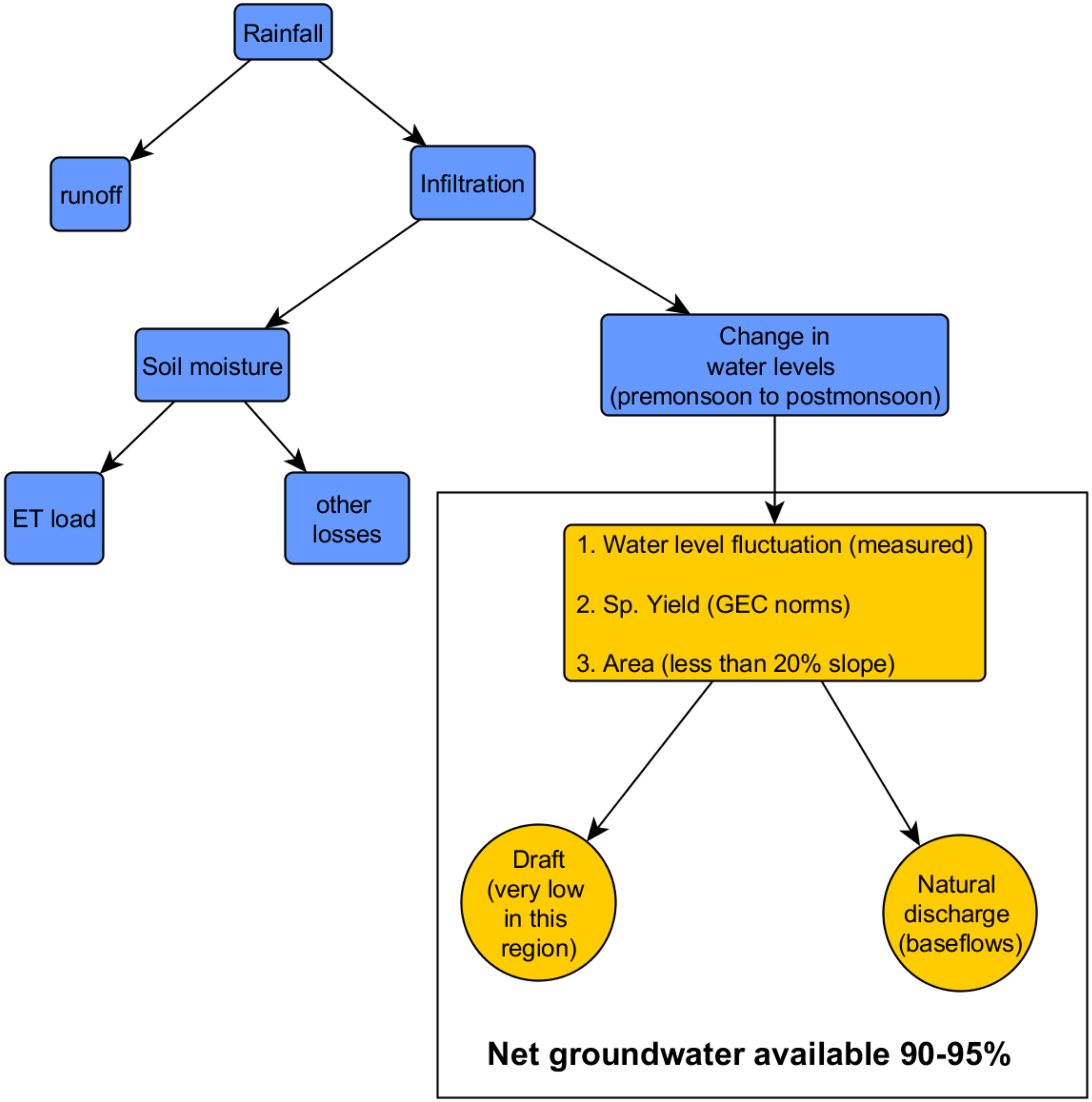

N
Legend
Stream
Chas Watershed
Aine Watershed
Dhanoshi Watershed
Taluka Polygon
73.150
73.200
73.250
73.300
73.350
73.400
73.450
73.500
20.000
19.950
19.900
19.850
19.800
CHAS WATERSHED
Jawhar
Mokhada
DHANOSHI WATERSHED
Vikramgad
AINE WATERSHED
Vada
2.5 0 2.5 5 7.5 10 km

Watersheds under study

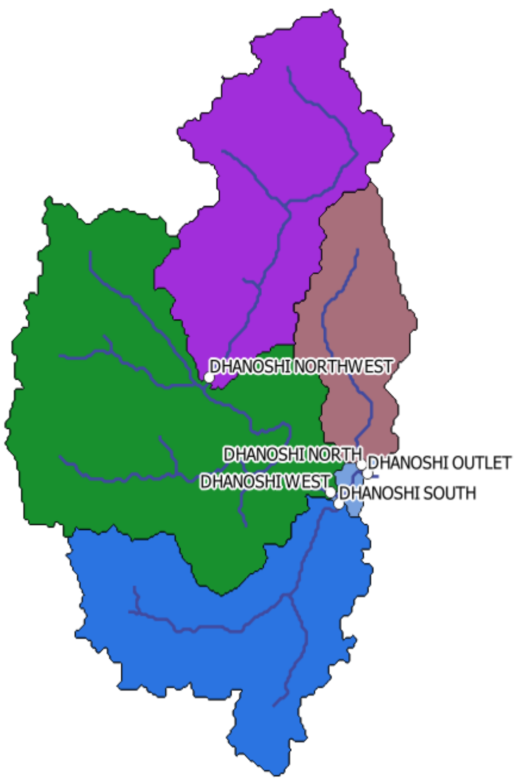
Sr. No	Watershed Name	Catchment Area in Ha	Villages In Watershed	Forest Cover
1	CHAS	7901	Chas, Osarvira, Brahmagaon, Ghosali, Beriste, Hirve, Poshera, Morhande, Gonde Bk/Morchondi and Dandwal	22%
2	DHANOSHI	3184	Jawhar Rural, Juni Jawhar, Dhanoshi, Aptale, Akhar, Sakur, Kadachimet and Pathardi	15%
3	AINE	1407	Chauk (partially), Dongarwadi and Aine	59%

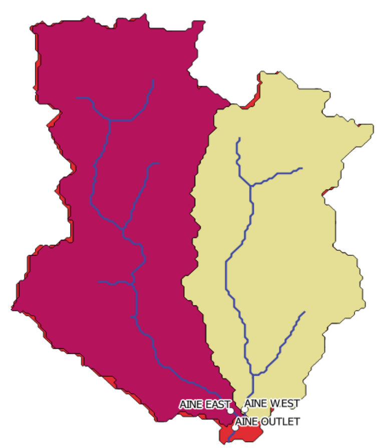
Estimating baseflows and GEC methodology

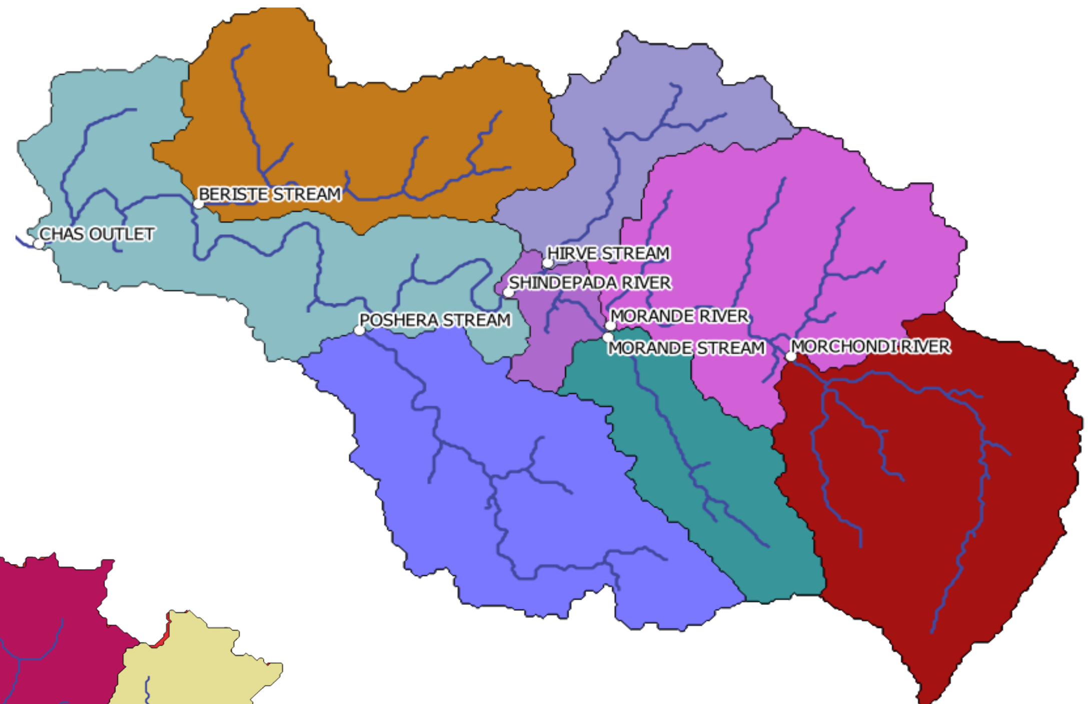
GEC97 METHODOLOGY



Measuring Post-monsoon baseflow in key locations

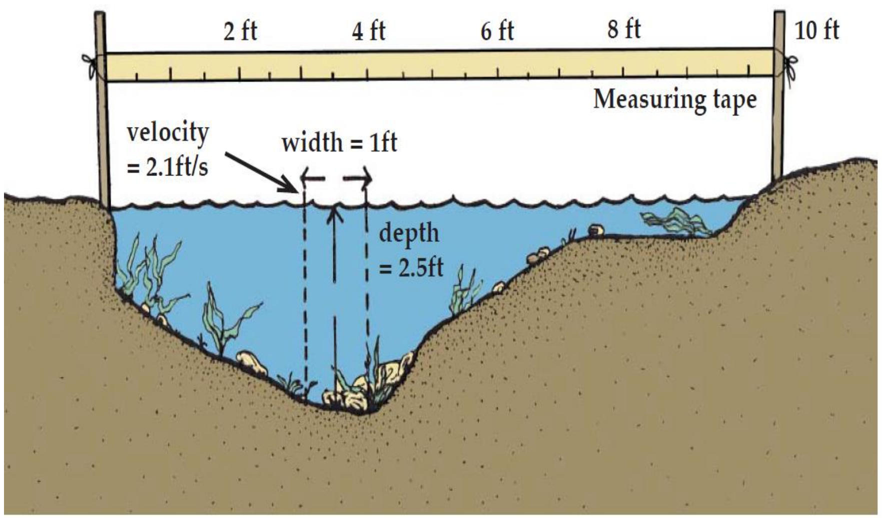






16 Outlets are monitored at an interval of 21 days. Total six readings are taken.

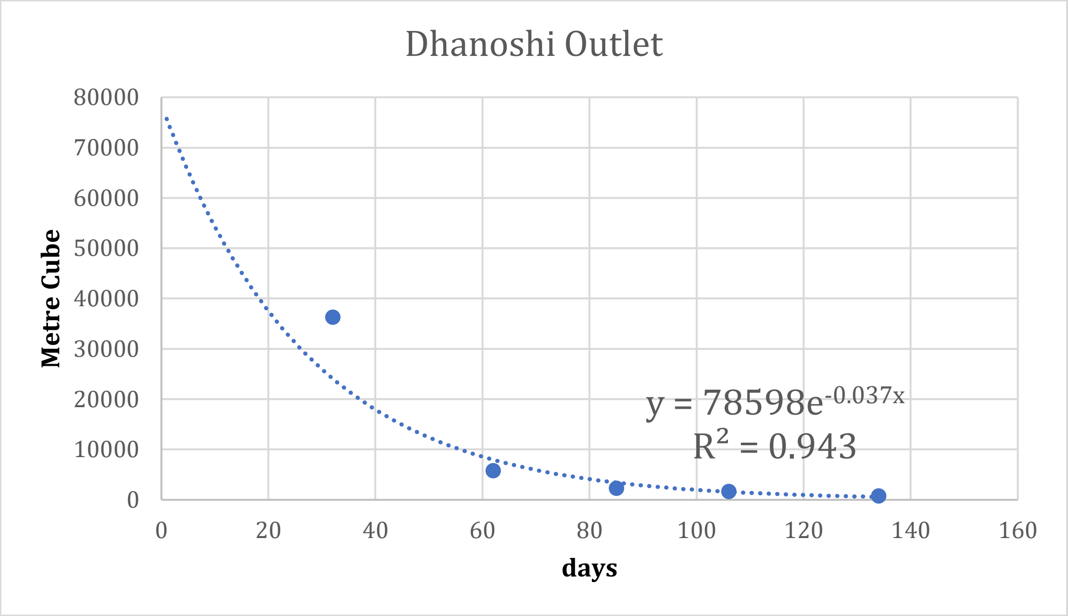
Pygmy current meter



Brief data collected during flow measurements

Watershed Number	Sr. No	Watershed Name	Catchment Area (ha)	Slope Area (%)		Forest Cover %	1 Flow (Lit/Sec)	2 Flow (Lit/Sec)	3 Flow (Lit/Sec)	4 Flow (Lit/Sec)	5 Flow (Lit/Sec)	6 Flow (Lit/Sec)
				0-5%	>20%							
1 (DHANOSHI)	1	DHANOSHI NORTH	364.3	9.90	18.15	10.95	58.78	9.39	3.21	1.16	0.48	0.00
	2	DHANOSHI NORTHWEST	778.5	7.66	21.22	9.94	139.15	36.96	12.35	6.36	2.46	
	3	DHANOSHI WEST	2061.6	8.67	6.33	13.64	332.03	48.23	22.44	12.04	5.90	1.49
	4	DHANOSHI SOUTH	735.6	23.00	25.40	21.87	60.64	12.96	9.52	5.71	2.06	2.00
	5	DHANOSHI OUTLET	3184.2	17.70	26.50	15.33	419.84	66.56	26.34	18.92	8.44	2.50
2 (AINE)	1	AINE EAST	804.5	0.00	46.23	63.83	18.03	5.37				
	2	AINE WEST	594.2	9.10	65.00	55.61	36.30	14.24				
	3	AINE OUTLET	1407	3.86	53.80	59.00	68.72	19.9	5.79	3.00	1.50	
3 (CHAS)	1	MORCHONDI RIVER	1464.1	12.15	40.84	41.50	66.78	24.59	13.24	2.82	1.31	0.00
	2	MORONDE RIVER	2749.3	13.78	28.84	31.27	187.90	84.66	60.29	30.97	8.64	1.63
	3	MORONDE STREAM	625.0	10.72	20.00	17.72	22.52	6.23	5.52	0.72	0.10	0.00
	4	HIRVE STREAM	587.7	9.70	25.48	21.65	25.00	8.41	2.13	0.50	0.00	
	5	SHINDEPADA RIVER	4136.2	12.63	26.74	27.54	242.21	129.65	63.18	flow abstr	13.32	1.50
	6	POSHERA STREAM	1350.2	18.44	13.55	4.29	26.30	11.95	5.89	1.00	0.81	0.00
	7	BERISTE STREAM	1126.4	8.50	40.62	22.38	54.00	9.86	13.36	3.00	0.20	0.00
	8	CHAS OUTLET	7901.4	11.82	29.75	22.52	406.40	215.17	71.13	31.21	6.19	2.00

Computation of baseflow and half life



$$\int_0^{134} 78598\mathrm{e}^{-0.037\mathrm{x}} dx \;= 210.93ham$$

$$0.037x = -\ln(0.5)$$

Half life = 18.73 days

Water balance using GEC97 methodology

Taluka	Recharge From Rain during monsoon (ham)	Provison for Natural Discharge (ham)	Net Ground Water Availability (ham)	Ground Water Available as % of Total Recharge (%)	Baseflows as % of Total Recharge (%)	Total Ground water Draft (ham)	Stage of Ground water Development	Category
Jawhar	3330.40	239.60	3090.80	92.81	7.19	164.08	5.31	SAFE
Mokhada	1680.65	84.88	1595.77	94.95	5.05	105.29	6.60	SAFE

Source: Report on the dynamic Ground Water Resource of Maharashtra (2011-2012)

Base-flow leaving the watershed as a fraction of total recharge

Watershed Number	Sr. No	Watershed Name	Catchment Area (ha)	Recharge (ham) by GEC methodology	Baseflow out (ham) by Flow Measurement	% baseflow out	Half Life in Days	Water level drop (mm)
1 (DHANOSHI)	1	DHANOSHI NORTH	364.3	42.94	47.63	110.93	12.84	130.74
	2	DHANOSHI NORTHWEST	778.5	88.32	102.74	116.33	16.12	131.97
	3	DHANOSHI WEST	2061.6	173.07	167.37	96.71	18.24	130.44
	4	DHANOSHI SOUTH	735.6	79.02	34.87	44.13	22.36	47.40
	5	DHANOSHI OUTLET	3184.2	337.02	210.93	62.59	18.73	66.24
2 (AINE)	1	AINE EAST	804.5	62.29	19.70	31.62	13.08	24.48
	2	AINE WEST	594.2	29.95	32.55	108.71	17.77	54.79
	3	AINE OUTLET	1407	93.60	59.86	63.94	15.07	42.54
3 (CHAS)	1	MORCHONDI RIVER	1464.1	103.94	72.91	70.14	15.75	49.80
	2	MORONDE RIVER	2749.3	234.77	170.94	72.81	23.10	62.18
	3	MORONDE STREAM	625.0	60.00	14.86	24.77	22.36	23.78
	4	HIRVE STREAM	587.7	52.55	39.58	75.30	11.75	67.34
	5	SHINDEPADA RIVER	4136.2	363.62	228.59	62.86	22.36	55.27
	6	POSHERA STREAM	1350.2	140.07	21.57	15.40	21.00	15.97
	7	BERISTE STREAM	1126.4	80.26	48.73	60.71	17.33	43.26
	8	CHAS OUTLET	7901.4	666.09	549.37	82.48	15.07	69.53

Water balance using GEC97 methodology

Taluka	Recharge From Rain during monsoon (ham)	Provison for Natural Discharge (ham)	Net Ground Water Availability (ham)	Ground Water Available as % of Total Recharge (%)	Baseflows as % of Total Recharge (%)	Total Ground water Draft (ham)	Stage of Ground water Development	Category
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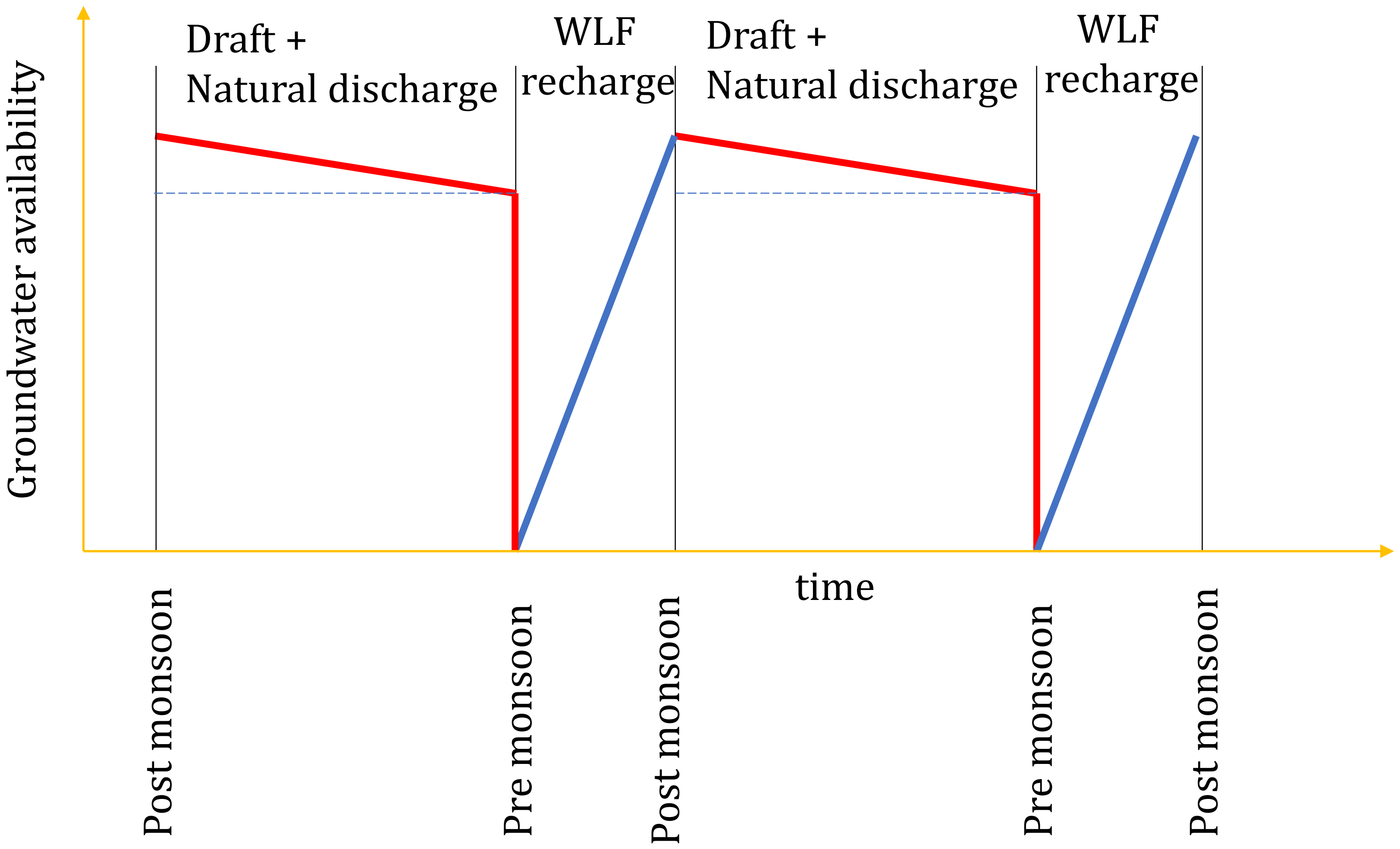
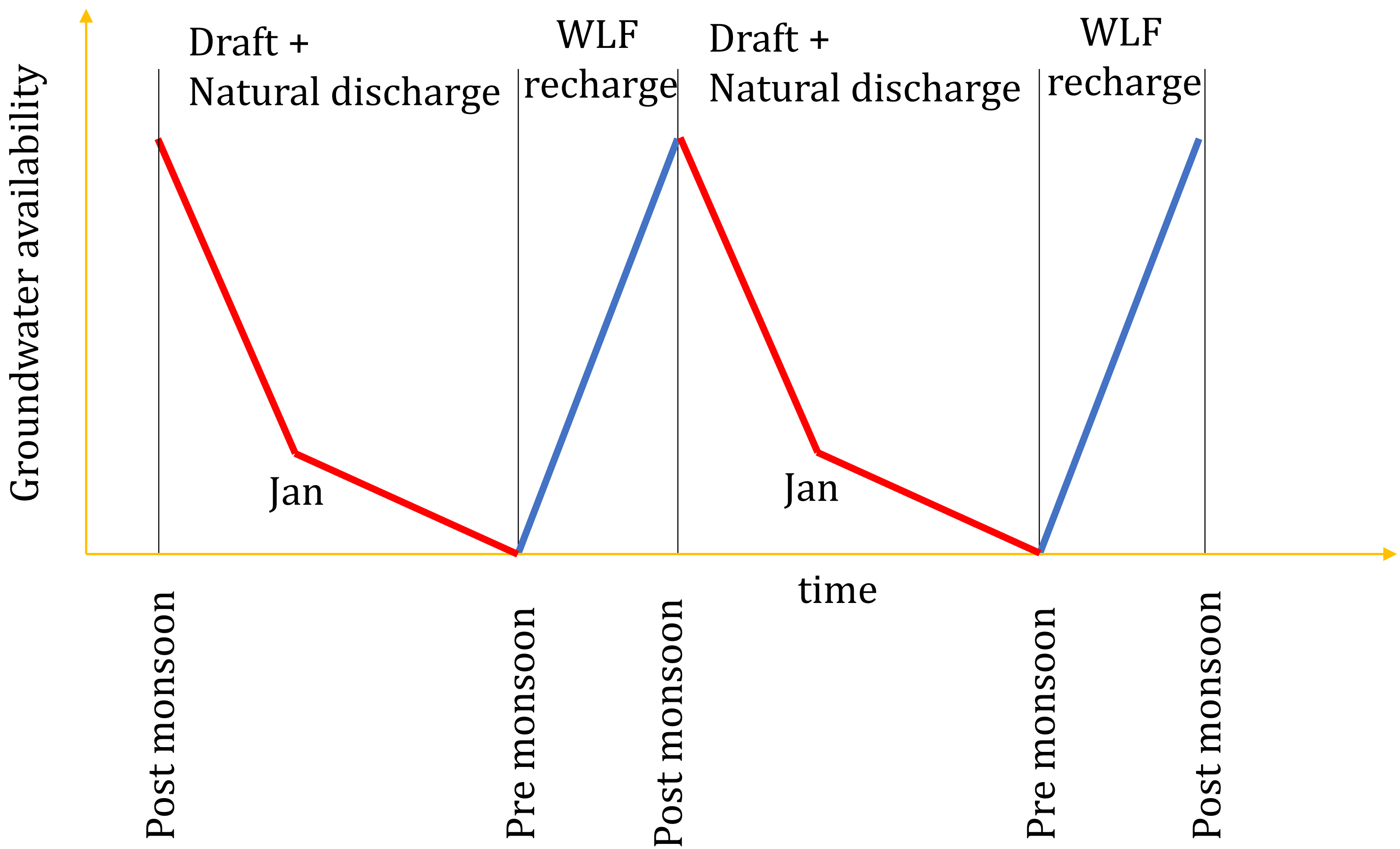
Source: Report on the dynamic Ground Water Resource of Maharashtra (2011-2012)

How GSDA assessment looks



What is happening in reality



Key observations

- The measured natural discharge showed that around 69% of recharged water has left the watershed as baseflows by January end which is around 14 times more than GEC assumption.

- Temporal variation of groundwater availability is not captured by GEC methodology

Soil moisture and ET load

- GSDA assumes $\Delta\text{Groundwater} = Baseflows +$ draft

- What constitutes baseflow?
  - Seepage from soil moisture
  - Groundwater discharge

$$\Delta\text{Soil moisture} + \Delta\text{Groundwater} = Baseflows + Evapotranspiration\ load + \text{draft}$$

  - What is the effective specific yield considering soil moisture and ET?

$$(Area * Depth) * Specific\ Yield = Baseflows + Evapotranspiration\ load$$

Estimating effective specific yield considering soil moisture and ET

$$(Area * Depth) * Specific\ Yield = Baseflows + Evapotranspiration\ load$$

Area = area of the sub watershed

Depth = average thickness of top aquifer

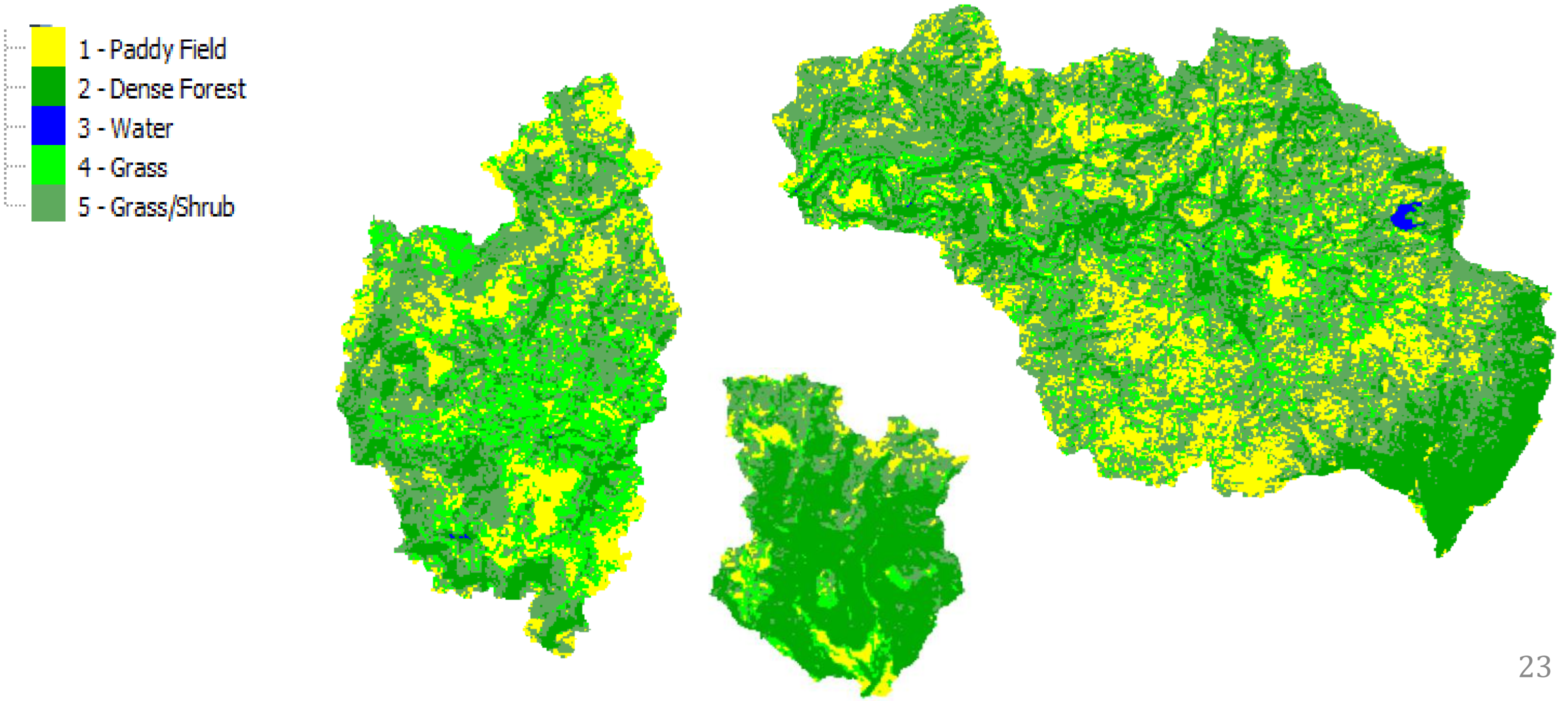
Baseflows = measured baseflows

ET load = Assumed

Specific yield = Effective SP Yield considering ET and soil moisture

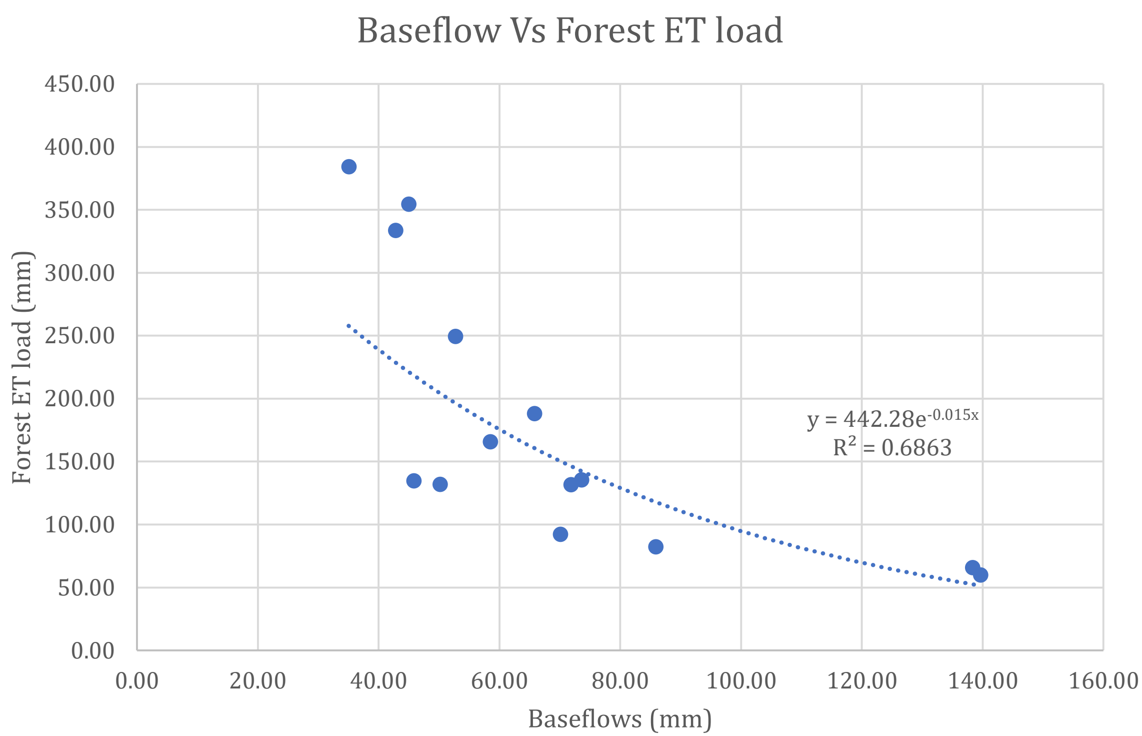
evapotranspiration load estimation (used SCP classification tool)

Land Use/Cover	Number of Days (Post Monsoon)	mm/day ET load
Paddy	30	3.5
Grass	20	2
Natural Forest	243	2.5



Effective Specific yield considering ET and soil moisture

Watershed Name	Paddy ET (cubic metre)	Forest ET (cubic metre)	Grass ET (cubic metre)	Total ET Load (ham)	Baseflow (ham)	Specific Yield %
DHANOSHI NORTH	63976.50	226354.50	96732.00	38.71	47.63	**7.07**
DHANOSHI NORTHWEST	222169.50	439587.00	177372.00	83.91	102.74	**4.83**
DHANOSHI WEST	420147.00	1599243.75	506016.00	252.54	167.37	**4.25**
DHANOSHI SOUTH	145530.00	916353.00	159660.00	122.15	34.87	**4.00**
DHANOSHI OUTLET	631449.00	2775303.00	768060.00	417.48	210.93	**4.17**
AINE EAST	41485.50	2157475.50	64692.00	226.37	19.70	**15.49**
AINE WEST	76545.00	2537466.75	104184.00	271.82	32.55	**12.18**
AINE OUTLET	124267.50	4714625.25	168300.00	500.72	59.86	**13.61**
MORCHONDI RIVER	202702.50	3450539.25	24300.00	367.75	72.91	**7.42**
MORONDE RIVER	411169.50	4884664.50	544500.00	584.03	170.94	**6.44**
MORONDE STREAM	110092.50	628762.50	150264.00	88.91	14.86	**4.08**
HIRVE STREAM	101493.00	724443.75	133884.00	95.98	39.58	**5.54**
SHINDEPADA RIVER	646002.00	6476253.75	869688.00	799.19	228.59	**5.80**
POSHERA STREAM	497542.50	328596.75	293076.00	111.92	21.57	**2.21**
BERISTE STREAM	197221.50	1430844.75	251604.00	187.97	48.73	**5.70**
CHAS OUTLET	1534869.00	10106673.75	1698192.00	1333.97	549.37	**5.64**

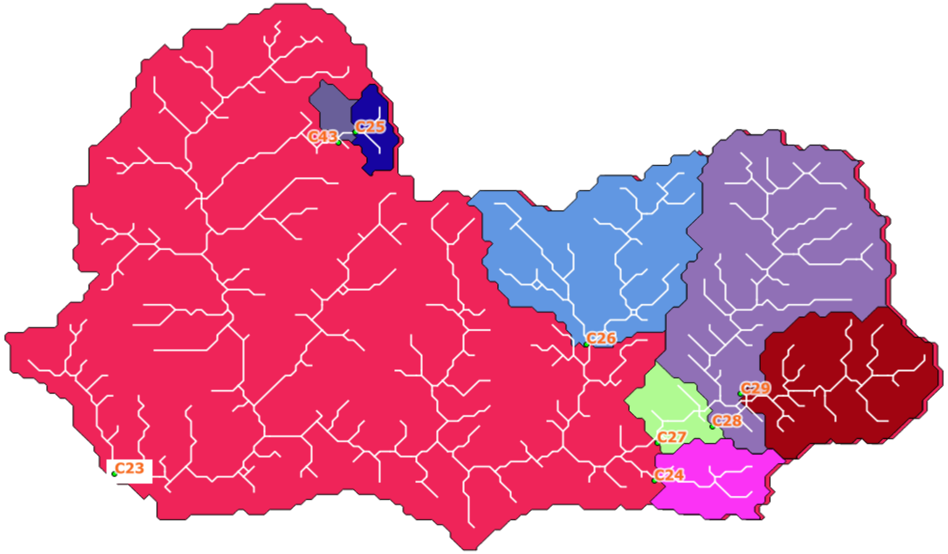


Baseflows reduces with increasing forest cover,

One probable justification
- Deeper root system → more soil thickness → more water storage capacity

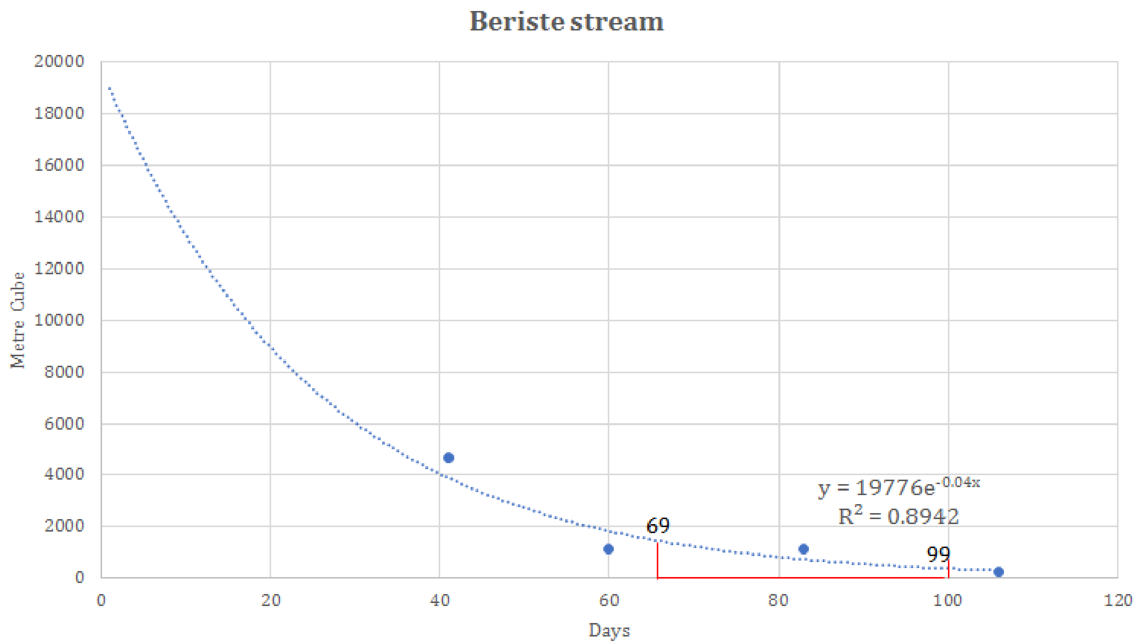
Root systems in study region

Well water-level drop and base-flow relationship



Beriste Stream Watershed with well watersheds

Well Number	Catchment area in (ha)	Differential Catchment area (ha)	Drop in water level (m)	Total Volume of water drop considering 2.4% Sy
C25	9	9	3.92	8467.2
C43	13	(13-9) = 4	1.00	960
C26	99	99	0.32	7603.2
C29	69	69	0	0
C28	209	(209-69) = 140	0	0
C27	226	(226-209) = 17	0.07	285.6
C24	26	26	1.60	9984
C23	1064	(1064-13-226-99-26) = 700	0.02	3360
Total Volume drop (cubic metre) =				30660



$$\int_{69}^{99} 19776e^{-0.04x}dx = 21866.64 \ cubic \ metre$$

Volume of water decreased (by well level drop) =Well drop volume – Domestic Load

(between 08-12-2016 to 07-01-2017)

= 30660 – 1693.02

= 28966.98 cubic metre

Volume of base-flows leaving the watershed = 21866.64 cubic metre

(between 08-12-2016 to 07-01-2017)

Volume of base-flows leaving the watershed = 99979.23 cubic metre

In November 2016

Key observations

- The flows in the early months post monsoon (October-November) are greater than what can be attributed to groundwater drop alone. This indicates that the excess must have come from seepage from soil moisture held in the top few meters of the surface.

Well Analysis

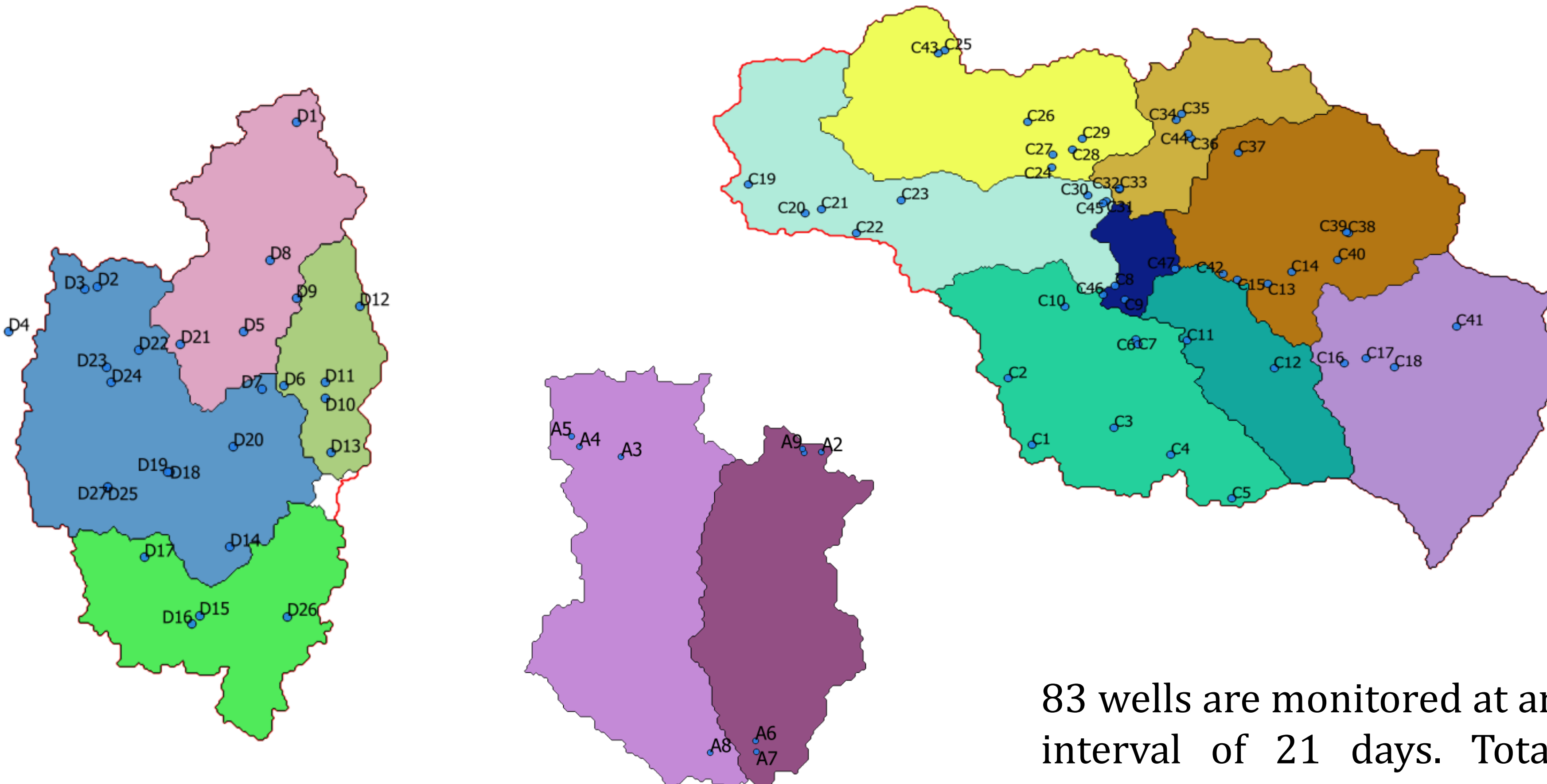
Well analysis

What influences well levels

What we have seen

1. Looked at well drop, monitoring of well levels throughout dry months
2. Location of the well (which stream)
3. Well watershed
4. Looking at forest cover in well catchment
5. Interventions around the well

Monitoring Post-monsoon groundwater levels in key locations



83 wells are monitored at an interval of 21 days. Total seven readings are taken.

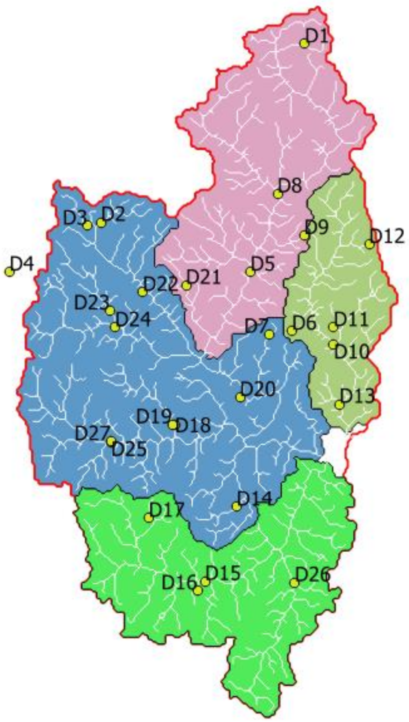
Brief data collected during well monitoring

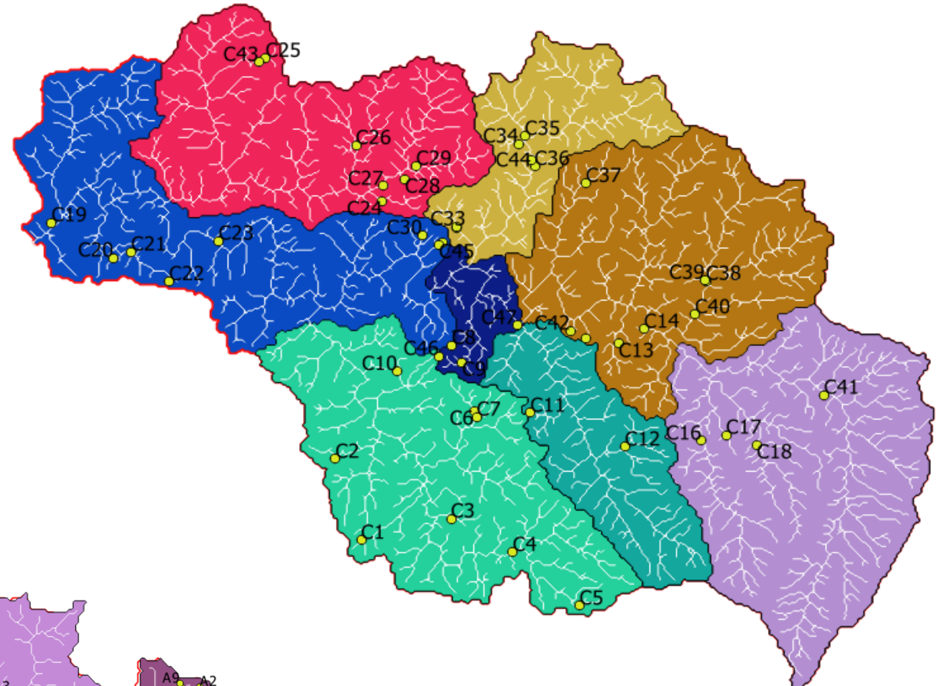
Sr. No	Location description	Height of Water Column (m) 1	Height of Water Column (m) 2	Height of Water Column (m) 3	Height of Water Column (m) 4	Height of Water Column (m) 5	Height of Water Column (m) 6	Height of Water Column (m) 7
C1	Naviwadi	5.5	5.10	4.89	4.66	4.48	3.92	3.46
C2	Wargadpada	4.2	3.06	2.65	2.33	1.60	0.45	0.30

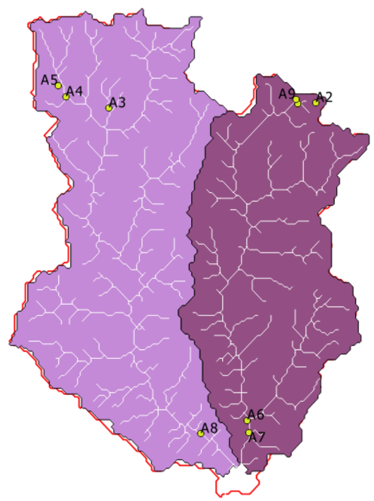
Sr. No	Location description	Lat	Long	Elevation from Mean Sea Level (m)	Order (10pixels)	Rock Depth (Metre Below Ground)	Hamlet Elev From Mean Sea Level(m)	mean drop (mm/day)
C1	Naviwadi	19.93305	73.3644166	412	2	7	437	13.40
C2	Wargadpada	19.9438333	73.36095	391	1	2	417	26.88

Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Category	Distance to well (m)	Paddy %	Forest %	perinnial ity	total_load Cubic Metre
C1	Naviwadi	2	10.086	PDW	309	32.4	1.85	10	510.3
C2	Wargadpada	1	19.391	FW	418	17.61	1.42	8	0.0

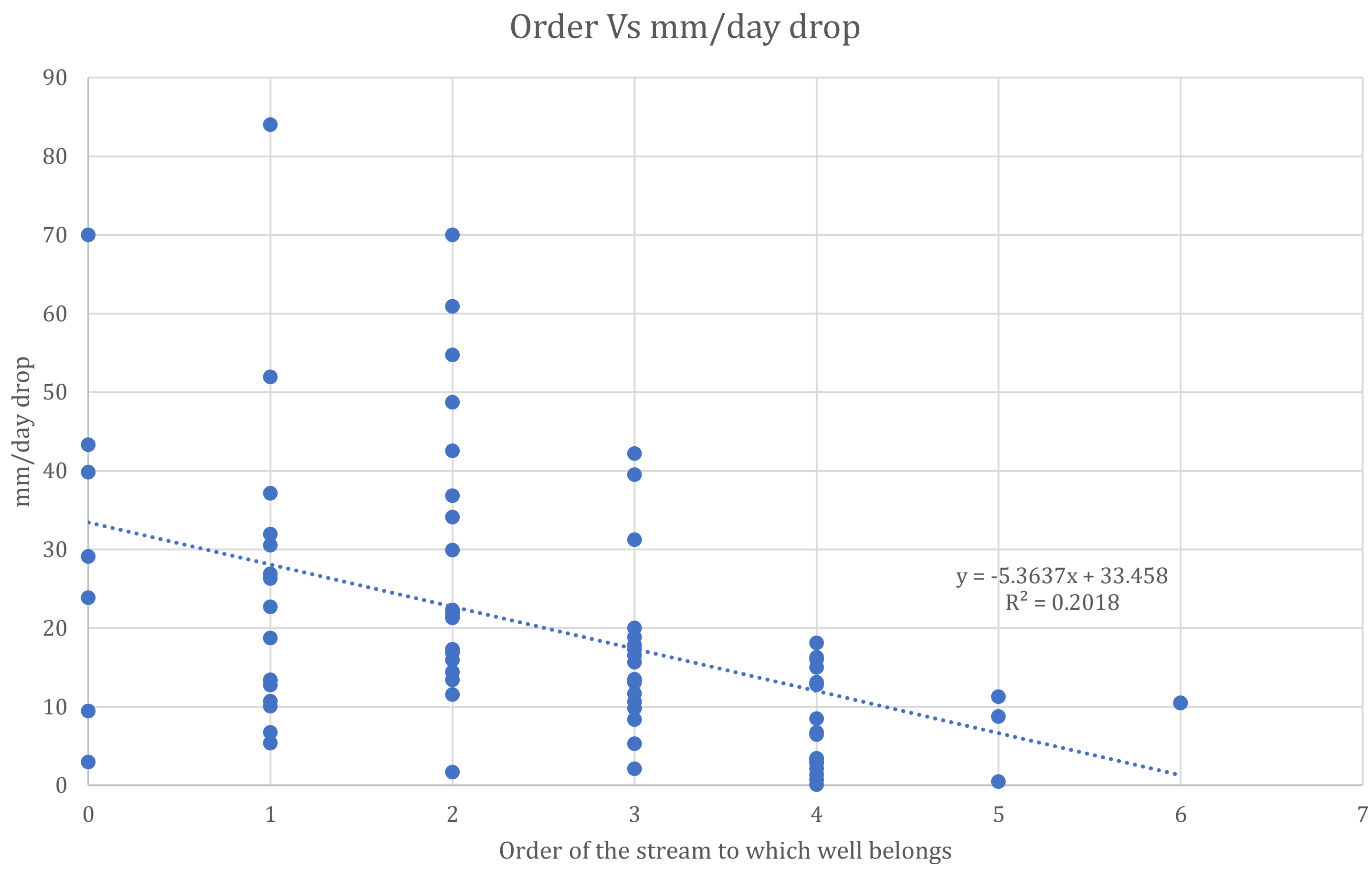
Wells marked on stream







Wells marked on stream map (generated by using 10pixel threshold)

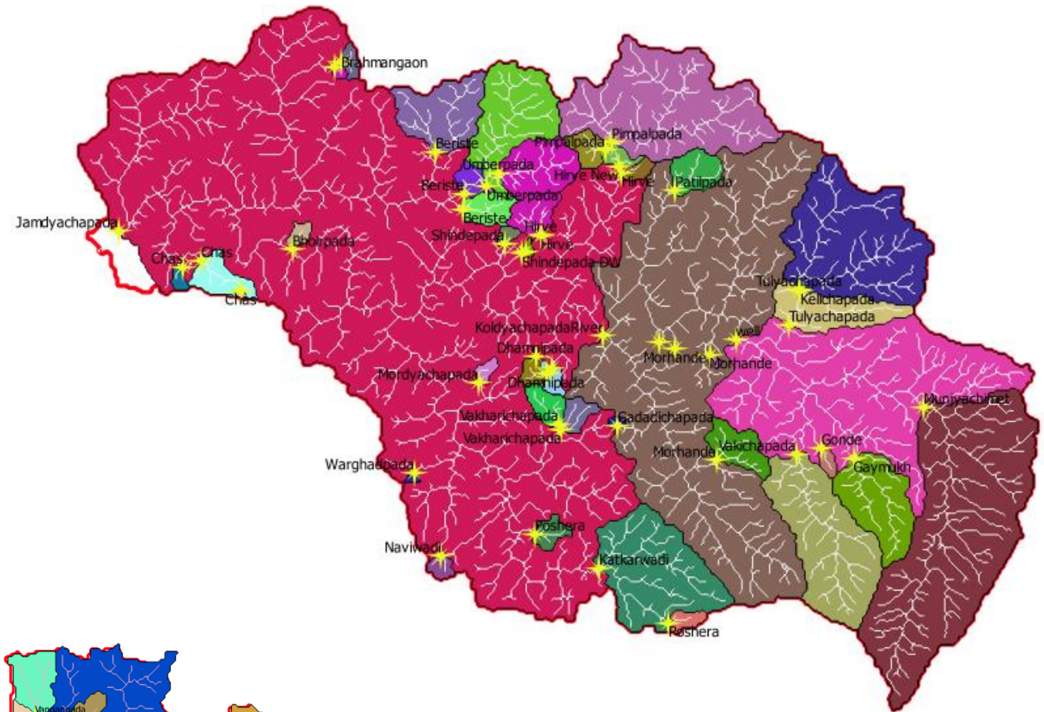


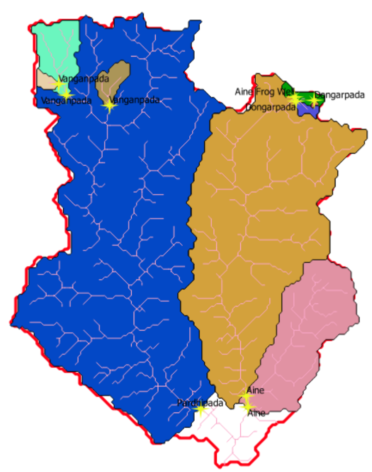
Higher the stream order lower is the drop rate

Wells in lower order stream but having lesser drop rate

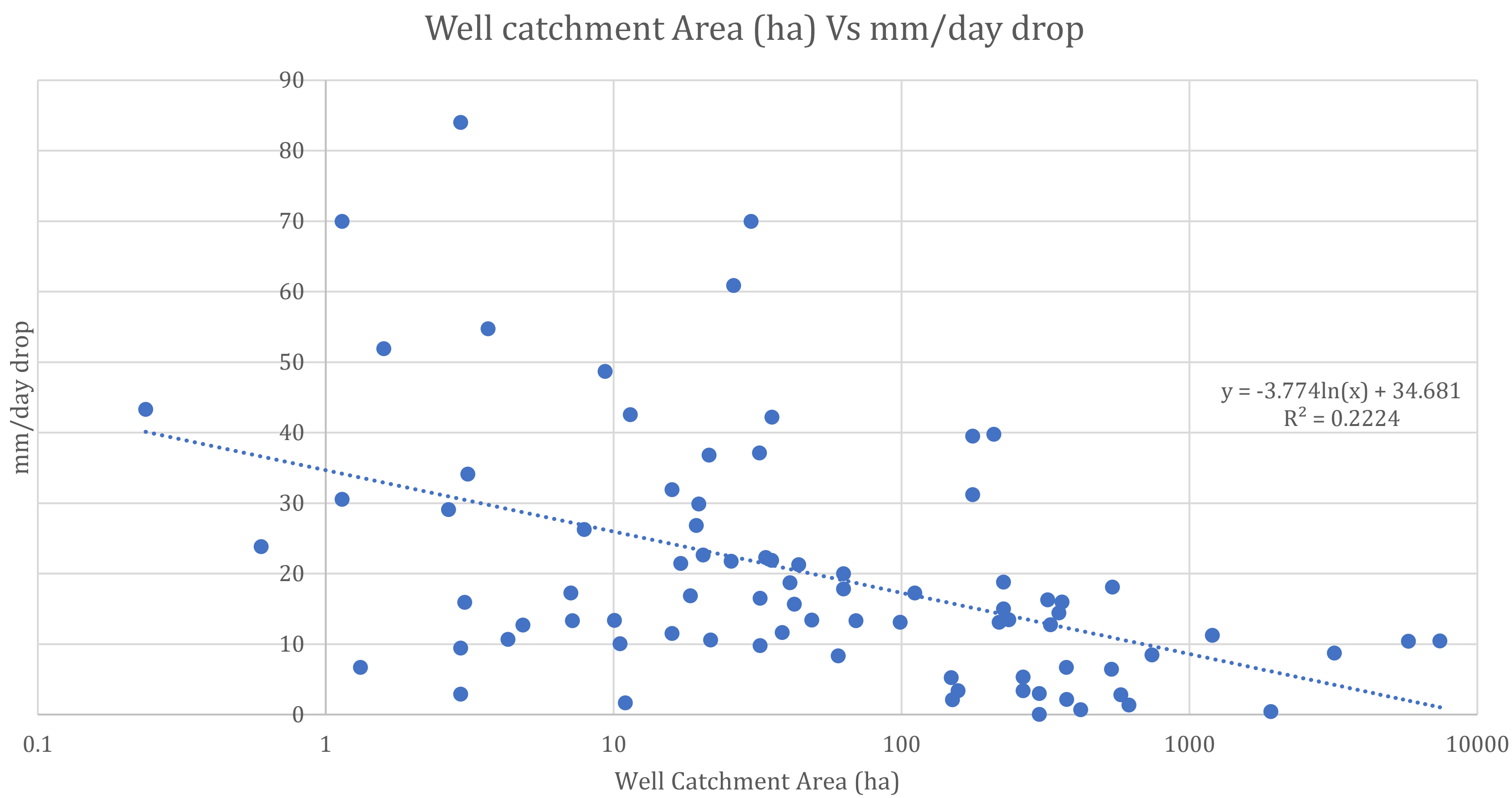
Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Paddy %	Forest%	mean mm/day	Comment
C46	Morhande Orchard	0	2.947	34.375	31.25	2.95	Percolation from upstream farm, good forest cover in catchment, located in flat land
C22	Chas Pada (road side)	0	2.947		40.625	9.47	Farm well, Less used, has good forest cover
D16	Ramkhind DW well	1	264.5	11.69	25.32	5.37	Good forest cover, Percolation tank upstream
D9	Gorpatte	1	1.322	100		6.72	FW,No Load
D21	Chautyachiwad i	1	10.54	13.27	4.42	10.08	One person died drowning, so no DW load, or else drop would have been more
D6	Alimal DW well	1	4.304	8.51	38.29	10.71	Has Good Karwanda Forest Cover with Contour trenches in its catchment
C10	Mordyachapad a	1	7.193	55		13.33	Sub Surface Bund helping to reduce drop rate
D11	Kelichapada in stream	1	48.861	17.89	4.51	13.43	Good Catchment area with moderate load
C20	Chas Pada 1	1	41.067	10.81	34.23	18.72	Good Catchment Area with significant load and has forest cover in its catchment
C5	People tree	2	10.99	69.67	0.81	1.69	No Load, in paddy fields flat land
C3	Roadside before Poshera	2	15.958	47.67		11.54	Flat land, Less load SDW
C1	Naviwadi	2	10.086	32.4	1.85	13.40	In good flat paddy field of a stream, with moderate load
A2	Dongarpada DW	2	3.04	25.8	3.22	15.95	SDW, Dry by 5th reading by constant load
A3	Vanganpada	2	18.499	31.03	21.67	16.87	House hold well in flat paddy field and has good plantation in its catchment
A9	Aine Frog Well	2	7.108	12	9.33	17.30	No load, Washing Clothes Only

Well watershed



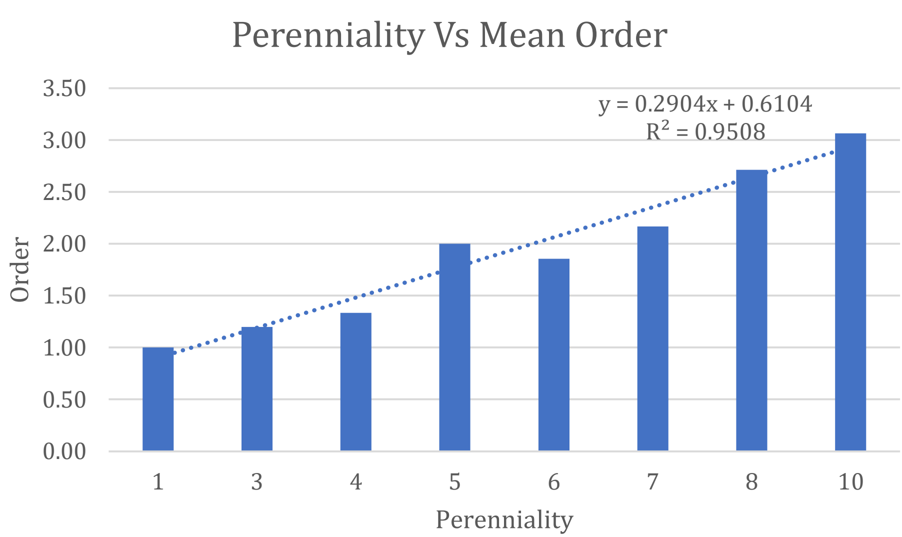


Well watersheds delineated on 3 main watersheds.
Same well watersheds are used for Land cover analysis at well watershed level

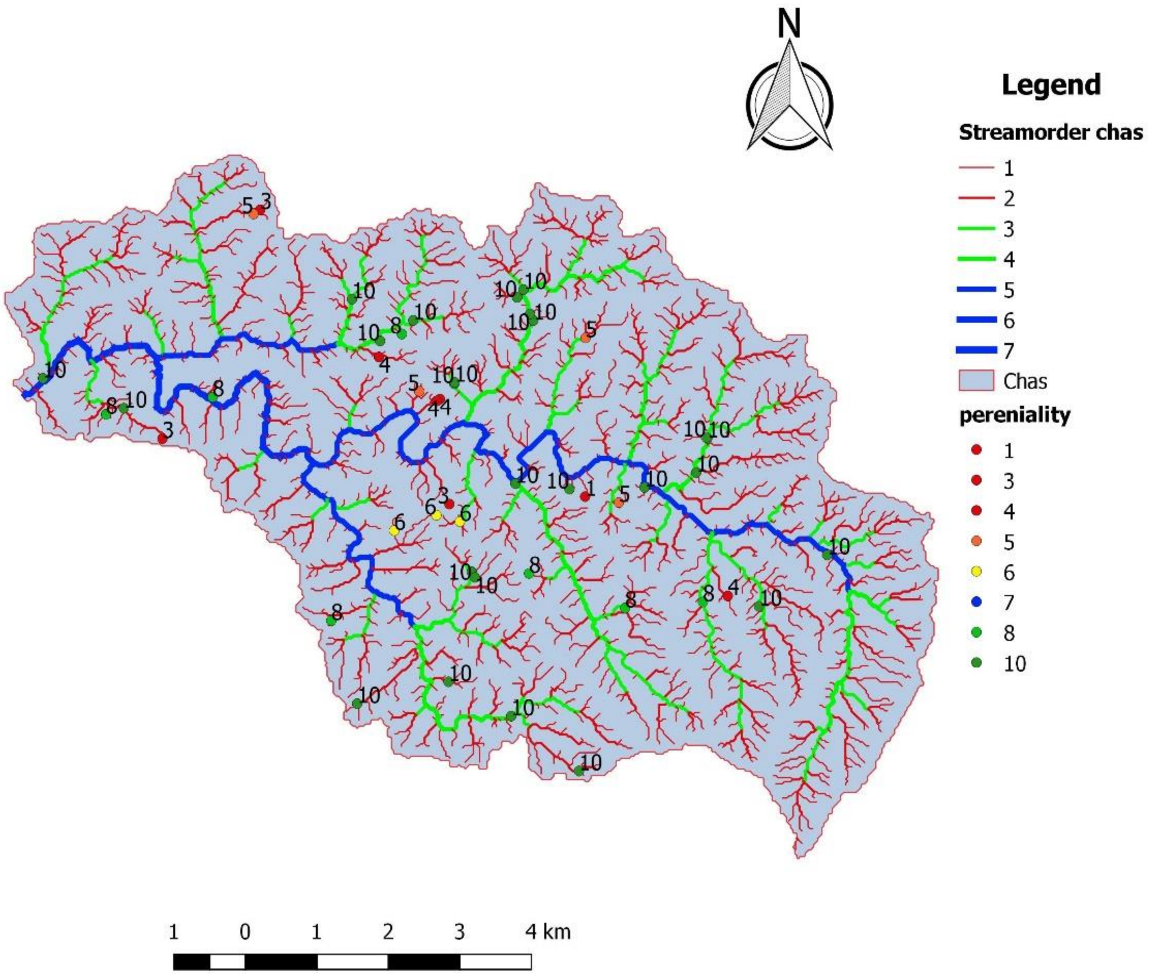

Well catchment Area (ha) Vs mm/day drop
mm/day drop
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
1000
10000
Well Catchment Area (ha)
y = -3.774ln(x) + 34.681
R² = 0.2224

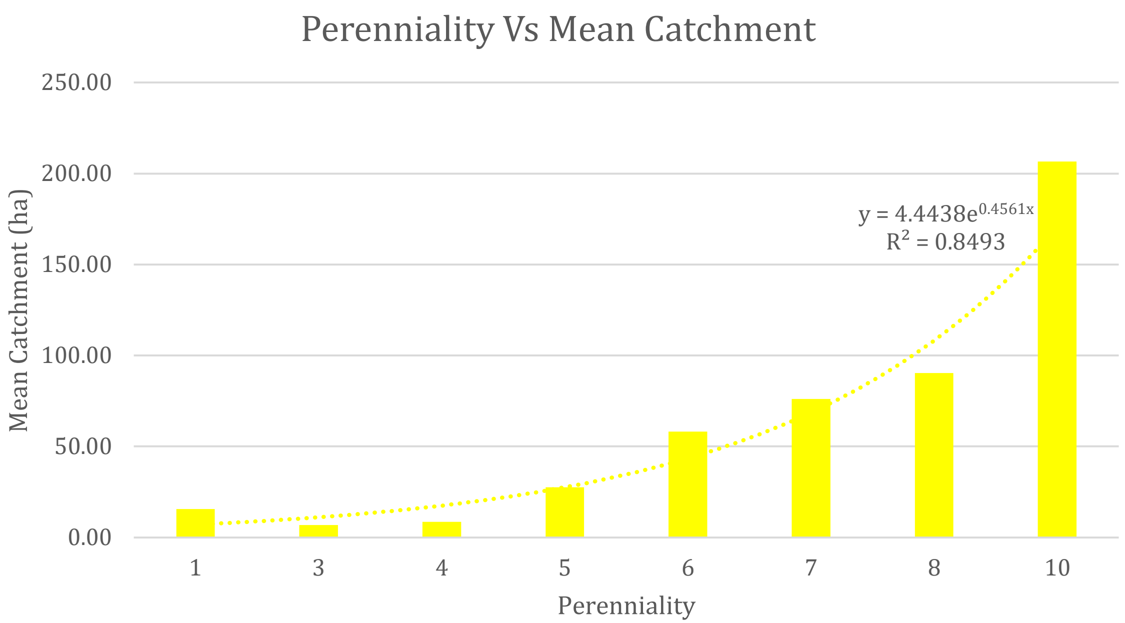
Order, Catchment and Forest cover effect on perenniality

Perenniality Number	Going Dry By	Number of data points
1	December 8th	2
3	January 28th	5
4	February 18th	6
5	March 11th	5
6	April 9th	7
7	May 1st	6
8	May 22nd	7
10	Sustains still June with similar load	45

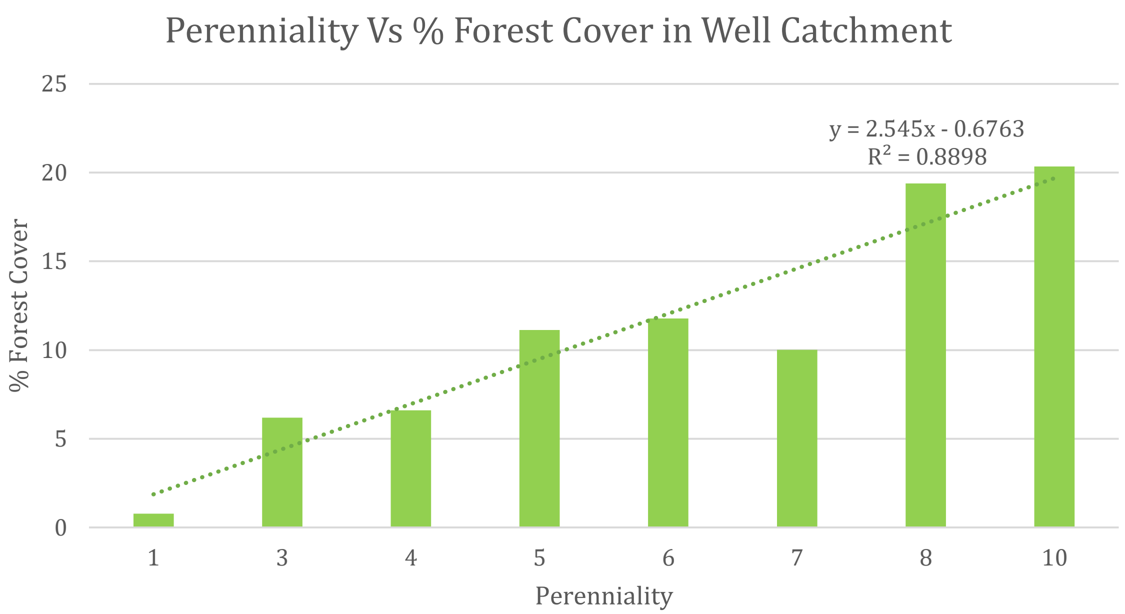


Colour coded order map with perenniality mapped on it

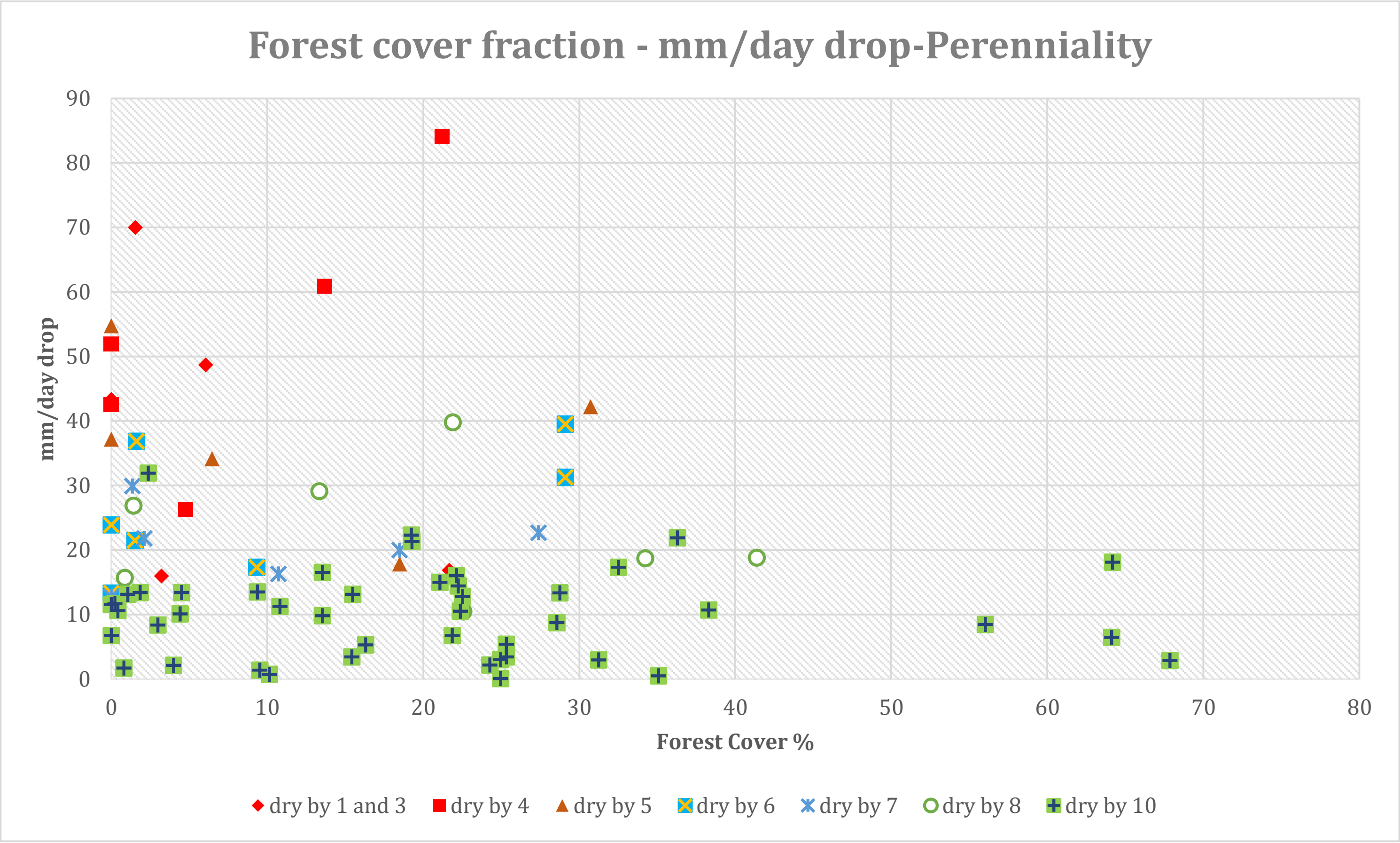




Perenniality Vs Mean Catchment
250.00
200.00
150.00
100.00
50.00
0.00
Mean Catchment (ha)
y = 4.4438e^0.4561x
R² = 0.8493
1
3
4
5
6
7
8
10
Perenniality

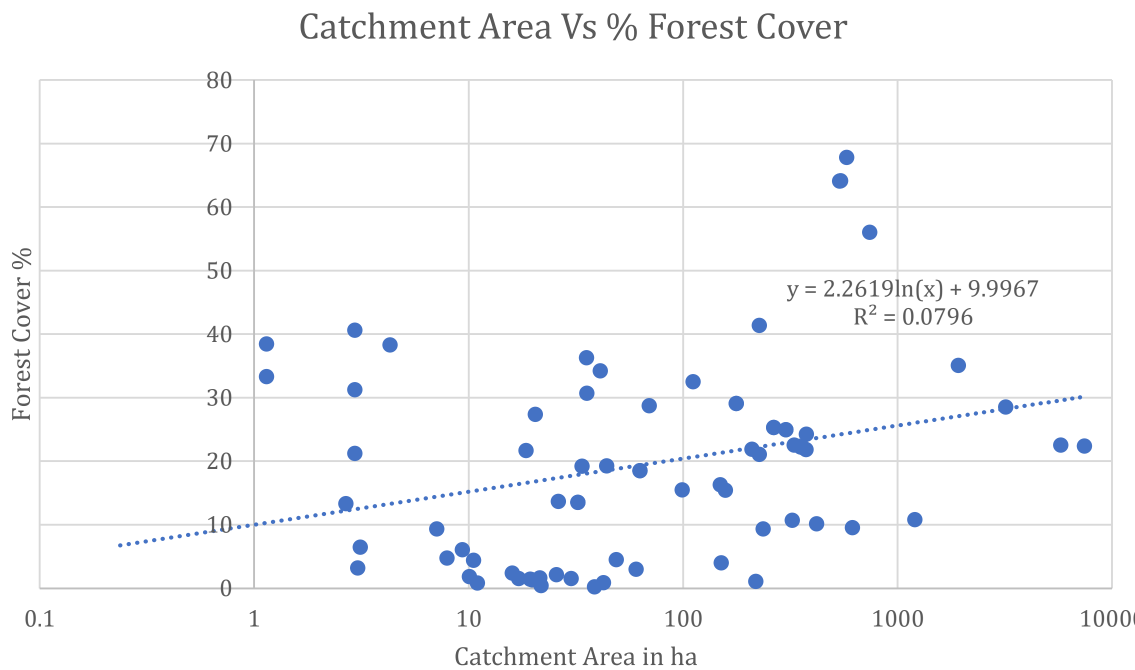


Perenniality Vs % Forest Cover in Well Catchment
25
20
15
10
5
0
% Forest Cover
y = 2.545x - 0.6763
R² = 0.8898
1
3
4
5
6
7
8
10
Perenniality

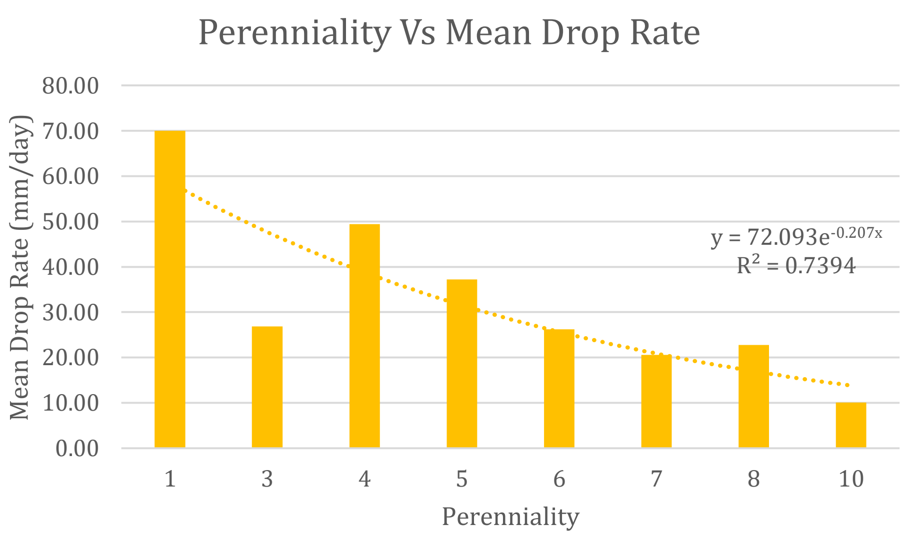


82% of the wells which had more than 19% forest cover in their catchment were perennial

only 6 (18%) wells out 33 wells were non-perennial



forest cover and large well-watersheds, both separately seem to ensure low drop rates and perenniality

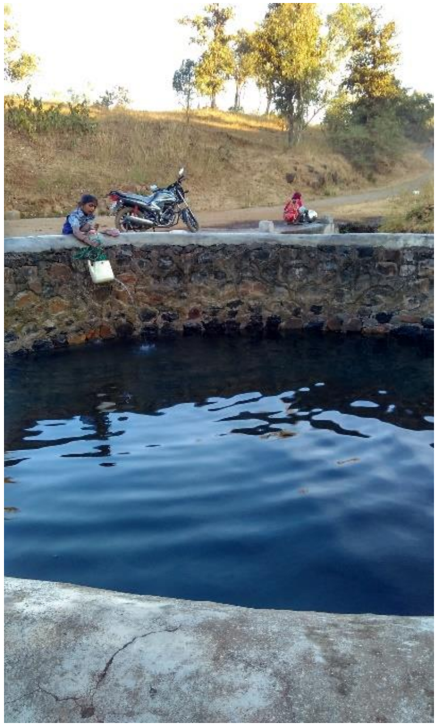


Effect of structural interventions

Sr. No	Location description	Order	Category	Structure	Structure location	perinniality	HH	mean mm/day	Effect Good/Bad
D26	Pathardi DW	3	PDW	CNB	CNB downstream	10	49	5.29	Good
C27	Beriste stream umberpada	4	SDW	CNB	CNB downstream next to well	10	112	15.01	Good
D25	Dohare pada	3	PDW	KT Weir	KT weir upstream	6	49	31.24	Bad
D27	Doharepada DW	3	PDW	KT Weir	KT weir upstream	6	119	39.52	Bad
D15	Ramkhind Ashram Shala Well	4	PDW	Earthen Bund	Earthen Bund Upstream	10	40	3.40	Good
D16	Ramkhind DW well	1	PDW	Earthen Bund	Earthen Bund Upstream	10	193	5.37	Good
C38	Kelichapada	4	PDW	Earthen Bund	Earthen Bund Upstream	10	100	0.08	Good
C39	Tulyachapada	4	FW	Earthen Bund	Earthen Bund Upstream	10		3	Good
C40	Tulyachapada Road Side	4	FW	Earthen Bund	Earthen Bund Upstream	10		2.16	Good
C10	Mordyachapada	1	PDW	SSB	SSB downstream next to well	6	33	13.33	Good/Bad
C43	Brahmangaon New	2	WASHING	SSB	SSB downstream next to well and SSB upstream	5		34.13	Bad
C25	Brahmangaon	2	PDW	SSB	SSB upstream before well	3	150	48.71	Bad
C29	Umberpada Subsurface Bund Well	3	SDW	SSB	SSB Downstream	10	58	13.34	Good
D6	Alimal DW well	1	PDW	CCT + Shrubs	CCT with Shrub Forest upstream	10	30	10.71	Good

CNB

- Wells have very less drop and perenniality is ensured when CNB is built in near downstream of the well and well is within the backwater submergence of the CNB
- Even outside the study watersheds, similar structures built by AROEHAN are helping in securing drinking water sources



- No benefit is found if the structures like CNB are built on upstream of the well

Earthern bunds (tanks)

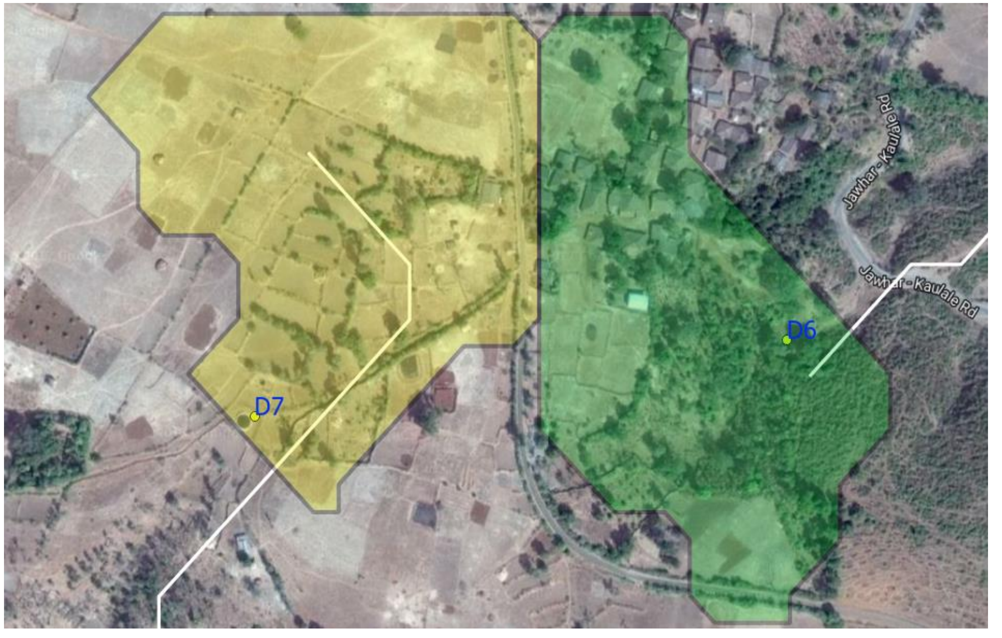
As Seen n the wells downstream Ramkhind earthen bund (earthern bund of storage area of 4.4 ha) (2 wells monitored) and Tulyachapada Earthen Bund (3 Wells Monitored), all were perennial and maximum drop rate was 5.37mm/day with significant load

Sub Surface Bund (SSB)

- As sub surface bund stops/obstructs discharge of subsurface water it increases the net storage of water in well watershed, Downstream subsurface bunds were found to be helpful where as upstream SSBs were found to be less effective

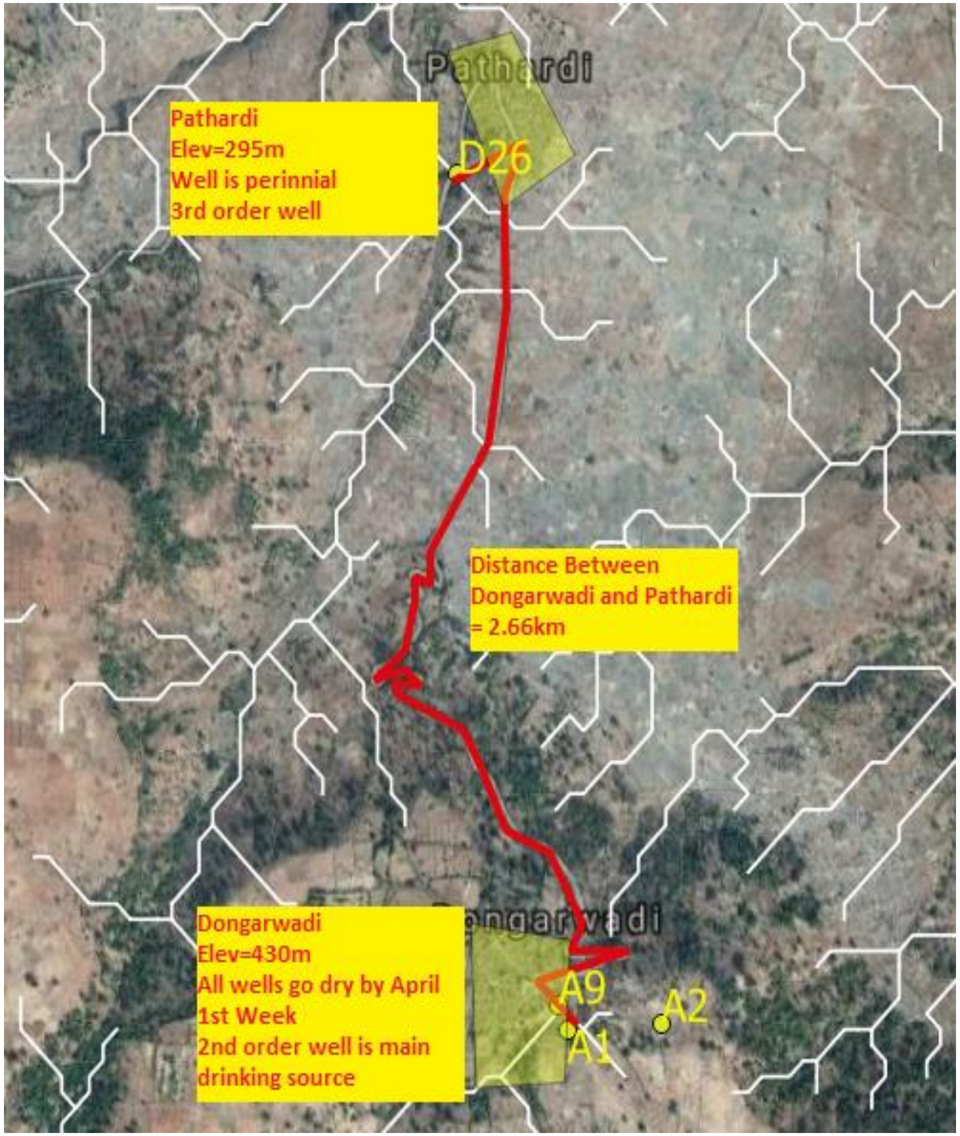
Contour trenches and shrub forest

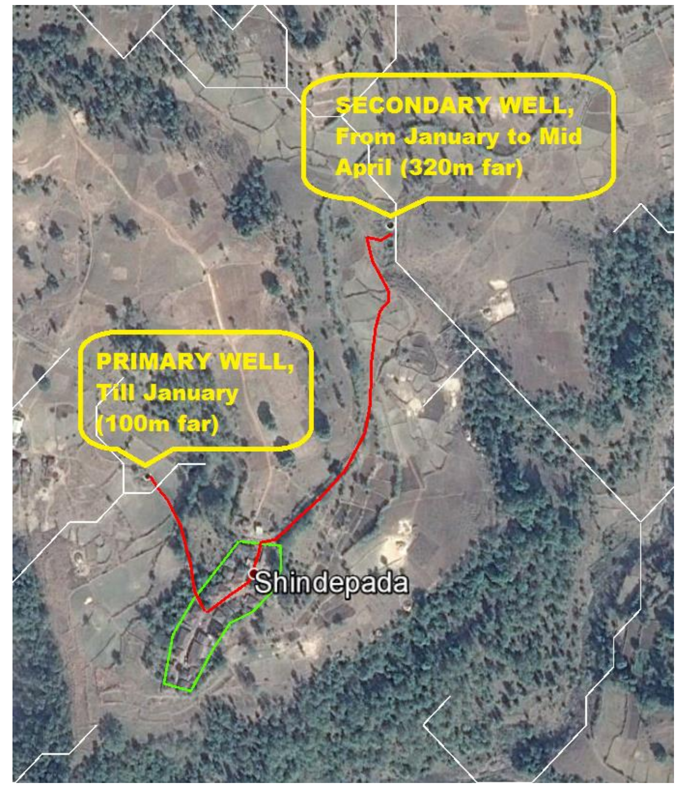
- A micro watershed study comparing two wells on the same kind of terrain with similar sloping land but different land cover one with contour trenches and 38% shrub forest in its catchment area (D6, 4.3ha catchment area) and another with 11% paddy land and remaining grassland with no forest cover (D7, 4.8ha catchment area)



The D6 well (Alimal DW) is perennial with 20 households depending on it, and D7 (Alimal Non DW) goes dry by beginning of April. D6 has 1 m extra soil thickness than D7 well

Movement of people for water in summer months (few examples)





Conclusions

- GEC methodology needs to be modified to incorporate local factors in Jawhar and Mokhada i.e., much higher baseflows.
- Observation well water levels in Jan and May (already monitored by GSDA) can also be incorporated in the water balance to capture temporal variation.
- The combination of well-levels and flows taken together also seem to indicate that soil-moisture as a stock and evapo-transpiration as a flow, are important to the understanding of regional water availability.
- Forest cover and large well-watersheds, both separately seem to ensure low drop rates and perenniality. This indicates benefits of area treatment.
- Drainage-line watershed interventions seem to help in extending well water availability. However, a more detailed analysis is required.

Scope for future work

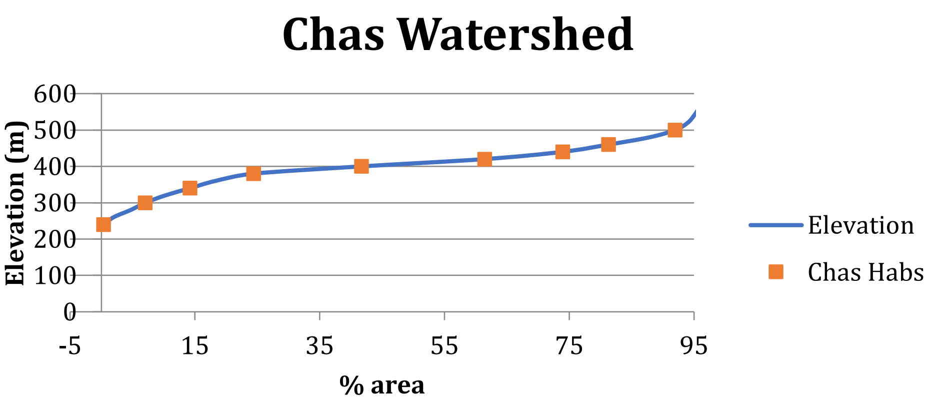
- Estimation of on field evapotranspiration rates will help to understand the system better and do better water balance.
- Better analysis of stream flows into its components, i.e., groundwater flows and seepage from soils, would be useful to understand the impact of afforestation and area-treatment watershed activities.
- Specific Yield Estimation using Well Hydrograph (by continuous monitoring of wells) and other Specific Yield determination methods can be tried in the study region (Lisa Shevenell, 1996) (Udayakumar G, et. al., 2015).
- ET load estimation and Seasonal change in ET load can be can be tried using surface energy balance method (Using MODIS remote sensing data) (Mark E. Savoca, et. al., 2013).
- People Narrative about the reduction of forest cover over years and decrease in water availability draws focus. There is good scope to analyse the forest cover change (decadal) in the study area and study the water availability in past decades considering changing demography.

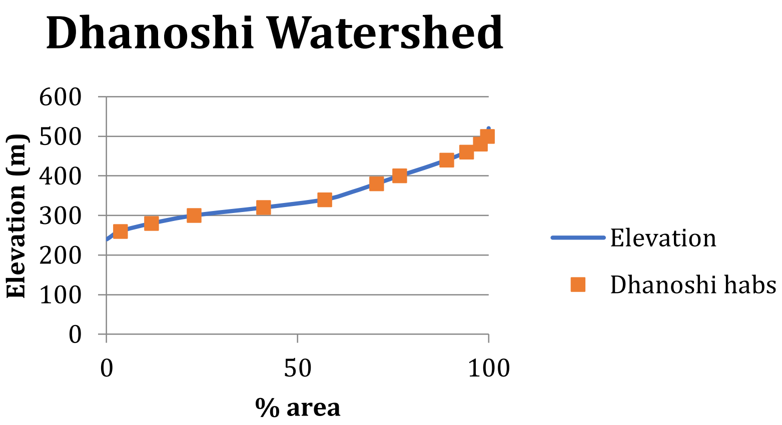
Thank You

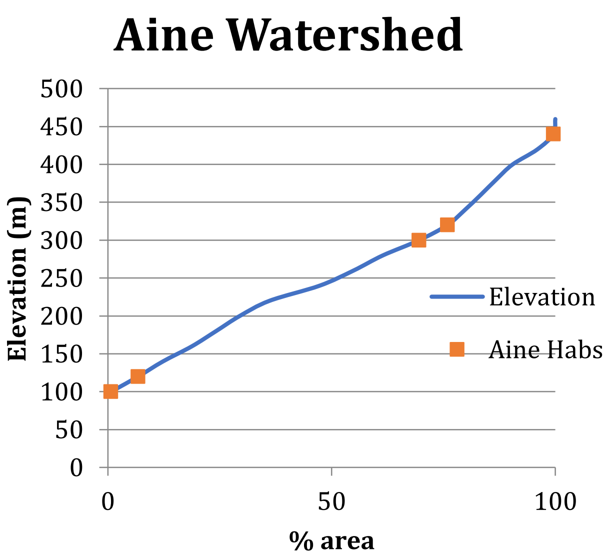

Thank You

Other analysis tried

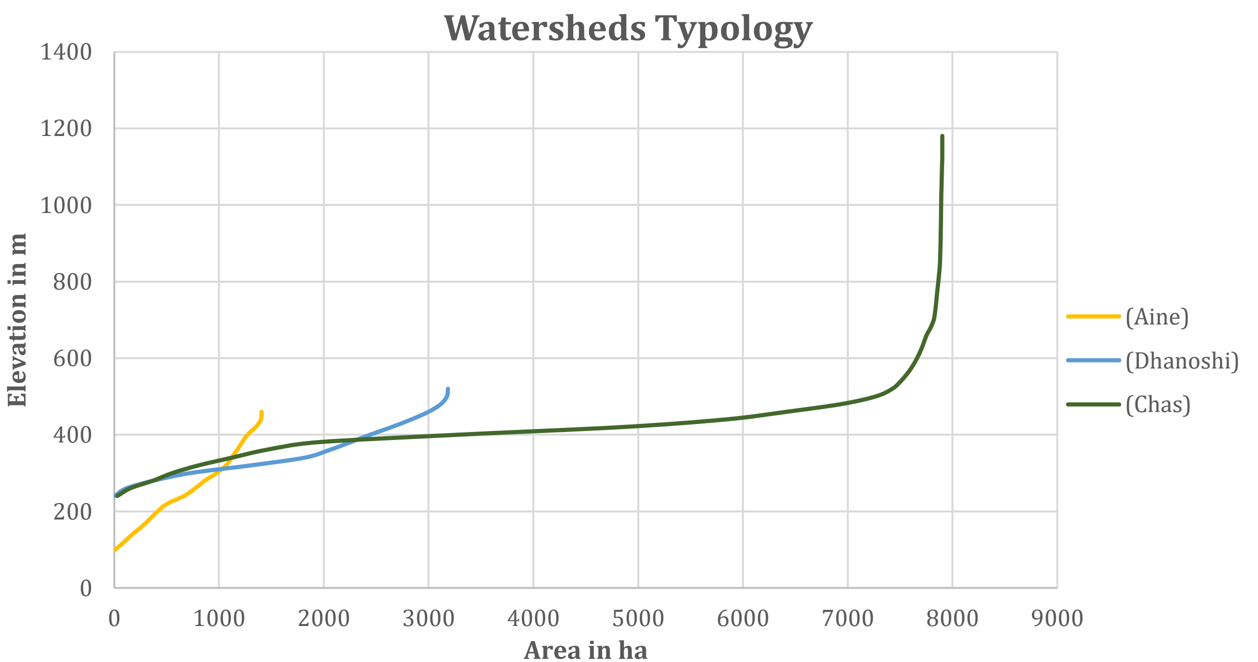
Watershed Typology and stress mapping



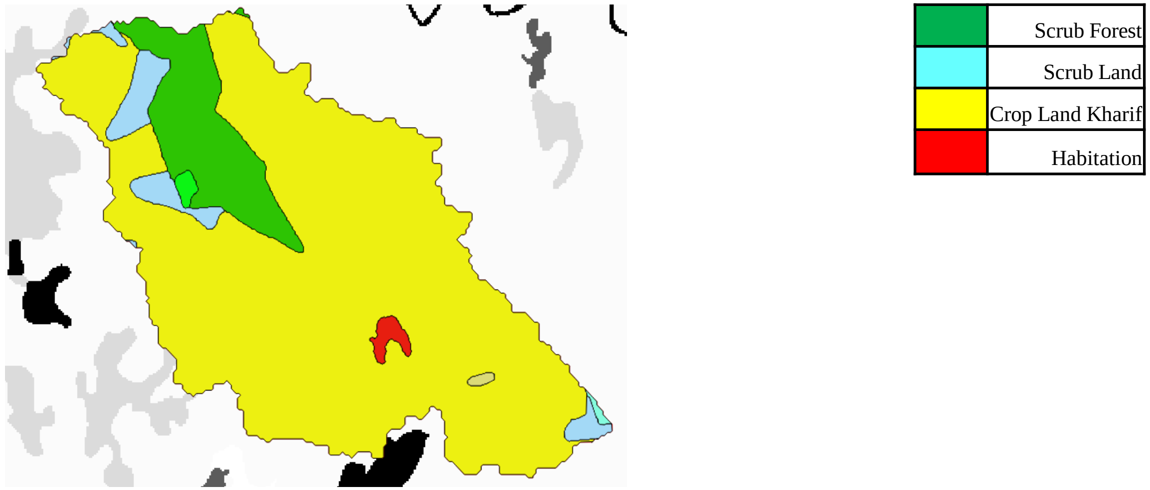




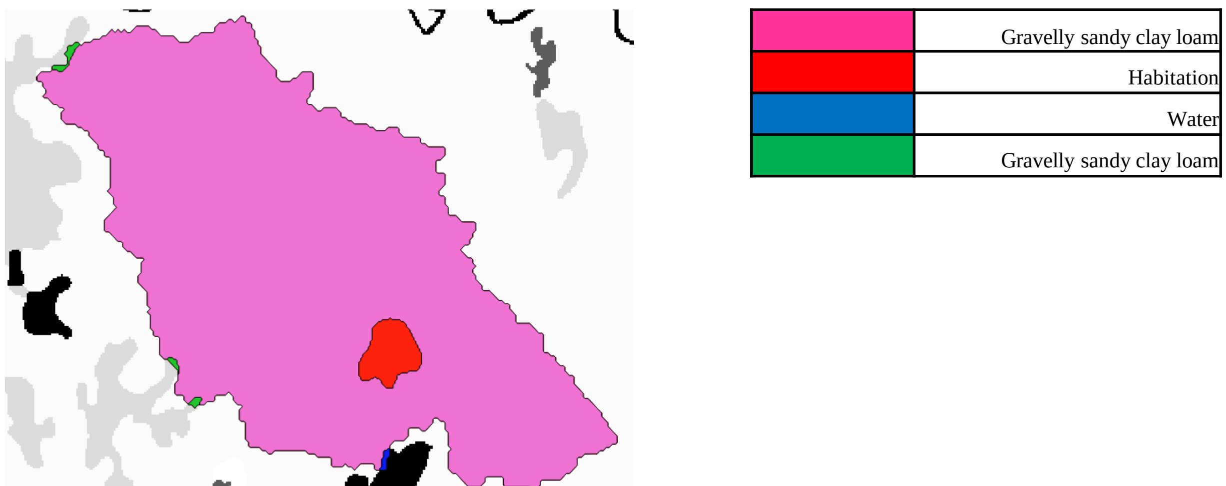

Aine Colour Coded
Elevation
Aine Habs Not stressed
Aine Stressed Habitation
Elevation (m)
% area
0
50
100
150
200
250
300
350
400
450
500
0
20
40
60
80
100


Watersheds Typology
Elevation in m
Area in ha
(Aine)
(Dhanoshi)
(Chas)
0
200
400
600
800
1000
1200
1400
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

Complete water balance using Curve number



LULC classification of Poshera watershed (MRSAC)



Soil Type of Poshera watershed (MRSAC)

Annual water balance using curve number

Total Rainfall in Mokhada Region = 2530.9mm (in 2016)

Direct Runoff = 1590.71

Water available excluding direct runoff = 940.19 mm

$$Water\ available\ excluding\ Direct\ runoff\ = Baseflows\ during\ monsoon + Baseflows\ after\ monsoon + ET\ load\ during\ monsoon + ET\ load\ after\ monsoon$$

Baseflows during monsoon = 494 mm

As this method does not include the effect of slope in it, it is discontinued.

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Key Observations in GSDA

- In the studied watershed, groundwater balance is carried out as per GEC methodology (using water level fluctuation) i.e. using well levels monitored by GSDA, specific yield and area norms as per GSDA, except the natural discharge component which is measured at the outlet of sixteen watersheds during dry season.
- According to GEC methodology 90-95% of the of the total recharged groundwater (Calculated by GEC Methodology) is available during the whole dry season, which does not reflect reality. The reason as per GEC methodology is 1. Very less draft (Which is true) and 2. Very low natural groundwater discharge (which is contested).
- The measured natural discharge (base-flows) showed that around 69% of recharged water (as per GEC methodology) has left the watershed as baseflows by January end**.** This suggests that for hilly areas of Western Ghats, incorporation of a seasonal groundwater assessment will inform the administration about the ground situation which is likely to unfold in the summer months.
- GEC does not have a temporal component in water balance. The water availability is estimated at the end of monsoon and draft is numerically subtracted which does not reflect temporal reality.
- Though the study area comes under safe watersheds according to GSDA's stage of development (5-6%), it is clear why the people here are facing acute water problems in summer months.
- The flows in the early months post monsoon (October-November) are greater than what can be attributed to groundwater drop alone. This indicates that the excess must have come from seepage from soil moisture held in the top few meters of the surface.

Suggestion to GSDA

- While it is difficult to have stage measurement at all small watershed level at all times, (due to economic constraints), one-time studies of all watersheds to capture key parameters such as half-times, afforestation fraction, soil-moisture vs. Groundwater fraction of stream flows. This would be helpful in yearly planning as well as in long-term monitoring of the health of watersheds.
- Observation well water levels in Jan and May (already monitored by GSDA) can also be incorporated in the water balance, so that, it will show how water availability decreases with respect to time.

Limitations of Present Study

- Baseflow measurement immediately after monsoon was not done, this should be taken care for further studies of this kind for more accurate measurement of baseflows.
- As we see the baseflow out column in our estimation table, Dhanoshi North, Dhanoshi Northwest and Aine west's baseflow exceeds the recharge (calculated as per GSDA methodology), this might be because of the error in the recharge calculation, as we exclude hilly areas from recharge calculation, it might be a case where hilly slopes with good forest cover might have contributed to recharge, which is not considered.

Key Observations ET and Soil moisture

- It was observed that wherever the forest cover is good in the well watersheds, these wells have been perennial. Since, the natural forest roots were found to go as deep as 3-6 metres, creating a pathway for more water to infiltrate they create more space to store water. On the other hand, more forest cover does lead to more evapotranspiration load and less natural discharge of water (like in the form of baseflows). Thus, afforestation does increase local access to drinking water but may not contribute to bulk-water availability such as for rabi irrigation.
- The baseflows ceasing early in the dense forested watersheds (Aine) do explain this phenomenon.
- It is also observed that trees/shrubs help in reducing soil erosion and keep the soil intact.
- The flows in the early months post monsoon (October-November) are greater than what can be attributed to groundwater drop alone. This indicates that the excess must have come from seepage from soil moisture held in the top few meters of the surface.

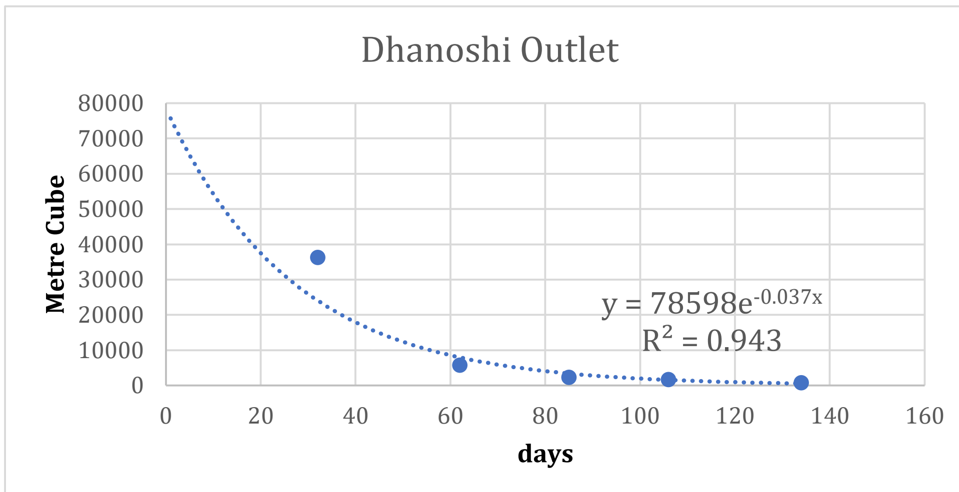
Limitations of present study

- As the current study completely done by assuming Evapotranspiration rates from existing literature, it may not match the true rate.

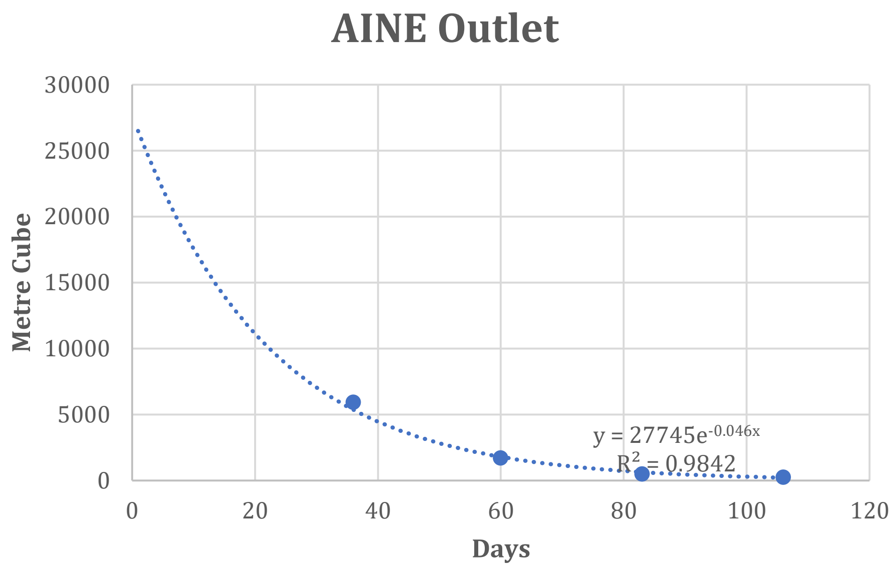
Key observations from well analysis

- It was observed that most of the wells in the stream of order 3 or above were perennial
- Wells which are in lesser order but performing well had good forest cover in their catchment or had very less load
- Well watersheds seem to be an important determinant of perenniality. Thus, as in spring-sheds, well-sheds too deserve a systematic study, especially while proposing new locations. (82% of wells having more than 19% of forest cover were perennial)
- Post Monsoon Horticulture aspirations and growing mogra (jasmine) look to be unsustainable (using well water for irrigating them, when drinking water source is going dry). But growing trees like mango and cashew looked to be more sustainable (they need to be watered for first one or two years only) and in fact helpful in holding more water in sub surface.
- Rural Drinking Water supply norms (availability of funds per capita) is a hurdle for selecting the sustainable drinking water source for ridge hamlets, where the scope for area and drainage treatment is very less.

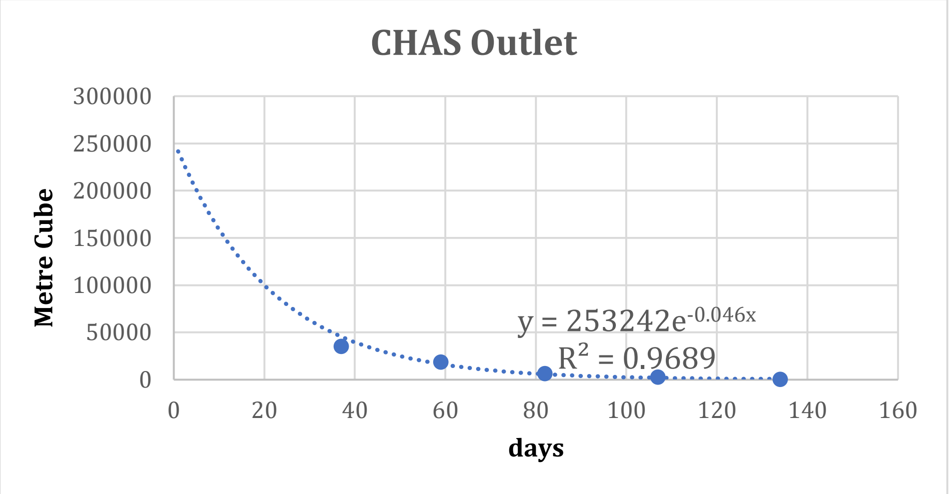
Back up slides



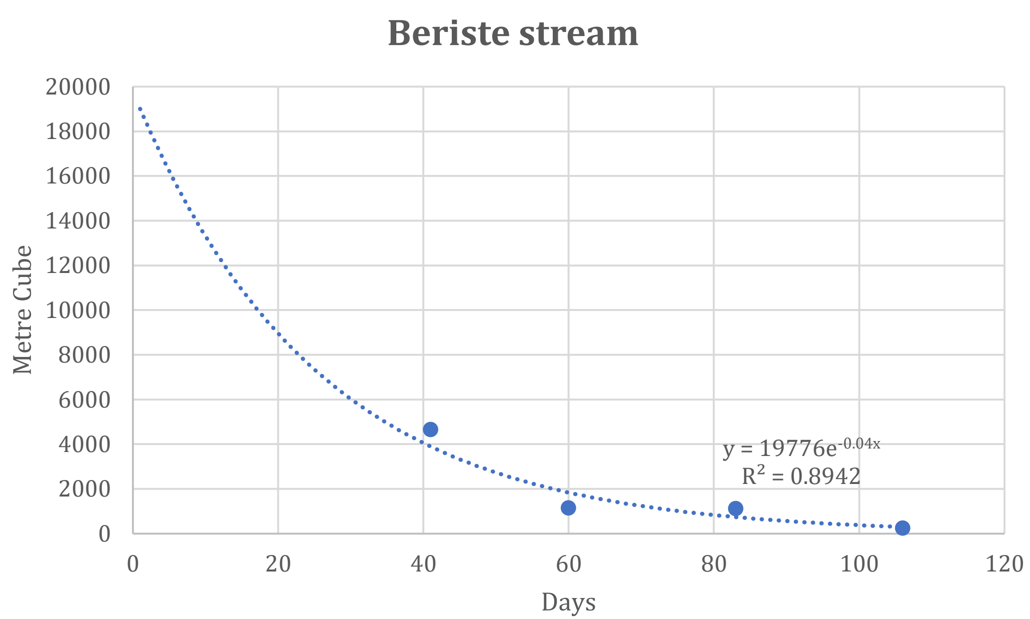
$$\int_0^{134} 78598\mathrm{e}^{-0.037\mathrm{x}} dx \; = 210.93 ham$$



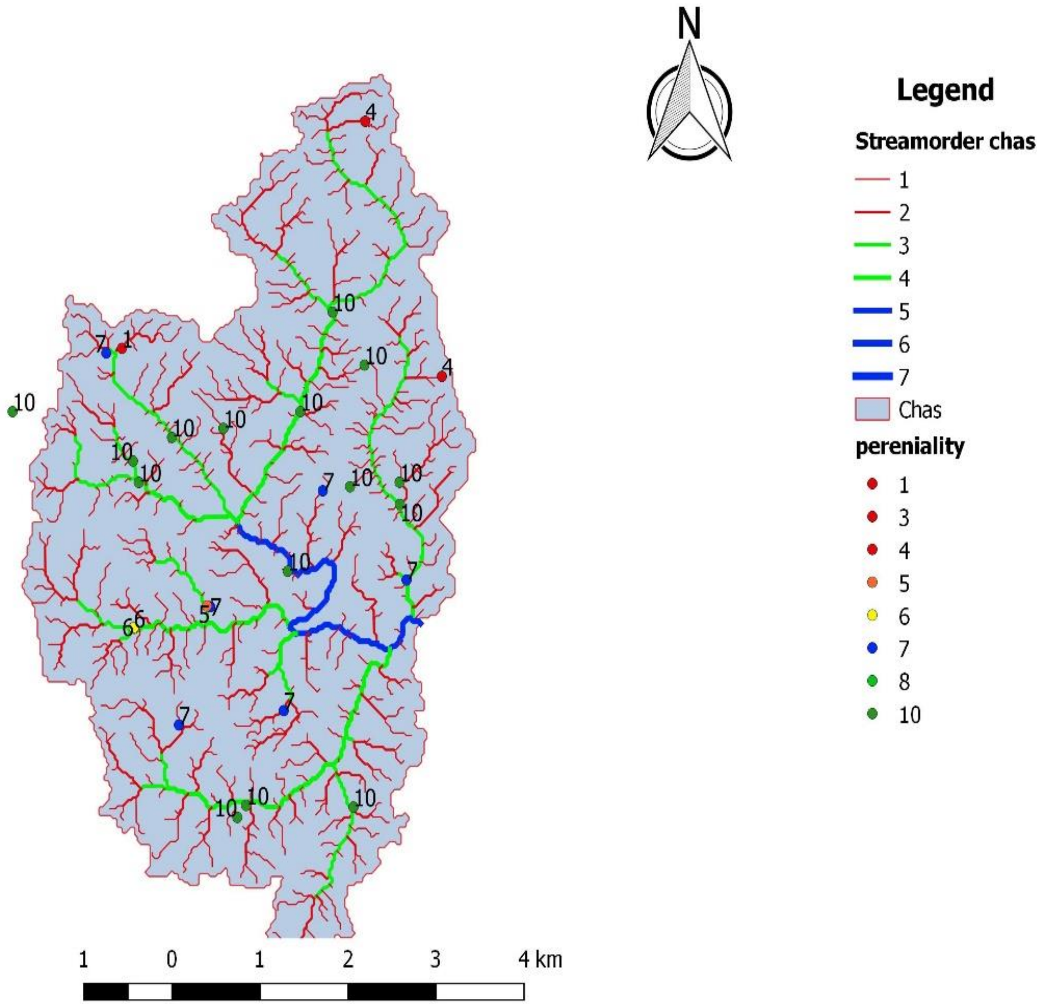
$$\int_0^{106} 27745\mathrm{e}^{-0.046\mathrm{x}} dx \; = 59.86 ham$$



$$\int_0^{134} 253242\mathrm{e}^{-0.046x} dx \; = 549.37 ham$$



$$\int_{69}^{99} 19776\mathrm{e}^{-0.04\mathrm{x}} dx \; = 21866.64 \; cubic \; metre$$


N
Legend
Streamorder chas
1
2
3
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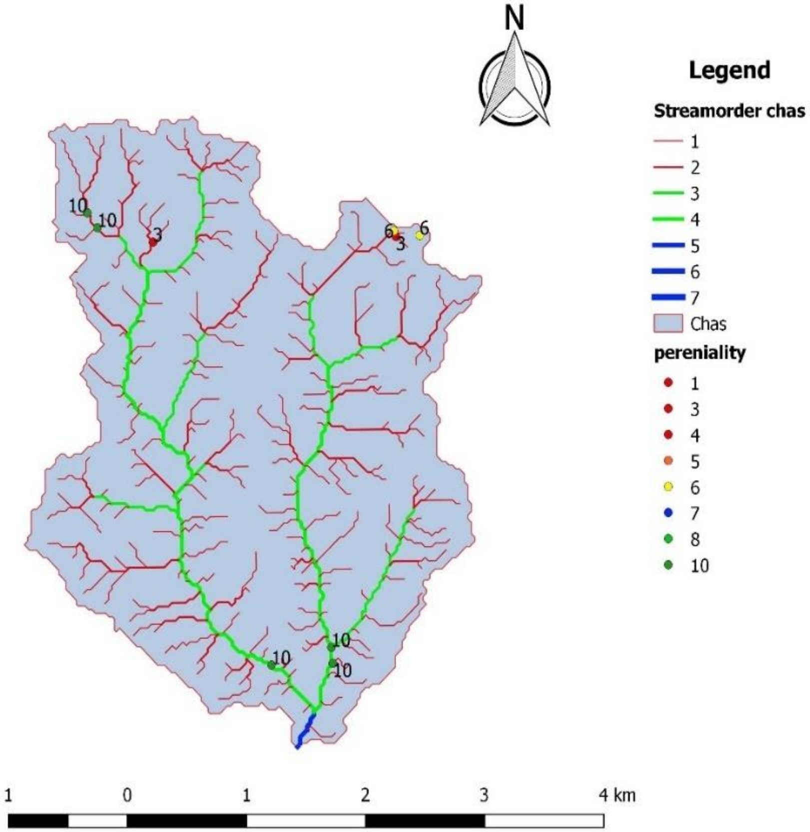
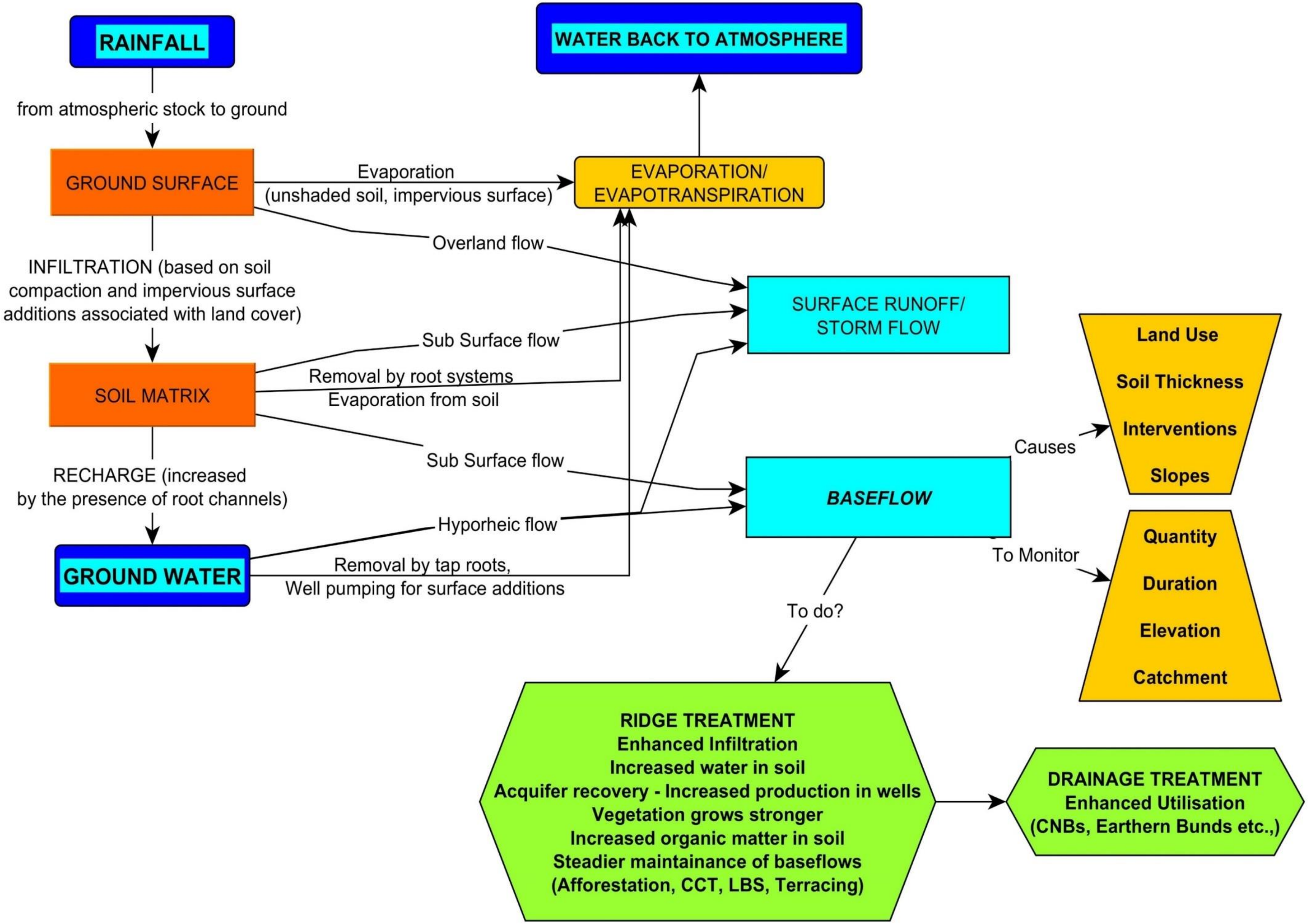
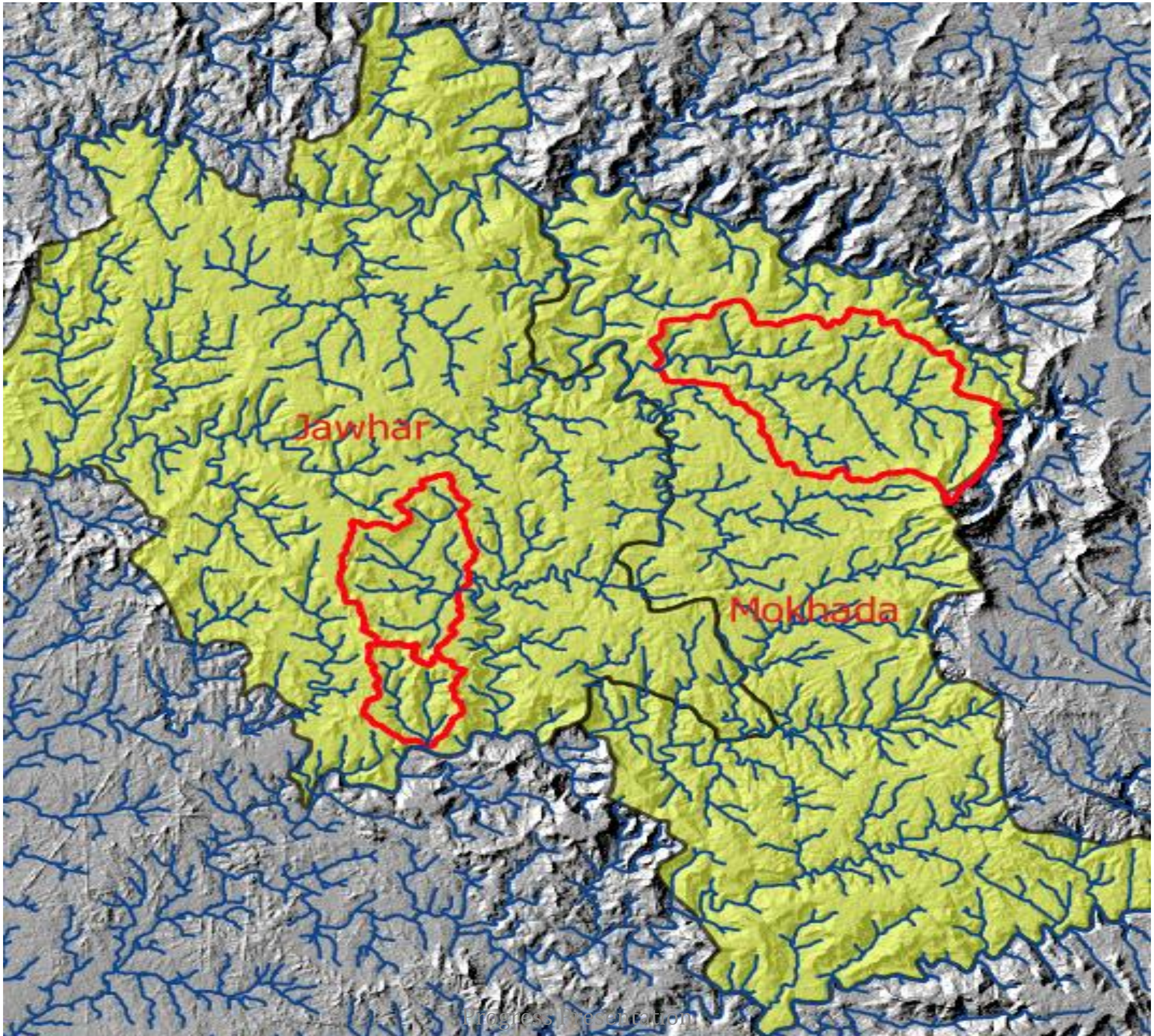
5
6
7
Chas
pereniality
1
3
4
5
6
7
8
10
1
0
1
2
3
4 km


N
Legend
Streamorder chas
1
2
3
4
5
6
7
Chas
pereniality
1
3
4
5
6
7
8
10
10
10
3
6
6
3
10
10
10
1
0
1
2
3
4 km



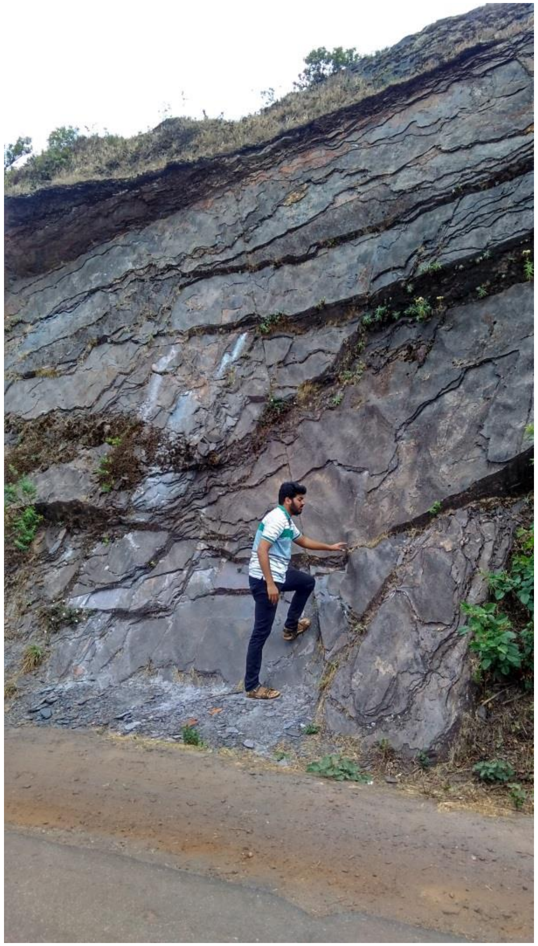
Conceptual Model

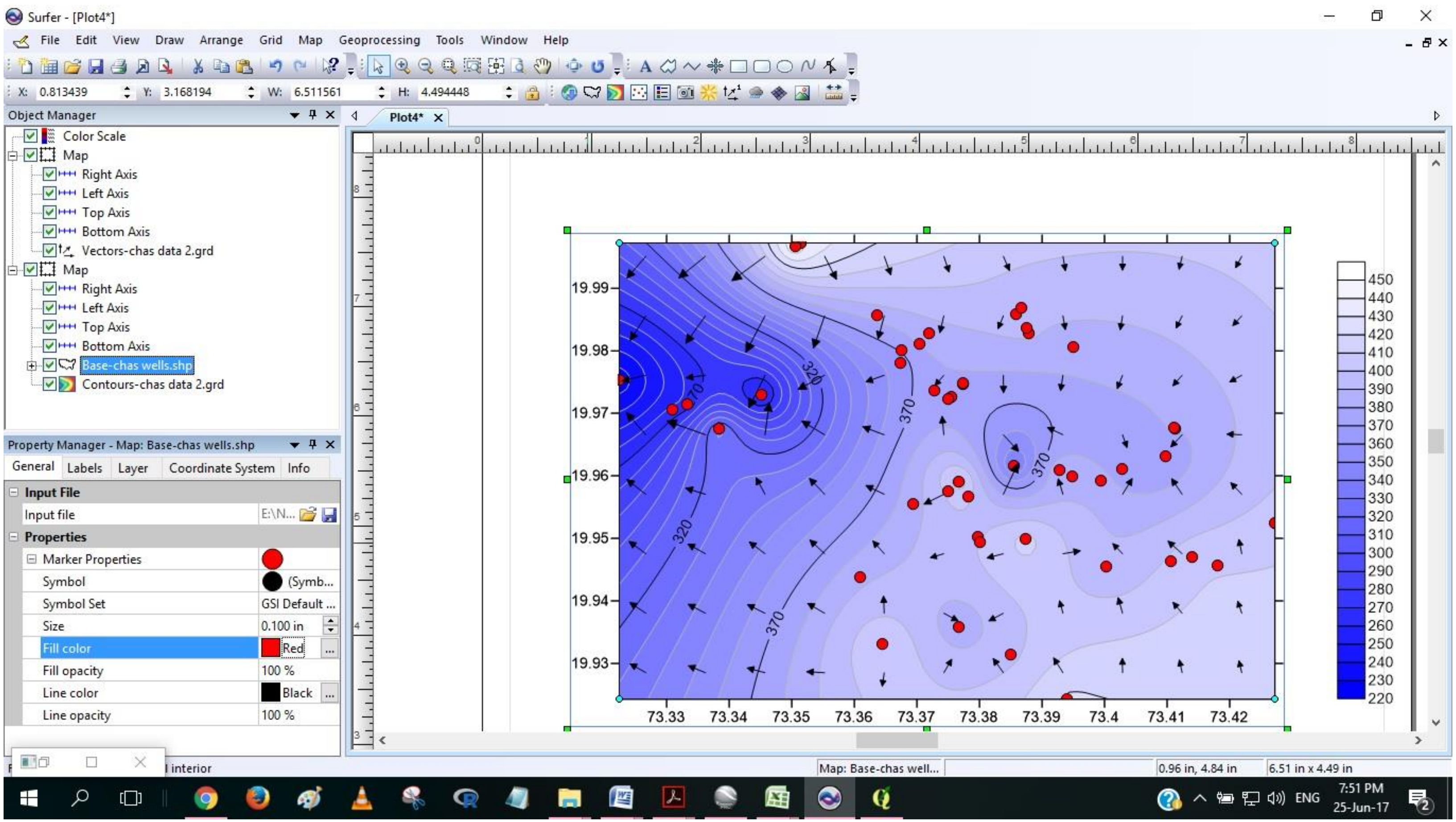

Jawhar
Mokhada

Watershed Activities done by different Departments in JYS

Watershed Activities by Different Departments					
Department of Minor Irrigation		Department of Agriculture		Forest Department	
Drain line Treatment	Area Treatment	Drain line Treatment	Area Treatment	Drain line Treatment	Area Treatment
Pukka Bunds	Village Ponds	CNB	CCT	CNB	Vanikaran
KT bunds	Recharge Ponds	ENB	Terracing	Gabion Bunds	Tree Plantation
Pukka Bund Repair	Village Pond Repair	Diverted Bund	Juni Bhaat Sheti	Forest Bund desilting	Samtalchar
KT bund repair	Recharge Pond Repair	CNB Repair	Horticulture		Forest Ponds
Concrete Nala Bund		ENB Repair	Tree plantation		LBS
		ENB Desilting	Farm Ponds		
		CNB Desilting	LBS		
			Farm Pond Repair		

Source: JYS infrastructures





Surfer - [Plot4*]
File Edit View Draw Arrange Grid Map Geoprocessing Tools Window Help
X: 0.813439 Y: 3.168194 W: 6.511561 H: 4.494448
Object Manager
Color Scale
Map
Right Axis
Left Axis
Top Axis
Bottom Axis
Vectors-chas data 2.grd
Map
Right Axis
Left Axis
Top Axis
Bottom Axis
Base-chas wells.shp
Contours-chas data 2.grd
Property Manager - Map: Base-chas wells.shp
General Labels Layer Coordinate System Info
Input File
Input file E:\N...
Properties
Marker Properties
Symbol (Symb...
Symbol Set GSI Default ...
Size 0.100 in
Fill color Red
Fill opacity 100 %
Line color Black
Line opacity 100 %
Plot4*
19.99
19.98
19.97
19.96
19.95
19.94
19.93
73.33 73.34 73.35 73.36 73.37 73.38 73.39 73.4 73.41 73.42
320
370
450 440 430 420 410 400 390 380 370 360 350 340 330 320 310 300 290 280 270 260 250 240 230 220
Map: Base-chas well...
0.96 in, 4.84 in
6.51 in x 4.49 in
ENG
7:51 PM
25-Jun-17