Water Allocation Methodology

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The objective of this document is to provide a water allocation framework that would enable spatio-temporal mapping of access and aggregate availability to demand side cropping patterns based on two main variables -

1. Seasonal water access in different forms
2. Crop hierarchy considering its water demands and market returns

The purpose of developing this methodology is to provide a mapping of water allocation to farms to enable provision of better planning advisory as well as estimation method for critical project development indicators such as water productivity.

The water allocation methodology will be developed by studying farmer irrigation practices and seasonal water access in different zones for selected villages in project area. Criteria will be decided to categorize the water accessibility from different interventions, and categorize the crops based on their watering demands/risks and returns. Norms will be overlayed to quantitatively estimate the water availability in different categories at spatial and seasonal level. These criteria and norms will be delineated based on existing water balance outputs, well surveys, watering practices in village and marginal returns.

This framework will be fixed at farm level and then scaled up to village level or cluster level by designing a watershed based sampling methodology for same. Survey tool will be used for this purpose. Data for well surveys and watering practices will be gathered through primary survey whereas data to compute marginal returns may be secondary. The secondary data sources will be investigated for this purpose and data source for computation of market returns will be fixed.

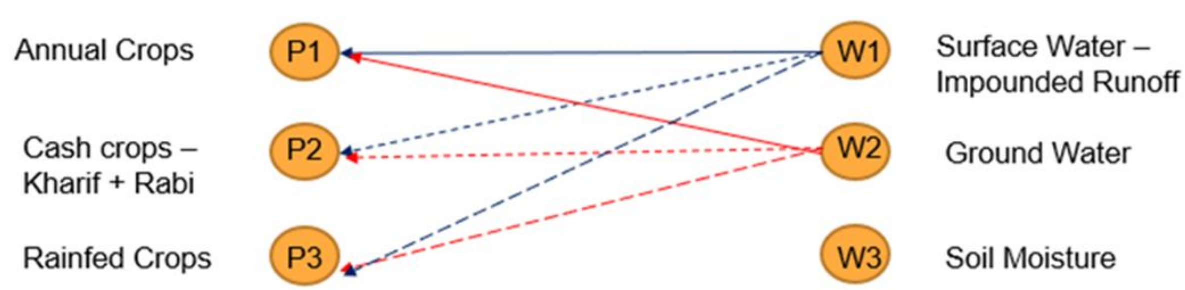


Fig 1: Mapping of water access

Figure 1 shows a possible framework for the categorization of supply and demand side. This is illustrated below -

1. **Estimation of water access**

The water access is assumed here to be from three components

- W1 - surface water which is available from impounded runoff or lift from stream proximity comes under W1 category. Surface water is mainly available from drain line interventions like Cement Nala Bunds, K.T Weir, runoff based inlet-outlet farm ponds. This water is available from

runoff during 4 months of monsoon period June to September for kharif cropping season and its availability goes on declining after that, during rabi season. Hence management of runoff during monsoon is very essential for W1 water availability in post monsoon.
- W2 - Groundwater from wells or borewells or percolation from runoff impounding structures comes under this category. Groundwater availability depends on rainfall pattern as well as bio-physical parameters of the region. It also varies seasonally and is not guaranteed. This allocation is to be studied at regional level within the village to access and allocate seasonal availability in near stream, away from stream, upstream and downstream regions within village.
- W3 - Soil moisture available from improved agriculture practices like compartment bunding, levelling, cropping pattern management estimated through water budget is considered in this category. It is observed during farmer surveys that rabi crops like gram taken after short kharif crops like moong require one watering less as compared to those taken after soybean, this is due to more amount of soil moisture available after short kharif crops. This practice is also a type of cropping pattern management which gets accounted in water budget.

2. **Estimation of crop hierarchy**

The crop hierarchy is set up considering the farm level irrigation practices, market risks and returns for the crops. It depends on farmer's decision making factors for planting a particular crop in his farm and to water a particular crop from among the sowed crops. The factors affecting farmer choice are market returns, input investment costs and watering risks which depend on seasonal water availability in farm and seasonal crop water demand. The crop hierarchy basically depicts the preference of watering for crops by farmers.

With this background various factors for categorization of crop hierarchy are illustrated below -

a. Watering requirement risks - This risk depends on water demand schedule for crops and seasonal water availability
b. Market returns and economic risk - Marginal profit per hectare on crops and investment risk

Based on above factors the categorization can be done as follows -

- P1 - high risk-high return horticulture crops like orchards come under this category. These crops are high investment crops which need regular waterings all year round. Farmer suffers huge losses in case of failure. These can only be taken by farmers who can arrange for water throughout the year or those having capacity to bear the losses in case of failure due to drought. As the economic input investment in these crops is high, the watering demand is throughout the year and cannot be guaranteed in indian monsoon, and the market value is flexible these crops have high investment risks and get the first preference for watering by the farmers. Due to this the watering requirement for these crops is considered as compulsory load in the village water budget.
- P2 - These are the crops which have medium risks-high returns eg. small vegetables which can be taken multiple times in a season but have much fluctuation in market rates. The return for these crops depend on market rates. Wheat, groundnut can be other examples. Cotton, soybean, Tur are more resilient examples in this category which give some yield in rainfed cases and higher yields in irrigated cases. So P2 crops can be said to consist of two subclasses. Subclass 1. Which need regular waterings and comparatively higher investment than other subclass. Vegetables, wheat,

groundnut etc. come under this subclass 1. Subclass - 2. Which are more resilient and provide higher yield if given 1-3 waterings. Cotton, tur are examples in this subclass. Farmers usually choose to irrigate P2 crops over P3 crops, as they give better market returns. In general P2 crops have lower economic investment than P1 crops and so have lower investment risks. These shorter duration seasonal P2 crops also have lower watering risk as compared to annual crops in P1 category due to their seasonal nature.

- P3 - The low risks-low returns rainfed crops mainly cultivated for subsistence fall in this category. Maize, bajra, jowar can be the examples for this. In case of failure these are also used as fodder for animals. In case of good yield they are stored for usage and surplus is sold to market. Farmers with no water sources for irrigation usually take up only P3 crops or more climate resilient P2 crops. These require lower input economic investment than P2 crops, do not have much market returns and so have the last preference for watering. So watering demand for P3 crops is considered as ignored or discretionary watering demand in village water budget.

This categorization allows us to classify the compulsory and discretionary water demand at individual and village level. Based on this the available water is allocated to P1, P2 and P3 crops. This allocation methodology will allow scenario analysis for different cropping patterns and rainfall year. This analysis will help develop advisory such as maximum allowed P1 crop area in village, number of wells, farm ponds etc.

The water allocation framework design will consist of -

1. Cropwise - input cost, market value, profit, seasonal watering requirement per hectare.
2. Water availability - W1, W2 and W3 water availability in season
3. Norms for water allocation
4. primary and secondary datasets required for above points.

This water allocation framework will be used for planning as well as indicator measurement.

Indicator Measurement Framework

Transition of Water Accounting Framework to Indicator Measurement Framework will be done in following manner. The farmers will be categorized based on their cropping hierarchy and access to water. The movement of project beneficiary farmers from lower category to higher category will be tracked. To do this farm level indicators mapped to PDO (project development objective) level result indicators will be designed based on water accounting framework.

Key indicators are mentioned below -

1. Water access index - may be based on water availability for protective irrigation, availability of 1 - 2 irrigations for P2 crops in kharif, 1-2 irrigations for P2 crops in rabi etc. (norm for irrigation water in mm will be fixed in this case)
2. Water productivity index - will be based on farmer survey for water accounting and yield
3. Farm level water balance - will be provided as advisory for varying rainfall years and cropping scenarios which may be useful for farm level planning

Sampling:

A methodology will be developed for farmer selection within the village. This will be a systematic selection methodology based on watershed characteristics and stream proximity. This will allow us to capture spatial and temporal variability.

Farm level indicator measurement will be done for project beneficiaries through this sampling methodology whereas these farm level indicators and survey data will be utilized for computation of village level indices. Further, village selection methodology may also be defined for indicator computation at cluster level. This will also be based on watershed characteristics. Sample size for farmer survey and other norms will be defined. Water budget, crop operating points and water access details from farmer survey will be used to compute indices at zone and village level.

Possible outcomes at village level will be

1. Water Access index based on current cropping pattern and crop operating points
2. Water productivity index
3. Maximum area under P1 crops for sustainability (sustainability may be defined as water availability for protective irrigation)

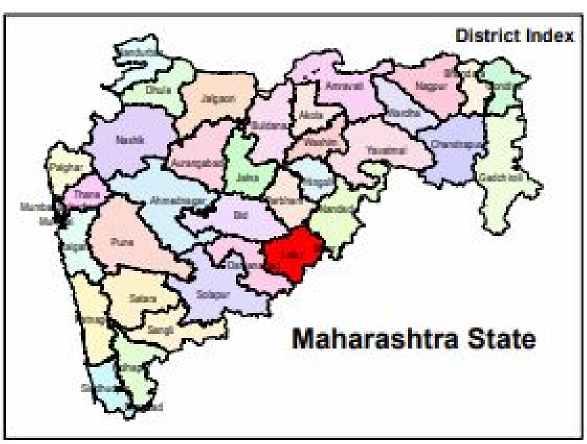
Survey Instruments:

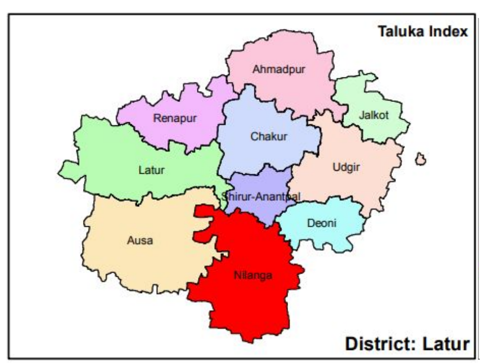
A farmer survey app will be developed for this purpose which will incorporate separate sections utilizable for analytical and indicator monitoring purposes. These sections will consist of

1. General information of farmer - gat area, farmer category, watering assets and sources, benefits availed through PoCRA
2. Cropping pattern and watering information - crop hierarchy
3. Well profile and watering - W2 access
4. Watering sources and assets - Access in other categories
5. Socio-economic information - yields, crop loans, subsidy, allied sources of income

An interlinked relational database will be proposed which may utilize available information from DBT app, FFS app and other PoCRA PMU datasets for indicator measurement.

Shelgi Village





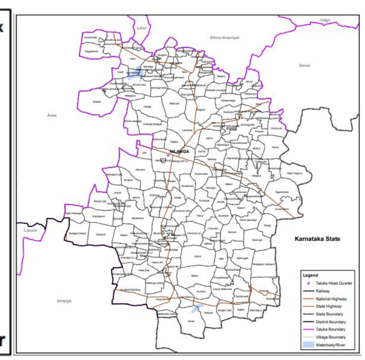


Fig 2: Shelgi village location

This is a sample water allocation method description given for village Shelgi. Shelgi village is located in Nilanga Taluka of Latur district in Maharashtra state. It lies in Assured rainfall zone with rainfall in the range of 700 - 900 mm. The village has an area of 814 hectare and is divided into 4 watershed zones for the purpose of soil and water conservation structures planning in PoCRA project. Following maps show the zones, soil, landuse and drainage profile for Shelgi village.

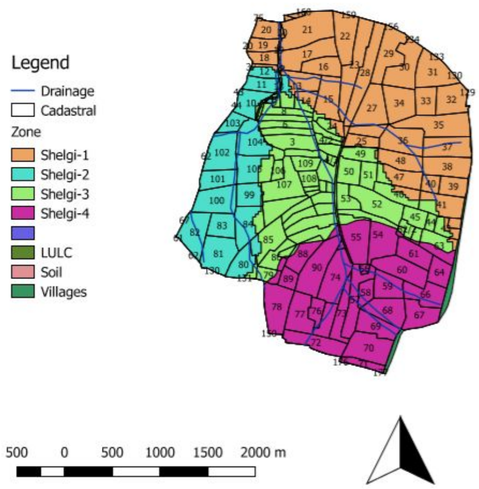


Fig 3: Zone map

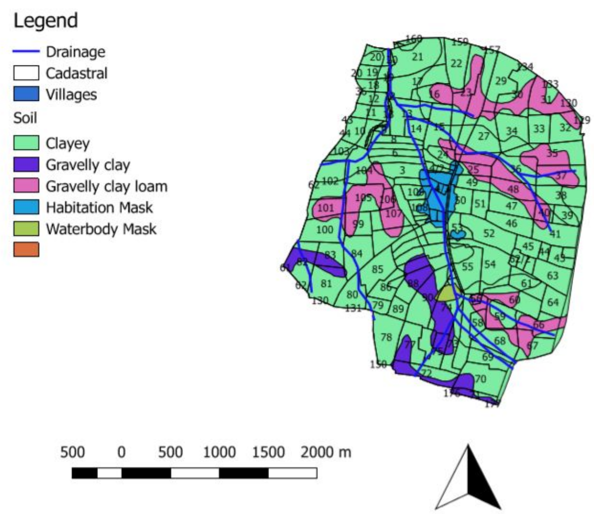


Fig 4: Soil texture map

As per the MRSAC soil texture map majority of soil in village is clayey with some portions of gravelly clay loam and gravelly clay. The depth of top-soil layer is largely varying and changes even within farm boundaries from shallow to deep. This was observed during field visit and conforms to some extent with MRSAC soil depth map. The LULC map shows area under cropping in different seasons.

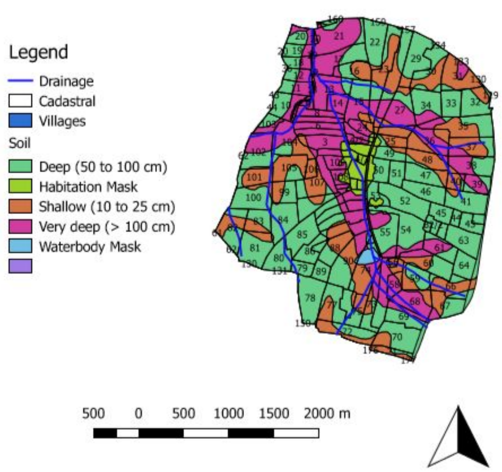


Fig 5: Soil depth map

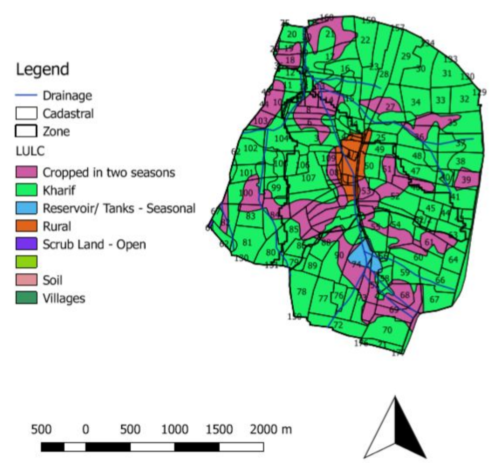


Fig 6: LULC map

Rainfall: The village lies at 9 km distance from Aurad rainfall circle and following graph shows the rainfall and runoff for last 6 years for the village. As the runoff depends on rainfall pattern and watershed characteristics consisting of soil texture, soil depth, land use, slope etc. These have been considered spatially at point level with 100 m resolution and temporally at daily time-step in the water balance model. So the percentage of runoff varies for each rainfall year, which is the critical determinant for a good or bad agricultural year. This is because less amount of runoff would mean that soil and water conservation structures in village will not get filled completely. The ground water recharge is also variable based on above watershed characteristics. The rainfall runoff graph reveals that 2014 was a bad rainfall year and 2016 was a good rainfall year. While 2017 was an average rainfall year based on total rainfall till monsoon end date October 10th.

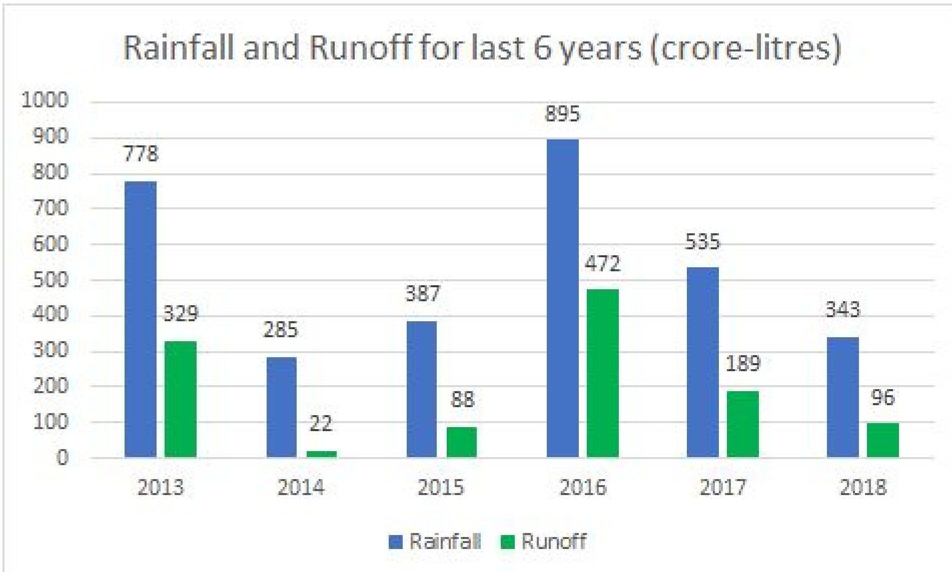


Fig 7: Rainfall-Runoff graph

Village cropping pattern: The cropping pattern in the village for year 2018 is shown in current cropping pattern table. The crops have been categorized into hierarchies based on irrigation given. The compulsory and discretionary demands for current cropping scenario have then been estimated. Figure __ shows the overall season wise village cropping pattern.

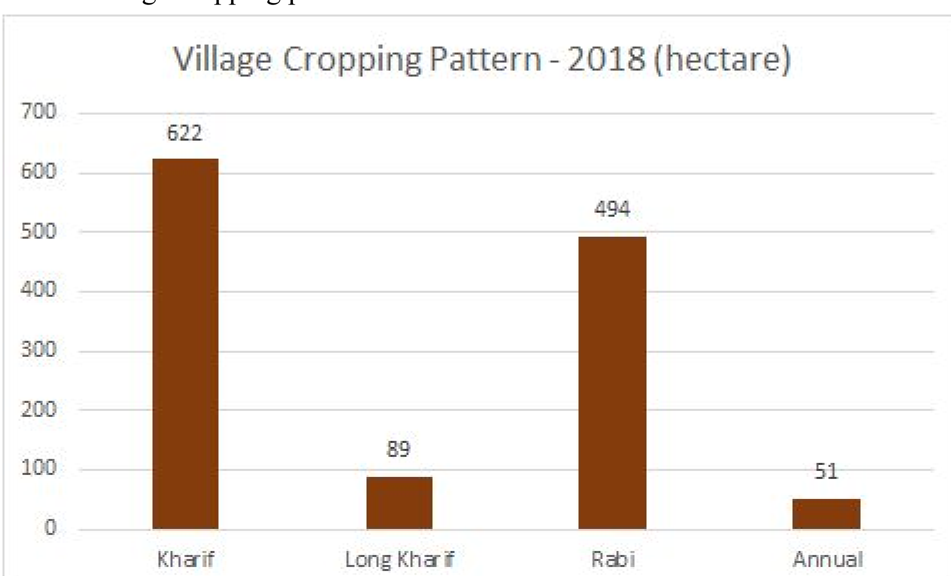


Fig 8: Village cropping pattern

The detailed cropping pattern for village is as follows -

This table provides area under crop (hectare) in each zone along with its crop hierarchy as observed through data from field visit to Shelgi. The annual crops have been considered in P1 category, crops given waterings are considered in P2 category and crops not watered are considered in P3 category. Further there are few crops like cotton, tur, soybean which are watered by farmers at individual level based on water availability. Otherwise they are rainfed. The percentage of area for these crops that is under irrigation and the percentage that is rainfed will further refine the classification for the village. In this case 30% of crop area under Tur is considered to be irrigated and in P2 category and remaining rainfed in P3 category. The irrigation requirement and total water demand are considered in this way.

Table 1: Current cropping pattern in hectare

	2018 Cropping pattern	283	123	193	215		crop priority
Crop Season and Landuse	Crops in English	Zone1 (ha)	Zone 2 (ha)	Zone 3 (ha)	Zone 4 (ha)	Village (ha)	Crop Priority
Kharif_Main	moong	19.0	8.1	18.91	18	64.0	P3
Annual	pomegranate				4	4.0	P1
Kharif_Main	sorghum	23	12.75	15.38	18.18	69.3	P3
Kharif_Main	soybean	160.0	58	94	115	427.0	P3
Long_kharif	tur	28.34	18.4	23.78	18.48	89.0	P3 (70%), P2 (30%)
Kharif_Main	udid	16.2	7.3	15.3	13.2	52.0	P3
Kharif_Vegetables	vegetables	4	1	2	3	10.0	P2
Rabi	gram	91	40	30	49	210.0	P3
Rabi	rabi_fodder	7	3	6	4	20.0	P3
Rabi	rabi_groundnut	4	1	2	3	10.0	P2
Rabi	rabi_onion	15	9	12	10	46.0	P2
Rabi	rabi_sorghum	25	30	26	19	100.0	P3
Rabi	rabi_vegetables	13	2	6	4	25.0	P2

Rabi	rabi_wheat	18	15	19.2	20.2	72.4	P2
Landuse	current fallow crop	22.47	10.45	15.63	11.14	59.7	NA
Landuse	Non Agri	3	1	1	8	13.0	NA
Landuse	wasteland	7	6	7	6	26.0	NA
	Total Area in hectare	260.53	112.55	177.37	203.86	814	

*all areas are in hectare

Village level interventions and allocation

Following table provides details of existing interventions in village and storage capacity. It also delineates the interventions into three categories - surface water W1, ground water W2, and Soil moisture W3. for interventions like compartment bunding 90% of storage capacity is considered to be available through soil moisture W3 and 10% is considered as available through W2 ground water.

Assumptions -

1. Two fillings in good rainfall year - unless modified by field staff.
2. 1 filling in bad rainfall year. In case of runoff being lower than storage capacity for 1 filling. The runoff impounded in structures through 1 filling is reduced by factor 0.7.
3. Fixed W1, W2 and W3 structures - as a one time process.

These norms will be refined for better estimation

Table 2: Existing interventions in village (all values in TCM)

Current structures	Zone1 (TCM)	Zone 2 (TCM)	Zone 3 (TCM)	Zone 4 (TCM)	Water allocation
FP with lining	0	1.1	0	0	GW filled - so not considered
FP inlet outlet	0	0	1.1	0	W1
Percolation Tank	0	0	0	5	W1
MNB	0	0	3.5	7	W1
CNB	8.4	0	0	4.2	W1
Total Capacity in TCM	8.4	1.1	4.6	16.2	29.2

Based on these classifications the 2018 water allocation table for current state is given below -

Table 3: Water allocation - current state 2018

Current state 2018 year								
Water availability	**Available TCM**		**Irrigation demand**	**Deficit TCM**	**PET TCM**	**Irrigation allocation TCM**	**yield %**	**Area ha**
W1 surface water	29.2		P1 crops: annual	32	43.1	31.5	**1.00**	1.6
W2 ground water	-		P2 crops: Kharif	59	176.5	49.6	**0.95**	4.0
GW recharge from rain	51.9		P2 crops: Rabi	865	927.0	-	**0.07**	61.4
W3 soil moisture	-		P3 crops	1,948	4,039.7		**0.52**	412.5
Available runoff (50%)			377.7656					

The allocation is done here as follows -

1. the compulsory load here is P1 crop deficit - 32 TCM. Water available through interventions and ground water recharge is first allocated to fulfill this compulsory water demand.
2. The remaining water from supply side is then allocated to fulfill irrigation demand of P2 kharif crops. As these would be watered first based on seasonality before P2 rabi crops.
3. In this sequence water allocation is done for P1, P2 kharif, P2 rabi and P3 crops based on available water.

This framework will be further refined to separate out protective irrigation demand for P2 and P3 crops such as soybean, tur, cotton. It will also be refined on seasonal level for better allocation.

This allocation framework provides us a glimpse of water security for different crops in crop hierarchy at village level.