

# Land Evaluation for Irrigation in Cotton Growing Yavatmal District, Maharashtra

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**Abstract** – The reconnaissance soil survey on a scale of 1:50,000 in debt driven cotton growing Yavatmal district, Maharashtra was carried out to generate soil map with forty eight mapping units as thirty three shrink-swell soil series association on basaltic landforms in northern/ central parts and in sandstone/ limestone cappings in south-eastern parts of wani valley. These soil mapping units were evaluated for irrigation using parametric method and symbol formulae of FAO guidelines for exploring the irrigation potential in drought prone Yavatmal district. The results showed that ten soil mapping units on moderate slopes (5 to 8 per cent) with shrink-swell properties (188832.7 hectares, 13.89 per cent) are evaluated as suitable for surface methods whereas eleven soil mapping units (274744.3 hectares, 20.22 per cent) is slightly suitable for drop irrigation having moderate to slow subsoil permeability, severe stoniness over 5 to 8% slopes and moderate to severe erosion. The main limiting factors for surface and/or sprinkle irrigation methods in this area were soil texture, slope, gravel, surface stone cover whereas calcium carbonate content, alkalinity and subsoil permeability for drop irrigation. The Irrigation intervals based on soil available water holding characteristics and daily consumptive use of water were computed for wheat, cotton and sugar cane. The results showed that the irrigation intervals varied from  $8.9 \pm 1.4$  days for wheat,  $8.6 \pm 1.4$  days for cotton and  $10 \pm 1.6$  days for sugar cane. The land resource datasets combined with evaluation methods and GIS tool were helpful in delineating suitable zones for irrigation methods and also to estimate irrigation intervals for major crops grown in the region.

**Keywords** – Land Evaluation, Irrigation, Shrink-Swell Soils, Soil Map, Yavatmal.

## I. INTRODUCTION

India's irrigated agriculture sector is fundamental to economic development and poverty alleviation with its four fold expansion from 23 million hectare (M ha, in 1951) to 90 M ha in 1997. Recently, it was estimated that the irrigation development potential in India has been upgraded to 139.9 M ha, comprising of 58.46 M ha through major and medium irrigation and 81.43 M ha from minor irrigation [1]. Growth rate of irrigated area continues to fall from 4.23 % per year during the 1970s to 3.08% per year in 1980s and to 2.56% in the 1990s [2]. The Ministry of Agriculture (MOA) estimated the area of 8.53 M ha was affected by water logging and salinisation [3] which in contrast to the reports of Ministry of Water Resources as 1.5 M ha by water logging, 3.1 M ha by salinity and 1.3 M ha by alkalinity [4].

Twenty per cent of the cultivable area is served in Maharashtra by irrigation infrastructure. Today, the irrigated infrastructure covers 4.5 million ha, as compared

with potentially irrigable area of 12.6 million ha [5]. The irrigation developed so far till June, 2005 is 0.874 Mha. from state sector schemes and 0.304 Mha. from local sector schemes. Irrigation potential created as a percent of gross sown area is only 19 per cent for the region as a whole. At least 30% irrigation coverage is required for drought proofing. The irrigation potential developed in Vidarbha comprises 1.76 lakh ha irrigation potential as created by Ex-malguzari tanks constructed way back in 16-17<sup>th</sup> century. Many tanks are constructed in pre-independence era, whose irrigation potential is 0.48 lakh ha. This implies that only 9.43 lakh ha irrigation potential is developed in Vidarbha after independence, which is about 0.16 lakh ha/year [6]. The soil resource inventories in Maharashtra have shown that 1.5 per cent total geographical area (TGA) in command areas of Godavari, Ghod, Purna, Manar, Mula, Pravara, Nira and Krishna river basins was occupied by moderately to strongly saline/sodic soils [7]. Determining the suitability of land for irrigation method requires evaluation of soil properties, the topography of the land within the field and water quality to be used for irrigation [8], [9], [10]. Coarse textured soils have larger pores in size than the fine ones and therefore allow for more water flow under saturated conditions and the opposite is true under the saturated one [11], [12]. Slope, texture and soil depth were the severe limitations for irrigation reported in basaltic terrain of Ethiopia [13], where as drainage, salinity, soil depth were the limitations reported in vertisols of India [14] and of sodicity, erosion, drainage, organic carbon and calcium carbonate in Mula command area of Ahmednagar [15]. The vertisols and vertic intergrades of basaltic terrain in Jayakwadi command area revealed severe limitations of sodicity, low permeability and effective rooting depth for irrigation [16] with an irrigation frequency of 14 days on deep vertisols to 7 days for shallow vertic intergrades [17]. Likewise, parametric system using GIS (Geographical Information System) was used to determine suitable areas for different irrigation methods in southern Ankara [18] and in North Molasani Plain in Iran [19] and in Miheh plain of the Chahar Mahal and Bakhtyari province in the center of Iran [20]. Henceforth, the objective of this study is to evaluate and compare the suitability of vertisols and vertic intergrades for gravity and drop irrigation methods in semiarid and drought prone cotton growing Yavatmal district in Maharashtra where irrigation potential is 6.8 per cent of total cultivated area.

## II. MATERIALS AND METHODS

### Description of study area

Yavatmal is situated in the eastern (Vidharbha) region of the Maharashtra state between 19°26' to 20°42'N Latitude and 77°18' to 79°98'E Longitude. This district covers 13582 km<sup>2</sup> area (4.41% of the state) with a population of 20,77,144 (2.63% of the state) and 43 % of rural families live below poverty line. The total cultivated area is 8.84 lakh hectares with double cropped area of 41189 , low cropping intensity(101%) and low irrigation potential (7%). The main rivers are Wardha, Penganga, Pus and Arunavati with furrow and basin irrigation methods for sugar cane, cotton and wheat whereas border systems for citrus. The climate is hot and dry with moderately cold winters. Eighty per cent of the total annual rainfall is received during the south west monsoon varying from 1,125 mm in eastern parts of wani to 889 mm in western parts of darwha and 1099.5 mm in central yavatmal. The cotton is grown in 52% total cultivated land (8.84 lakh hectares under rainfed leading to economic crisis and an epicenter of farmer's suicide in the state). The occurrence of prolonged dry spells during cotton

critical stages (branching and flowering) often coincides with dry spells and reduces cotton yield.

### Land Resource Data

A reconnaissance soil survey was carried out using 1:50000 scale toposheets of Survey of India (SOI) and Indian Remote Sensing (IRS)-P6 false colour composites (11<sup>th</sup> April /10<sup>th</sup> May, 2006) as base maps to prepare land form map [21]. Fourteen landforms were identified as:- hills and ridges in northern and central parts of Yavatmal (12.6 per cent of total area), upper, middle and lower plateaus (398240.4 ha, 29.34 per cent of total area), Isolated hills/elongated hills mesa and butte, escarpments, upper and lower pediplains (17.74 per cent) and gently to moderately sloping alluvial plains, intervening valleys in south western parts (8.05 per cent) and gullied stony gravelly wastelands (3.48 per cent). The soil profiles were studied upto a depth of 2m or to lithic contact and recorded morphological properties [22] and classified as per keys to soil taxonomy upto subgroup level [23]. Thirty three soil series were defined and used for setting series class limits [24]. The soil mapping units were defined as the associations of soil series and derived soil map of 48 mapping units (Fig.1) under Geomedia environment [25].

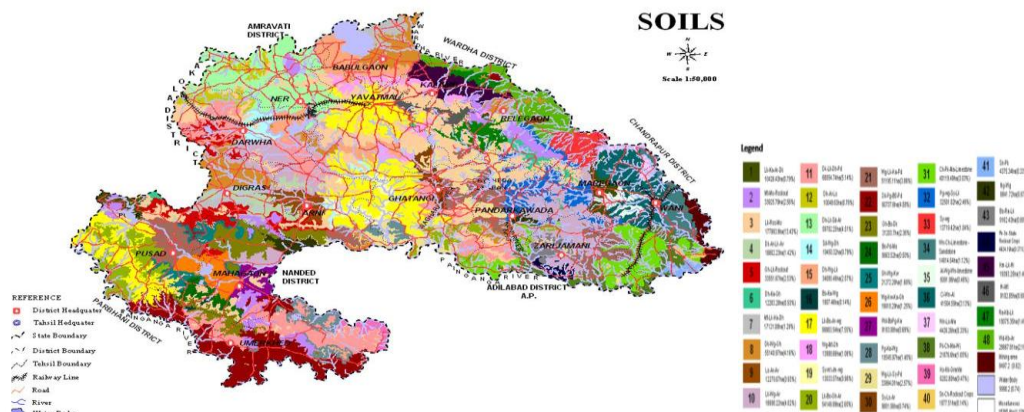


Fig.1. Soil map of yavatmal district

### Laboratory analysis

Horizonwise soil samples were collected and sieved through 2 mm sieve for fine earth fraction. The routine and standard procedures were used for particle size analysis by international pipette method, bulk density by clod method [26], pH, Electrical conductivity (1:2 soil water ratio), organic carbon by wet digestion method, calcium carbonate by acid neutralization method, exchangeable bases with IN normal ammonium acetate extractable and cation exchange capacity (CEC) with ammonia distillation method [27] and water retention at -33kPa and -1500kPa using pressure plate membrane apparatus [28].

### Land evaluation for Irrigation

The steps in land evaluation for irrigation were listed as under:-

Step 1- Soil map and present land use/land cover map was prepared as an input into GIS

Step 2- Limiting symbol formulae was used to define soil and salinity limitations of each series in the numerator and topography and drainage limitations in the denominators

Step 3- Development of capability index using soil texture, soil depth , CaCO<sub>3</sub> content, salinity/alkalinity , drainage and slope for each soil series identified in the district[9].

Step 4. Soil units were rated by multiplying the proportion of each soil type by its respective soil rating. Rating of non-irrigable portions of a complex should not be added to irrigable portions to determine the final soil category.

Step.5- Decision rules were proposed for irrigation and derived priority areas suitable for irrigated agriculture using Geomedia.

### Parametric evaluation

The parametric evaluation system [9]was applied using standard granulometrical and physico-chemical characteristics of a soil profile. The different land characteristics that influence the soil suitability for irrigation are rated and a capability index for irrigation (Ci) is calculated according to the formulae:

$$Ci = A * B/100 * C/100 * D/100 * E/100 * F/100$$

Where: Ci: capability index for irrigation; A: rating of soil texture; B: rating of soil depth; C: rating of CaCO<sub>3</sub>



status; D: salinity/alkalinity rating; E: drainage rating and F: slope rating. The capability classes are defined according to the value of the capability (or suitability) index (Ci)

Capability Index	Class	Definition	Symbol
>80	I	Excellent	S1
60-80	II	Suitable	S2
45-60	III	Slightly suitable	S3
30-45	IV	Almost unsuitable	N1
<30	V	Unsuitable	N2

2. *Rating soil mapping units:* Soil units mapped as complexes were rated by multiplying the proportion of each soil type and its summation to get respective final soil rating [29]. For example:- Soil mapping unit Lo-Ar-Av

Proportion of unit	Capability index	Partial soil rating
35 (Loni series )	90	3150
35(Arni series)	73	2555
30(Arunavati series)	81	2430
Final Soil Rating		$\frac{8135}{100} = 81.35$

3. *Weighted mean:* Weighted means were calculated by multiplying with individual horizon thickness and their summation divided by total thickness.

4. *Available depth of soil water:* available depth of water is calculated as  $d = \frac{Fc - PWP}{100} \cdot BD \cdot D$  where FC=

field capacity (Water held at -33 kPa), PWP=permanent wilting point (water held at -1500 kPa), BD= bulk density ( $Mgm^{-3}$ ), D= thickness of horizons . For each series, these values were calculated, multiplied with proportion of series in each mapping unit and their summation was considered as final value for each mapping unit. These values were used for computing Irrigation interval as =  $\frac{\text{allowable soil water depletion}}{\text{daily water use}}$

The allowable soil water depletion was 50% for wheat and cotton and 65% for sugar cane and daily water use was 0.6 mm/day for wheat, 0.75 mm/day for cotton and 0.95 mm/day for sugar cane.

### III. RESULTS AND DISCUSSION

#### *Brief Description of morphological properties of soils*

The shallow Lakhi and very shallow Gahuli series are dominant on basaltic hills and ridges. These soils are well drained, dark grey to brown matrix with 10YR hue and clay textured (Table 1). The moderately deep, well drained and neutral Hirdi series on upper plateaus have dark brown matrix and distinct slickensides within one meter. The shallow Jamwadi, very deep Kalmab and moderately deep Katherwadi series are dominant on middle plateaus of Yavatmal and Darwah region. These soils have very dark greyish brown to dark greyish brown matrix with clay texture, mildly alkaline, hard and compact cambic horizons in Jamwadi but sodic, strongly alkaline slickensided zones in Katherwadi and moderately alkaline in Kalamb series. The lower plateaus (<320m) in south eastern parts have moderately deep and well drained Koulambi series having very dark grey and moderately alkaline cambic horizons. The Korta and Ralegaon soil series on isolated hills have dark brown to black subsurface layers with prominent slickensided zones. The very shallow, well drained, dark brown Moho series and moderately deep Waghari series with dark grey matrix and cambic clay horizons are associated with mesas, buttes and escarpments of basaltic hills . The upper and lower pediplains have Apti, Borgaon, Dhanora, Kharbhi, Saykheda and Selodi series. These soils have dark greyish brown to dark brown matrix with slickensided with in one metre in Apti and Saykheda. The gently to very gently sloping alluvial plains have deep Arunavati with calcium carbonate enriched B horizons and very deep Chanoda, Loni, Pandhurna and Wani soil series with moderately alkaline clayey slickensided zones. The intervening valleys have Dhanki, Sindola, Wanodi and Nagdhari soils with greyish brown to dark greyish brown/light yellowish brown matrix, moderately to strongly alkaline and presence of slickensides in subsoil horizons except in Nagdhari series.

Table 1: Landforms and soils with selected morphological properties

Land forms (Area(ha)/percent)	Soil series	Thickness(cm)		Matrix colour(moist)*		Texture *		Other features
		A	B	A	B			
Hills and ridges (170970/12.6)	Gahuli	17	-	10YR3/3	-	gc	-	Very thin ochric horizons with lithic contact below 50cm
	Lakhi	26	-	10YR3/3	-	c	-	Moderately alkaline, dark brown ochric horizons
Upper plateaus (64712/4.8)	Hirdi	12	63	7.5YR3/2	7.5YR3/2	c	c	Slickensides within 1m with neutral reaction
Middle plateaus (236055/17.4)	Jamwadi-	20	20	10YR3/2	10YR3/1	c	gc	Mildly alkaline thin and hard cambic horizons
	Kalamb	20	94	10YR4/2	10YR3/2	c	c	Moderately alkaline slickensided zone
	Katherwadi	12	84	10YR3/2	10YR3/2	c	c	Strongly alkaline sodic slickensided zones within 1m
Lower plateaus (97472/7.2)	Koulambi	20	69	10YR3/1	10YR3/2	c	c/l	Moderately alkaline cambic horizons
Isolated hills	.Korta-	20	30	7.5YR3/1	7.5YR3/1	c	c	Slightly alkaline, very hard cambic



(92440/6.8)	.Ralegoan	19	131	10YR3/2	10YR3/2	zc	zc	horizons Moderately alkaline slickensided zones within 50cm
	Moho	7-	-	7.5YR3/2	-	cl	-	Neutral, thin, ochric layer
Measa and Butte (85696/6.3)	Waghari	19	29	10YR3/2	10YR3/2	c	c	Moderately alkaline with pressure faces in cambic horizons
Escarpments (62716/4.6)	Met	20	-	5YR3/2	-	c	-	Moderately alkaline, lithic contact within 50cm
Upper pediplains (175599/12.9)	Borgoan	16	51	2.5Y5/2	2.5Y3/1	zc	zc	High value, clay increase, low chroma
	Dhanora	13	17	10YR3/2	10YR3/2	c	zc	Thin cambic horizon
	Kharbi	20	110	10YR3/2	10YR3/1	c	c	Moderately alkaline, slickensided zones
Lower pediplains (214729/15.8)	Apti-	13	57	10YR4/2	10YR3/2	c	c	Pressure faces and slickensides within 1m
	Saykheda	15	69	10YR3/3	10YR3/4	c	zc	Moderately alkaline slickensided zones
	Selodi	12	138	10YR4/2	10YR3/2	zc	c	Strongly alkaline, slickensided zones, strongly effervescent
Gently to Moderately sloping plains (45827/3.4)	.Arni	18	76	10YR3/2	10YR3/2	zcl	zcl	Cambic with pressure faces and slickensides
	Chikhalgoan	13	82	10YR4/2	10YR3/2	cl	zc	Pressure faces and slickensides within 1m
	.Penganga	15	65	10YR3/2	10YR3/2	zc	c	Moderately alkaline, slickensided zones with in 1m
Very gently to Gently sloping alluvial plains (15659/1.2)	Arunavati	19	76	10YR4/3	10YR5/4	cl	gcl	Gravelly calcium carbonate enriched
	.Chanoda-	13	137	10YR4/2	10YR3/1	zc	c	Cambic/slickensided zone with low chroma
	.Loni	15	135	10YR5/4	10YR4/4	zcl	zcl	Moderately alkaline, thick slickensided zone
	Pandhurna	13	137	10YR4/3	10YR3/3	l	cl	Moderately alkaline with coarse angular aggregates
	Wani	12	128	10YR3/2	10YR3/1	c	c	Moderately alkaline with slickensided zones
Intervening valleys (47864/3.5)	Dhanki	15	155	10YR3/2	10YR3/3	c	c	Moderately alkaline, slickensided zones
	Nagdhari	13	127	10YR6/4	10YR3/4	zcl	zcl	Moderately alkaline, sodic, prismatic aggregates
	Wanodi	15	137	10YR3/2	10YR3/2	c	c	Moderately alkaline with slickensided zones
	Sindola	12	40	10YR3/2	10YR3/1	zc	zc	Moderately alkaline, cambic horizons
Gullied and Stony gravelly waste lands (47253/3.2)	Maregaon	15	27	10YR3/2	10YR3/2	c	c	Moderately alkaline, cambic horizons
	Pandharkawada	11	-	10YR4/3	-	c	-	Neutral brown, ochric horizons
	Wanjari	13	27	10YR3/6	10YR3/4	c	c	Mildly alkaline, developed over limestone
Gullied and Stony gravelly waste lands (47253/3.2)	Maregaon	15	27	10YR3/2	10YR3/2	c	c	Moderately alkaline, cambic horizons
	Pandharkawada	11	-	10YR4/3	-	c	-	Neutral brown, ochric horizons
	Wanjari	13	27	10YR3/6	10YR3/4	c	c	Mildly alkaline, developed over limestone

Note:- Texture\*----- sc=clay, zcl=silty clay loam, l=loam, zc =silty clay, gcl=gravelly clayloam, cl=claylo

### Physical and chemical characteristics of soils

The particle distribution data shows that Nagdhari (P22) and Waghari (P30) have clay less than 35 per cent in soil control section with fine loamy particle size, but Loni (P17) and Saykheda (P27) series have fine silty particle size with silt content exceeding 40 per cent (Table 2). The Apti (P3), Chanoda (P6), Dhanki (P8), Hindi (P10), Lakhi (P18) and Penganga series (P25) have very fine particle size with clay more than 60 per cent [23] but in other soils, the particle size is fine. These expansive clay soils have bulk density of 1.57 to 1.79 Mg m<sup>-3</sup> causing root hinderence and aeration [30] and COLE value of 0.1 to 0.2 indicating very severe shrink swell hazard [31]. The high COLE values in these soils indicate dominance of smectites controlling the degree of shrinkage [32]. These soils have mean plant available water of 12.65 per cent with 2.95% of standard deviation. The plant available

water can be approximated with multiple regression equation with R<sup>2</sup> value of 0.294, and F value of 2.25.

Plant available water (%) = - 6.39 + 0.156 (sand) + 0.283 (silt%) + 0.189 (clay %) - 0.433 (organic carbon g/kg) - 0.022 (calcium carbonate, g/kg)

These soils are moderately to strongly alkaline with low salt concentration (Table 2). Sixty seven per cent of soils are low in organic carbon (less than 0.5) and remaining 33% soils are medium (0.5 to 0.75%). The calcium carbonate content less than 1% is observed in Dhanki series (P8) whereas as less than 6% in case of Chanoda (P6), Jamwadi (P11), Koulambi (P13), Katherwadi (P14), Korta (P15), Kharbhi (P16), Loni (P17), Moho (P20), Nagdhari (P22), Penganga (P25), Ralegaon (P26), Sindola (P29) and other soils the CaCO<sub>3</sub> content is in between 5 to 10%. The weighted mean of calcium carbonate is 125.48 g/kg for Arunavati (P1), 122.4 g/kg for Saykheda (P27),



94.6 g/kg for Waghari (P30) and 75.46g/kg for Wani (P32).

These soils are deficient in available nitrogen with mean of 33.17 mg/kg and phosphorus with mean of 00.74 mg/kg (Table 2). This observation is in agreement with the earlier reports of fertility status of black soils in India [33]. The DTPA extractable iron shows below critical limit (<4mg/kg) [34] in Kalamb (P12), Nagdhari (P22), Pandhurna (23), Ralegaon (P26) and Sindola soils (P29) where as in other soils, DTPA extractable iron is medium (4 to 6 mg/kg). The DTPA extractable Zn is 0.2mg/kg (P12) to 1.5mg/kg (P11). The Zn contents below critical limit(<1mg/kg) is recorded in Gahuli (P9), Kalamb (P12), Nagdhari (P22), Ralegaon (P26), Sindola (P29) and Wanodi (P31) but in other soils, zinc is medium [35].

### Irrigated systems and crops

The district has sixteen tehsils with 5 per cent of area under irrigation and have tehsil wise variations in area under surface and well irrigation systems (Table 3). The irrigated land is forty one thousand hectares, out of which 47 per cent is under wheat (19309 ha), 22 per cent under sugarcane and 13 per cent under cotton and 14 per cent under groundnut. The per cent area under irrigation more than 5 % is observed in Umardhed (11%), Pusad (8.0%), Digras (6.4%), Yavatmal (6%) and Ner (5.2%). These areas are drought prone with severe crop losses and suicidal deaths of cotton growers. At least 30 per cent irrigation coverage is required for drought proofing [6], but none of the sixteen tehsils having that much of irrigation coverage.

Table 2: Physical and chemical characteristics of soils

Soil series	Particle size distribution (<2mm)			BD (Mgm <sup>-3</sup> )	PAWC (%)	ASW (cm/m)	COLE	pH	OC	CaC O <sub>3</sub>	CEC (cmol/kg)	Available		DTPA extractable	
	Sand	Silt	clay									N	P <sub>2</sub> O <sub>5</sub>	Fe	Zn
1.Arunavati(Av)	49	32.7	18.3	1.57	12.0	18.1	0.10	8.5	3.9	125.5	38.0	34.1	0.5	6.6	0.7
2.Arni(Ar)	13	49.8	37.2	1.79	20.4	34.5	0.22	8.7	3.9	-	51.4	28.3	1.7	5.0	0.9
3.Apti(Ai)	3.2	30.2	66.6	1.74	10.1	12.2	0.19	8.8	2.9	145.5	53.0	58.4	0.8	7.3	0.7
4.Borgaon(Bo)	12	39.4	48.6	1.62	10.3	11.2	0.19	8.4	5.1	69.4	54.4	46.7	0.7	5.6	0.8
5.Chikhalgaon(Ci)	24.8	39.0	36.2	1.61	12.6	23.7	0.15	8.4	3.2	65.0	40.1	35.2	0.5	6.4	0.9
6.Chanoda(Ch)	2.8	28.7	68.5	1.83	15.8	42.9	0.21	8.1	1.4	40.2	67.1	39.7	0.9	7.0	0.8
7.Dhanora(Dh)	6.1	41.3	52.6	1.69	10.16	5.1	0.19	8.1	6.5	64.5	70.0	31.2	0.7	4.9	1.1
8.Dhanki(Dk)	1.3	34.3	64.4	1.72	11.9	34.7	0.23	8.1	4.6	7.1	70.1	40.4	0.1	7.2	1.0
9.Gahuli(Gh)	10.2	39.5	50.3	1.48	11.1	2.8	0.15	8.0	2.5	5.6	61.7	-	-	7.4	0.4
10.Hirdi(Hi)	2.6	31.4	66.0	1.71	15.5	22.6	0.18	6.9	5.8	-	53.4	-	-	7.6	0.7
11.Jamwadi(Jm)	13.1	38.2	48.7	1.79	10.9	7.8	0.21	7.6	7.4	42.8	72.6	55.9	1.6	4.2	1.5
12.Kalamb(Km)	3.2	41.2	55.6	1.64	14.8	38.6	0.18	8.1	2.7	-	59.5	-	-	1.2	0.2
13.Koulambi(Ka)	19.9	39.0	41.1	1.69	10.6	15.8	0.21	8.2	4.2	106.5	61.5	51.5	1.3	7.4	1.0
14.Katherwadi(Kw)	11.6	34.4	54.0	1.74	17.0	28.4	0.20	8.9	4.1	-	56.5	52.6	0.6	7.3	0.8
15.Korta(Ko)	23.1	24.0	52.9	1.79	10.1	8.9	0.24	8.0	2.8	38.1	62.5	46.7	0.5	5.4	1.1
16.Kharbi(Kb)	11.8	30.0	59.2	1.74	16.3	36.5	0.21	8.1	3.2	-	60.8	37.5	2.8	5.3	0.9
17.Loni(Lo)	12.7	49.0	32.3	1.57	16.2	40.9	0.18	7.9	1.0	8.4	46.0	28.3	1.0	6.4	0.8
18.Lakhi(Lk)	5.4	28.0	67.0	1.70	11.6	5.1	0.20	8.4	2.6	16.5	66.9	-	1.5	7.9	0.7
19.Met(Mt)	20.4	33.1	46.5	1.65	11.8	3.9	0.18	6.6	5.7	-	52.2	78.4	4.7	8.0	1.5
20.Moho(Mo)	20.9	31.0	48.1	1.56	11.6	8.0	0.17	7.2	1.3	3.5	57.3	63.1	0.7	9.3	1.1
21.Maregaon(Ma)	7.5	33.2	59.3	1.71	16.1	11.6	0.19	8.1	6.6	21.9	63.4	52.4	1.2	6.4	0.7
22.Nagdhari(Ng)	10.7	40.0	49.3	1.69	9.4	27.9	0.11	8.3	0.8	-	46.8	-	-	1.1	0.4
23.Pandhurna(Pd)	26.4	33.4	40.1	1.57	13.6	31.9	0.22	8.2	4.7	87.7	51.3	42.5	0.7	5.8	0.8
24. Pandharkawada (Pk)	29.4	18.2	52.4	1.52	11.7	1.9	0.15	7.5	3.6	4.1	62.6	-	-	7.5	0.7
25.Penganga(Pg)	1.5	34.4	64.1	1.79	11.2	18.9	0.21	8.3	5.3	63.9	50.8	37.9	0.5	5.5	0.9
26.Ralegaon(Ra)	9.9	44.6	45.5	1.70	12.6	18.3	0.17	8.2	4.8	-	54.4	-	-	0.7	0.7
27.Saykheda(Sy)	28.0	42.7	29.3	1.58	8.6	20.5	0.15	8.4	4.5	112.5	49.5	44.6	0.5	6.4	0.8
28.Selodi(Sd)	4.3	35.5	59.2	1.77	14.7	39.2	0.19	8.9	2.6	112.6	66.7	42.7	0.5	7.1	0.9
29.Sindola(Sn)	5.7	41.3	53.0	1.69	15.9	14.1	0.17	7.7	4.1	-	53.0	-	-	1.5	0.3
30.Waghari(Wg)	27.6	36.4	36.0	1.61	8.6	6.7	0.20	8.3	6.9	94.6	67.1	56.0	1.1	6.0	0.8
31.Wanodi(Wd)	4.3	38.4	57.3	1.68	12.2	31.0	0.20	8.3	1.6	-	41.2	25.8	0.4	4.7	0.4
32.Wani(Wn)	18.8	33.6	48.4	1.70	15.5	36.7	0.21	8.3	2.9	75.5	56.7	31.0	0.5	6.2	0.8
33.Wanjari(Wj)	20.3	38.1	41.7	1.55	7.2	4.5	0.16	7.8	6.6	61.6	46.9	80.4	0.1	7.4	0.6

Table 3: Area under different systems of irrigation and crops (ha)

Tehsil	Area(ha)		Total	Wheat	Gram	Cotton	Groundnut	Sugar Cane	Area (ha)
	Surface	Well							
1.Ner	278	1039	1317	670	75	240	30	23	1038
2.Babulgaon	51	555	606	526	74	149	45	10	804
3. Kalamb	740	925	1665	629	49	394	36	12	1130
4.Yavatmal	426	1499	1925	1448	184	160	962	138	2953
5.Darhwa	527	1074	1601	1169	156	72	819	318	2534
6.Digras	707	938	1645	1032	167	180	123	667	2169
7.Pusad	1925	1927	3852	2845	36	202	1028	1432	5543
8.Umarkhed	2739	3240	5979	3543	610	110	169	3936	8368
9.Mahagaon	778	741	1519	918	46	209	514	1087	2774
10.Arni	693	1066	1759	890	160	160	817	1144	3171
11.Ghatanji	295	742	1037	603	34	84	340	57	1118
12.Kelapur	232	725	957	1040	27	2196	13	10	3286
13.Ralegaon	392	865	1257	1156	5	873	44	36	2114
14.Maregaon	105	671	776	789	62	195	25	7	1078
15.JhariJamni	135	740	875	789	45	90	556	4	1484
16.Wani	32	817	849	1262	10	213	112	2	1625
Total (ha)	10055	17564	27619	19309	1740	5527	5633	8883	41189
% of total				47	4.0	13.0	14.0	22.0	100

**Land capability and suitability for irrigation**

The land capability index is computed for judging the suitability for irrigation and defined soil, topography and drainage limitations with standard symbols for irrigable soil mapping unit in Yavatmal district (Table 4). The excellent soil mapping Lo-Ar-Av (9) covering 0.87% have soil associations of Loni series (LCI of 90), Arni series (LCI of 73) and Arunavati series (LCI of 81). These soils have moderate to slow subsoil permeability, medium to heavy top soil texture, deep with unweathered hard rock/calcareous material with slight alkalinity problem, moderate to strong micro relief variations and moderate erosion status. This unit is evaluated as suitable for both surface and drop irrigation systems. The excellent soils for irrigation is mostly concentrated in Digras and Arni tehsils of Pus valley under Arunavati river (Fig 2).

Ten soil mapping units (4, 12, 22, 27, 30, 34, 35, 36, 37 and 48) are evaluated as suitable for irrigation covering 188832.7 ha (13.89%). These units have 12 series associations viz., Arni, Aпти, Chikalgaoan, Chanoda, Dhanki, Kalamb, Koulambi, Kharbi, Nagdhari, Pandhurna, Wanodi and Wani with moderate to slow subsoil

permeability, 15 to 40% subsoil stoniness, heavy to very heavy top soil texture, deep with unweathered hard rock/calcareous material with slight salinity and alkalinity problem over gently sloping to sloping with maximum transversal slopes of 5 to 8%, slightly to moderate micro relief variations and slight to moderate water erosion status. Under these conditions short intervals of irrigation schedule will take place for eroded terraces. These are suitable for surface irrigation in lower landscapes but drop irrigation in uplands [36]. The surface irrigation method can be safely operated in a zone with relatively low Intake rate and nutrient losses from the bottom of the root zone and to increase water application efficiency [37].

The slightly suitable soils for irrigation include 11 soil mapping units (21) for irrigation covering 20.22 per cent of area (274744.3 ha). These units have dominant soil associations of Borgaon, Dhanora, Katherwadi, Penganga, Ralegaon, Saykheda and Selodi having moderate to slow subsoil permeability and severe stoniness over 5 to 8% slopes with moderate to severe erosion. On these landscapes, sprinkler system is commonly adopted for irrigating summer groundnut in the region.

Table 4: Land capability and suitability for irrigation systems in yavatmal district

Land capability class for irrigation	Soil series association	Capability index for irrigation		Area		Limitations		
		Gravity	Drop	(ha)	(%)	Soil	Topography	Drainage
Excellent (I)	Lo-Ar-Av(9)	81	83	11813.9	0.87	4zHz	Aa3E1	W101F1
				11813.9	0.87		11813.9	0.87
Suitable(II)	Dk - Ar -Lk- Av(4)	52	57	17389.4	1.28	4gV(f)-A1	Aa1E1	W101F1
	Dh-Ar-Lo(12)	56	63	9553.7	0.71	Cb2E3	W101F1	
	Dk-Pg-Bo-Pd(22)	55	63	56172.7	4.13	4gV(f)-A1	Aa1E1	W101F1
	Wd-Bo-Pg-Ka(27)	52	61	8492.9	0.62	4gV(f)	Ba2E2	
	Sy -Lo-Ar(30)	68	71	8804.6	0.65	4gV(g)	Bb1E1	W101F1
	Wn-Ch-(34)	49	53	13793.6	1.02	4gV(f)	Bb2E2	W101F1
	Ai-Wg - Wn(35)	47	54	5634.1	0.41	4gV(f)1-ZA2	Cc2E2	W101F2
	Ci- Wn -Ai(36)	52	67	38385.1	2.82	4gV(f)1-HA1	Cb2E1	W101F2
	Wn-Lo -Ma(37)	56	53	4093.6	0.3	4gV(f)	Bb2E2	W101F1
	Wd-Kb-Ar(48)	53	54	26513	1.95	4gV(f)	Bb2E2	W101F1
				188832.7	13.89	4gV(f)	188832.7	13.89
Slightly suitable (III)	Lk-Ka-Ar -Dk(1)	47	48	9361.3	0.69	3zVz-3Z	Ee2E3	
	Dk-Lk-Dh-Pd(11)	47	49	62781	4.62	4gV(f)-A1	Aa1E1	
	Dh- LK-Sd -Ar(13)	49	53	55298.4	4.08	Cb2E3	W101F1	
	Sd-Wg-Dh(14)	49	50	9665	0.71	4gV(f)-A2	Ba1E2	W101F1

	Bo-Ka-Wg(16)	44	51	1764.1	0.13	4gV(f)2-HA1	Bb2E1	W101F2
	Lk-Bo-Ar-Dk(17)	44	46	71759	5.28	2zVz-3Z	Ed2E2	
	Bo-Pd-Mo(24)	47	58	6162.7	0.45	4gV(f)2-HA1	Bb2E1	W101F2
	Sy –Wg(33)	45	47	12507.4	0.92	3gH(g)-2S	Cb2E2	W101F1
	Bo-Ra-Lk(43)	44	51	8473.8	0.62	4gV(f)2-HA1	Bb2E1	W101F2
	Km-Lk-Hi(45)	49	34	17935.7	1.32	3GVZ1-ZA1	Ba2E2	W101F2
	Ra-Kb-Lk(47)	47	42	17299.5	1.27	3gVg-1S	Cb2E2	

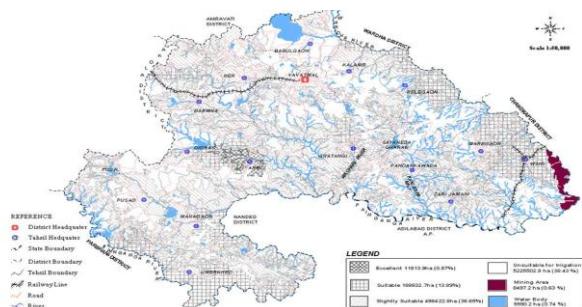


Fig.2. Suitability map for gravity irrigation

*Available soil water, Irrigation intervals and fertility capability for irrigable units*

The mean available soil water content of twenty two soil units is 22±3.4 cm/m with coefficient of variation of 15.22 per cent (Table 5). For these soil units, the irrigation intervals vary from 8.61±a.35 days for cotton to 8.9±1.4 days for wheat and 10±1.64 days for sugar cane. The excellent mapping unit(Lo-Ar-Av) have available soil water of 27.3 cm/m where as ten suitable mapping units have mean of 23.17cm/m±2.53cm/m and in eleven slightly suitable units have mean of 20.53±3.36cm/m. The crop coefficient (kc) of cotton with growth cycle of 190 days to be 0.46, 0.70, 1.01 and 0.39 at four different stages [38] are used to compute mean irrigation intervals which is varying from 8.8 days for cotton to 9.1 days for wheat and 10.1 days for sugarcane in case of suitable units but 8.2 days for cotton to 9.71 days for sugarcane in slightly suitable units [17]. The fertility capability classification [39] shows that calcareous loamy top vertic soil association in excellent units are deficient in nitrogen,

phosphorus and zinc where as hard root restricting and sodium enriched subsoils in case of suitable and of stony to gravelly root restricting vertic soil associations on gullied escarpments and clayey, calcareous soils in Pus and Wardha valleys of slightly suitable units. The cracking clay soils in the vicinity of Jayakwadi command area were rated as ‘suitable for irrigation with moderate or severe limitations’ and possible crops included field crops of grain sorghum, wheat, cotton, and oil seeds [16]. Water infiltration rates as high as 20 mm / hr have been measured on such soils but reduce to less than 2 mm / hr as quickly as a half an hour after the water application commenced [40].

The importance of climate for cotton based systems in Maharashtra is critically analysed and reported that the rainfall of 250 to 325mm from squaring to peak flowering stage was found to be critical [41]. Hence the climate of Yavatmal for cotton is moderately suitable with short dry spells at critical stages of cotton during September to October. This region experiences 12 to 20 normal dry weeks followed by 3 to 8 weeks of wet weeks from 35 years of daily rainfall data using standard precipitation index [42] Cotton as principle *kharif* crop occupies 52 per cent of total cultivated area and needs 2 to10 irrigations after cessation of with the consumptive use of 650 to 1000 mm [43]. If rainfall is less and distribution is not proper, light irrigation maybe given from germination to four leaf stage. At this time, cotton is susceptible to drought. This exercise is useful to delineate vulnerable areas for crop saving irrigation in times of short dry spells and also to raise rabi wheat under canal irrigated areas of Pus, Arunavati and Penganga valley regions.

Table 5: Available soil water(ASW), irrigation intervals and fertility capability of each irrigable soil mapping unit

Soil series/ Suitability class	ASW (cm/m)	Irrigation interval (days)			FCC (Fertility capability class)	Area	
		Wheat	Cotton	Sugar Cane		ha	(%)
Excellent (I) Lo-Ar-Av(9)	27.3	11.4	10.9	13.0	CCdvv-LLdvv(clayey, dry, ustic, vertic calcareous soils associated with loamy top soils deficient in nitrogen, phosphorus and zinc.	11813.9	0.87
Suitable (II) Dk - Ar -Lk- AV(4)	23.9	9.9	9.6	11.3	CCdvv-LLdvv(n(clayey type vertic, ustic, calcareous soils associated with loamy with hard root restricting layers and sodium enriched clay soils with high shrink-swell potentials. These soils are generally deficient in nitrogen, phosphorus, iron and zinc.	188832.7	13.89
Dh-Ar-Lo(12)	25.4	10.6	10.2	12.1			
Dk-Pg-Bo-Pd(22)	21.6	8.1	7.8	9.3			
Wd-Bo-Pg-Ka(27)	22.6	9.4	9.1	10.7			
Sy -Lo-Ar(30)	21.7	9.1	8.7	10.3			
Wn-Ch(34)	24.5	8.7	8.4	9.9			
Ai-Wg – Wn(35)	18.2	7.1	6.8	8.0			
Ci- Wn –Ai(36)	21.5	8.2	7.9	9.4			
Wn-Lo –Ma(37)	26.3	9.5	9.1	7.8			
Wd-Kb-Ar(48)	26.0	10.8	10.4	12.3			
Slightly suitable (III) Lk-Ka-Ar –Dk(1)	26.5	11.1	11.0	12.6	C”Rdb-CCdvv(Clayey with more than 35 % gravels , hard root restricting layers within 50cm, dry, ustic on severely eroded plateau tops and escarpments and	274744.3	20.22
Dk-LK-Dh-Pd(11)	19.6	8.2	7.8	9.3			
Sd-Wg-Dh(14)	19.7	8.2	7.9	9.3			



Bo-Ka-Wg(16)	20.0	8.3	8.1	9.5	on stony gullied pediplains. These soils are associated with clayey, dry, ustic , vertic, calcareous soils occurring on gently sloping plains of Pus, Wardha and Penganga valleys).		
Lk-Bo-Ar-Dk(17)	22.6	9.4	9.1	10.7			
Bo-Pd-Mo(24)	18.4	7.7	7.4	8.7			
Sy -Wg(33)	13.6	5.7	5.5	6.5			
Sn-Ch-Roc(40)	23.4	9.8	9.2	11.1			
Bo-Ra-Lk(43)	18.8	7.8	7.5	8.8			
Km-Lk-Hi(45)	20.1	8.4	8.1	9.5			
Ra-Kb-Lk(47)	23.2	9.7	9.3	10.9			
Mean ±Sd	22±3.4	8.9±1.37	8.61±1.35	10.0±1.64			
Cv(%)	15.22	15.37	15.69	16.31			

#### IV. CONCLUSIONS

The soil resource evaluation for irrigation in debt - driven and drought - prone cotton growing Yavamal district showed that the suitable land for irrigation is only fifteen per cent of total cultivated area. The parametric evaluation further showed 14 per cent of irrigable by surface methods on moderate slopes (5 to 8 per cent) are evaluated as suitable for surface methods whereas 20.22 per cent by drop irrigation. The irrigation frequencies of irrigable mapping units varied from 9 days for cotton and wheat and 10 days for sugarcane This exercise helps in designing crop calendar under irrigated tract as per soil water retention characteristics and water availability for diversified cropping systems.

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