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Research Article

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Irrigation water: Its influence on the quality of soils in Amravati district, Maharashtra

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Summary

Poor quality of both surface and groundwater is a limiting factor for the irrigation of many black soil areas of the Purna Valley, Maharashtra. The present study is a humble effort to flag some of the concerns of these valley raised by the farmers in Amravati district representing the Vidarbha region of Maharashtra. Irrigation sources are river, canal and predominantly wells in the study area. Samples of irrigation water and soils were collected and analysed from four tehsils of Amravati district, Vidarbha, Maharashtra to assess the quality of irrigation water and its impact on black soils. Soil samples (Shirala-Amravati, Darapur- Daryapur, Wathoda- Bhatkuli and Temburkheda- Warud) were analysed to study the influence of irrigation water on soil characteristics. It was observed that the water used for irrigation in Shirala soil is in the class C3S2 with sodium adsorption ratio (SAR) value ~12, electrical conductivity (EC) 1.8 dSm^{-1} and Na^+ 14.0 $mmol_c l^{-1}$ which increased the EC of soils. The higher concentration of Na^+ and Mg^{2+} ions is responsible for drainage impairment. The irrigation water of Wathoda (C4S1) increased EC values of irrigated soils. The reduced saturated hydraulic conductivity (sHC) in irrigated soils as compared to unirrigated soils is attributed to the higher concentration of sodium. The water used for irrigation in Temburkheda and Darapur are similar in quality (C3S1). The soils of Darapur experienced significant increase in EC as compared to Temburkheda soils. This was also associated with decrease in the values of soil drainage (sHC :0.14-0.17 cmh^{-1}) in the Darapur soils. Moreover, exchangeable as well as water soluble Na^+, Mg^{++}cations and EC also increased in the upper layers of the irrigated soils due to application of poor quality irrigation water. This caused deterioration of the soil quality. With the help of temporal datasets of soils the effect of irrigation water on soil properties was assessed. The soils which were rainfed showed improved condition in terms of several physical and chemical properties; however, the soils when irrigated with poor quality water brought several problems in soils in terms of physical and chemical properties. Immediate measures are necessary in the study area.

Key words : Irrigation water, Influence, Quality of soils

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Introduction

Maharashtra covers nearly 20 per cent of its land under irrigation (4.2 Mha). In Vidarbha, the total irrigated area is 0.7 Mha, which accounts to 14 per cent of the gross cultivated land. Amravati district is spread over 12,210 sq.km land having nearly 7.0 lakh ha area under cultivation with 0.9 lakh ha of its area under irrigation.

Black soils (Vertisols) are dominant in Amravati district. Rainfalls in this area is generally short in duration and have long dry spells leaving very less residual moisture in soils for the benefit of *Rabi* crops. The farmers suffer either due to water stagnation in *Kharif* or no moisture left for the second crop (*Rabi*). Therefore, irrigation becomes the necessity. Irrigation sources in this area are predominantly wells. It has been found that most of the natural river and well water in this area havehigh to very high salinity and low to medium sodicity (Nimkar *et al.*, 1992; Kadu *et al.*, 1993 and Balpande *et al.*,1996). Irrigation with waters that have high concentration of sodium relative to divalent cations (*i.e.* waters containing more sodium) deteriorates the soil structure. This may ultimately result in a loss of soil productivity because of the reduction in permeability of water and air, offering resistance to root penetration. Poor quality of irrigation water may affect the soil health by affecting the physical and chemical properties responsible for normal growth of crop plants. Therefore, water is a limiting factor for the irrigation of these soils.

Soils of Amravati district, despite of low level of sodicity (ESP$\geq$ 5) show severe drainage problem, causing water stagnation in the rainy season that highly affect the sowing of *Kharif* crop. Crop failure due to lack of stored moisture is another problem of these soils. The use of natural water sources for irrigation (river or well) aggravates the soil physical condition to such an extent that the farmers are forced to abandon irrigation (Nimkar *et al.*, 1992).

It has been found that arid, semi-arid and coastal regions groundwater is either the major or only source of irrigation to supplement the scanty rainfall (Yadav *et al.*, 1983). The majority of ground waters in these regions are of poor quality due to excessive salt concentration, high sodium adsorption ratio (SAR) and or residual sodium carbonate (RSC) values. Scarcity of good quality of water forces the farmers to use easily available saline or sodic water for irrigation (Girdhar,1996).

For the proper land resource management of the area it is very essential to have a proper assessment of the soil and water resources that are integral part of crop planning for a sustainable land use without degrading the precious natural resources like soils. Therefore, the present study has been taken upto assess the quality of the irrigation water and its influence on the black soils of Amravati district.

Resource and Research Methods

Amravati district lies between $20^0$30' and $21^0$46' N latitude and $76^0$37' and $78^0$27' E longitude. The soils of Amravati district are derived from Deccan trap and shows wide variation in their depths. Rainfed agriculture is dominant in this area with cotton, redgram, soybean, greengram and chickpea as the major crops. Orange is the main crop in Warud tehsil. The soils are deep, calcareous, clayey and dark greyish brown to dark brown in colour. Cracks generally extend up to the slikensided zones.

Climate:

The area is characterized by a semi-arid (moist) climate with 975 mm average annual rainfall (Balpande *et al.*,1996) and experiences dry season from October through June and wet season from July to September receiving 85-90 per cent of the total rainfall. April and May are the hottest months and December and January are the coolest months. The soils have typic tropustic moisture regime and hyperthermic temperature regime (Van Wambeke, 1985).

Groundwater:

The groundwater is very brackish in most part of the district. In the Purna valley the average annual recharge to the groundwater is approximately 8 per cent of the annual rainfall (Elangovan,1985). Adyalkar (1963) postulated that this exceptional salinity is because of its marine origin from the intrusion of a stretch of sea water in to the Purna sub-basin. However, Muthuraman *et al.* (1992) did not find any match between the ratios of cations to anions with saline water of this tract. Accordingly, they opined the phenomenon as a diagenetically altered meteoric water with a long residence time.

Sampling sites:

Twenty four irrigation water samples were collected from different sampling sites along four talukas of Amravati district *viz.*, Amravati, Daryapur, Bhatkuli and Warud from different sources (wells, tube wells and rivers) (Fig. A). These samples were analysed for electrical conductivity (EC), pH, cations (Ca^{+2}, Mg^{+2}, Na^{+},

K^+) and anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}) as per standard methods outlined by Richards (1954). Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were computed using standard equations available (Jackson, 1973). The water quality was determined as per USSL classification.

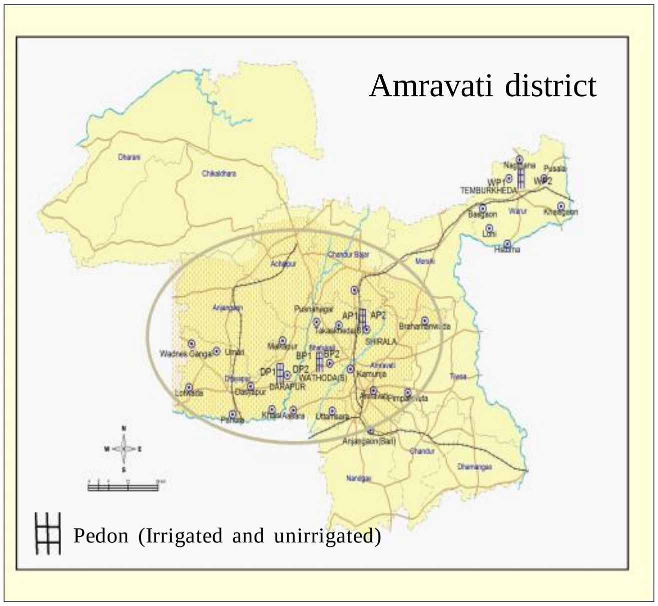

Fig. A: Sampling sites of Amravati district

Eight pedons were dug and studied to see the impact of irrigation water on the soils (irrigated and unirrigated) at four different locations along with irrigation water samples. Samples from minipits (with irrigation water samples) were also done and analyzed at different locations to see the spatial variability of soils and water in above four talukas of Amravati district (Fig. A).

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Chemical composition and quality of irrigation water:

Quality of irrigation water depends on total concentration of soluble salts, relative proportion of sodium to other cations (ESP). In order to avoid deleterious effect of poor quality water on soil properties on plant growth, it is desirable to have quality assessment prior to its use for irrigation. A scheme proposed by the United States Soil Salinity Laboratory (Richards, 1954) has been generally accepted to evaluate irrigation water. The quality of irrigation water is a key issue in irrigated agriculture. Injudicious irrigation even with good quality water, may turn many good soils into saline and alkali ones (Rajput and Polara, 2013).

Study of climatic conditions, traversing along the fields and dialogues with the farmers of Amravati district particularly in saline tract of the Purna valley indicated that intensive crop production in semi-arid region hasto depend on irrigation for growing second crop (*Rabi*) or even for the *Kharif* season when there are long dry spells. Table 1 gives the composition of twenty four water samples which represents the irrigation sources of sampled pedons and minipits along the four tehsils in Amravati district. The data showed that pH of irrigation water in selected sites of Amravati district was in the range of 7.3 to 8.7 with Amravati tehsil in the range 7.6 to 8.4, Daryapur tehsil with 7.3 to 8.6, Bhatkuli tehsil 7.8 to 8.7 and Warud tehsil 7.6 to 8.2 .

Electrical conductivity measures total soluble salts in irrigation water. USSL originally proposed four salinity classes, *viz.*, C1 class of water with EC less than 0.25 dSm^{-1} considered safe and no likelihood of any salinity problem, medium salinity class (C2) with EC between 0.25 to 0.75dSm^{-1}, needs moderate leaching; high salinity class (C3) with EC between 0.75 to 2.25 dSm^{-1} and very high salinity class (C4) with EC more than 2.25 dSm^{-1}. Kanwar (1961) included C5 class of water with EC from 5-20 dSm^{-1}, particularly for Indian soils.

The electrical conductivity of irrigation water in the area was in the range of 0.5 to 7.1 dSm^{-1} with Warud tehsil showing lowest EC values (0.7 to 1.0 dSm^{-1}) and Daryapur tehsil water had the highest EC (1.4 to 7.1 dSm^{-1}) (Table 1). Bumbla and Abrol (1972) also suggested 1.5 dSm^{-1} as an upper permissible safe limit of EC of water for irrigating black soils when semi tolerant crops are to be grown. Considering the above criteria water from Shirala (Well), Kamunja (Pedhi river) in Amravati tehsil; Darapur (well) and Panora (river) in Daryapur tehsil; Wathoda, Purnanagar, Aasara and Khartalegaon (all wells) is unsuitable for irrigation. The irrigation water of Warud tehsil having low EC values can be considered to be safe for irrigation.

In addition to the degree of salinisation, the type of salinisation, the sodium hazard and concentration of residual sodium carbonate have to be taken into account. Therefore, Richards (1954) suggested sodium adsorption ratio (SAR) as an indiactor for water quality ; accordingly water can be classified as low sodium water (S1-SAR O-10), medium sodium water (S2-SAR,10-18), high sodium water (S3- SAR 18-26) and very high sodium water (S4- SAR>26).Sodium adsorption ratio (SAR) values of irrigation water in Amravati tehsil ranged from 0.5 to 11.8 with Shirala well water showing the highest SAR (11.8) followed by Pedhi river water at Kamunja (6.1) in S1 class alongwith others in the tehsil having SAR values less than 1.0. The SAR of the irrigation water in Daryapur tehsil was in the range 4.8 to 13.7 with Wadner Gangai showing the highest value. Bhatkuli tehsil water belonged to the class S1 with exception of Khartalegaon which had higher value (17.0). Irrigation water of Warud tehsil had low SAR values ranging from 0.5 to 6.1 (Table 1).

The residual sodium carbonate (RSC) (CO_3^{--}+ HCO_3^{--}- Ca^{++}+ Mg^{++}) has been widely used for characterising the sodium hazard of water. According to the criteria proposed by Wilcox *et al.* (1954), water with more than 2.5 $mmol_c l^{-1}$ of RSC is not suitable, 1.25 to 2.5 $mmol_c l^{-1}$ is marginal and less than 1.25 $mmol_c l^{-1}$ is safe for use. RSC of the water used for irrigation in Amravati tehsil soils varied from -3.5 to 10.1 $mmol_c l^{-1}$, RSC of Darapur and Bhatkuli tehsil water was in the range -4.6 to 38.4 $mmol_c l^{-1}$ and -0.2 to 17.0 $mmol_c l^{-1}$, respectively. Warud water showed comparatively lower values of RSC ranging from -3.3 to 5.6 $mmol_c l^{-1}$. Amongst the cation, sodium was dominant over the combined concentration of calcium and magnesium in most of the irrigation water samples. The sodium concentration in Amravati tehsil water ranged from 0.7 to 14.0 $mmol_c l^{-1}$.

Table 1: Taluka wise values of cations and anions of well/ tube well and river water samples of Amravati district

Tehsil	Village	Source	pH	(1) EC	Cations ($mmol_c l^{-1}$)				Anions ($mmol_c l^{-1}$)				(2)	(3)	(4)	(5)	Ca/	(6)
				(dSm^{-1})	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO^{--}_4	RSC	SAR	MAR	SMAR	Mg	Class
Amravati	Shirala	Well	8.4	1.8	0.3	2.5	14.0	0.01	1.1	11.8	3.2	0.86	10.1	11.8	2.9	39.0	0.1	C3S2
	Amravati	Well	7.6	1.2	4.3	3.0	2.0	0.01	__	3.8	4.4	1.62	-3.5	1.0	0.8	2.2	1.4	C3S1
	Anjangaon	Well	8.1	0.9	1.8	4.0	1.3	0.01	__	2.3	2.0	3.15	-3.5	0.8	1.5	2.9	0.5	C3S1
	Kamunja	River	8.3	1.8	2.6	3.6	10.8	0.31	0.9	7.8	5.6	3.01	2.5	6.1	1.2	10.6	0.7	C3S1
	Pimpalkhuta	Well	8.1	0.5	1.9	2.3	0.7	0.02	__	3.5	1.2	0.22	-0.7	0.5	1.1	1.8	0.8	C2S1
	Brahmanwada	Well	8.0	0.5	1.8	1.8	0.9	0.01	__	3	1.6	0.11	-0.6	0.7	1.0	1.9	1.0	C2S1
Daryapur	Darapur	Well	8.5	1.6	0.9	2.4	11.5	0.02	0.9	9.7	3.2	1.11	7.3	9.0	1.6	18.8	0.4	C3S1
	Panora	River	8.5	3.4	3.8	10.6	12.9	0.31	1.6	8.2	14.8	3.81	-4.6	4.8	1.7	11.0	0.4	C4S1
	Wadnergangai	T.well	8.6	1.6	0.3	1.6	13.4	0.01	1.1	9.9	3.6	0.27	9.1	13.7	2.3	36.8	0.2	C3S2
	Malkapur	T.well	8.2	1.4	0.4	5.4	8.5	0.01	__	7.9	4.0	1.31	2.1	5.0	3.7	22.7	0.1	C3S1
	Darapur	Well	7.3	7.1	11.1	33.9	25.8	0.02	---	6.6	37.2	7.00	38.4	5.4	1.7	12.7	0.3	C4S1
Bhatkuli	Wathoda	Well	8.3	3.0	0.6	11.2	19.0	0.04	0.7	10.9	12.8	4.09	-0.2	7.8	4.3	39.0	0.1	C4S1
	Purnanagar	T.well	7.9	2.0	0.3	3.9	13.8	0.02	__	13.2	3.6	1.88	9.0	9.5	3.6	39.2	0.1	C3S1
	Uttamsara	Well	8.3	1.0	0.8	3.4	4.8	0.01	__	6.9	2.0	0.56	2.7	3.3	2.1	9.7	0.2	C3S1
	Takarkheda	T.well	8.7	1.3	0.3	3.9	7.6	0.01	1.6	8.3	2.4	0.35	5.7	5.2	3.6	23.2	0.1	C3S1
	Aasara	Well	7.8	2.2	8.9	8.9	4.3	0.08	__	4.1	14.0	2.87	13.8	1.4	1.0	3.0	1.0	C4S1
	Khartalegaon	Well	8.7	4.2	0.5	2.3	20.1	1.28	2.2	17.6	14.8	2.92	17.0	17.0	2.1	42.3	0.2	C4S2
Warud	Temburkhed	Well	7.9	0.9	1.5	3.5	3.5	0.02	_	6.4	2.0	0.13	1.4	2.2	1.5	5.6	0.4	C3S1
	Nagthana	Well	8.0	0.9	3.4	3.6	0.9	0.01	__	3.7	2.4	1.05	-3.3	0.5	1.0	1.7	0.9	C3S1
	Haturna	Well	8.0	1.0	0.7	2.2	7.3	0.02	__	8.5	1.2	0.51	5.6	6.1	1.8	14.2	0.3	C3S1
	Bargaon	Well	8.2	1.0	0.8	3.9	4.7	0.02	__	7.0	2.6	0.38	2.3	3.1	2.2	9.6	0.2	C3S1
	Loni	Well	8.1	0.8	0.9	4.2	2.6	0.02	__	4.6	2.7	0.34	-0.5	1.6	2.2	6.0	0.2	C3S1
	Pusala	Well	7.8	1.0	1.8	3.2	1.8	0.06	__	4.8	2.8	0.38	-0.2	1.1	1.3	3.2	0.6	C3S1
	Khairgaon	Well	7.6	0.7	2.7	1.8	0.9	0.01	__	4.9	1.6	0.11	0.4	0.6	0.8	1.6	1.5	C2S1

EC : Electrical conductivity; RSC: Residual sodium carbonate; SAR: Sodium adsorption ratio; MAR: Magnesium adsorption ratio;
SMAR : Sodium magnesium adsorption ratio; Irrigation water class was determined following Richards (1954) : where C refers to EC (Salt concentration) and S refers to sodium (SAR)

Daryapur tehsil showed higher levels of sodium ranging from 8.5 to 25.8 $mmol_c l^{-1}$ and in Bhatkuli tehsil it was in the range 4.3 to 20.1 $mmol_c l^{-1}$. In general Magnesium and calcium were second and third in order of dominance but Warud water shows the dominance of Mg^{++} over Na^{+}. Among the anions, the concentration of bicarbonate and chloride was relatively high followed by sulphate in most of the water samples (Fig. A).

Influence of irrigation water on the physical and chemical properties of black soils:

In order to find out the inter-relationship between the soil and water characteristics esspecially the impact of poor quality irrigation water on soils. The soil and water samples from eight pedons (one each under irrigated and unirrigated condition) were collected from each of the four talukas (Shirala- Amravati taluka, Darapur- Daryapur taluka, Wathoda- Bhatkuli taluka and Teburkheda- Warud taluka) from Amravati district were collected and analysed.

Soils of selected pedons are fine to very fine, smectitic, hyperthermic, Typic Haplusterts. All the soils are very deep with very high clay content (45.2 to 77%) having subangular blocky structure becoming blocky in subsoil with very sticky and very plastic consistence. Most importantly, the soils of the irrigated and unirrigated sites of Amravati district have resembling texture having similar substrate (Table 2). Therefore, they are comparable.

The EC of the irrigation water collected from the irrigated profile sites in Amravati district ranged from 0.9 to 3.0 dSm^{-1} (Table 1). (Temburkheda 0.9, Darapur 1.6, Shirala 1.8 and Wathoda 3.0 dSm^{-1}) which falls under class C3 and C4, unsuitable for irrigation. The irrigation water of the study area falls under low to medium category of sodicity where the water of Shirala belonged to S2 class and Darapur, Wathoda, Temburkheda to class S1. As per criteria mentioned for RSC, the irrigation water from Shirala, Darapur are unsuitable for irrigation with RSC 10.1 and 7.3, respectively. Temburkheda irrigation water is marginally suitable (RSC 1.4). Wathoda water has low RSC value due to the dominance of Mg^{++}ions concentration (Table 1). When all the parameters (EC, SAR, RSC) were considered, the water used for irrigation is unsuitable for irrigation in clayey soils of Amravati district. The quality of water used for irrigation follows the trend: Temburkheda (C3S1) > Darapur (C3S1) > Shirala (C3S2) > Wathoda (C4S1).

While evaluating the effect of irrigation water of above quality, the pH of soil did not reflect any specific comparable trend, but could show higher values of pH in irrigated soil than unirrigated soil of Darapur profile particularly in the upper layer. The EC of the irrigated soils ranged from 0.18 to 0.66 dSm^{-1} and 0.13 to 0.21 dSm^{-1} in unirrigated soils. EC was higher in all the irrigated profiles than unirrigated. Highest impact was observed in Wathoda (Irrigated-0.7 dSm^{-1}, Unirrigated-0.2 dSm^{-1}).

In general, calcium was the dominant exchangeable cation at all the sites. In Shirala irrigated soil, exchangeable calcium content was followed by magnesium, sodium and potassium but in unirrigated profile Na^{+} concentration was less than K^{+}, suggesting the contribution of irrigation water (C3S2) to increase ESP. Similar trend was observed in other irrigated soils except Temburkheda soils.

ESP of irrigated profiles in Shirala (1.9-9.1), Darapur (6.8-8.8), Wathoda (1.7-6.1) were higher in all the layers with respect to unirrigated (0.7-1.0, 0.9-1.7 and 1.0-1.8). Temburkheda irrigated soil showed marginal rise in the

Table 2 : Quality of soils (Weighted mean average values)

Particulars	Soil layer (cm)	Amravati		Daryapur		Bhatkuli		Warud	
		Irrigated	Unirrigated	Irrigated	Unirrigated	Irrigated	Unirrigated	Irrigated	Unirrigated
Clay %	0-30	65.6	65.5	66.8	69.8	73.0	67.4	45.2	51.4
	30-50	65.4	67.4	67.6	72.5	77.3	68.6	51.5	56.3
	50-100	69.3	71.2	60.7	63.5	69.8	64.0	51.1	44.3
Silt %	0-30	29.9	29.1	29.8	28.0	23.8	29.6	53.3	43.9
	30-50	30.3	29.4	29.9	25.2	19.8	28.5	44.6	41.1
	50-100	26.4	25.3	34.9	32.3	27.1	26.6	46.0	52.5
Sand %	0-30	4.5	5.3	3.4	2.2	3.2	3.1	4.1	4.7
	30-50	4.3	3.2	2.6	2.4	2.8	2.8	3.9	2.7
	50-100	4.3	3.6	4.4	4.2	3.1	9.4	2.9	3.2

ESP values over unirrigated profile upto 50 cm depth (Table 3).

The data on the composition of saturation extract of the soils are presented in Table 4. Electrolyte conductivity (ECe) of irrigated soils have been increased over unirrigated soils following the trend of ECiw. An increasing trend of rise in the ECe in the layers indicates that the irrigation water facilitates excessive accumulation of salts in the irrigated profiles.

Bicarbonates, chlorides and sulphates were the dominant anions in irrigated soil of Shirala and Darapur (2.2-5.7, 1.4-7.2, 1.1-2.1 $mmol_c l^{-1}$ and 2.7-3.9, 1.2-2.5, 1.7-3.3 $mmol_c l^{-1}$) with much higher concentration than the unirrigated profiles (1.6-2.6, 0.5-1.4, 0.4-1.1 $mmol_c l^{-1}$ and 1.8-2.8, 0.5-1.1, 0.2-0.4 $mmol_c l^{-1}$). Wathoda irrigated profile had very high values of chlorides and sulphates (12.9 and 11.8 $mmol_c l^{-1}$) over unirrigated soils (1.2 and 0.8 $mmol_c l^{-1}$). Temburkheda irrigated soils showed upper layers with increased anion concentration than unirrigated soils (Table 4). Among the soluble cations

Table 3 : Comparative soil properties of irrigated and unirrigated soils

Soil layer (cm)	pH	EC (dSm^{-1})	Extractable bases [cmol (p^+) kg^{-1}]				ESP*	Saturated hydraulic conductivity ($cmhr^{-1}$)
			Ca^{2+}	Mg^{2+}	Na^+	K^+		
Pedon 1. Shirala soil – Amravati tehsil (Irrigated)								
0-30	8.4	0.28	53.5	10.1	5.5	1.4	9	0.08
30-50	8.2	0.24	66.7	9.1	2.0	1.4	3	0.22
50-100	8.1	0.21	53.8	11.1	1.3	1.5	2	0.26
Pedon 2. Shirala soil – Amravati tehsil (Unirrigated)								
0-30	8.2	0.15	45.9	8.3	0.4	1.4	1	0.71
30-50	8.3	0.17	45.3	13.2	0.5	1.2	1	0.48
50-100	8.3	0.16	42.1	5.8	0.5	1.2	1	0.41
Pedon 3. Darapur soil – Daryapur tehsil (Irrigated)								
0-30	8.7	0.27	45.5	1.0	4.9	2.2	9	0.14
30-50	8.6	0.26	49.9	1.5	4.1	1.0	7	0.16
50-100	8.4	0.36	44.9	1.1	5.0	0.9	9	0.19
Pedon 4. Darapur soil – Daryapur tehsil (Unirrigated)								
0-30	8.0	0.21	58.1	0.7	0.6	1.5	1	0.40
30-50	8.1	0.13	42.7	0.6	0.5	1.3	1	0.42
50-100	8.2	0.13	45.5	0.8	0.5	1.1	1	0.46
Pedon 5. Wathoda soil – Bhatkuli tehsil (Irrigated)								
0-30	7.9	0.66	48.0	1.2	4.2	1.3	6	0.17
30-50	7.9	0.44	48.7	1.1	2.5	1.0	4	0.22
50-100	7.9	0.53	47.6	1.3	1.0	1.0	2	0.26
Pedon 6. Wathoda soil – Bhatkuli tehsil (Unirrigated)								
0-30	7.9	0.16	52.2	1.2	0.8	1.5	1	0.65
30-50	8.1	0.16	56.4	0.8	0.7	1.2	1	0.67
50-100	8.2	0.17	48.6	0.9	0.6	0.9	1	0.93
Pedon 7. Temburkhed soil – Warud tehsil (Irrigated)								
0-30	8.3	0.19	35.2	12.0	1.3	1.4	3	0.98
30-50	8.3	0.18	36.1	12.2	1.3	1.0	3	0.71
50-100	8.5	0.19	35.2	13.6	1.7	1.0	4	0.47
Pedon 8. Temburkhed soil – Warud tehsil (Unirrigated)								
0-30	8.3	0.17	34.5	11.3	0.6	2.5	1	1.63
30-50	8.3	0.18	33.0	13.6	0.5	1.4	1	0.72
50-100	8.4	0.18	33.2	13.7	1.2	1.1	4	0.78

*ESP- Exchangeable sodium percentage

sodium shows dominance in Shirala and Darapur in all the layers (1.3-9.9 and 3.8-6.9 $mmol_c l^{-1}$), these values were too high when compared (0.3-1.0 and 0.3-1.0 $mmol_c l^{-1}$) with the unirrigated sites. Wathoda soil shows increase in values of soluble sodium and magnesium (2.0-14.9 and 1.7-5.2 $mmol_c l^{-1}$) due to irrigation over unirrigated condition (0.4-1.1 and 0.6-1.2 $mmol_c l^{-1}$). Temburkheda soil remained unaffected and had only little increase of sodium in surface, may be due to good drainage conditions. Soluble Ca/Mg ratio was decreased in all the irrigated profiles in comparison with unirrigated soils.

Sodium adsorption ratio (SAR) of Shirala and Wathoda irrigated soils raised in upper layer (6.1 and 6.6) as compared to unirrigated which was 0.4 and 0.5. SAR of Darapur irrigated soil was increased throughout the profile (3.6-9.0) which was very high compared to unirrigated soil (0.3-0.8). Temburkheda site too had impact of rise in SAR values in 100 cm depth. The soluble sodium percentage was increased at all the sites in

Table 4 : Composition of saturation extract of soils (Weighted mean average values)

Soil layer (cm)	ECe (dSm^{-1})	Soluble anions ($mmol_c l^{-1}$)			Soluble cations ($mmol_c l^{-1}$)				SAR*	Soluble sodium %
		HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+		
Pedon 1. Shirala soil – Amravati tehsil (Irrigated)										
0-30	1.59	5.7	7.2	2.1	3.6	1.5	9.9	0.17	6.1	65
30-50	0.83	3.8	3.3	1.1	3.4	1.3	3.4	0.10	2.0	34
50-100	0.59	2.2	2.0	1.3	3.1	0.9	1.3	0.10	0.9	23
Pedon 2. Shirala soil – Amravati tehsil (Unirrigated)										
0-30	0.36	2.6	0.5	0.4	2.2	0.7	0.3	0.08	0.4	11
30-50	0.27	2.3	0.5	0.4	1.4	0.6	0.4	0.04	0.4	17
50-100	0.33	1.9	0.8	0.6	0.6	0.7	0.7	0.03	0.7	24
Pedon 3. Darapur soil – Daryapur tehsil (Irrigated)										
0-30	0.73	3.9	1.7	1.8	0.9	0.5	5.8	0.15	9.0	80
30-50	0.61	3.0	1.2	1.8	0.8	0.4	4.5	0.21	5.9	77
50-100	0.94	3.3	2.5	3.3	1.4	0.6	6.9	0.05	6.7	76
Pedon 4. Darapur soil – Daryapur tehsil (Unirrigated)										
0-30	0.26	1.8	0.5	0.4	1.7	0.5	0.3	0.10	0.3	9
30-50	0.30	2.3	0.6	0.3	2.1	0.6	0.4	0.05	0.3	12
50-100	0.35	2.4	0.7	0.3	1.9	0.7	0.6	0.06	0.5	17
Pedon 5. Wathoda soil – Bhatkuli tehsil (Irrigated)										
0-30	2.47	1.9	12.9	7.1	7.0	3.1	14.9	0.12	6.6	59
30-50	1.23	1.7	2.7	7.3	4.9	1.7	5.7	0.07	3.0	43
50-100	1.50	1.0	1.8	11.8	9.2	3.2	2.0	0.09	0.9	14
Pedon 6. Wathoda soil – Bhatkuli tehsil (Unirrigated)										
0-30	0.34	1.5	1.2	0.4	2.0	0.6	0.4	0.09	0.5	14
30-50	0.31	1.6	0.8	0.5	1.6	0.6	0.5	0.07	0.5	18
50-100	0.34	2.2	0.4	0.8	1.7	0.7	0.6	0.05	0.6	20
Pedon 7. Temburkhed soil – Warud tehsil (Irrigated)										
0-30	0.52	3.0	1.4	0.8	2.2	1.0	1.7	0.11	1.4	36
30-50	0.48	2.3	1.7	0.8	2.1	1.0	1.6	0.05	1.3	34
50-100	0.45	1.8	2.0	0.5	1.2	0.6	2.3	0.05	2.6	58
Pedon 8. Temburkhed soil – Warud tehsil (Unirrigated)										
0-30	0.44	2.8	0.5	1.2	2.4	0.9	0.5	0.13	0.6	14
30-50	0.37	2.9	0.3	0.6	1.9	0.7	0.8	0.05	0.7	34
50-100	0.41	3.0	0.4	0.6	1.4	0.6	1.7	0.08	1.8	45

*SAR – Sodium adsorption ratio

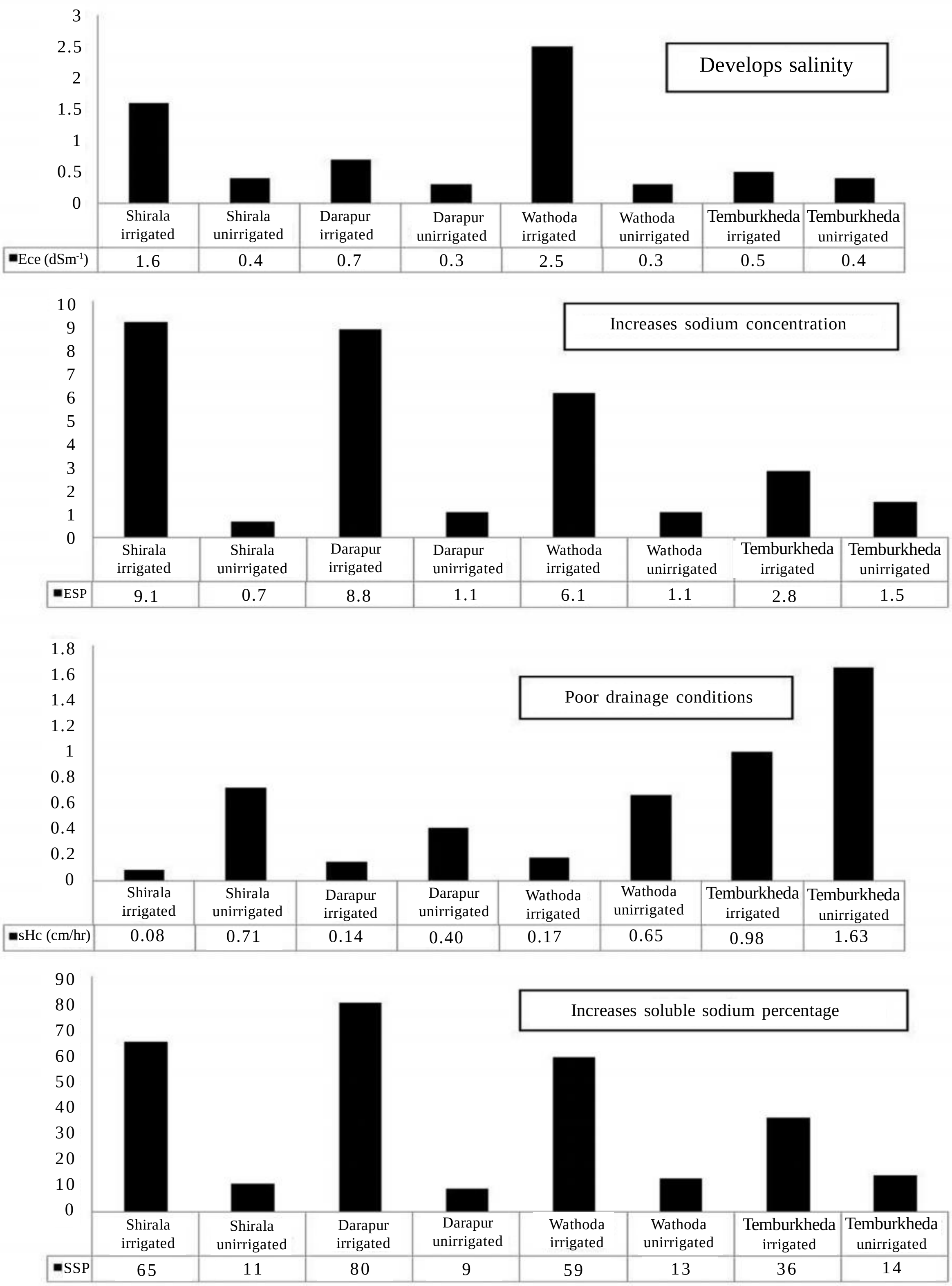

Fig. 1: Comparison of soil parameters: Effect of irrigation water

Table 5: Changes in selected soil properties over time and due to irrigation in soils of Daryapur tehsil in Amravati district, Maharashtra

Particulars	Depth (cm)	Unirrigated		Irrigated
		Chendikapur* 1990	Darapur 2010	Darapur 2010
Location			20°57'55"N, 77°29'31.8"E	20°57'41.9"N, 77°29'29.5"E
Physical properties of soils				
BD (Mg m^{-3})	0-30	1.7	1.7	1.7
	30-50	1.7	1.8	1.8
	50-100	1.8	1.8	1.8
sHC (cm hr^{-1})	0-30	0.30	0.40	0.14
	30-50	0.26	0.42	0.16
	50-100	0.21	0.46	0.19
AWC (%)	0-30	16.5	25.0	21.4
	30-50	14.4	20.5	19.0
	50-100	16.9	18.8	19.6
Chemical properties of soils				
pH	0-30	8.3	8.0	8.7
	30-50	8.4	8.1	8.6
	50-100	8.6	8.2	8.4
EC (dS m^{-1})	0-30	0.61	0.21	0.27
	30-50	0.50	0.13	0.26
	50-100	0.64	0.13	0.36
% OC	0-30	0.6	0.6	0.7
	30-50	0.6	0.5	0.7
	50-100	0.5	0.5	0.6
% $CaCO_3$	0-30	6.5	5.5	6.9
	30-50	7.3	8.0	8.6
	50-100	11.1	10.7	11.9
CEC [cmol(p^+)] kg^{-1}	0-30	50.8	59.8	55.7
	30-50	49.7	60.5	60.6
	50-100	50.7	59.4	57.7
ESP	0-30	3.7	1.1	8.8
	30-50	3.5	0.9	6.8
	50-100	3.8	0.9	8.7
pHs	0-30	7.8	8.1	8.6
	30-50	7.8	8.2	8.4
	50-100	7.9	8.2	8.2
ECe (dS m^{-1})	0-30	1.95	0.26	0.73
	30-50	1.61	0.30	0.61
	50-100	2.19	0.35	0.94
SAR	0-30	3.2	0.3	9.0
	30-50	3.0	0.3	5.9
	50-100	3.3	0.5	6.7
SSP	0-30	40.8	8.5	79.8
	30-50	41.2	11.5	76.6
	50-100	40.2	17.4	76.0
Irrigation water				
			pH	8.5
			EC(dS m^{-1})	1.6
			SAR	9.0
			CLASS	C3S1
Reference		Nimkar (1990)	Present work	

* This spot is 1.5 km within Darapur irrigated and unirrigated pedons. Chendikapur and Darapur has similar soils

irrigated soils rendering soil sodicity.

Inspite of the poor irrigation water, the sHC of Temburkheda irrigated soil (4.5-9.8 $mmhr^{-1}$) was higher when compared with other soils in the district, which might be influenced by the amount of total clay, fine clay and silt fraction and lower ESP, SAR, SSP and Na^+ concentration in comparison with other irrigated soils of the district. In all the other sites sHC had been influenced by the use of poor quality of irrigation water.

Changes in the soil properties of the study area over last 20 years:

In order to assess the changes in soil properties over the period in Daryapur tehsil, an effort was made to compare selected soil parameters with the present findings during 2010 with the available data during 1990's.

Daryapur tehsil:

The properties of soils like bulk density, organic carbon and calcium carbonate remained unaffected during a span of 20 years under unirrigated conditions. An increase in the saturated hydraulic conductivity was also recorded (0.30, 0.26 and 0.21 cm hr^{-1} to 0.40, 0.42 and 0.46 cm hr^{-1}) in the surface (0-30 cm) and subsurface (30-50 and 50-100 cm) layers. Similarly, available water capacity (AWC) was also increased during two decades. Soil reaction (pH) was decreased (8.3-8.6 to 8.0-8.2). Similarly significant decrease in EC values was recorded (0.61, 0.50 and 0.64 to 0.21, 0.13 and 0.13 dSm^{-1}) along with ESP (3.7, 3.5 and 3.8 to 1.1, 0.9 and 0.9) and SSP (40.8, 41.2 and 40.2 to 8.5, 11.5 and 17.4) in present unirrigated soil over the data recorded previously.

Effect of irrigation:

The drainage status in case of irrigated soils shows that there is a significant decrease in saturated hydraulic conductivity (0.14 to 0.19 cm hr^{-1}) than the present unirrigated soils (0.21 to 0.30 cm hr^{-1}) and the soils previously studied which depicts impaired drainage condition after irrigation. The increased ESP of irrigated soils supports this. No significant effect of irrigation was seen in respect of organic carbon and calcium carbonate content over years and present unirrigated conditions. A tremendous increase in the ESP, SAR and SSP was noticed as an effect of irrigation (Table 5). The study suggests that the soils which are rainfed showed improved condition in terms of several physical and chemical properties, however, when irrigated with poor quality water these soils lost their quality as evidenced by physical and chemical properties (Table 5) (Padekar, 2014 and Padekar *et al.*, 2014).

Conclusion:

The soil quality of irrigated sites of Amravati district have been deteriorated because of several reasons such as high clay content of soil, irrigation of poor quality water, high exchangeable and water soluble sodium and magnesium and drainage of the irrigated soils which has been impaired due to increase in ESP after irrigation. Farmers may, therefore, should confine to rainfed agriculture as far as possible and mayavoid continuous use of well or river water. Water as well as soil samples should be checked at regular intervals.

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