Is irrigation water causing degradation in black soils?

Groundwater is the major or the only source of supplemental irrigation in the arid, semi-arid and coastal regions[1]. Poor quality irrigation water in shrink–swell soils (i.e. Vertisols or black cotton soils) causes poor drainage (due to low saturated hydraulic conductivity (sHC)), increase in pH (due to soil reaction), high exchangeable sodium/magnesium percentage and increase in bulk density of soil. Therefore, quality of irrigation water is a key issue in irrigated agriculture, particularly in black soils where due to high clay content of the shrink–swell type of soil, the drainage problem is more likely. In India, shrink–swell soils (Vertisols) developed in the alluvium derived from the weathering of Deccan basalt[2], are found mostly in the Peninsular region extending from 8°45′N to 26°0′N lat. and 68°0′E to 83°45′E long. Majority of shrink–swell soils (Vertisols) covering nearly 76.4 mha (ref. 3) in India occur in the lower piedmont plains or valleys[4], or in microdepressions[5].

The shrink–swell soils contain a high proportion of swelling clays such as smectites. However, their unique physical properties are the greatest limitation to the dominantly low-input agriculture requiring careful management in order to tap the potential and at the same time avoiding any further decline in soil quality. A thorough understanding of the quality of these soils is crucial to develop and implement farming practices that will keep them productive for the current and future generations[6,7]. Vertisols of the Purna Valley, which is spread over the districts of Amravati, Akola and Buldhana in Maharashtra, are generally free from any perceptible evidence of salt efflorescence on the soil surface. However, they do have the problem of poor drainage conditions. This adverse physical condition of the soil is due to its poor hydraulic conductivity caused by inadequate soil drainage, which in turn is mainly caused due to the impairment by sodium in the exchange complex. Additionally, there are other factors and processes that are inherently related to the development of sodicity in these shrink–swell soils. These additional factors/processes are not yet understood completely[8]. Considerable portion of these soils is reported to have developed salinity and waterlogging[8,9]. The Soil Survey Department of Maharashtra has also reported this problem on both banks of the Purna River[10]. Moreover, the soil in these areas generally remains waterlogged even after the rains which disrupts the sowing of *kharif* crops on several occasions. As a consequence, farmers are unable to maintain a sustainable production of agricultural crops.

The present study was undertaken in four tehsils (i.e. blocks) of Amravati district dominant in black soils where, despite the low level of sodicity (exchangeable sodium percentage (ESP) ≥ 5), the soils have severe drainage problem, causing water stagnation in the rainy season which adversely affects the sowing or post-sowing operations in the *kharif* season. Crop failure due to lack of stored moisture is another problem in this part of Maharashtra dominated by these soils. The use of natural freshwater (viz. river or well) for irrigation aggravates the physical condition of the soil to such an extent that many farmers are forced to abandon irrigated agriculture in most parts of the district[11]. In Maharashtra, the total irrigated area is 4.2 mha,

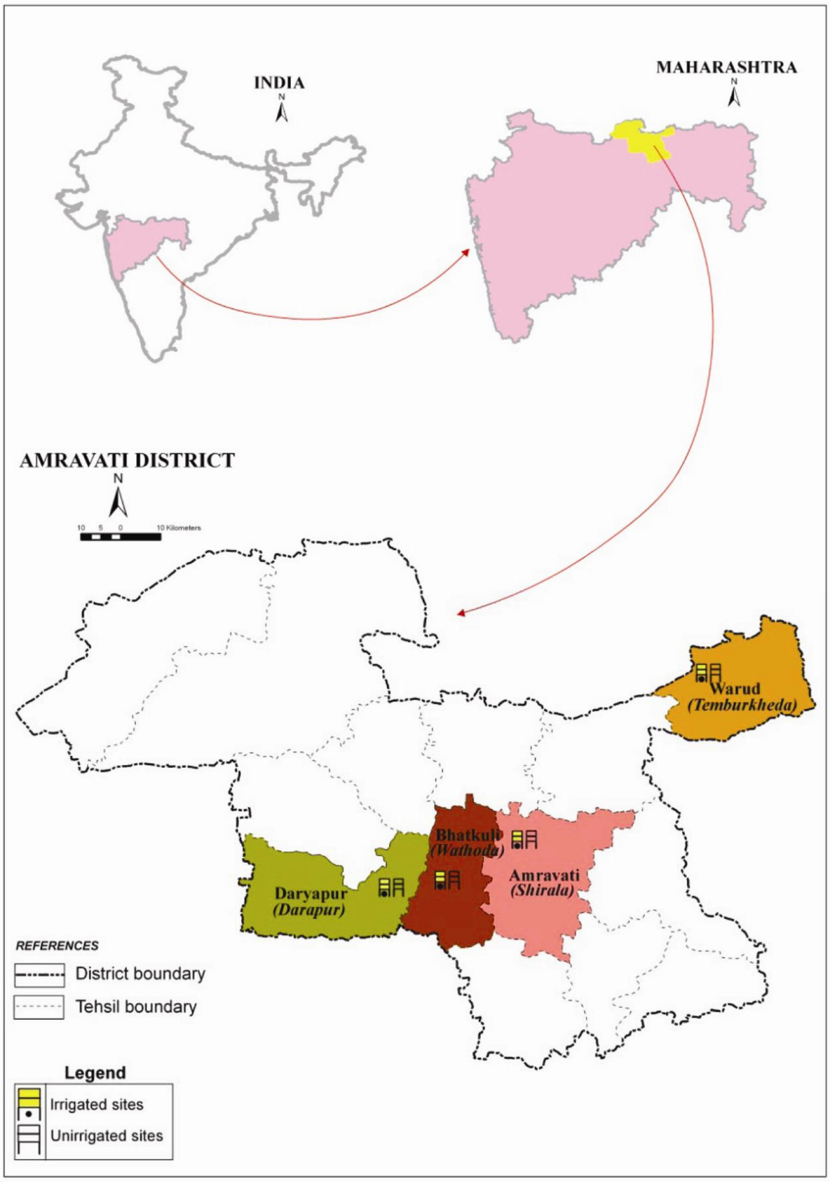

Figure 1. Sampling sites of Amravati district, Maharashtra.

Table 1. Chemical composition of irrigation water[a]

Soil site	Mg^{2+} ($mmol_c l^{-1}$)	Na^+ ($mmol_c l^{-1}$)	pH	EC[b] (dSm^{-1})	SAR[c]	RSC[d]	Water class[e]
Amravati	2.5	14.0	8.4	1.8	11.8	10.1	C3S2
Daryapur	2.4	11.5	8.5	1.6	9.0	7.3	C3S1
Bhatkuli	11.2	19.0	8.3	3.0	7.8	–0.2	C4S1
Warud	3.5	3.5	7.9	0.9	2.2	1.4	C3S1

[a]Irrigation water collected during March, 2011; [b]Electrical conductivity; [c]Sodium adsorption ratio; [d]Residual sodium carbonate (1.25 milliequivalent per litre (meq l^{-1}); safe for irrigation; 1.25–2.5 meq l^{-1}; marginal; >2.5 meq l^{-1}; unsuitable for irrigation[17]; [e]C3S1, High salinity and low sodicity; C3S2, High salinity and medium sodicity; C4S1, Very high salinity and low sodicity[13].

Table 2. Comparative properties of irrigated and unirrigated representative soil from Amravati district (weighted mean average values)[a]

Soil layer (cm)	pH	EC (dS m^{-1})	Extractable bases (cmol(p^+)kg^{-1}) Ca^{2+}	Mg^{2+}	Na^+	K^+	ESP[b]	Saturated hydraulic conductivity (cm h^{-1})
Pedon 1. 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 2. 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

[a]On an average 50 kg N kg ha^{-1} and 30 kg P_2O_5 kg ha^{-1} with very little K fertilizer are added for cotton, pigeon pea and soybean under irrigation. Interestingly, similar doses of fertilizers were also added for cropping under unirrigated condition. [b]Exchangeable sodium percentage.

which accounts for 19.6% of the gross cultivated land. In Vidarbha, 14.1% (0.7 mha) of the land is irrigated. Amravati district has nearly 6.9 lakh ha area under cultivation, with 0.9 lakh ha irrigated (14.0%) land area. The dominant crops of this area are cotton (*Gossypium* spp.), red gram (*Cajanus cajan*), green gram (*Vigna radiata*), soybean (*Glycine max*), chickpea (*Cicer arietinum*) and irrigated wheat (*Triticum aestivum*). Irrigation sources are predominantly wells, tube wells and to a lesser extent rivers. Farmers often complain about the gradual deteriorating condition of the soils due to application of irrigation water, but they also appreciate the necessity of life-saving irrigation during dry spells in the *kharif* season and also to raise the second crop in the *rabi* season. In view of this, we investigated a few representative soil samples, both under irrigation and without irrigation to find out the extent of soil degradation.

Eight soil profiles of about 150 cm depth were excavated from four locations (two each of irrigated and unirrigated soils) at Amravati, Daryapur, Bhatkuli and Warud tehsils of Amravati district (Figure 1). The soil samples were collected along with irrigation water samples during the last week of March 2011. After studying the morphological properties in the field, layer-wise samples of soil were collected for analysis[12,13]. The irrigation water, wherever available, was also collected for analysis. Soil cores were collected from the various zones for determination of bulk density.

In order to avoid deleterious effect of poor-quality water on soil properties and plant growth, it is desirable to have quality evaluation prior to its use for irrigation. The electrical conductivity (EC) of the irrigation water collected from the irrigated profile sites in Amravati district ranges from 0.9 to 3.0 dS m^{-1}, which is considered as unsuitable for irrigation (Table 1). Besides salinity, the type of salinization, viz. the sodium hazard measured as sodium adsorption ratio (SAR) has also been taken into account. The irrigation water of Amravati is more sodic (S2) than the water at Daryapur, Bhatkuli, and Warud with class S1 (Table 1). Water containing CO_3^{2-} and HCO_3^- ions, in excess of Ca^{2+} and Mg^{2+}, often leads to greater alkali formation than water containing sodium alone, as indicated by the SAR value[14]. This occurs due to the precipitation of calcium and magnesium ions resulting in an increase in the SAR value. This led to the development of the concept of residual sodium carbonate (RSC) for evaluating high carbonate water in view of quantitative evaluation of precipitation of Ca^{2+} and Mg^{2+} ions as carbonate. The irrigation water from Amravati and Daryapur is unsuitable for irrigation with unacceptably high RSC values of 10.1 and 7.3 respectively. Irrigation water used in Warud tehsil is marginally suitable (RSC 1.4). Water from Bhatkuli tehsil had low RSC values due to the dominance of Mg^{2+} ion concentration (Table 1). Considering all these three parameters (viz. EC, SAR, RSC), the irrigation water was rated unsuitable for clayey soils of Amravati district. The quality of water used for irrigation shows the following trend: Warud (C3S1) > Daryapur (C3S1) > Amravati (C3S2) > Bhatkuli (C4S1).

Irrigation caused an increase in pH, EC, exchangeable Na^+, Mg^{2+} and K^+. Similarly, after irrigation, ESP increased by 7–9 times in all the layers compared to the unirrigated profile (Table 2). A considerable decrease in the saturated hydraulic conductivity has been recorded when the soils are irrigated. This shows marked decrease in drainage properties of the soils due to irrigation.

From the data it appears that the soil quality of irrigated sites in Amravati district has deteriorated because of various reasons such as high clay content of soil, high exchangeable and water-soluble sodium and magnesium. Moreover, deteriorating physical and chemical properties have resulted in poor conditions of soil due to irrigation using poor-quality water. It is important to note that soils with low EC and high values of exchangeable sodium lead to greater problems of sodicity and waterlogging[15,16]. Water as well as soil samples should be tested at regular intervals. Reclamation measures such as addition of non-swelling material to the surface to improve surface layer porosity and addition of chemical amendments like gypsum along with deep chiselling and other methods (e.g. any of the suitable phytoremediation measures) can be adopted.

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