Research Article

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Characterization and mapping irrigation water quality of coconut groves in Coimbatore and Tiruppur districts of Tamil Nadu, India

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Abstract

It is essential to characterize and map the irrigation water quality to foresee its adverse effect on soil health and productivity. A study was undertaken to generate irrigation water quality maps of coconut land cover in Coimbatore and Tiruppur districts of Tamil Nadu, India using geographic information system (GIS). Samples were collected from 110 geo-referenced collection sites. The irrigation water quality was assessed and thematic maps were developed. From the maps it was found that nearly 12 per cent area had poor quality irrigation water with respect to pH. Majority of the samples were safe and only around 10 per cent samples showed salinity hazard. Based on sodium adsorption ratio (SAR) the irrigation water of major area were in fair (53%) and poor (50%) classes. Irrigation water quality in terms of residual sodium carbonate (RSC) in nearly 42 per cent of the coconut land cover was under unsuitable class. The soluble sodium percentage (SSP) based classification showed good quality irrigation water in most of the area (97%). Around 51 per cent of the area was having irrigation water of unsatisfactory quality based on potential salinity. The permeability index (PI) of the irrigation water of 14 per cent area was found to be unsatisfactory.

Keywords: Characterization, coconut, irrigation, land cover, mapping, water quality

Introduction

Factors affecting crop yield and quality are site-specific (Reetz and Fixen, 2000). The management of spatially and temporally dynamic factors like irrigation water is important in a successful site-specific management strategy. Over drafting of ground water and its quality deterioration are the major threats to crop production (Boumans *et al*., 1988). At the farm level, continuous use of poor quality irrigation water and improper irrigation management adversely affects the soil physical and chemical properties and ultimately affects the productivity of soil.

To assess the irrigation water quality related constraints and to foresee its adverse effect on soil health and crop productivity, it is essential to characterize and map the irrigation water quality. There are several studies related to the regional level assessment of irrigation water quality. Mahendran and Arunachalam (2002) studied the quality of well waters of coastal belts of Radahapuram taluk, Tirunelveli, Tamil Nadu. Minakshi *et al*. (2006) assessed the ground water quality of Rupnagar district of Punjab. Pradhan *et al.* (2011) studied the ground water quality of 'Gohana' Block of Haryana.

The quantity and irrigation water management practice varies with the crop. In the case of perennial plantations like coconut (*Cocos nucifera* Linn.), which stands for decades and being irrigated with more water (under irrigated condition), monitoring the effects of water quality on soil property is necessary. Mapping irrigation water quality may help the coconut groves to protect the soil health and improve crop productivity. Hence, a study was undertaken with the objective to generate irrigation

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water quality maps of coconut land cover of Coimbatore and Tiruppur districts using GIS.

Materials and methods

Study area

The study area covers coconut land cover of Coimbatore and Tiruppur districts of Tamil Nadu state, India. Geographical area of the Coimbatore and Tiruppur districts together is 9,908 square kilometers. Coimbatore district has coconut as major crop in an area of 80,712 hectares with a productivity of 14,831 nuts ha^{-1} and Tiruppur district has 49,598 ha of coconut with a productivity of 8,239 nuts ha^{-1} in the year 2010-11 (CDB, 2011).

Groundwater quality analysis

An extensive survey was carried out covering 110 geo-referenced collection sites located across Coimbatore and Tiruppur districts. The coconut plantations in these districts are not contiguous, hence, the irrigation water sources of coconut cover were considered for the field studies. Irrigation water samples were collected from 73 sites in Coimbatore district and from 37 sites in Tiruppur district.

Water samples were collected in polypropylene containers, which were rinsed with sampling water several times before taking samples and samples were collected directly from the outlet points after continuous discharge from the source for 10 to 20 minutes. About one liter water was collected to obtain a reasonably good representative sample. The water samples were analyzed within 48 hours for their chemical composition and the methods adopted for analysis were as follows, pH using pH meter (USSL, 1968), EC by conductometry method (USSL, 1968), Ca and Mg by Versenate titration method (Diehl *et al.*, 1950), Na and K by flame photometry method (Stanford and English, 1949), CO_3 and HCO_3 by titration with 0.1 N H_2SO_4 (AOAC, 1950), Cl by titration with 0.1 N $AgNO_3$ (AOAC, 1950) and SO_4 by turbidimetry method (Tandon, 1995).

From the analytical results of the irrigation water, the quality parameters *viz*., residual sodium carbonate (RSC), sodium adsorption ratio (SAR), potential salinity (PS), soluble sodium percentage (SSP) and permeability index (PI) were computed. In all the calculations, concentrations were expressed in meq L^{-1}.

RSC (Richards, 1954)

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

SSP (Richards, 1954)

$$SSP = \frac{Na^{+}}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100$$

SAR (Richards, 1954)

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+} + Mg^{2+})/2}} \times 100$$

PS (Doneen, 1975)

$$\text{Potential salinity} = Cl^{-} + \sqrt{SO_4^{2-}}$$

PI (Doneen, 1975)

$$\text{Permeability index} = \frac{(Na^{+} + HCO_3^{-})}{Ca^{2+}+Mg^{2+}+Na^{+}} \times 100$$

Mapping irrigation water quality using GIS

The sample sites were geo-coded using the latitude and longitude recorded using GPS during the survey conducted. The base map was prepared using the digital map of the study area, coconut land cover map and the digitized sample sites.

Database on irrigation water quality parameters were developed and updated with sample numbers using microsoft excel package. The database was then exported to ArcGIS 8.2 *via* dBase IV format and the attribute table was geo-coded using sample number as the key field. Using the coconut land cover map and database developed on irrigation water quality, the thematic maps on irrigation water qualities were generated.

Results and discussion

The irrigation water quality has a role in the development of salinity/alkalinity in the soil, thereby affecting the soil quality. The amount of soluble salts and excess of sodium in the irrigation water determine the uptake by the crops which may lead to the yield variations. Hence, irrigation water quality of coconut land cover in Coimbatore and Tiruppur districts were assessed for various quality parameters (Table 1) and thematic maps of

Table 1. Range and mean values of irrigation water quality parameters of Coimbatore and Tiruppur districts

District		pH	EC (dS m^{-1})	SAR	RSC (meq L^{-1})	SSP (%)	PS (meq L^{-1})	PI
Coimbatore	Min	7.00	0.02	0.69	-28.54	16.31	0.80	51.02
	Max	8.93	6.47	9.61	16.65	71.26	105.30	429.74
	Average	7.56	1.74	3.79	3.81	43.33	17.54	146.16
	CV (%)	4.37	78.15	62.06	199.44	31.60	107.33	47.81
Tiruppur	Min	6.61	0.16	0.40	-102.43	17.58	1.77	43.96
	Max	7.97	9.28	10.89	9.23	66.87	145.59	325.98
	Average	7.50	2.29	4.35	-5.23	41.56	25.59	111.95
	CV (%)	3.70	87.41	65.14	-369.49	28.00	110.24	50.91

EC- electrical conductivity, SAR - sodium adsorption ratio; RSC - residual sodium carbonate; SSP - soluble sodium percentage, PS - potential salinity and PI - permeability index

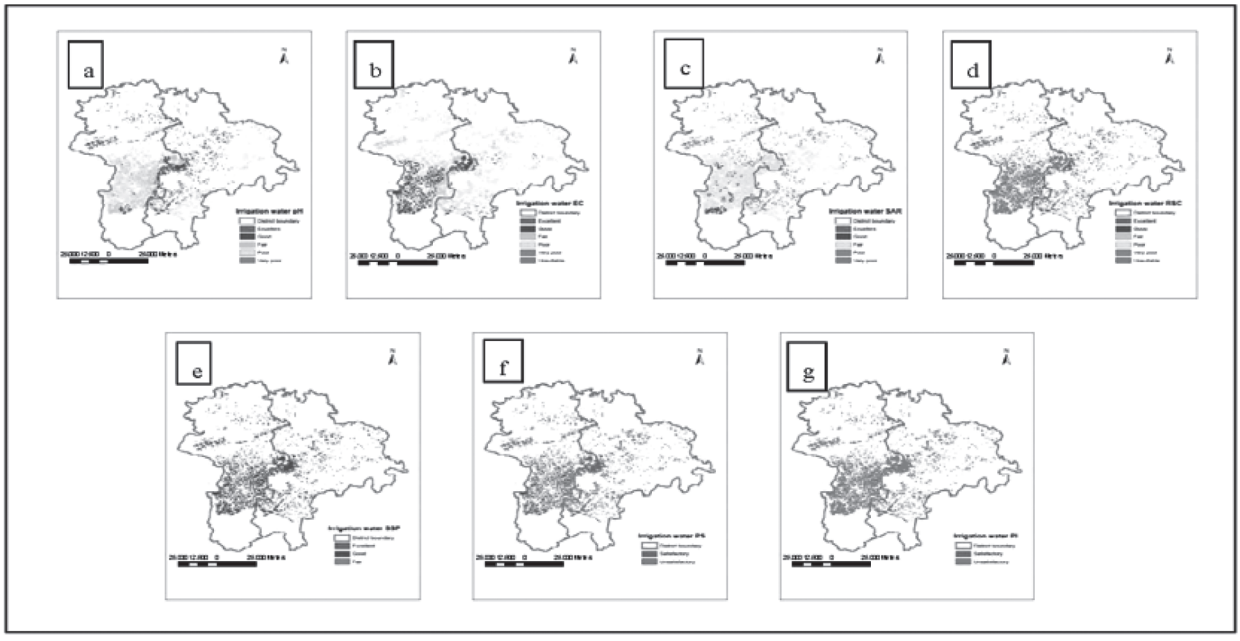

Fig. 1. Irrigation water quality thematic maps of the study area, a) pH, b)EC, c) SAR, d) RSC, e) SSP, f) PS and g) PI potential

irrigation water quality parameters (Fig. 1) in the coconut land cover were developed and the spatial information of the extent of the area coming under different water quality classes were determined (Table 2).

pH of the water

Irrigation water pH of the study area ranged from 6.61 to 8.93 with a mean of 7.54 and CV per cent of 4.16. In Coimbatore district, pH ranged from 7.00 to 8.93 and the mean value was 7.56 and the CV per cent was 4.37. In Tiruppur district pH of irrigation water ranged between 6.61 and 7.97 with a mean of 7.50 and the CV per cent of 3.70.

The irrigation water quality of the coconut land cover was classified as excellent, good, fair, poor and very poor based on pH and were found to exist in 21 (23,869 ha), 24 (2,706 ha), 43 (48,217 ha), 12 (13,836 ha) and 0.03 (38 ha) per cent of the coconut land cover, respectively. Nearly 50 per cent of the irrigation water may not have any salinity hazard.

Table 2. Irrigation water quality limitations and their area extent in the coconut land cover of Coimbatore and Tiruppur districts

SI. No	Parameter	Class	Area (ha)	Per cent to the total area
1	pH			
		Excellent (6.5-7.5)	23869	21
		Good (7.5-8.0)	27061	23
		Fair (8.0-8.5)	48217	42
		Poor (8.5-9.0)	13836	12
		Very poor (9.0-10)	38	0.03
		Unsuitable (> 10)		
2	EC (dS m^{-1})			
		Excellent (< 0.5)	1223	1
		Good (0.5-1.5)	47701	42
		Fair (1.5-3.0)	51982	46
		Poor (3.0-5.0)	11562	10
		Very poor (5.0-6.0)	382	0.3
		Unsuitable (> 6)	172	0.2
3	SAR			
		Excellent (< 1)	612	0.5
		Good (1-2)	7033	6
		Fair (2-4)	59683	53
		Poor (4-8)	44643	40
		Very poor (8-15)	1051	0.9
		Unsuitable (> 15)	-	-
4	SSP (%)			
		Excellent (< 30)	2771	2
		Good (30-60)	109544	97
		Fair (60-75)	707	0.6
		Poor (75-80)	-	-
		Very poor (80-90)	-	-
		Unsuitable (> 90)	-	-
5	RSC (meq L^{-1})			
		Excellent (< 1.0)	51676	46
		Good (1.0-1.25)	1280	1
		Fair (1.25-2.0)	4797	4
		Poor (2.0-2.5)	3536	3
		Very poor (2.5-3.0)	4013	4
		Unsuitable (> 3.0)	47720	42
6	Potential salinity (meq L^{-1})			
		Unsatisfactory (>15)	57103	51
		Satisfactory (<15)	55918	49
7	Permeability index			
		Unsatisfactory(>100)	16321	14
		Satisfactory (<100)	96701	86

Electrical conductivity (EC)

Salinity hazard is determined using EC of the irrigation water. The EC range observed in Coimbatore district was 0.02 to 6.47 dSm^{-1} with a mean of 1.74 dSm^{-1} and the CV per cent of 78.15. In Tiruppur district, the EC of irrigation water ranged from 0.16 to 9.28 dSm^{-1} with the mean of 2.29 dSm^{-1} and the CV per cent of 87.41.

Based on EC the irrigation water quality was classified as excellent in 1(1,223 ha), good in 42 (47,701 ha), fair in 46 (51,982 ha), poor in 10 (11,562 ha), very poor in 0.3 (382 ha) and unsuitable in 0.2 (172 ha) per cent area. Majority of the area were safe and only around 10 per cent area showed salinity hazard. Similarly Balachandar *et al.* (2010) reported that around 24 per cent of observation wells of Coimbatore district had doubtful irrigation water quality (EC>2250 micro mhos cm^{-1}) with respect to EC.

Sodium adsorption ratio (SAR)

The SAR value of irrigation water gives the information about the ill effects of exchangeable sodium. Richards (1954) proposed calculation of SAR using calcium, magnesium and sodium. Sodium hazard is also usually expressed in terms of the SAR. SAR of the irrigation water in the study area was found to be within the range of 0.40 – 10.89 with a mean value of 3.97. The data showed CV per cent of 63.47. In Coimbatore district, SAR ranged from 0.69 to 9.61 with the mean of 3.79 and the CV per cent derived was 62.06. In Tiruppur district SAR of irrigation water ranged from 0.40 to 10.89 and the mean was 4.35 with a CV per cent of 65.14.

Based on SAR, the irrigation water was excellent in 0.5 (612 ha) per cent, good in 6 (7,033 ha) per cent, fair in 53 per cent (59,683 ha), poor in 40 (44,643 ha) per cent and very poor in 0.9 per cent (1,051 ha) of the samples under coconut land cover of the two districts. Alkali hazard is high when the SAR value is high since the proportion of sodium is high. If calcium and magnesium predominate, the SAR value is low which leads to low alkali hazard. The results showed that around 40 of the area having the irrigation water with high sodium hazard. Chemical amendments like gypsum have to be applied to the soil while irrigating with high SAR water.

Soluble sodium percentage (SSP)

SSP of the irrigation water sample ranged from 16 to 71 per cent in the study area with mean value of 43 per cent and CV per cent of 30.5. In Coimbatore district the irrigation water samples showed SSP ranging from 16 to 71 per cent with the mean of 43 per cent and CV per cent of 31.60. In Tiruppur district SSP of irrigation water samples ranged from 18 to 67 per cent and the mean was 42 per cent with the CV per cent of 28.

The SSP based irrigation water quality was found to be good in 1,09,544 ha area (97%), excellent in 2 per cent (2,771 ha), and fair in 0.6 per cent (707 ha) of the coconut land cover.

Residual sodium carbonate (RSC)

RSC is an index used to determine the bicarbonate hazard as well as to distinguish between the different water classes for irrigation purposes. RSC value of irrigation water samples in the study area ranged from -102.43 to 16.65 meq L^{-1} with the mean value of 0.83 meq L^{-1}. The CV per cent found in the samples was very high (1615.48%). In Coimbatore district, RSC of irrigation water ranged between -28.54 to 16.65 meq L^{-1} with the mean value of 3.81 meq L^{-1} and CV per cent of 199.44. The RSC of irrigation water samples of Tiruppur district ranged from -102.43 to 9.23 meq L^{-1} and the mean found was -5.23 meq L^{-1} with the CV per cent of 369.49.

From the thematic map it was estimated that irrigation water quality in terms of RSC was excellent in 46 per cent (51,676 ha), good in 1 per cent (1,280 ha), fair in 4 per cent (4,797 ha), poor in 3 per cent (3,536 ha) and very poor in 4 per cent (4,013 ha) area in the coconut land cover. Nearly 42 per cent (47,720 ha) of the coconut land cover was having irrigation water of unsuitable class based on RSC. RSC gives an account of accumulation of excess carbonate and bicarbonate in the soil. When the irrigation water containing CO_3 + HCO_3 higher than Ca+Mg is used for irrigation, development of alkali soils (saline or non-saline) may be expected (Eaton, 1950). Continuous use of water having RSC more than 2.5 meq L^{-1} (45.77 % of the area) leads to salt build up which may hinder the air and water movement by clogging the soil pores and lead to degradation of the physical condition of soil. Irrigation water having RSC values ranging from 2.5-4 meq L^{-1} can be used effectively with the addition of gypsum.

Potential salinity (PS)

Potential salinity values in the study area ranged from 0.80 to 145.59 meq L^{-1} with the mean of 20.07 meq L^{-1} and the CV per cent was 107.33. In Coimbatore district PS ranged from 0.80 to 105.30 meq L^{-1} with the mean of 17.54 meq L^{-1} and CV per cent of 107.33. It ranged from 1.77 to 145.59 meq L^{-1} with the mean of 25.04 meq L^{-1} and CV per cent of 107.33 in Tiruppur district.

Around 50.52 per cent (57,103 ha) of the coconut land cover of Coimbatore and Tiruppur districts were having irrigation water of unsatisfactory quality based on PS. Hence, in these areas the salts of chloride and sulphate ions in the irrigation water are sufficiently soluble to produce saline soil condition (Doneen, 1975).

Permeability index (PI)

In the study area, permeability index of irrigation water samples ranged from 43.95 to 429.74 with the mean value of 135.55 and CV per cent of 47.81. In Coimbatore district permeability index ranged between 51.02 to 429.74 with the mean value of 47.81 and CV per cent of 47.81. Permeability index of irrigation water samples of Tiruppur district ranged from 43.95 to 325.98. The permeability index of the irrigation water of 14 per cent (16,321 ha) of the coconut land cover of Coimbatore and Tiruppur districts were found to be unsatisfactory. This high value of permeability index indicates the low permeability of water into soil (Doneen, 1975).

Conclusion

The most important quality parameter which limits the irrigation water quality in the study area was found to be SAR and it is poor or very poor in 40.43 per cent area which expresses alkalinity hazard and may develop permeability and infiltration related hazard in the soil. The poor irrigation water quality is due to high salt content especially sodium followed by chloride and sulphates. Hence the spatial information generated in the thematic maps especially on SAR followed by RSC and PS may help in the irrigation water

management, thereby protect soil health from hazards of long term use of poor quality irrigation water in the study area.

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