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Establishing Relationship Between Saturated Paste Electrical Conductivity (EC_e) and Soil:Water Electrical Conductivity ($EC_{1:2}$) in Some Shrink-swell Soils of Nagpur District, Maharashtra

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Abstract : Soil salinity is a major environmental hazard which adversely affects plant growth, crop production, soil and water quality and agricultural productivity. Soil salinity is determined by measuring electrical conductivity of soil water suspension. Though saturation paste EC_e closely relates with plant growth and development but its measurement is laborious and time-consuming, specifically, in clayey soils when large number of samples are to be analyzed. Measurement of $EC_{1:2}$ (1:2 Soil: water suspension) is very quick and economical. Therefore, a need is felt to develop a relationship between EC_e and $EC_{1:2}$ so that the values of $EC_{1:2}$ could easily be related to EC_e. For this, a laboratory experiment was conducted on 196 shrink-swell soils samples representing four soil series of Nagpur district. Soils were artificially salinized with solutions (salt) of 0.2, 0.5, 1 and 2% of chloride salts (NaCl, $CaCl_2$, $MgCl_2$ and their mixture) and replicated three times. The results indicate that a significant relationship (r=0.96) exists between EC_e and soil $EC_{1:2}$ and soil EC_e can be reliably predicted from $EC_{1:2}$ in shrink -swell soils.

Keywords : *Soil salinity, electrical conductivity, saturated paste, shrink-swell soils*

Introduction

Soil salinity is a prevalent environmental hazard in arid and semi-arid regions around the world (Hillel 2000). Soil salinity adversely affects plant growth, crop production, soil and water quality, and it eventually results in soil erosion and land degradation (Corwin and Lesch 2003). Soil salinity impacts are not limited only to the environment but also extend to the economy. Globally, more than 800 Mha of land are estimated to be salt affected (FAO 2008). An area of 6.74 Mha in India suffers from salt accumulation, out of which 3.78 Mha are sodic, while, 2.96 Mha are saline soils (Mandal *et al*. 2010). Nearly 7.0 Mha of agricultural land is affected by varying degrees of salt problems in India. By 2025, area projected under salt affected soils in India is about 13 Mha (Sharma and Chaudhari 2012). In India,the shrink-swell soils occupy about 26.62 Mha of which 5.6 Mha are in Maharashtra. In basaltic terrain, sub soil-sodicity in Nagpur (Lingade *et al.* 2008) and irrigation induced salinity/sodicity in some pocket of Amravati district have been reported (Padekar *et al.* 2014).

Conventionally, soil salinity is measured by collecting soil samples and analyzing the samples in the laboratory to determine their solute concentrations or electrical conductivity (Nanni 2006 and Brunner *et al.* 2007). Until the 1950's, the salt contents of soils were estimated from the electrical conductivity of saturated pastes. With the advancement in the understanding of saline soils, it was found that the plant responds to the salt concentration of soil solution rather than the total salt content of the soil. Therefore, the conductivity of the

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saturation extract is recommended as a general method for estimating soil salinity in relation to plant growth (USDA 1954 and Rhoades *et al*. 1989). The use of saturation extracts as a method of measuring and referencing salinity provides a direct relationship with the field moisture range for most soils.

The measurement of electrical conductivity in soil water suspensions of different ratios such as 1:1, 1:2, 1:5 and 1:10 can be determined more easily. However, the ion concentrations and electrical conductivities of the extracts of different soil water ratios are typically lower than those of saturated paste extracts as a result of the increased dilution effect. Despite the differences in results among these methods, many commercial soil salinity laboratories are analyzing soil salinity samples using extraction methods of different soil to water ratios because of its simplicity, reduced monetary and time investments (Franzen 2003 and Zhang *et al*. 2005).

Furthermore, in soil laboratories, pH is measured in 1:2.5 soil: water extracts (Jackson 1967). In India, soil pH of Vertisols (shrink-swell soils) is measured in 1:2 soil water extracts. If suitable conversion coefficients are determined, EC can also be measured in the same extract allowing to make two measurements at once. There is a need to convert $EC_{1:2}$ to EC_e in order to assess plant response. The benefits of converting results of 1:1, 1:2.5 or 1:5 soil to water ratios to saturated paste extracts equivalents are potentially large. Soil salinity laboratories can minimize the cost and time associated with soil salinity analysis by using less costly methods of different soil to water ratios while, still maintaining a high level of accuracy and precision. This paper attempts to establish a relationship between saturated paste electrical conductivity (EC_e) and soil $EC_{1:2}$ in some shrink-swell soils of Nagpur district, Maharashtra for quick assessment of soil salinity for taking appropriate management of these soils.

Material and Methods

General description of the area

Nagpur district (20°30' to 21°45'N latitude and 78°15' to 79°40'E longitude),comprising an area of 9931 sq. km. situated in the eastern part of Maharashtra (Fig. 1). The general elevation of the district ranges between 150 m and 600 m above MSL. Physiographically, the area covers hills and ridges, very gently to gently sloping plateau, gently to moderately sloping plateau, subdued hills and valleys, piedmont alluvial plain and flood plain.

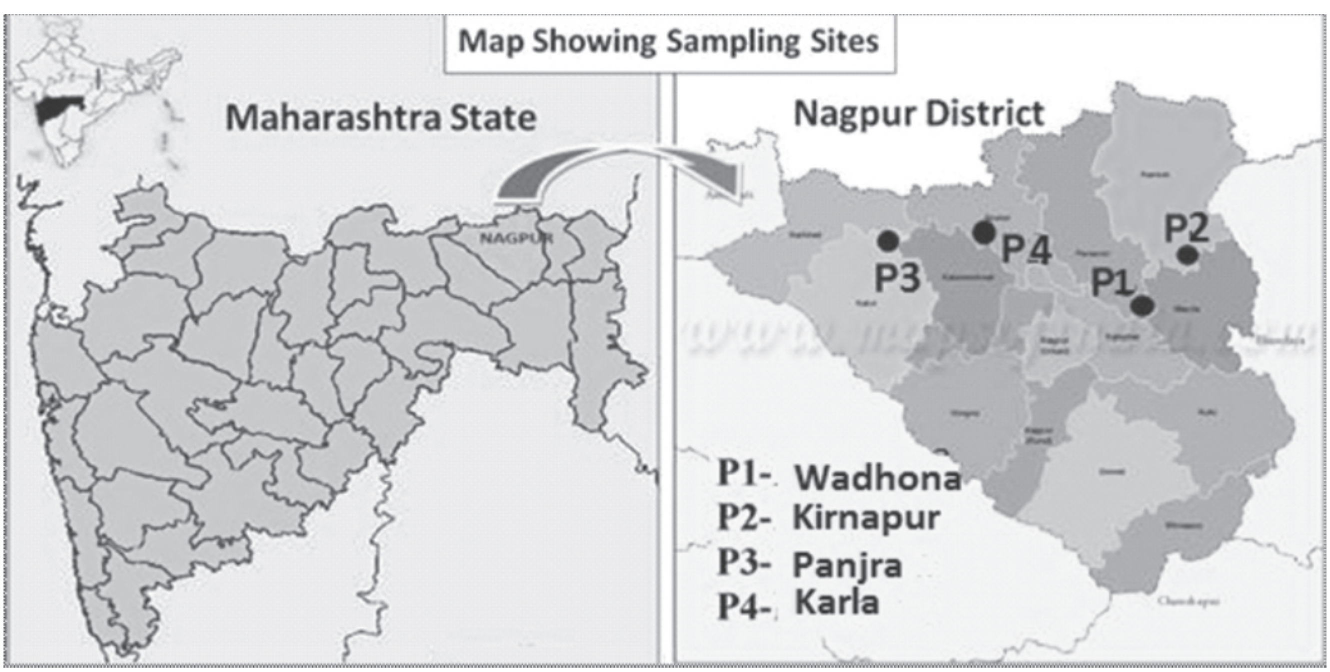

Fig.1. Location map of sampling site

The climate of the area is tropical dry sub-humid with hot summer and generally dry weather except during the south-west monsoon season having mean annual temperature of 26.8°C and mean annual rainfall of about 1127 mm. The soil temperature and moisture regimes are *hyperthermic* and *ustic*, respectively. The agricultural crops grown during *kharif* includes cotton (*Gossypium sp.)*, paddy (*Oryza sativa*), pigeon pea (*Cajanus cajan*), and wheat (*Triticum aessivum),* gram (*Cicer arietinum*) during *rabi* season. Important horticultural crop of the area is mandarin (*Citrus reticulata)*.

Soil sample collection and soil treatment

Surface soils of four established series, namely, Wadhona, Kirnapur, Panjra and Karla were collected from Nagpur district, Maharashtra. The physical and chemical properties of the soils are given in table 1. The textural class of selected soils was clay except Wadhona which is silty clay loam. These soils were salinized for 24 hours in the laboratory with four salinity levels (0.2, 0.5, 1 and 2 %) of chloride salts (NaCl, $CaCl_2$, $MgCl_2$ and their mixture). Each level of artificially salinized soil was replicated three times. After salinization, the samples were air-dried, crushed and passed through a 2 mm sieve.

Extract preparation and analysis

Saturation paste extract: Saturated paste were prepared by adding distilled water to approximately 250 g soil sample with stirring until it reached a condition of complete saturation (Rhoades 1982).The saturated pastes were allowed to equilibrate for 18 hours. The soil extracts were obtained by centrifugation and filtered using Whatman#42 filter paper and analyzed for saturated paste electrical conductivity (EC_e).

Soil : water extract: Soil to water suspensions (1:2) were prepared by adding 40 ml of distilled water to 20 g of oven-dried soil sample. The containers including suspensions were shaken for 1 min by hand 4 times at 30-minute intervals (Rhoades 1982). The suspensions were filtered using Whatman #42 filter paper to obtain the extracts. The extracts were analyzed for determination of soil : water electrical conductivity ($EC_{1:2}$).

Table 1. Physical and chemical properties of soils

Soil Properties	Wadhona	Kirnapur	Panjra	Karla
pH (1:2)	7.9	7.8	8.7	7.9
$EC_{1:2}$ (dSm^{-1})	0.17	0.31	0.23	0.13
Sand %	8.6	17.5	1.8	1.1
Silt%	56.5	26.6	23.1	22.2
Clay%	34.9	44.4	66.5	59.1
O.C . %	0.56	1.12	1.05	0.59
$CaCO_3$%	Nil	Nil	3.0	1.94
CEC (cmol (+) kg^{-1})	40	40	68.7	62.6
Exchangeable bases (cmol (+) kg^{-1})				
Ca^{2+}	26.1	30.6	32.4	41.4
Mg^{2+}	8.1	7.2	16.2	21.6
Na^{+}	0.30	0.35	0.78	0.52
K^{+}	0.30	0.61	0.83	0.17

Results and Discussion

Effect of salt treatments on saturation extract EC_e of different soils

The descriptive statistics of the EC_e and $EC_{1:2}$ values of 196 soil samples analysed in the laboratory are presented in table 2. The data indicate that EC_e and $EC_{1:2}$ values of salt-treated soil samples varied between 0.52 and 12.18 dSm^{-1} and 0.15 and 4.16 dSm^{-1}, respectively.

The effect of salinization with different salt types and salt concentrations (levels) on the saturation extract EC_e of soils are depicted in figure 2. In general, it is observed that EC_e values in different soils increased with the increase in salt concentration. The data indicate that soils treated with NaCl solution resulted in higher saturation extract EC_e values followed by $CaCl_2$, mixture and $MgCl_2$ treated soils (Fig. 2). The results also

Table 2. Descriptive statistics of electrical conductivity (dSm^{-1}) in treated soil samples

Statistics	Wadhona	Kirnapur	Panjra	Karla
ECe in saturated paste extracts				
Number of samples	49	49	49	49
Mean	17.18	16.65	16.93	17.46
Standard Error	1.73	1.62	1.67	1.74
Median	13.05	14.37	14.31	15.08
Minimum	0.61	0.96	0.98	0.52
Maximum	12.09	11.33	11.68	12.18
$EC_{1:2}$ soil: water				
Mean	4.39	4.46	5.31	5.51
Standard Error	0.47	0.48	0.55	0.59
Median	3.40	3.34	4.03	4.50
Minimum	0.19	0.32	0.19	0.15
Maximum	3.27	3.37	3.84	4.16

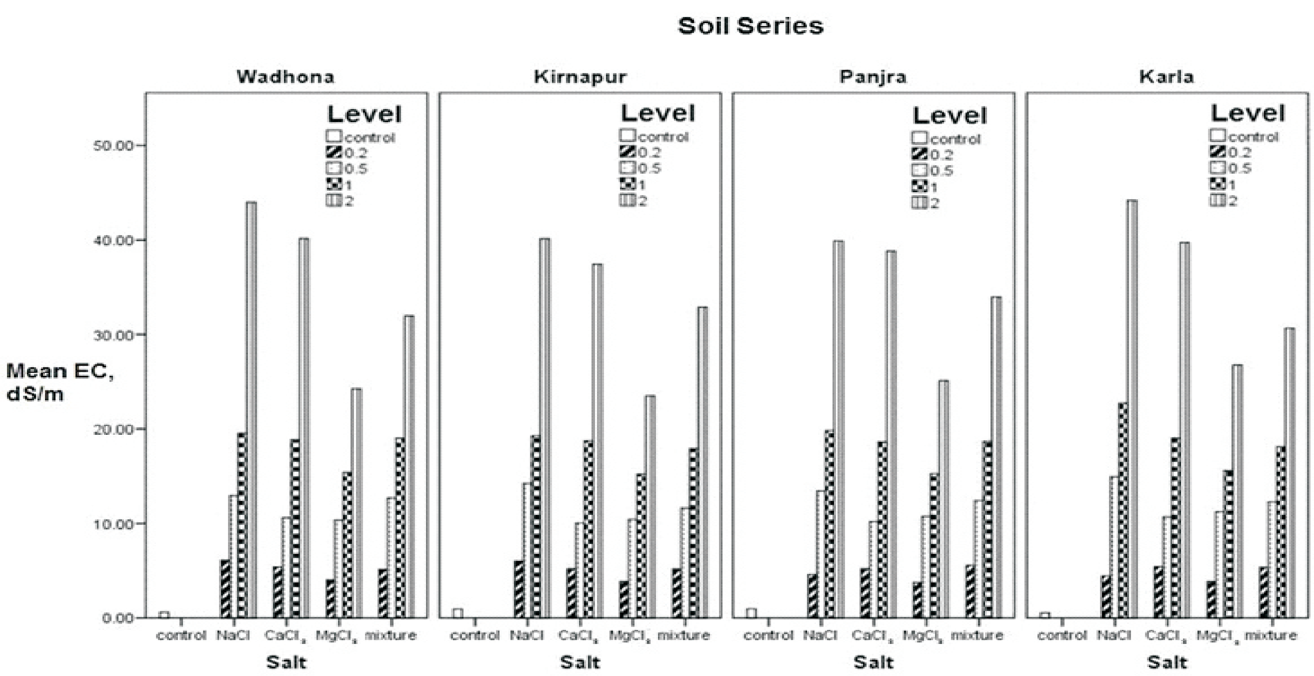

Fig. 2. Bar diagram showing EC_e values of soils treated with different concentration of salt solution

indicate (Fig.2) that there was no significant variation in soil salinity (EC_e values) among the soils of four soil series at different concentrations for different salt types.

Relationship between saturation extract EC_e and soil EC (1:2)

The electrical conductivity of saturated paste (EC_e) *versus* soil to water ratio ($EC_{1:2}$) for soils series is presented in figure 3. The regression equations developed between EC_e and $EC_{1:2}$ for all the four soil series are given in table 3. Electrical conductivity of saturated paste extract was highly correlated with $EC_{1:2}$ for all the soil series. Neither the slopes nor the R^2 values changed drastically when intercepts are not included in the regression equations (Table 3). The results indicate that the values of EC_e were nearly 2.5 to 3.0 times the values of $EC_{1:2}$ of soil water suspension in all the four series. Franzen (2003) and Sonmez *et al*. (2008) observed that the influence of soil to water ratio is more pronounced than soil texture on electrical conductivity values.

Combined data of soil series (Fig. 4) depicts the relationship between soils $EC_{1:2}$ and saturated extract EC_e. Very high correlation (r=0.98**) between $EC_{1:2}$ and EC_e indicate that EC_e values can be reliably predicted from $EC_{1:2}$ data. The simple regression equation obtained for prediction of EC_e in shrink-swell soils in the Nagpur is as follows:

$$EC_e = 3.12 \times EC_{1:2} + 1.73 \quad (R^2=0.96)$$

Where, EC_e and $EC_{1:2}$ values are in dSm^{-1}

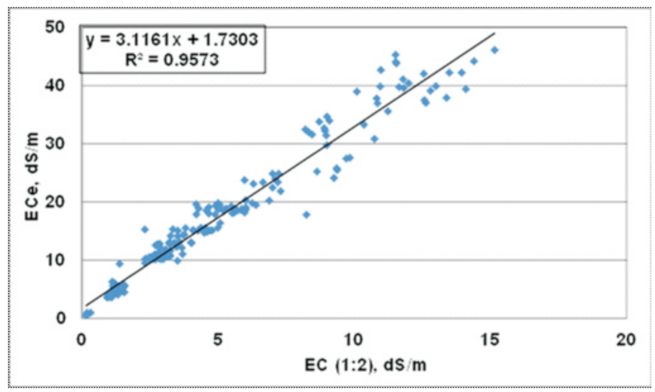

Fig. 4. Relationship of saturated paste electrical conductivity (EC_e) and soil $EC_{1:2}$ for combined soil series data.

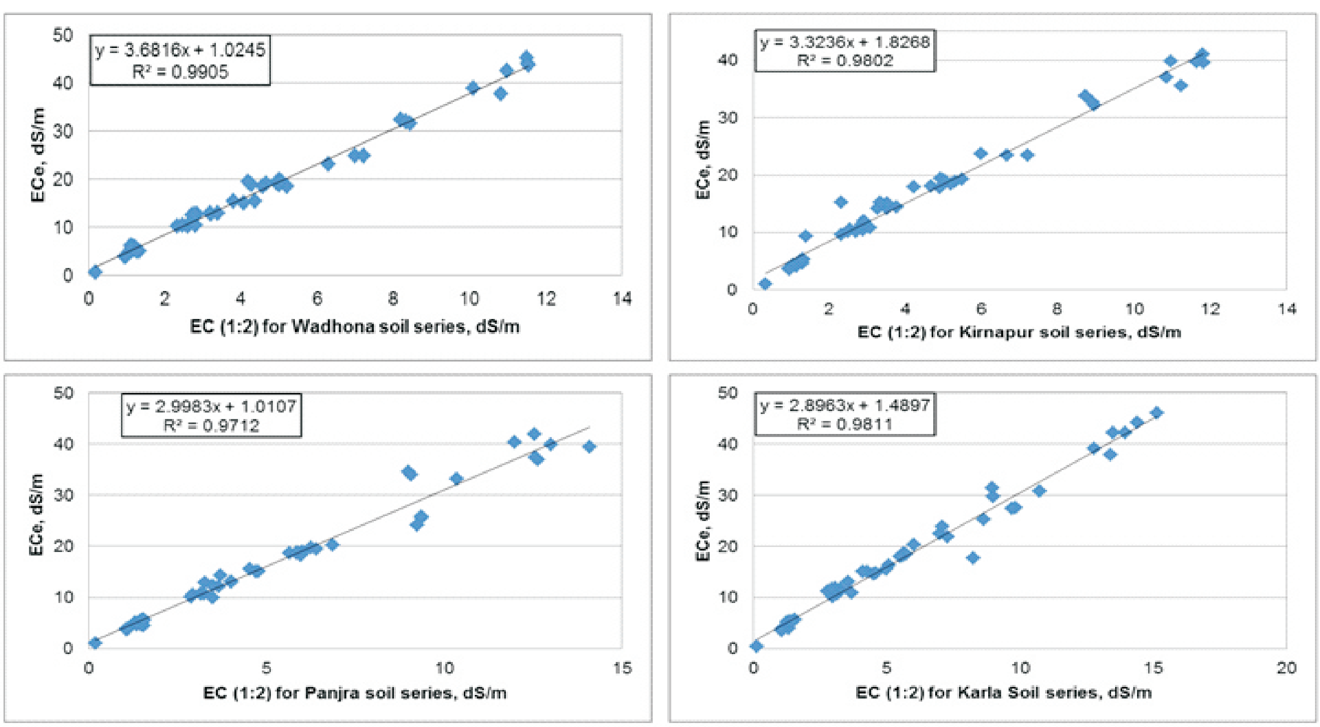

Fig. 3. Relationship between saturated paste electrical conductivity (EC_e) and soil $EC_{1:2}$ in different soil series.

Table 3. Coefficient of determination (R^2) and regression equation in different soil series

Soil Series	With intercept		Without intercept	
	Regression equation	R^2	Regression equation	R^2
Wadhona	EC_e=3.68x + 1.03	0.99	3.83x	0.99
Kirnapur	EC_e=3.32x + 1.83	0.98	3.59x	0.97
Panjra	EC_e=3.00x + 1.01	0.97	3.12x	0.97
Karla	EC_e=2.29x + 1.49	0.98	3.07x	0.98

Conclusion

The result showed that soil series had influence on relationship between saturated soil paste electrical conductivities (EC_e) and soil to water ratio ($EC_{1:2}$). Both combined and soil series-specific regression equation are derived and presented. The choice of using equation is left to the reader. When more precise result is required, the equation based on soil series could be used.

References

Brunner P., Li, H.T., Kinzelbach W. and Li, W.P. (2007).Generating soil electrical conductivity maps at regional level by integrating measurements on the ground and remote sensing data. *International Journal of Remote Sensing* **28**, 3341-3361.

Corwin D. and Lesch S. (2003). Application of soil electrical conductivity to precision agriculture. *Agronomy Journal* **95,** 455-471.

FAO (2008). FAO Land and Plant Nutrition Management Service. www.fao.org.

Franzen D. (2003).Managing saline soils in North Dakota. North Dakota stateuniversity extension service,Fargo. http:// www.ag.ndsu.edu/ pubs/ plantsci/ soilfert/ sf1087-1 .htm

Hillel D. (2000).Salinity management for sustainable irrigation:Integrating science, environment and economics.World Bank Publications, Washington DC.

Lingade S.R., Srivastava R., Prasad J. and Saxena R.K. (2008).Occurrence of sodicvertisols in Nagpur district, Maharashtra. *Journal of the Indian Society of Soil Science* **56**, 231-232.

Mandal A.K., Sharma R.C., Singh G. and Dagar J.C. (2010). Computerised database of salt-affected soils in India.Technical Bulletin, CSSRI, Karnal. pp28.

Nanni M.R.D.(2006).Spectral reflectance methodology in comparison to traditional soil analysis. *Soil Science Society of America Journal* **70**, 393-407.

Padekar D.G., Bhattacharyya T., Deshmukh P.D., Ray S.K., Chandran P. and Tiwary P.(2014). Is irrigation water causing degradation in black soils? *Current Science* **106**, 1487-1489.

Rhoades J.D. (1982). Soluble salts, In: Page, A.L. (Ed.), Methods of Soil Analysis, Part 2, Second Edition, American Society of Agronomy, Inc., Madison, WI, USA, p. 167–179. Agronomy Monograph No 9.

Rhoades J.D., Manteghi N.A., Shouse P.J., Alves W.J. (1989). Estimating soil salinity from saturated soil–paste electrical conductivity. *Soil Science Society of America Journal* **53**, 428–433.

Sharma D.K. and Chaudhari S.K. (2012). Agronomic research in salt affected soils of India: An overview. *Indian Journal of Agronomy* **57** (3rd IAC Special Issue), 175-185.

Sonmez S., Buyuktas D. and Asri F.O. (2008). Assessment of different soil to water ratios (1:1, 1:2.5, 1:5) in soil salinity studies. *Geoderma* **144**,361-369.

USDA (1954).Diagnosis and Improvement of Saline and Alkali soils.Agricultural Handbook No. 60. USSL, Riverside, CA, USA.

Zhang H., Schroder J.L., Pittman J.J., Wang J.J. and Payton M.E. (2005). Soilsalinity using saturated paste and 1:1 soil to water extract. *Soil Science Society of America Journal* **69**, 1146–1151.

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