

Spatial Variability of Salinity in Saline Soils

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Abstract : This study addresses to a major problem experienced during leaching of saline soils, i.e., to quantify and estimate mean value of initial salinity of the soil. The study was undertaken to test and recommend new options for studies related to spatial variability of soil salinity on the basis of flood frequency analysis procedures for estimating initial salinity to be used in various models of leaching. In describing the spatial variability of the soil electrical conductivity, classical statistical techniques have been used. The relative effectiveness of four transformations and five distributions has been reported. Although in the present study, Pearson type III distribution visually and logically should give the best results, yet it is observed that several options are statistically equivalent. It is also brought that for leaching, EC at middle probabilities, i.e., 3 confidence levels (50%, 80% and 90%) can be used to estimate initial salinity as per the strategies, instead of using the mean values.

Key words: Spatial variability, electrical conductivity, flood frequency analysis procedure, leaching.

Recent investigations have revealed that physico-chemical characteristics of the soil are inherently variable with time and space. A major dilemma being faced by researchers, as well as planners, is how best to cope with spatial variability and how intensive should be the sampling intensity to arrive at meaningful values. In any leaching trial, one of the parameters, which would control the adequacy of leaching, is the amount of salts required to be drained as a function of the initial salinity.

While desired salinity is fixed, initial salinity varies widely over whole field to be leached. Thus, whether leaching of the field has been accomplished adequately or not would depend

upon how best is the prediction of initial salinity. A knowledge of spatial variability of field soils, therefore, is of importance not only for salinity studies but for most other investigations associated with the management of agricultural fields (Ball and Williams, 1968; Cline, 1944). Arbitrary soil sampling procedures may lead to too many samples, which is unnecessarily costly, or too few samples, which indeed is economical, but may not be sufficient to characterize an average field condition or to delineate major zones of major differences which would be amenable to preferential management practices.

Materials and Methods

The soil samples for this study were collected from 0.25 ha (100 m x 25 m) which was relatively leveled, part of bunded field from Sampla Farm of Central Soil Salinity Research Institute, Karnal. The soil samples from 0-30 cm layer were drawn from the

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Table 1. Statistical parameters of the EC series with different transformations

Series	Mean	Sigma	Skewness	Kurtosis
Original	7.18	3.24	0.72	3.01
Log	1.87	0.46	-0.15	2.32
Log-Log	0.59	0.27	-0.65	2.80
Cube root	1.89	0.29	0.14	2.36
SMEMAX	45.23	24.92	-0.0017	2.25
OSPT	2.23	0.63	-0.0008	2.32

centre of 5m x 5m grid thus making a total 100 samples. Electrical conductivity of these samples was determined in 1:2 soil water suspension utilizing a digital conductivity bridge. Theoretical approaches based on classical statistical techniques were used and different distributions and transformations were tested for their capacity in describing the observed/experimental data.

Results and Discussion

The electrical conductivity (EC) of samples taken from a field varied widely with maximum EC (1:2) of 16.1 dS m⁻¹ and minimum of 2.46 dS m⁻¹. Various statistical parameters of the original series as well as 5 additional transformations are presented in Table 1. The data reveal that the mean value is 7.18 dS

m⁻¹. The coefficient of skewness was quite large and beyond a range usually recommended for a distribution to be normal, coefficient of kurtosis of original series, however, was within the prescribed range described by Yevjevich (1972). Using both the parameters as a basis of justifying the conversion of an empirical distribution to a normal, it seems no transformations can be suited well. It appears that Pearson type III distribution would be the most appropriate distribution to describe the data series as it accounts for the skewness while kurtosis of the empirical distribution to be used in this distribution is well close to 3.0 (Table 1).

The value of EC worked out for a wide range of probabilities from 0.005 to 0.99 for

Table 2. Estimated EC at different probabilities utilizing 5 standard distributions and 4 transformations

Probability	EC (dS m ⁻¹)								
	Distribution					Transformations			
	Normal	Log-normal	Gumbel	Pearson type III	Log-Pearson type III	SMEMAX	Cube root	Log-log	OSPT
0.99	—	2.20	1.86	1.37	2.09	1.36	1.79	2.63	2.01
0.95	1.83	3.01	2.95	2.58	2.96	2.83	2.80	3.19	2.92
0.90	3.03	3.58	3.61	3.35	3.55	3.63	3.49	3.60	3.45
0.80	4.44	4.38	4.52	4.40	4.38	4.57	4.43	4.22	4.41
0.50	7.18	6.48	6.65	6.80	6.55	6.39	6.71	6.09	6.60
0.20	9.91	9.59	9.51	9.73	9.60	9.85	9.66	9.65	9.62
0.10	11.33	11.73	11.41	11.50	11.64	11.87	11.48	12.79	11.58
0.04	12.85	14.59	13.81	13.57	14.24	14.05	13.67	18.03	14.05
0.02	13.84	16.80	15.58	15.00	16.17	15.47	15.24	23.09	15.88
0.01	14.73	19.09	17.35	16.36	18.10	16.74	16.75	29.38	17.69
0.005	15.53	21.39	19.11	17.67	20.04	17.88	18.17	36.98	19.48

— calculated value is negative.

Table 3. Per cent error in EC compared to Pearson type III distribution

Probability	Per cent Error					
	OSPT	Gumbel	Log-Pearson	SMEMAX	Cube root	Log-normal
0.99	-46.0	-36.0	-52.60	0.70	-30.70	-60.60
0.95	-13.0	-14.0	-14.70	-9.70	- 8.60	-16.30
0.90	- 5.7	- 7.8	- 5.90	-8.30	- 4.20	- 6.90
0.80	- 0.2	- 2.6	0.40	-3.90	- 0.70	0.50
0.50	2.9	2.2	3.70	6.00	1.50	4.70
0.20	1.2	2.3	1.40	-2.10	0.80	1.50
0.10	0.9	0.8	- 1.20	-3.50	0.30	- 1.70
0.04	- 2.6	- 1.8	- 5.00	-3.30	- 0.70	- 7.50
0.02	- 6.0	- 3.9	- 7.80	-3.10	- 1.60	-12.00
0.01	- 7.9	- 6.0	-10.60	-1.80	- 2.10	-16.80
0.005	-10.0	- 8.2	-13.40	-2.90	- 2.80	-21.00

5 distributions and 4 transformations are presented in Table 2. It may be noted that there is a wide variation between the predicted values. The deviations are quite large in some cases at the two extreme ends, i.e., at probability of 0.005 or 0.99. In case of normal distribution, predicted value is negative at a probability of 0.99, while at a probability of 0.005, log-log transformation gives comparatively higher value. Hence, they are omitted for further analysis. In order to further confirm the results, OSPT transformation was modified for kurtosis with the procedure of Tiao and Lund (1970) and Box and Tiao (1973), in which the factor to bring skewness within the recommended limits was intro-

duced. In this case, the estimated value of EC at a probability of 0.005 will reduce to 17.7 instead of 19.45. As this value at this probability is very close to Pearson type III distribution, so it seems that Pearson type III would describe the empirical distribution of EC value for Sampla soil most accurately.

Relative error with different distributions and transformations were obtained by considering that values obtained with Pearson type III distribution are the most realistic values (Table 3). The per cent error is relatively large at higher probabilities and in most cases, it was reduced with decreasing probability and then again increased with further increase

Table 4. EC (1:2) and fraction of salts to be leached for 3 confidence levels utilizing various frequency distribution procedures

Techniques	EC (1:2), dS m ⁻¹		
	50%	80%	90%
Cube root	6.71 (85.0%)	9.66 (89.7%)	11.47 (91.3%)
Gumbel	6.65 (85.0%)	9.51 (89.5%)	11.41 (91.2%)
Log-normal	6.48 (84.6%)	9.59 (89.6%)	11.73 (91.5%)
Pearson type III	6.80 (85.3%)	9.74 (89.7%)	11.50 (91.3%)
Log-Pearson type III	6.55 (84.7%)	9.60 (89.6%)	11.64 (91.4%)
SMEMAX	6.39 (84.4%)	9.85 (89.8%)	11.87 (91.6%)
OSPT	6.60 (84.8%)	9.85 (89.8%)	11.87 (91.6%)
Average EC	6.60 (84.8%)	9.52 (89.6%)	11.60 (91.4%)

Values in parentheses indicate the fraction of salts of the initial salts to be leached for reclaiming saline soil for wheat cultivation.

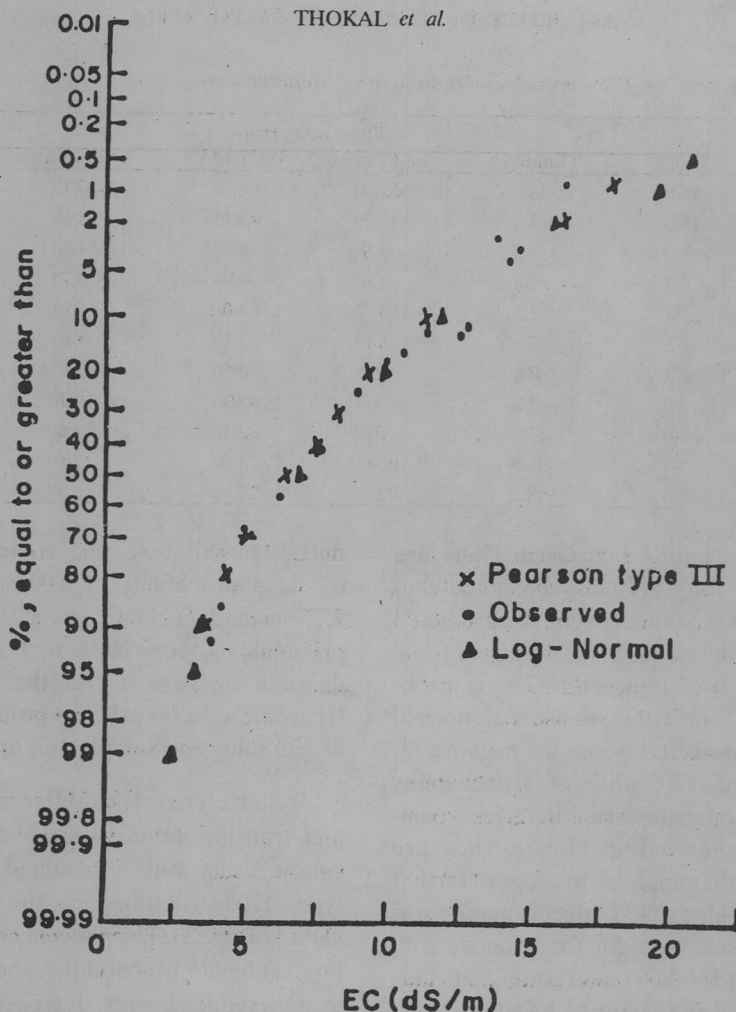


Fig. 1. Observed and predicted electrical conductivity plotted on normal probability

in probability. However, in case of SMEMAX transformation, the error does not follow this trend and error is more or less well distributed. On the other hand, maximum errors are noticed in case of long-normal distribution. It shows that Pearson type III distribution fits the data series well while minimum fit in with log-normal distribution, although the differences appeared to be minor (Fig. 1).

Comparison at middle probabilities

It may be worth while to note that at the middle value of probabilities, i.e., at 50%,

80% or 90%, more or less similar values of EC are obtained with different distributions and transformations (Table 4). From this analysis, it is apparent that if the interest is limited to this range, then one could use any of the distributions for studying spatial variability. It is a useful conclusion in the sense that interest is mainly limited to this range in most studies in agricultural research.

Assuming that the land is to be reclaimed for wheat cultivation, fraction of salts to be leached at 3 confidence levels are given in parentheses along with EC values (Table 4).

The germination of wheat will be affected in case soil salinity is not brought down below 1.0 dS m^{-1} (Gupta, 1986). It indicates that in case mean value is used as an input, nearly 85% of the salt initially present would have to be leached while the fraction will increase to 91.5% when 90% confidence level is used as the initial estimate of EC.

The effect of confidence level to be used could be well understood if it is hypothesised that each point represents equal area. Thus, 50% confidence level means that 50% of the observation in this particular case or in any study in future would have values lower than 6.60 dS m^{-1} , while remaining 50% values would have a salinity higher than 6.60 dS m^{-1} . Thus, if 85% salts are leached, then 50% of the area will continue to have higher salinities than the desired one. Once it is realised, it is apparent that mean value is not an appropriate value to be used in salinity appraisal programmes of an area. Although 90% confidence value would be more realistic as it would reclaim at least 90% of the area, yet 80% confidence value would also be appropriate in case other technical difficulties (could be in terms of dearth of water supply) do not permit the use of 90% confidence level.

Spatial variability is a real problem in saline soils. To estimate EC values before leaching and after reclamation would be important

in estimating crop productivity potential of the reclaimed lands. The classical statistical techniques are suitable for describing spatial variability of the soil electrical conductivity. For the test case, Pearson type III appears to be the best for describing the data series obtained from saline area at Sampla. However, it is suggested that different options should be tried, out of which, best one could be used so that set-forth criteria are met with. For adequate leaching, it is shown that instead of mean value, EC at one of the 3 confidence levels can be used to estimate initial salinity as per the strategies.

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