Project: Tools for estimating sodium hazard based on irrigation water quality reports

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Summary

A more accurate method of calculating sodium hazard for irrigation water was identified by researchers several years ago, but has not been put into wide use by many commercial analytical laboratories. As a result, there is a great deal of confusion created in the interpretation of sodium hazard measurements such as the sodium adsorption ratio (SAR), adjusted SAR (adj SAR) and adjusted sodium hazard (adj RNa). To help golf course superintendents identify the most accurate assessment of sodium hazard in their irrigation water, we have developed a mathematical model and accompanying spreadsheet. These tools will allow you to rapidly compute the sodium hazard for your irrigation water, based on data from your water quality reports. This value can be compared against PACE's water quality guidelines to determine whether your water is likely to cause soil problems such as poor infiltration.

Background

When irrigation water does not have the proper proportions of sodium, calcium and magnesium, significant problems with water infiltration and breakdown of soil structure can develop. Several procedures have been developed over the years to predict potential problems with irrigation water, including the Residual Sodium Carbonate (RSC) method, the Sodium Adsorption Ratio (SAR) method and the adjusted Sodium Adsorption (adj SAR) method. The adj SAR was developed to take into consideration the precipitation of calcium in the form of calcite (calcium carbonate). However, subsequent research revealed that the computation of the adj SAR was wrong and overestimated sodium hazard. A more accurate method, which takes several other factors – including the effects of salinity and bicarbonate on calcium precipitation – into account. This newer method generates a value known as adjusted sodium hazard or adj RNa. In some cases, the adj SAR is listed on water laboratory reports using these methods without any recognition or the type of computation used to report the sodium hazard.

Getting an accurate estimate of sodium hazard

Standard water quality test reports may contain several estimates of sodium hazard – including SAR, adjusted SAR, pHc, RSC and adj RNA – a situation that causes considerable confusion. In order to help identify the most accurate estimate of sodium hazard, we have consulted several publications (including FAO Handbook 29, which is the standard guideline that most researchers and practitioners rely upon) and academics (most notably Dr. Don Suarez of the USDA Salinity Laboratory in Riverside, CA), and based on this input we have generated a mathematical model and accompanying spreadsheet. The spreadsheet will allow you to rapidly compute the sodium hazard for your irrigation water, based on data from your water quality reports. If the lab that you use is basing their results on the newer, adj RNA method, then the number that you generate with the spreadsheet should be very close to the adj SAR number shown on your report. If your lab is using the older, less accurate methods of calculating sodium hazard, then the number you generate may be as much as 50% lower than the adj SAR value shown in your report.

Once you have generated a sodium hazard value for your irrigation water, it can be compared against PACE's water quality guidelines to determine whether your water is likely to cause soil problems such as poor infiltration.

Building the model -- definitions:

- adj RNa - Sodium hazard. This is the most accurate estimate of sodium hazard. It can be as much as 50% lower than other sodium hazard estimates such as SAR. In some cases adj RNa is refered to as the adj SAR.
- Ca meq/l - milliequivalents per liter of calcium in the water source
- Mg meq/l - milliequivalents per liter of magnesium
- HCO_3 meq/l - milliequivalents per liter of bicarbonate
- Na meq/l - milliequivalents of sodium
- HCO_3/Ca - ratio of bicarbonate meq/l to calcium meq/l
- Ca_x meq/l - Calcium in the irrigation water modified due to salinity of the applied water (ECw), its HCO_3/Ca ratio and the estimated partial pressure of CO_2 in the surface of the soil (P_{CO2} = 0.0007 atmospheres)
- ECw dS/m - irrigation water electrical conductivity

Building the model -- calculations:

Calculation of sodium adsorption ratio (SAR):

$$\mathbf{SAR} = \frac{\mathbf{Na}}{\sqrt{\frac{\mathbf{Ca + Mg}}{\mathbf{2}}}}$$

Calculation of adjusted sodium hazard (adj RNa):

$$\mathbf{adj\ RNa} = \frac{\mathbf{Na}}{\sqrt{\frac{\mathbf{Cax + Mg}}{\mathbf{2}}}}$$

Where:

$$\mathbf{Ca_x = 10^{(0.283 - (0.667 \times \log_{10}\left(\frac{HCO_3\ meq/l}{Ca\ meq/l}\right) + 0.022 \times dS/m)}}$$

Testing the model:

Log_{10} transformations for Ca_x and HCO_3/Ca ratios were used to develop the regression equation listed above for Ca_x. The FAO Handbook 29 Table 11 values are compared to the model results in Figure 1. The results are sufficiently accurate to use in computer programs and spreadsheets.

Figure 1. Evaluation of FAO Handbook 29, Table 11 values to estimates using the PACE Turf regression model to compute Ca_x. The model r^2 = 0.998 indicating that the model accurately represents the FAO Handbook 29 Table 11 values.

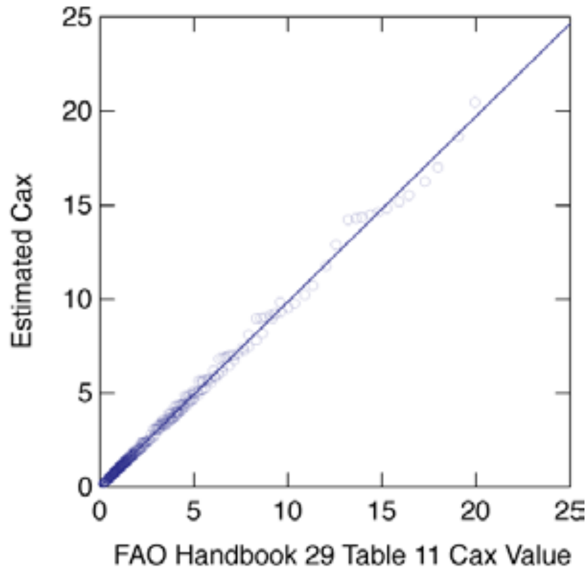

Table 1. Regression analysis for SAR, adj SAR and adj RNa. Results represent 1000 water samples analyses from golf courses. Dependent refers to the dependent (Y) variable, Independent refers to the independent (X) variable, Slope refers to the slope of the best-fit regression line, Intercept refers to the Y intercept of the regression line, R2 refers to the coefficient of determination, and P refers to the probability of the regression being due to random chance (values less than 0.05 are considered significant).

Dependent (Y)	Independent (X)	Slope	Intercept	R^2	P
adj RNa	adj SAR	0.62	0.01	0.95	0.000
adj SAR	SAR	2.78	-1.20	0.91	0.000
adj RNa	SAR	1.47	-.91	0.93	0.000

References:

Ayers, R.S., and D.W. Westcot. 1994. Water quality for agriculture. FAO Handbook 29. http://www.fao.org/docrep/003/t0234e/t0234e00.htm (valid 6/9/2010)

Suarez, D. L. 1981. Relation between pHc and Sodium Adsorption Ratio (SAR) and an alternative method of estimating SAR of soil or drainage waters. Soil Sci. Soc. Am J. 45:469-475.

Statistics

Regression results for $\log_{10}(HCO_3$ meq/l) and log10 (Ca_x meq/l) values from Table 11 in FAO handbook 29. Water electrical conductivity (DS_M dS/m) was not transformed:

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Dep Var: LOG10CAX   N: 324   Multiple R: 0.999   Squared multiple R: 0.998

Adjusted squared multiple R: 0.998   Standard error of estimate: 0.019

Effect         Coefficient    Std Error     Std Coef Tolerance     t   P(2 Tail)

CONSTANT             0.283        0.001        0.000      .     199.337    0.000
LOG10HCO3             -0.667        0.002       -0.993     1.000 -443.672    0.000
DS_M                 0.022        0.000        0.115     1.000   51.520    0.000


Effect         Coefficient    Lower 95%   Upper 95%

CONSTANT             0.283        0.280        0.286
LOG10HCO3           -0.667       -0.670       -0.664
DS_M                 0.022        0.021        0.023


Correlation matrix of regression coefficients
                      CONSTANT     LOGHCO3        DS_M
   CONSTANT              1.000
   LOG10HCO3            -0.102       1.000
   DS_M                 -0.679       0.000       1.000


Analysis of Variance
Source             Sum-of-Squares   df  Mean-Square     F-ratio       P

Regression                68.725     2       34.362   99749.518       0.000
Residual                   0.111   321        0.000


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Durbin-Watson D Statistic          0.032
First Order Autocorrelation        0.977
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