Methods to evaluate crop salt tolerance from field trials, a critical review of the Salt Farm Texel article

R.J. Oosterbaan, June 2019

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1. Introduction

The Salt Farm Texel has published a paper in the journal "Agricultural water management", written by G. van Straten et al. and entitled: "*An improved methodology to evaluate crop salt tolerance from field trials*".
(on line: https://www.sciencedirect.com/science/article/pii/S0378377418310370)

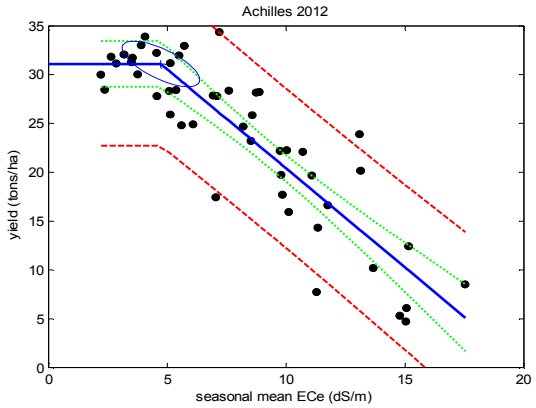
In the article only two methods are discussed: the Maas-Hoffman model (MH model) and the van Genuchten-Gupta model (vGG model). Both models are fitted to the data using the least squares method (LS method) by which the sum of the squares of the deviations of the model from the data is minimized. Both models use three parameters, of which the estimation errors can be found and when paired they show error-ellipses.

The data concern the yield of the potato variety Achilles (t/ha) versus the soil salinity expressed in electrical conductivity of the soil moisture (ECe, dS/m). The data were obtained repeatedly at varying ECe levels and during 5 years (2012-2016). In the article, the majority of the examples are given for Achilles 2014.

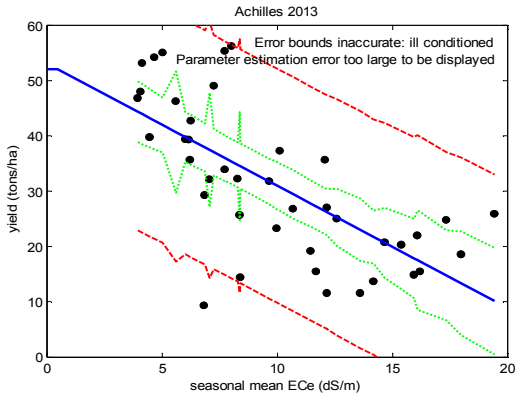
The MH model, which consists of an initial horizontal line connected to a downward sloping line while the connection point is called threshold or tolerance level. The vGG model is an S-curve that does not produce such a tolerance level as it is continuously descending and therefore the ECe value at which the yield is 90% of the initial yield is taken as a representative value for the salt tolerance.

2. The MH model as used for Achilles

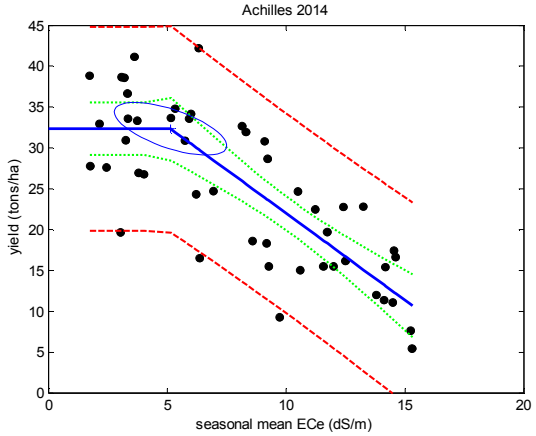
The Solver method in Microsoft Excel produces the following pictures of the MH model using the LS method for Achilles, indicating the level of the horizontal line segment by Yo:



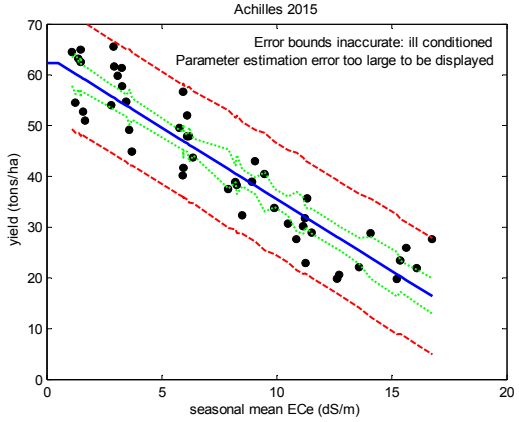
Yo=31 t/ha, Threshold=5 dS/m



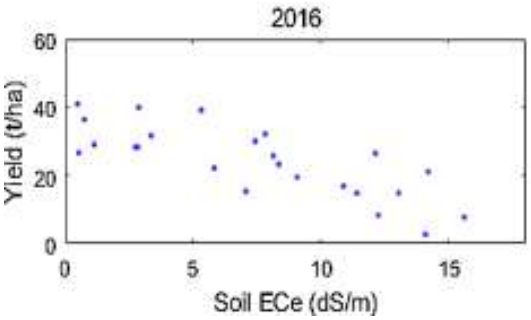
Yo=51 t/ha, Threshold=0 dS/m



Yo=33 t/ha, Threshold=5 dS/m



Yo=61 t/ha, Threshold=0 dS/m



Yo=35 t/ha, Threshold=4 dS/m

Summary

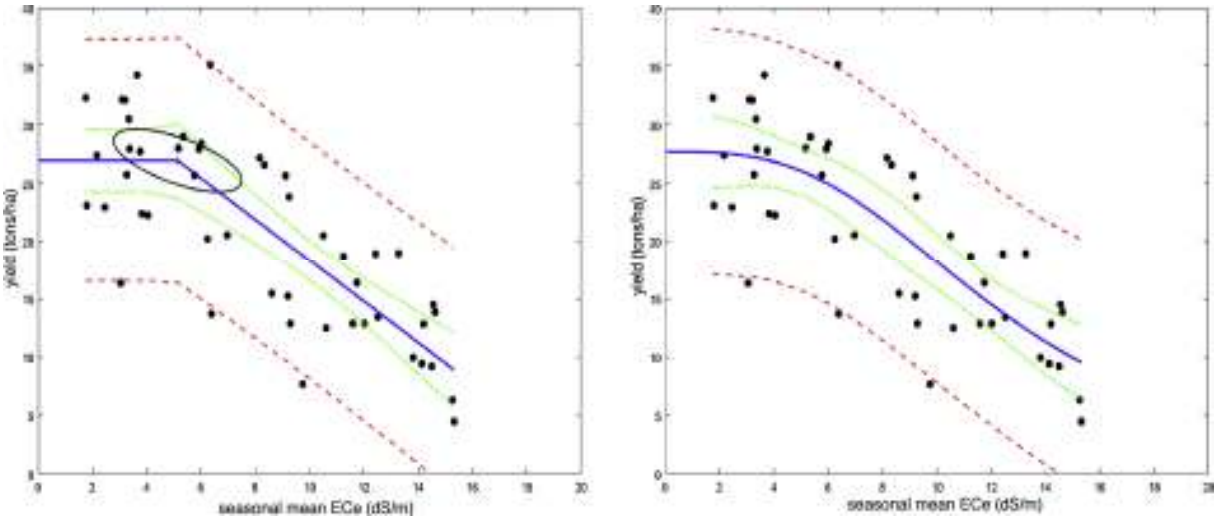
Year	Yield Yo	Threshold
2012	31 (low !)	5
2013	51	0 (zero !)
2014	33 (low !)	5
2015	61	0 (zero !)
2016	35 (low !)	4

It is noted that the threshold is lower as the Yo value is higher. In fact, at low yields, the threshold values are not representative for the variety Achilles. At yields above 50 t/ha (which is the normal range of the yield in the Netherlands), the threshold is zero. At yields around 30 t/ha farmers in the Netherlands would not be able to make a living, so data with low Yo yield levels should no be used.

3. Finding a tolerance index when the threshold is zero, the vGG model

Thus it is understandable that the authors would like to find some kind of tolerance index to characterize the critical salinity with a value greater than zero. Therefore they employ the vGG model using the ECe value at 90% yield.

The figure below (copied from the article) illustrates this principle for Achilles 2014: left the MH model, right the vGG (S-curve) model. The 90% yield in the vGG model corresponds to ECe=6 dS/m. Note that the Yo yield in these figures is only 27 t/ha. Somehow the data have changed!



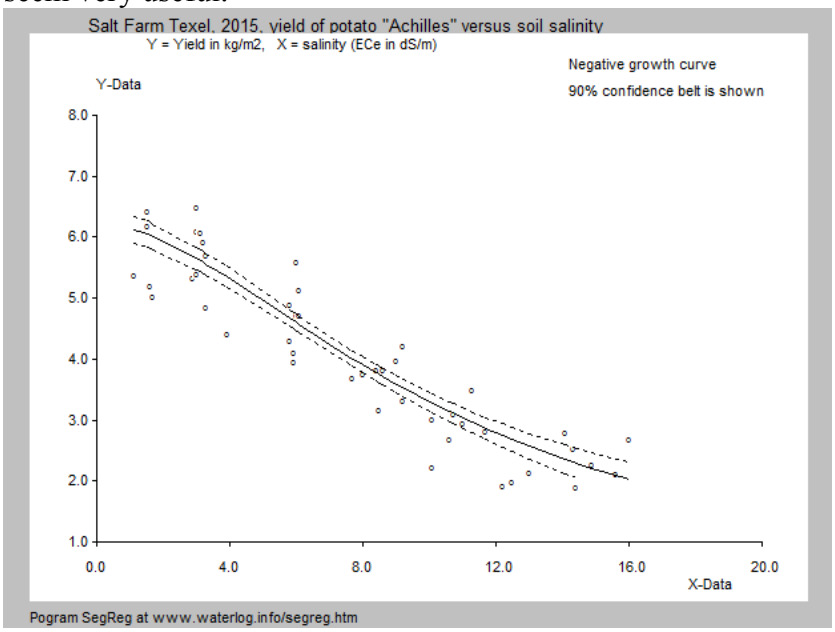
It is not known why the authors have selected the 90% yield level in the vGG model, and why not, say, 95% or 80%.

The authors do not use analysis of variance (ANOVA) to test whether the models are significantly different compared to a simple linear regression.
For the vGG model (Achilles 2014) the ANOVA table looks as follows:

Sum of squares of deviations	Degrees of freedom	Variance	Fisher's F-test	Probability (significance) (%)
Total 44.200	47	0.940		
Explained by lin. regress. 25.300	1	25.300	F(1,46)= 61.577	99.9 %
Remaining unexplained 18.900	46	0.411		
Extra explained by vGG model 0.533	2	0.271	F(2,44)= 0.666	48.1 %
Remaining Unexplained 18.375	44	0.408		

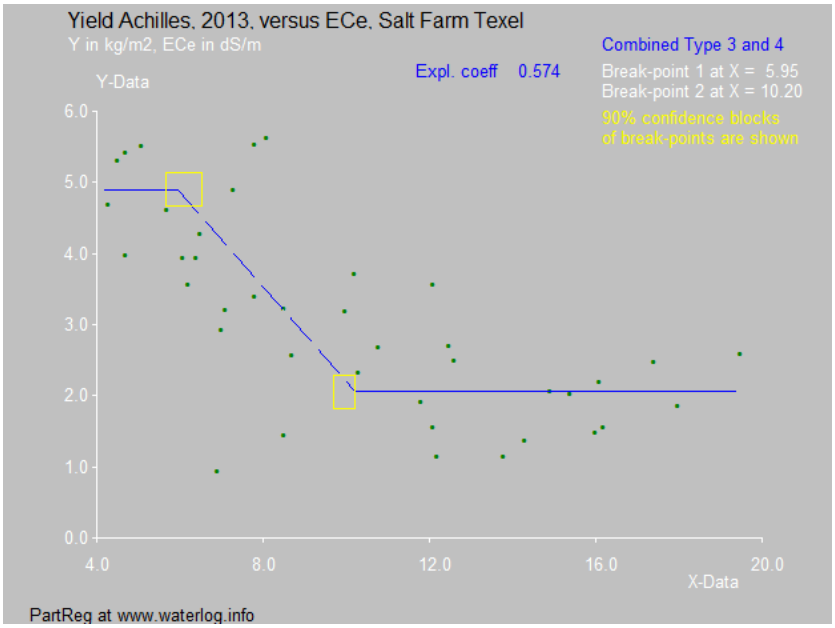
The above table shows that there is more than 50% chance that the vGG model is not valid. In such cases it would be preferable to use the ECe at 90% yield according to the straight line instead of the vGG model, if such a tolerance index is desirable at all.

For 2015, the vGG model looks almost like a straight line, see figure hereunder. It does not seem very useful.

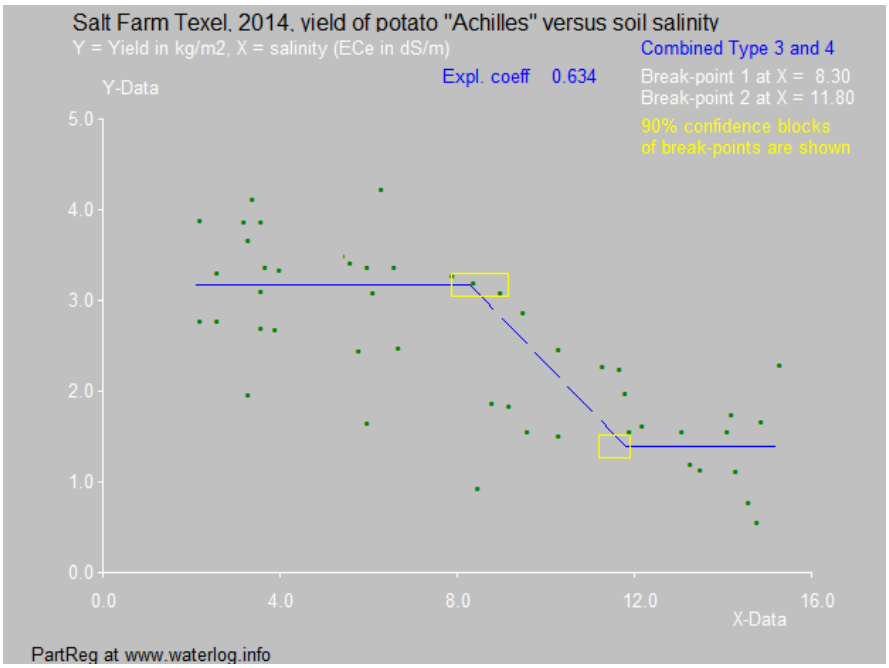


4. Explanation of failures of the MH model

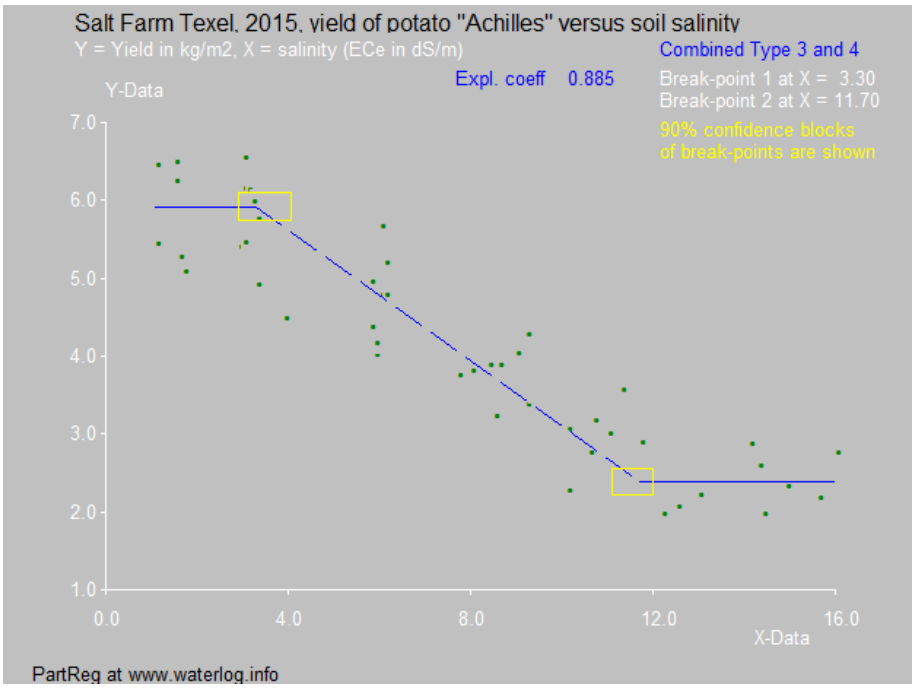
The following graphs clarify why the MH model fails to bring forward thresholds.



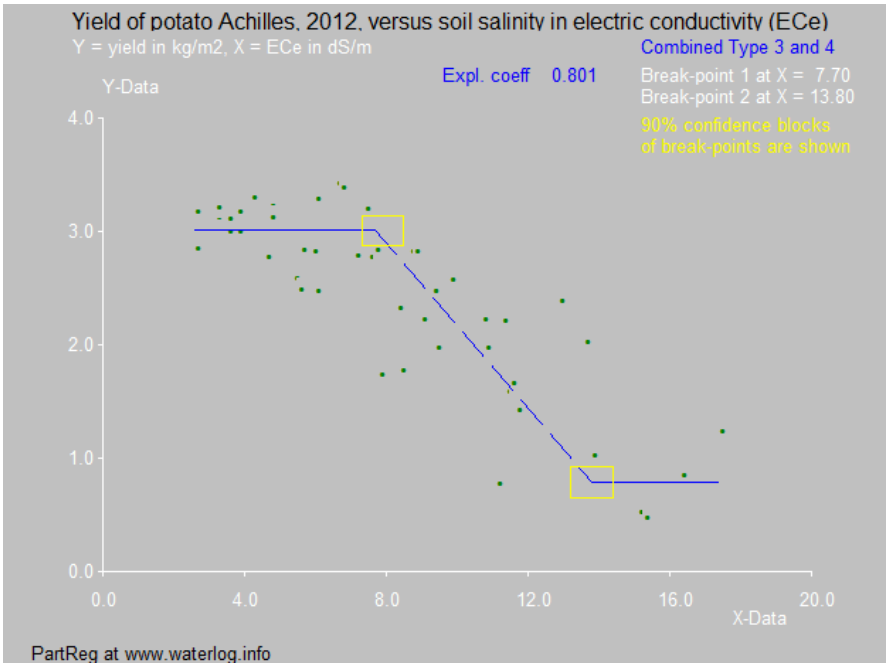
This figure (Achilles 2013), made by the PartReg method (explanation later), demonstrates a long horizontal tail which makes the downward sloping line in the MH model very flat so that the intersection point with the initial horizontal segment is drawn to the left, below the minimum ECe value measured. The MH model, therefore, cannot find a threshold.



This figure (Achilles 2014), made by the PartReg method (explanation later), also demonstrates horizontal tail and which has the same effect as explained under the previous figure. While not using the MH model based on the LS method, the threshold value becomes much larger, but keep in mind that the yield level is very low.



This figure (Achilles 2015), made by the PartReg method (explanation later), also demonstrates a horizontal tail which flattens the downward sloping line in the MH model so that the intersection point with the initial horizontal segment is drawn to the left, below the minimum ECe value measured. The MH model, therefore, cannot find a threshold.



This figure (Achilles 2012) tells the same story, be it that the horizontal tail end is not very pronounced. Yet the threshold (ECe=7.7 dS/m) is much higher than the ECe=5.5 according to the MH model calculalated with the LS algorithm applied over the entitre data domain.

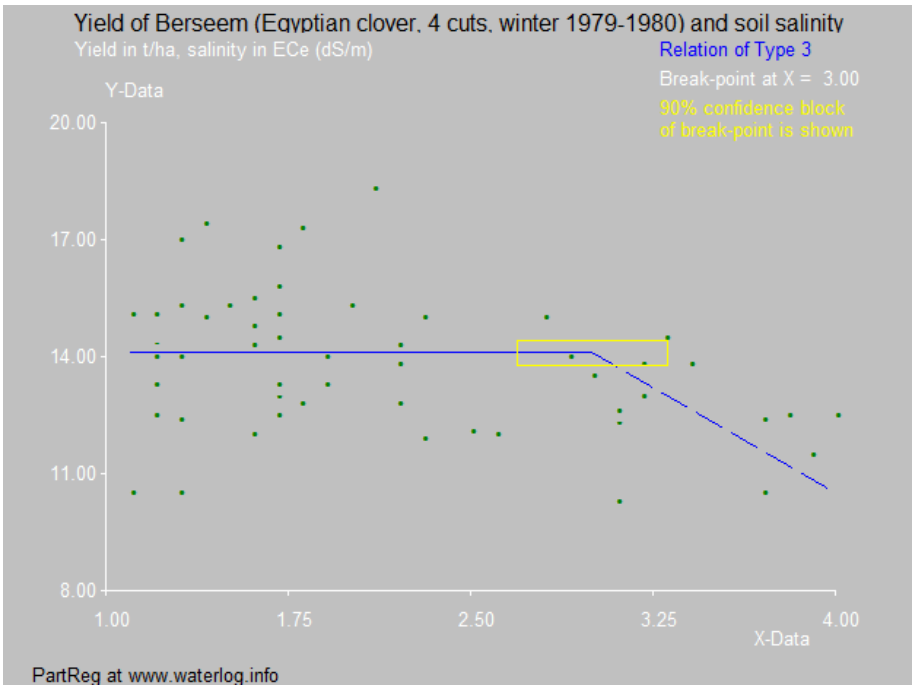
5. Explanation of the PartReg method

The PartReg method is NOT a model, but a calculation method. The name stems from partial regression. It simply tries to detect horizontal stretches in the data domain by linear regression under the condition that the regression coefficient is *insignificant* so that it can be assumed practically zero. The LS method is NOT used and the data beyond the horizontal stretch (es) play no role. Here no regression is done. The tail end does NOT influence the head end and vice versa, they are analyzed independently.

The method has been used in my article published in the International Journal of Agricultural Science entitled: "*Crop tolerance to soil salinity, statistical analysis of data measured in farm lands*". On line: https://www.iaras.org/iaras/filedownloads/ijas/2018/014-0008(2018).pdf

The PartReg method, contrary to the vGG model, has the advantage that it does find thresholds, while the Z-shape appears to exhibit some similarity with the S-curve.

In some cases, however, the Z-shape cannot be found, as in the following figure:



This figure shows similarity with the MH model but the way of determination is quite different.

6. Conclusions

The v. Straten article bases its conclusions on observation of only one crop (potato) and only one variety (Achilles). Not a very strong basis to draw general conclusions from.

During the 5 years of observation there was zero salt tolerance twice while in the other years the yield levels were too low to be representative. Not a very strong basis to draw general conclusions from

The failures the MH model calculated with the LS method to detect the tolerance level are owing to the trend of the data at the tail end. In these cases, the effort to find at least some kind of tolerance index using the vGG model has strong limitations.

It appears to be recommendable NOT to use models with LS methods for salt tolerance determination, but rather simple statistical regression techniques to detect the change of data trends from horizontal to sloping.

Using the MH model with LS techniques, a relation was found between yield level and salt tolerance. At low yield levels (like in 2013 and 2015) the salt tolerance has no meaning, while at high yield levels the tolerance is zero. Achilles is a very salt sensitive variety and, in fact, the examples used are not a good basis to claim that *an improved methodology* has been developed.

To test the success of the determination of a threshold or tolerance level, the ANOVA table has to be used. In the v. Straten article this was not done.

The confidence ellipses in the v. Straten article are all based on the application of the MH model using the LS method. As this approach appears to be not applicable, the ellipses have no value.