Methods to evaluate crop salt tolerance from field trials, a critical review of the Salt Farm Texel article entitled: "*An improved methodology to evaluate crop salt tolerance from field trials*", which gives no improvement at all, to the contrary.

R.J. Oosterbaan, June 2019. On www.waterlog.info public domain

Contents:

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://doi.org/10.1016/j.agwat.2018.09.008)

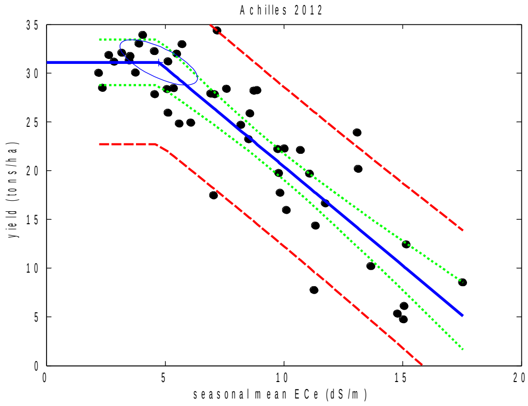
In the article only two methods are discussed: the Maas-Hoffman model (MH model) and the van Genuchten-Hoffman model (vGH model). Both models are fitted to the data using the least squares method (LS method) by which the sum of the squares of the deviations of the model from the data is minimized. Both 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.

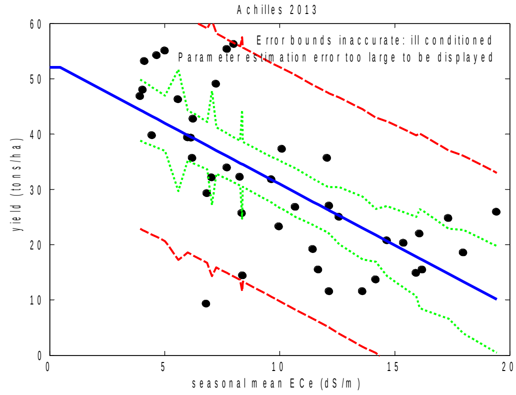
The MH model, which consists of an initial horizontal line connected to a downward sloping line while the connection point is called threshold or tolerance level. The vGH model is an S-curve that does not produce such a tolerance level as it is continuously descending and therefore the ECe value at which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

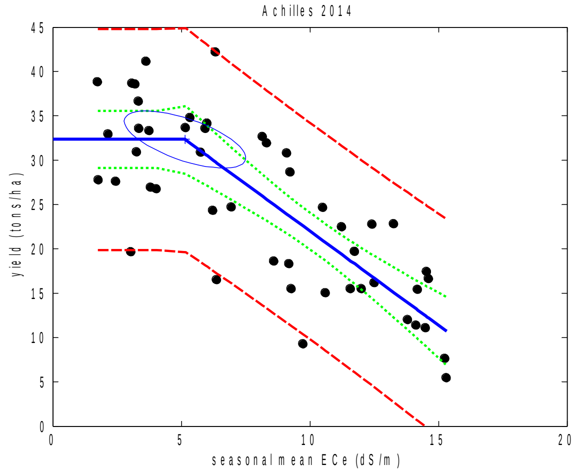
The Solver method in Microsoft Excel produces the following pictures of the MH model using the LS method for Achilles, indicating the level of the horizontal line segment by Yo:



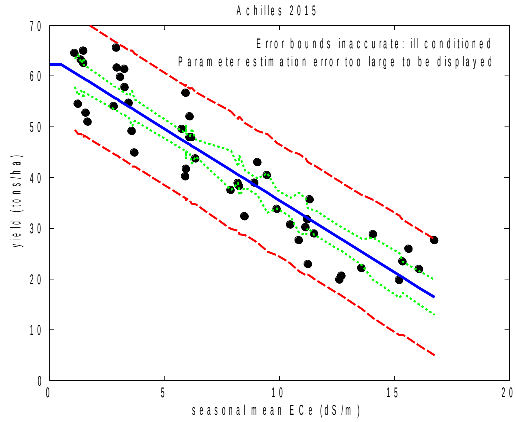
Yo=31 t/ha, Threshold=5 dS/m



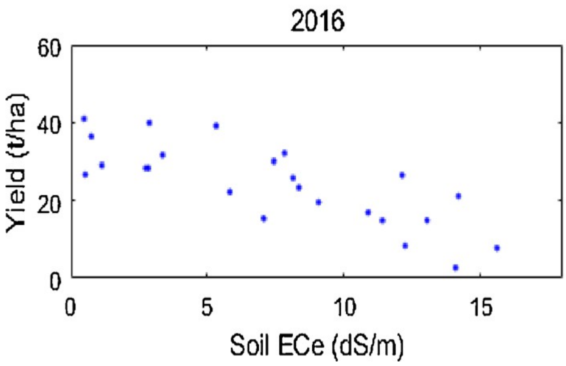
Yo=51 t/ha, Threshold=0 dS/m



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

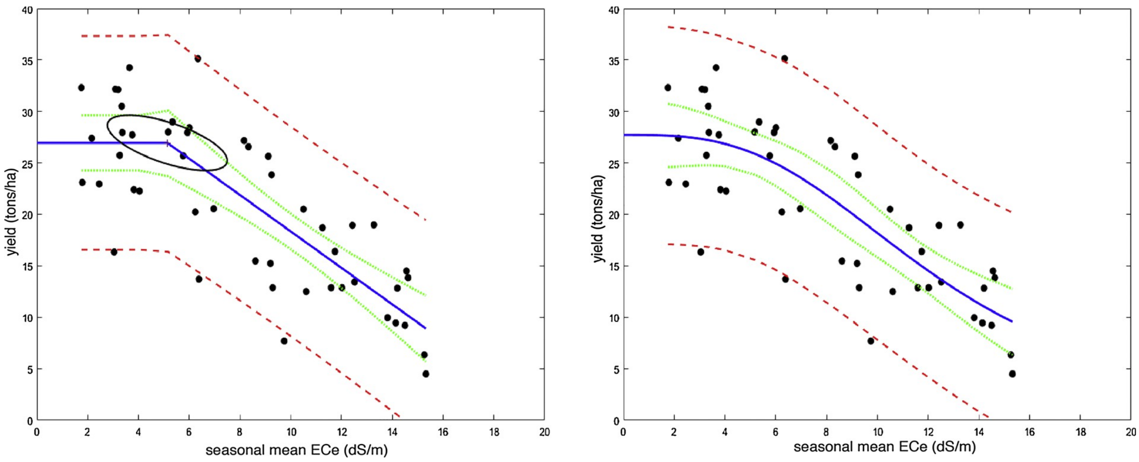
It is noted that the threshold is lower as the Yo value is higher. In fact, at low yields, the threshold values are not representative for the variety Achilles. At yields above 50 t/ha (which is the normal range of the yield in the Netherlands), the threshold is zero. At yields around 30 t/ha farmers in the Netherlands would not be able to make a living, so data with low Yo yield levels should not be used at all.

For Achilles 2014 it can be clearly seen that there are different upper and lower confidence limits of the threshold when one looks at the green lines or at the ellipse. That cannot be!

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

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 vGH 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 vGH (mirrored S-curve) model. The 90% yield in the vGH model corresponds to ECe=6 dS/m. Strange enough, its confidence interval is not shown. Note that the Yo yield in these figures is only 27 t/ha. Somehow the data have changed!



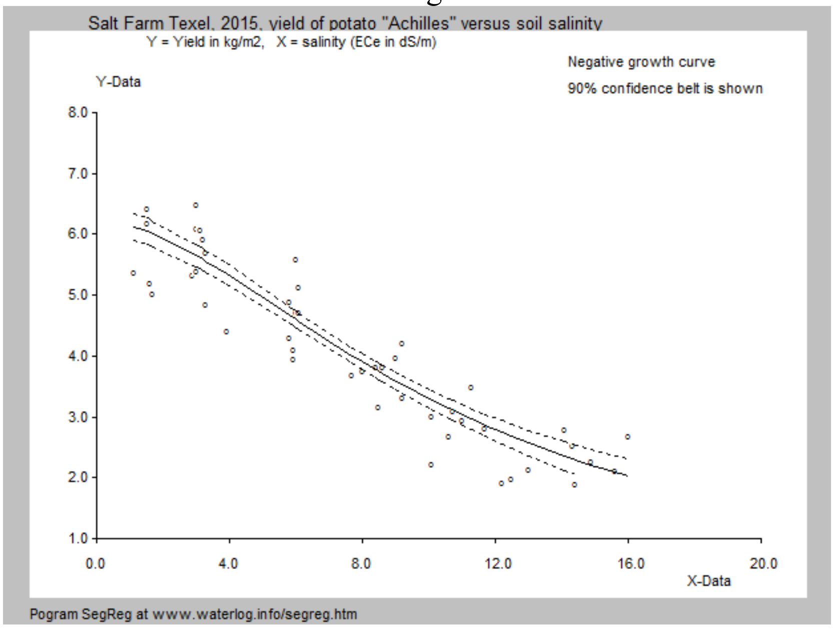
It is not known why the authors have selected the 90% yield level in the vGH model, and why not, say, 95% or 80%.

The authors do not show ECe confidence intervals for the 90% yield in the vGH model. Are they wider? Also, 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 vGH model (Achilles 2014) the ANOVA table looks as follows:

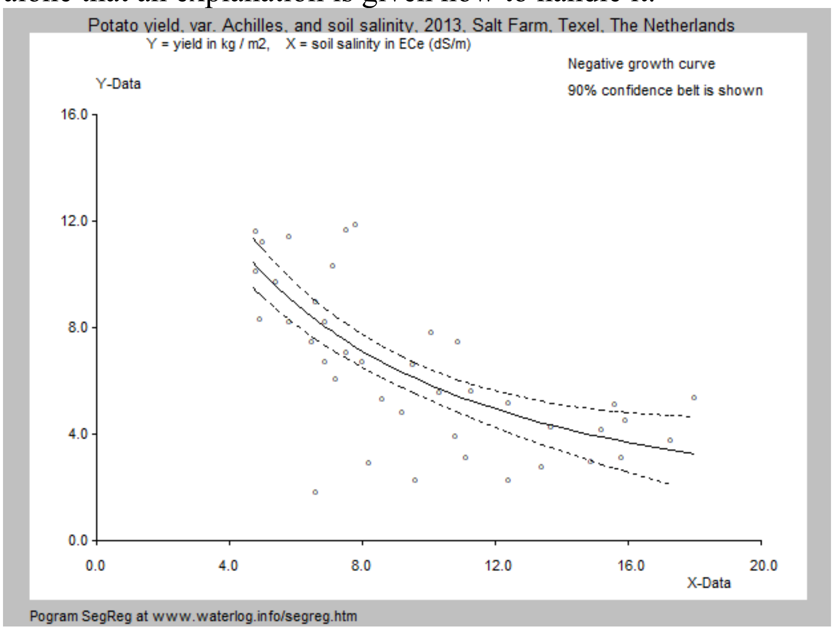
Sum of squares of deviations	Degrees of freedom	Variance	Fisher's F-test	Probability (significance) (%)
Total 44.200	47	0.940		
Explained by lin. regress. 25.300	1	25.300	F(1,46)= 61.577	99.9 %
Remaining Unexplained 18.900	46	0.411		
Extra explained by vGH model 0.533	2	0.271	F(2,44)= 0.666	48.1 %
Remaining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

The above table shows that there is more than 50% chance that the vGH model is not valid. The promoted van Genuchten (vGH) model is not as robust as claimed by the authors. In such cases it would be preferable to use the ECe at 90% yield according to the straight line instead of the vGH model, if such a tolerance index is desirable at all.

For 2015, the vGH model looks almost like a straight line, see figure hereunder. It does not seem very useful. See the Appendix to show that it is easy to find the vGH model fittting a linear data set that follows a straight line.

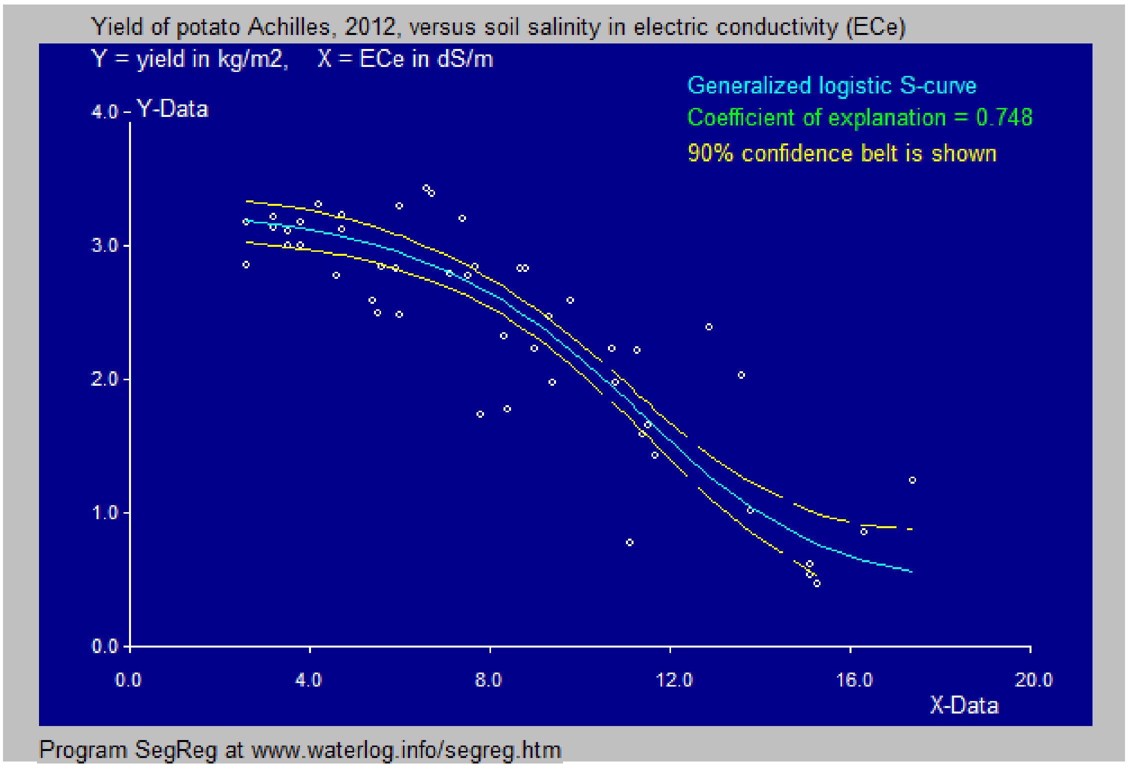


For 2013 the vGH model does not show a horizontal tendency in the lower range of X values. See figure hereunder. In the van Straten article, no attention is paid to this phenomenon let alone that an explanation is given how to handle it.



4. Comparison vGH model with the mirrored logistic S-curve

It has not been made clear in the article why only the vGH model was used and that no consideration was given to, for example, the mirrored logistic S-curve model. Below a picture is shown of the application of the mirrored logistic S-curve to the Achilles data of 2012.



The above figure demonstrates that the mirrored logistic S-curve is able to accomplish a very good fit and need not be inferior to the vGH model [Ref. 1].

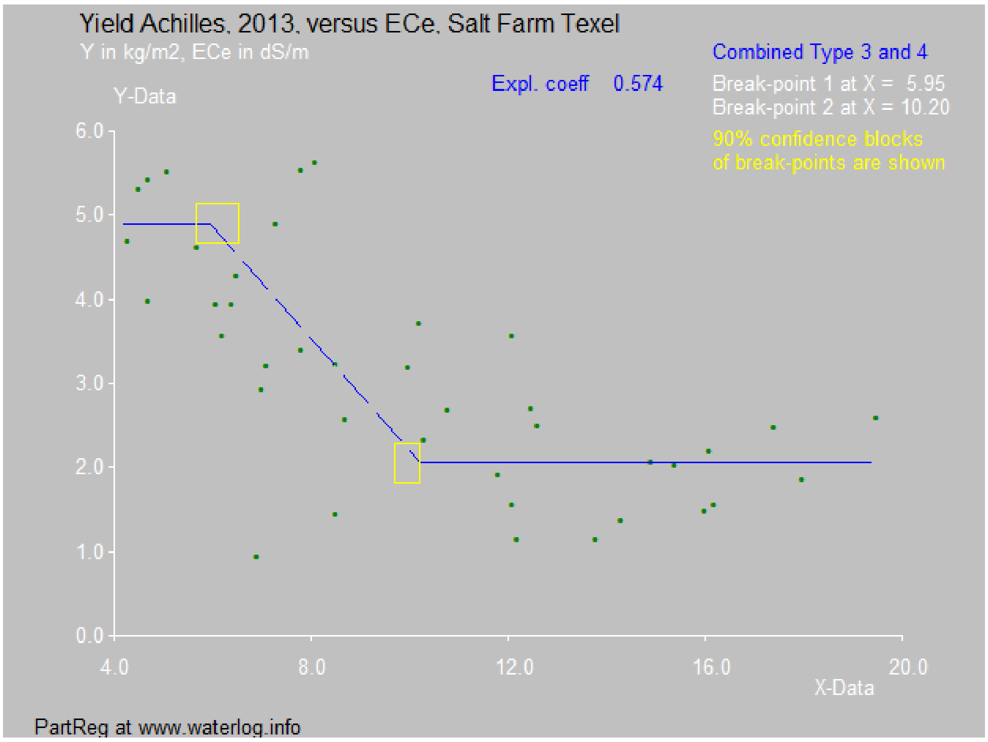
The vGH model is derived from the well known Fisk cumulative probability distribution. Unfortunately, this is not mentioned in the van Straten article.

There are many more (mirrored) cumulative probability distributions that can be used to develop mirrored S-curves. Of this, no mention is made either.

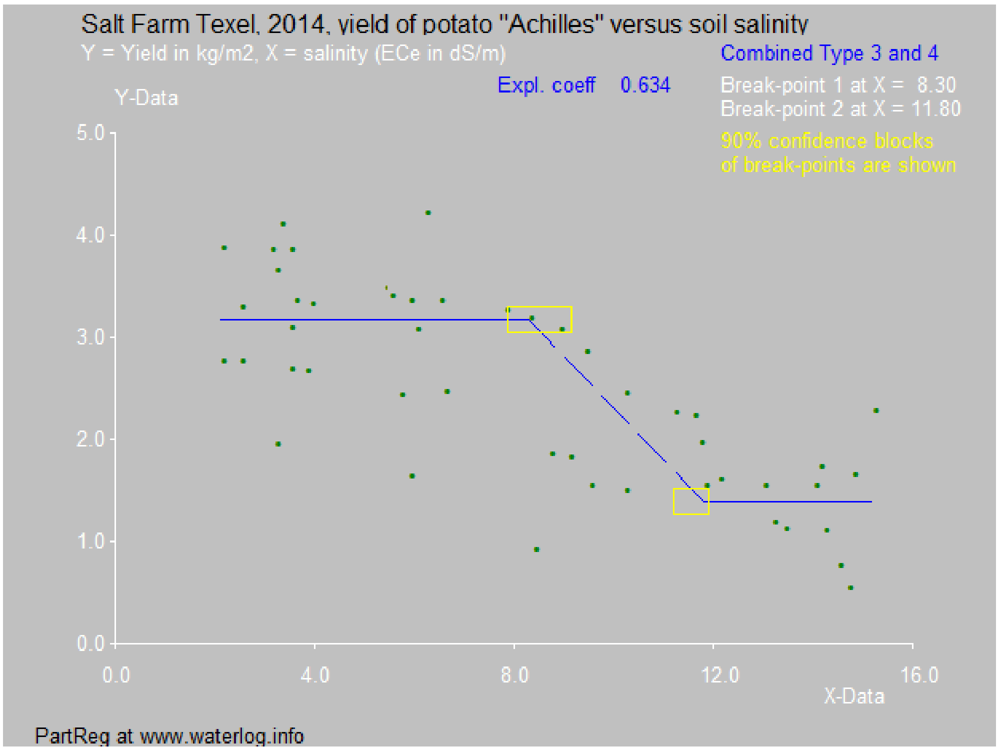
Nowhere in the van Straten article mention is made on how the parameters of the vGH distribution have been determined when using the principle of minimizing the sum of squares of the differences between observed and simulated yield values.

5. Explanation of failures of the MH model

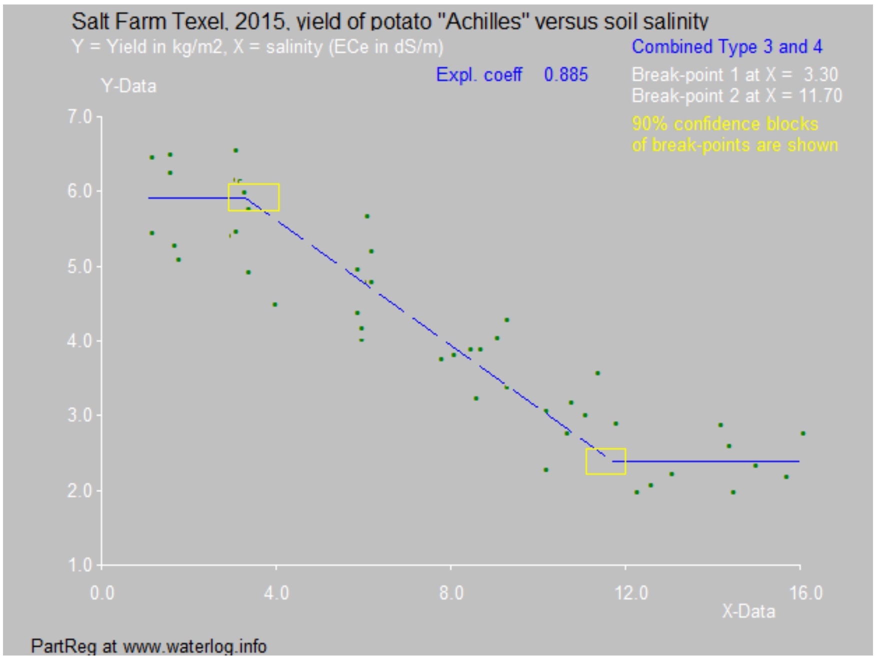
The following graphs clarify why the MH model fails to bring forward thresholds.



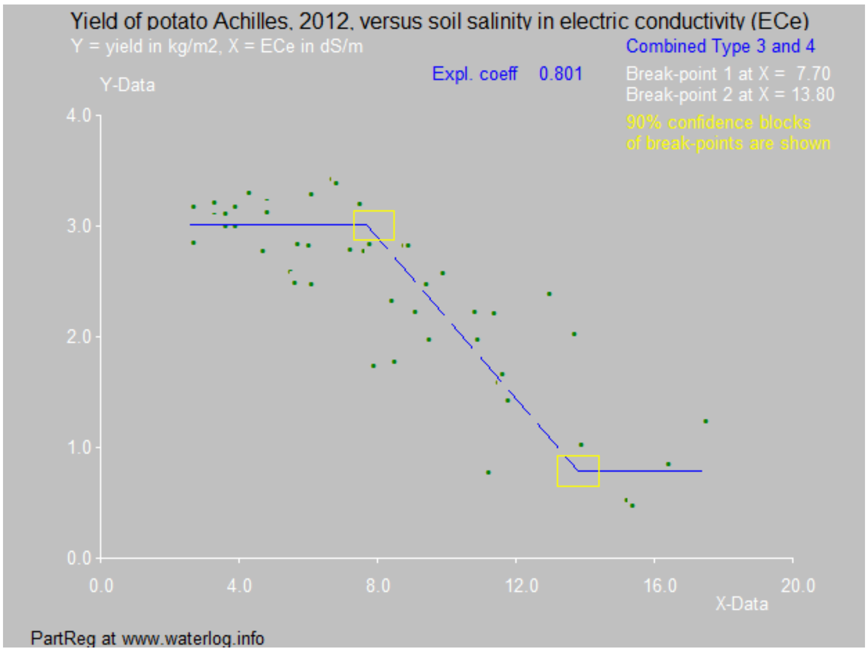
This figure (Achilles 2013), made by the PartReg method (explanation later), demonstrates a long horizontal tail which makes the downward sloping line in the MH model very flat so that the intersection point with the initial horizontal segment is drawn to the left, below the minimum ECe value measured. 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. The yield level, however, is the lowest of all.

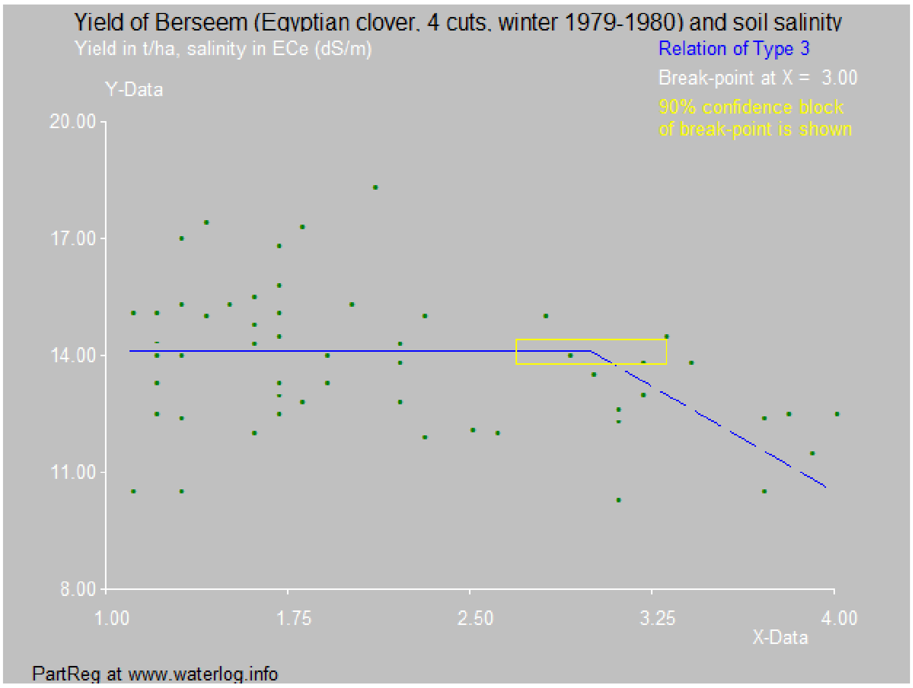
6. Explanation of the PartReg method

The PartReg method [Ref. 2] 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 or https://www.waterlog.info/pdf/AgrJournal.pdf

The PartReg method, contrary to the vGH 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.

7. Conclusions

1. 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.

2. 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

3. 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 vGH model has strong limitations.

4. 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.

5. 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.

6. The mirrored logistic S-curve is as powerful as the vGH model. In the v. Straten article the mirrored logistic S-curve is ignored without justification.

7. To test the success of the application of the vGH model, the ANOVA table has to be used. In the v. Straten article this was not done and as a result a vGH model was presented that according to the analysis of variance was unacceptable. This is in conflict with the principle recommendation in the article that use of the vGH model is advised.

8. Nowhere in the van Straten article mention is made on how the parameters of the vGH distribution have been determined while using the principle of minimizing the sum of squares of the differences between observed and simulated yield values.

9. The vGH model is derived from the well known Fisk cumulative probability distribution. Unfortunately, this is not mentioned in the van Straten article.

10. For figure 5 in the van Straten et al. article (see hereunder), the subscript reads: "Approximate 95% parameter confidence contours for all three parameter combinations, potato Achilles 2014. left: MH, right: vGH". Four of the six graphs show the yield on the Y-axis. However, the yield variable is definitely not a parameter, so these graphs remain questionable.

11. In the figure 5 given by van. Straten et al (see hereunder) it is seen that for the MH model, the expected salinity threshold value is ECethr =5 dS/m and the corresponding yield is 27. Furhter, for the vGH model, the expected median salinity value is ECe 50 = 12.4 dS/m while the corresponding expected yield is 28. The general trend of the yield – ECe relation is that the yield is descending with increasing ECe values. Yet, in figure 5, the yield at the higher ECe 50 value is (slightly) higher than the yield at the much lower ECethr value. This is contradictory and not possible.

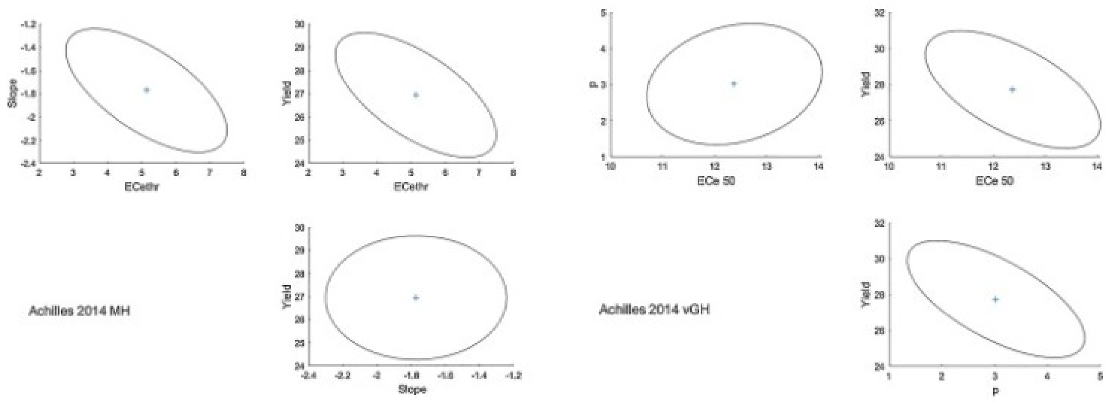


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Fig. 5. Approximate 95% parameter confidence contours for all three parameter combinations, potato Achilles 2014. left: MH, right: vGH.

12. Strange enough, the confidence ellipses shown in two of the MH models with a significant threshold, are not at all shown for the vGH models at the 90% yield level, although this level constitutes the crux of the article. Are they wider?

13. For Achilles 2013 the vGH model does not show a horizontal tendency in the lower range of X values. In the van Straten article, no attention is paid to this phenomenon let alone that an explanation is given how to handle it, even though this phenomenon hampers the application of the vGH model, that plays a crucial role in the article.

14. For Achilles 2014 it can be clearly seen that there are different upper and lower confidence limits of the threshold when one looks at the green lines or at the ellipse. That cannot be!

Final note

H. Steppuhn et al. , 2005, CROP ECOLOGY, MANAGEMENT & QUALITY; *Root-Zone Salinity: I. Selecting a Product–Yield Index and Response Function for Crop Tolerance* . In: Crop Sci. 45:209–220 (2005), Crop Science Society of America. On Line:
https://www.researchgate.net/publication/43257218_Root-zone_salinity_I_Selecting_a_product-yield_index_and_response_function_for_crop_tolerance
or:
https://pubag.nal.usda.gov/download/3381/PDF

have analysed crop response functions to soil salinity using various different S-curves. In the v. Straten article, the methods employed by Steppuhn et al. were disregarded, including a salinity tolerance index based on the vGH model.
In the second part of the Steppuhn article CROP ECOLOGY, MANAGEMENT & QUALITY*, Root-Zone Salinity: II. Indices for Tolerance in Agricultural Crops* , the authors use the Crop Tolerance Index $C_{50} + s*C_{50}$ where s is the mean of dY/dC from Y = 0.3 to 0.7 (C=soil salinity, Y=relative yield, C_{50} is C at Y = 0.5 or 50%, stemming from the vGH model). See on line:
https://www.researchgate.net/publication/43257126_Root-zone_salinity_II_Indices_for_tolerance_in_agricultural_crops

This proposal was also ignored by v. Straten et al.

8. References

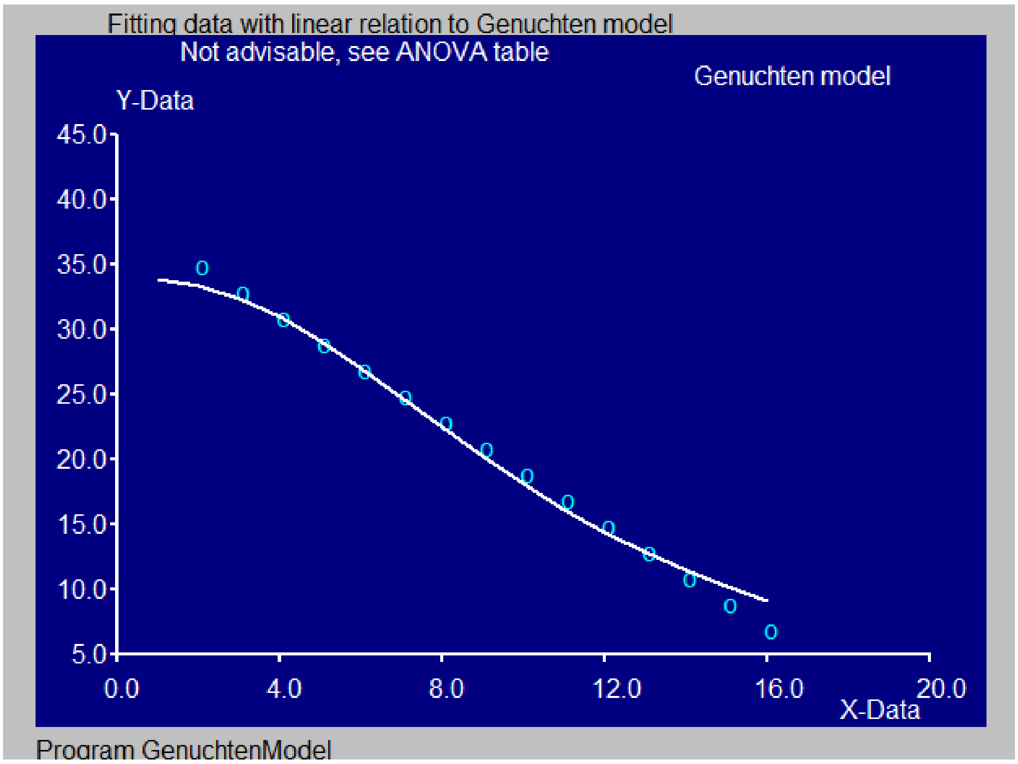
Ref 1. SegRegA, software for segmented and curved regressions Download from https://www.waterlog.info/segreg.htm

Ref. 2 PartReg, software for segmented regression with horizontal elements. Download from: https://www.waterlog.info/partreg.htm

Ref. 3. *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 or https://www.waterlog.info/pdf/AgrJournal.pdf

9. APPENDIX

The next figure demonstrates the fitting of data following precisely a linear (straight line) to the vGH model.
The model is deceptive.



Fitting data with linear relation to Genuchten model
Not advisable, see ANOVA table
Genuchten model
Y-Data
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
4.0
8.0
12.0
16.0
20.0
X-Data
Program GenuchtenModel