# Variations of leaching efficiency determined with soil salinity models calibrated in farm lands and related to soil texture.

R.J. Oosterbaan, 28-08-2019 On www.waterlog.info public domain

**Abstract**

The management of saline agricultural land depends to a great extent on the leaching efficiency of the soil in the root zone.

The leaching efficiency is used in soil salinity models like SaltMod [Ref. 1] and LeachMod [Ref. 2]. These models have been used extensively in practice and the practical experiences obtained with the leaching efficiency are summarized in this article.

There appears to be a considerable variation of the leaching efficiency depending on the type of soil, like swelling clay, stable clay, silty clay, loamy and sandy soils.

**Contents**



## 1. Water and salt balances of the root zone, definition of leaching efficiency

The water balance of the root zone reads:

$$I + R + A = E + P + \Delta w \qquad (1)$$

Here, I is the irrigation, R the rainfall, A the capillary rise of soil water from the underground, E the evapo-transpiration, P the percolation of soil water to the underground, and Δw the change in soil water content. The units may be mm/day or mm/month.

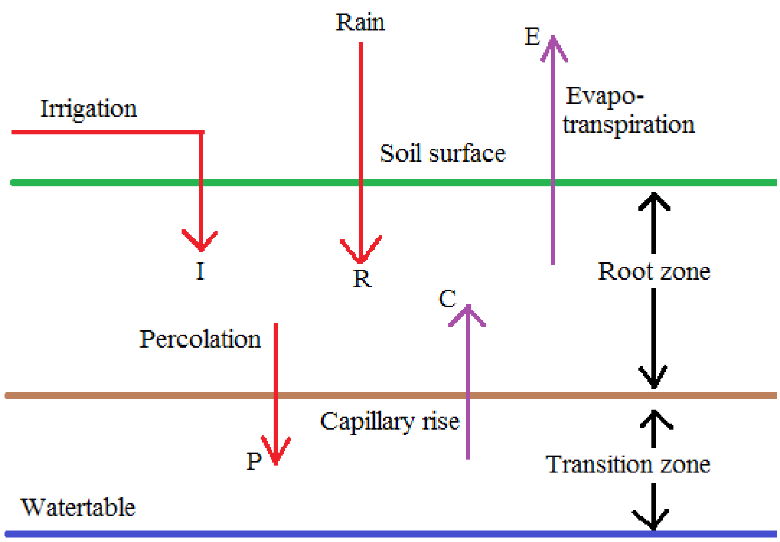


***Figure 1.*** *Water flows in the root zone*

Multiplying the water flow with the salt concentration of the water one obtains the salt balance. As the salt concentrations of rainfall and evaporation are negligibly small, the salt balance can be written as:

$$I.Ci + A.Ct = P.Cp + \Delta s \qquad (2)$$

Here, Ci is the salt concentration of the irrigation water, Cp the salt concentration of the percolation water, and Δs the change in salt storage in the soil. The units of salt concentration may expressed in terms of electrical conductivity (EC) in dS/m or mS/cm, which is proportional to the salt content per unit of water.

The salt concentration of the percolation water is a function of the salt concentration of the pore water (Cs):

$$Cp = F.Cs \qquad (3)$$

Here, Cs is the concentration of the pore water (soil moisture), and F the leaching efficiency of the soil pore system. It represents the ratio of the salinity of the percolation water to the average salinity of the soil pore water.

The leaching efficiency accounts for irregular patterns of downward flow through irregular the soil pore system, which may also vary with depth, and for the irregular distribution of salts dissolved in the water inside the pore system.

During a time step the change of the salt concentration of the soil water in the root zone is:

$$Cf - Co = \Delta s/W \qquad (4)$$

where Cf is the final salt concentration of the soil water at the end of the time step, Co is the initial salt concentration of the soil moisture at the beginning of the time step, and W is the amount of water contained in the soil pores of the root zone, equaling:

$$W = D.T \qquad (5)$$

where D is the depth of the root zone and T the total pore space of the soil in the root zone.

During a small time step the average salt concentration of Cs can be taken as:

$$Cs = 0.5*(Co+Cf) \qquad (6)$$

Combining Eq. 4, 5, and 6, one gets:

$$Cf = Co + (I.Ci+A.Ct)/D.T - 0.5*F.P.(Co+Cf)/D.T \qquad (7)$$

or explicitly in Cf:

$$Cf = [Co + (I.Ci+A.Ct)/D.T - 0.5*F.P.Co/D.T] / [1 + 0.5*F.P/D.T] \qquad (8)$$

## 2. Review of experiences with SaltMod

Below, the experiences with leaching efficiencies in different parts of the world using SaltMod [Ref.1] will be reviewed using the relevant publications chronologically in so far they could be accessed freely without payment and in so far they dealt with calibration of the leaching efficiency (LE).
With SaltMod, the calibration needs to be done empirically, assuming a range of LE values and selecting the value that leads to the closest fit of simulated to the observed salinity values.

### *2.1 Egypt, Nile Delta, 1898 [Ref. 3]*

In this case study SaltMod was used trying various values of the leaching efficiency (LE). It appeared that an LE value of 0.85 gave results that gave good correspondence between observed and simulated soil salinities (figure 2). The soils are clay loam.

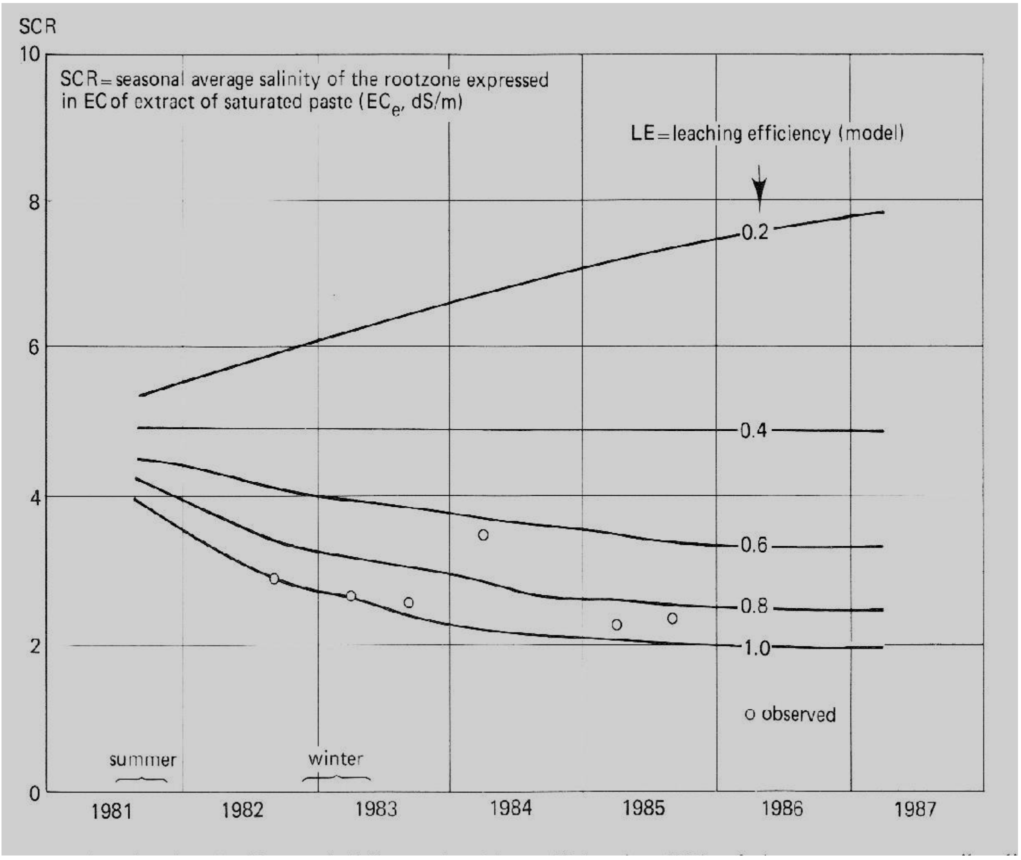


***Figure 2**. The simulated effects of different leaching efficiencies (LE) of the rootzone on soil salinity obtained with SALTMOD in the Nile Delta of Egypt [Ref. 3].*

### *2.2 India, South Gujarat, Ukai-Kakrapar, 2003 [Ref. 4]*

Using the same method as shown in figure 1, it was found that the optimal leaching efficiency is 0.70. Type of soil: clay. No illustration is available.

## 2.3 Portugal, Leziria Grande, 2005 [Ref 5]

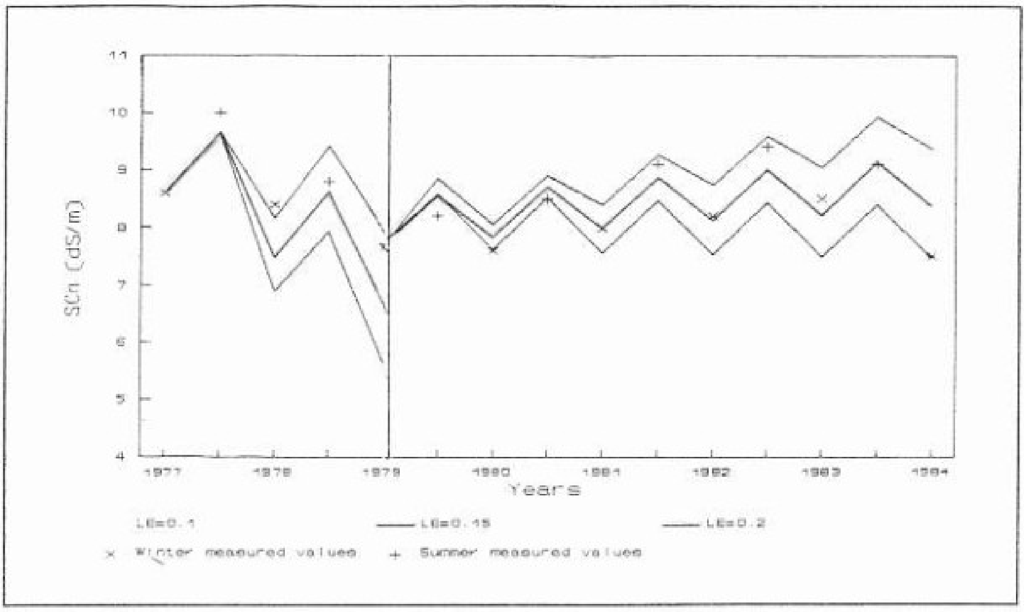


***Figure 3***. *From the leaching efficiency values 1.0, 1.5 and 2.0, the value 1.5 was selected as giving the best fit. It concerned a heavy clay soil with swelling properties.*

## 2.4 Turkey, South-East, Harran Plain, 2007 [Ref. 6]

Using the same method as shown in figure 1, it was found that the optimal leaching efficiency is 0.70 (see figure 3). The soil texture is clay with a high lime content.

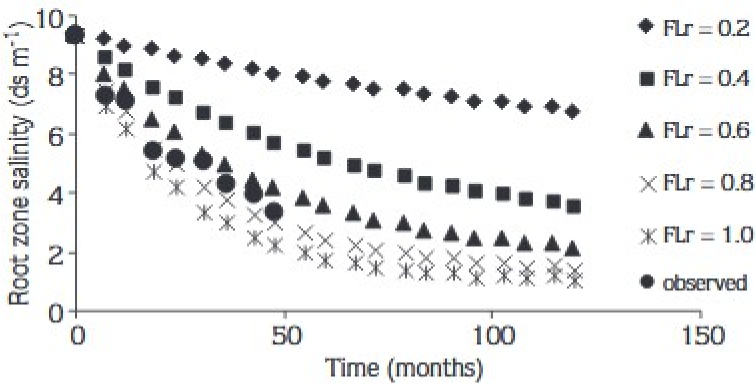


***Figure 4***. *A leaching efficiency FLr of 0.7 gives the best fit of the simulated to the observed soil salinity [Ref. 6].*

## *2.5 Thailand, Nong Suang district, 2008 [Ref. 7]*

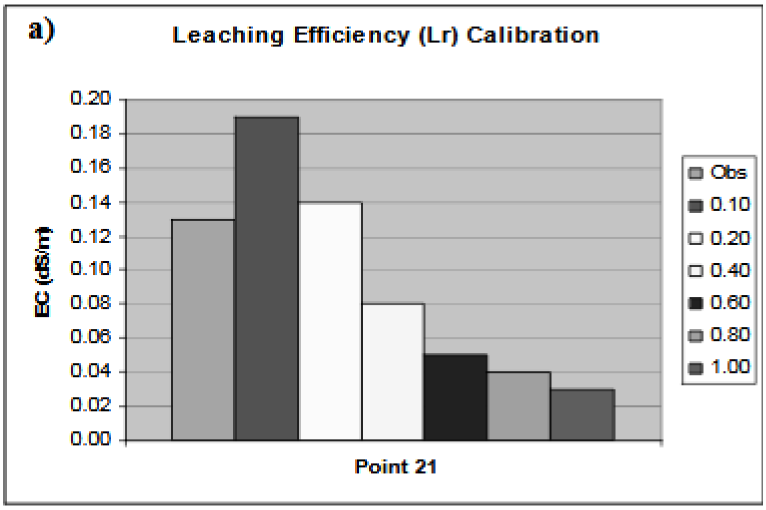


***Figure 4**. A leaching efficiency Lr of 0.2 gives the best fit of the simulated to the observed soil salinity [Ref. 7]. The soils are of the swelling clay type.*

## *2.6 Tunisia, 2012 [Ref. 8]*

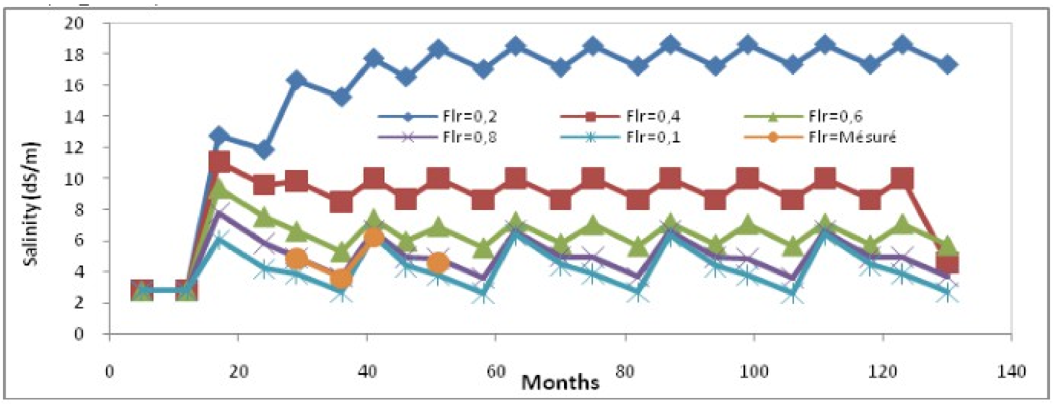


***Figure 5.** The best fit of simulated salinity with observed salinity is given by a leaching efficiency FLr =0.8 . It concerns a silty clay soil.*

***2.7 China, Hetao Irrigation district, 2019 [Ref. 9]***

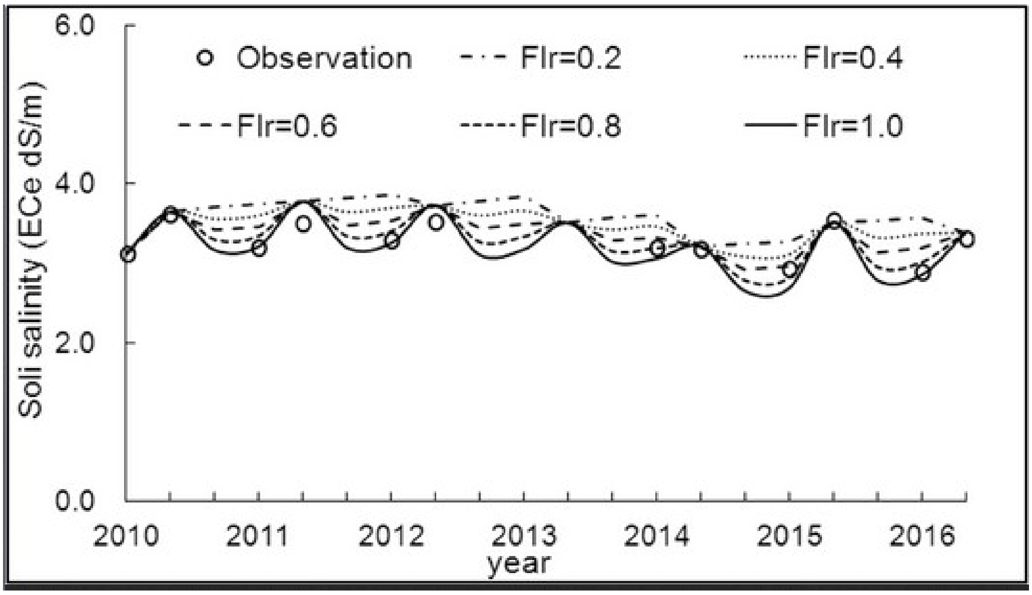


***Figure 6.*** *The best fit of simulated salinity with observed salinity is given by a leaching efficiency FLr =1.0 . It concerns a loamy soil.*

# 3. Review of experiences with LeachMod

LeachMod is a simplified version of SaltMod, in the sense that it is only one dimensional and only cropping pattern is allowed. This, on the other hand, makes it possible to use smaller time steps of 1 day to 1 week instead of 1 season. In addition, when measured soil salinities are available, the model can do the calibration of the leaching efficiency automatically if the user wishes.

The number of data in literature is limited.

### *3.1 Netherlands, island of Texel, 2016 [Ref. 10]*

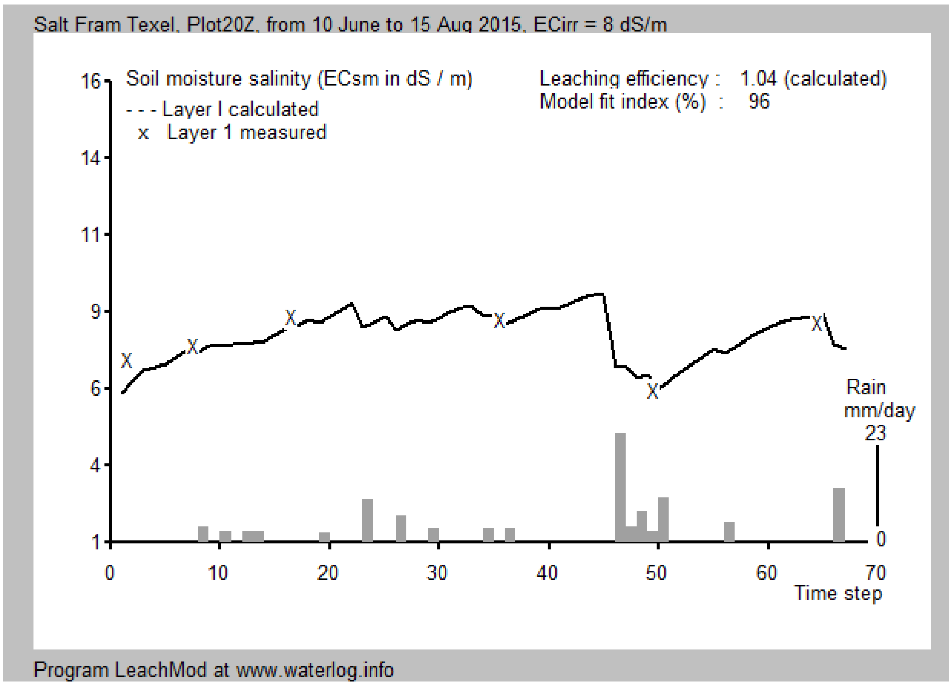


**Figure 7**. The leaching efficiency is optimized as LE=1.0. It concerns sandy soils.

### *3.2 Peru, Chacupe, 2018 [Ref. 11]*

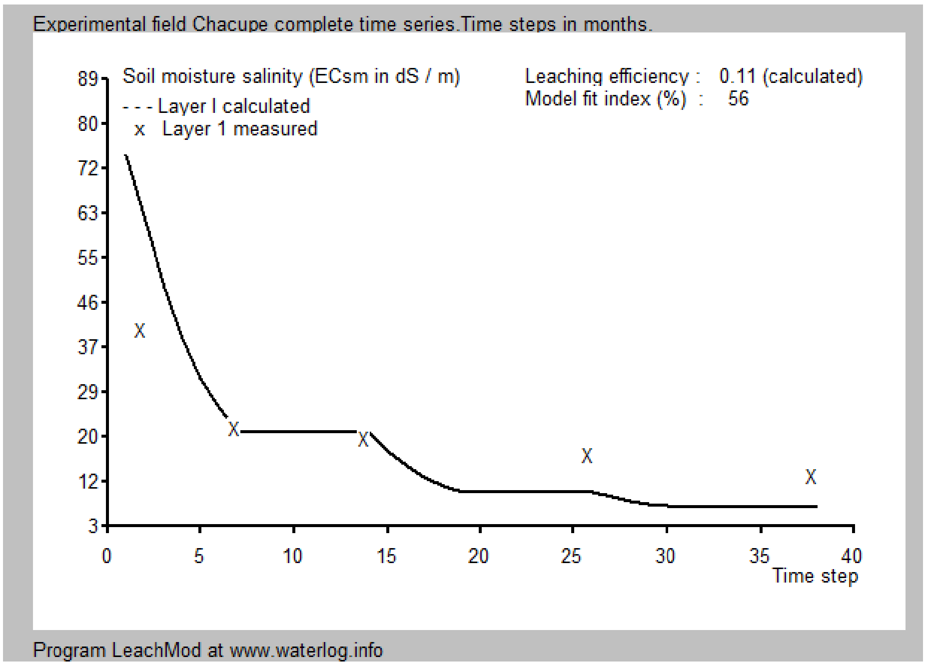


**Figure 8**. The leaching efficiency is optimized as LE=0.11.
It concerns vertisols (heavy clay soil of the swelling type).

## 4. Summary and conclusions

A summary of the leaching efficiencies is presented in the following table in which the type of soil is arranged from light (sandy) to heavy (clay)

| Type of soil | Country | Leaching efficiency |
|---|---|---|
| Sandy | Netherlands | 1.0 |
| Loamy | China | 1.0 |
| Silty Clay | Tunisia | 0.80 |
| Clay, Illitic | India | 0.70 |
| Clay, Illitic | Turkey | 0.70 |
| Clay, smectitic *) | Thailand | 0.20 |
| Clay, smectitic *) | Portugal | 0.15 |
| Clay, smectitic *) | Peru | 0.11 |

*) Also called vertisol, montmorillonitic, heavy clay, swelling clay, poorly structured

From the table it can be seen the the lighter soils have the highest leaching efficiency up to 1.0.

Well structured clay soils still have a relatively high leaching efficiency of about 0.7

Only poorly structured vertisols have a low leaching efficiency (0.20 or less).  When saline, they are difficult to reclaim.

## 5. References

[Ref. 1] SaltMod, free software for agro-hydro-soil-salinity modeling. Download from: https://www.waterlog.info/saltmod.htm

[Ref. 2] LeachMod, free software for hydro-soil-salinity modeling. Download from: https://www.waterlog.info/saltmod.htm

[Ref. 3] R.J. Oosterbaan and M. Abu Senna (1989). Using SALTMOD to Predict Drainage and Salinity in the Nile Delta. Annual Report 1989, International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. On line : https://www.waterlog.info/pdf/saltmod%20egypt.pdf or:
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[Ref. 10] A. de Vos et al. Crop salt tolerance under controlled field conditions in The Netherlands based on trials conducted by Salt Farm Texel. 2016
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[Ref. 11] R.J. Oosterbaan, 2019. Reclamation of a coastal saline vertisol by irrigated rice cropping, interpretation of the data with a salt leaching model. In: International Journal of Environmental Science. On line: https://www.iaras.org/iaras/filedownloads/ijes/2019/008-0006(2019).pdf or:
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