Premiação Fundação Bunge 2013
Recursos Hídricos e Agricultura

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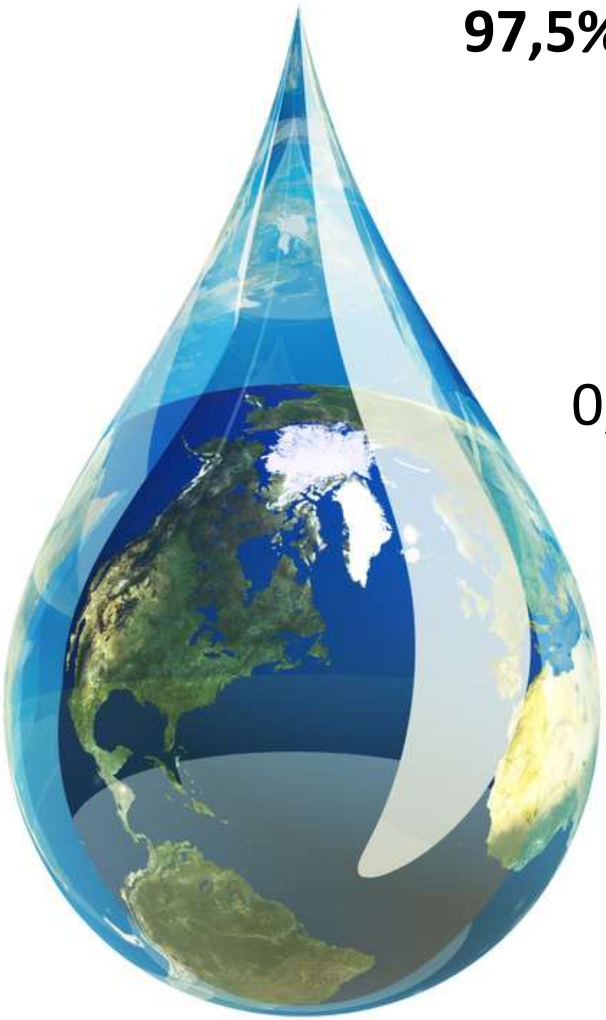
Física do Solo e Recursos Hídricos na Agricultura

São Paulo
2 de Outubro de 2013

Água no Planeta Terra (Stikker, 1998)



97,5% Salgada

2,5% Doce

69% Geleiras e neves eternas

29,8% Subterrânea

0,9% Reservatórios não prontamente disponíveis

0,3% Prontamente disponível

65% Agricultura

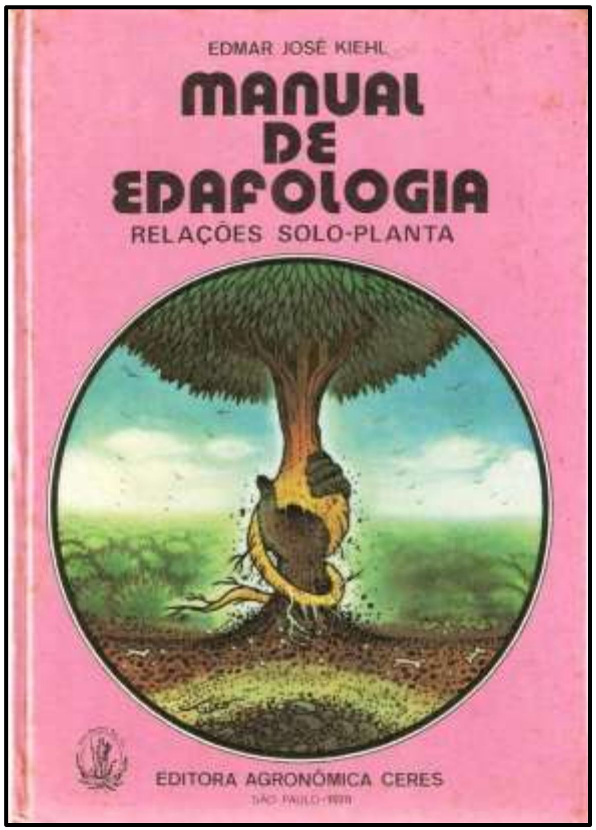
22% Indústria

7% Municípios

6% Perdidos

Soil Physics?

Kiehl, E. J. Manual de Edafologia. Editora Agronômica “Ceres” Ltda. São Paulo, 1979, pp. 262.

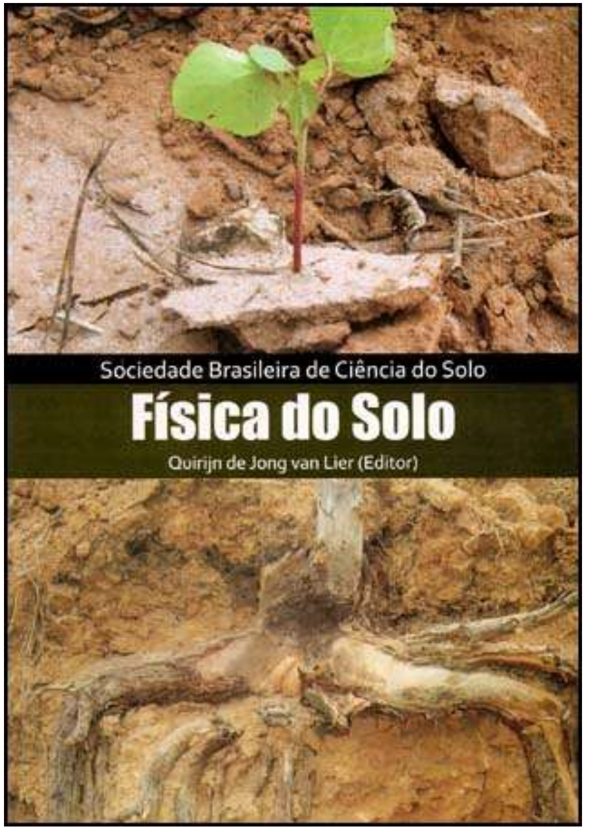


Sumário

1. Composição geral do solo
2. O perfil de solo
3. Amostragem do solo
4. Minerais de argila
5. **Densidade aparente do solo**
6. **Densidade real do solo**
7. **Porosidade**
8. Textura
9. Superfície específica
10. Estrutura
11. Consistência
12. Cor do solo
13. **Água do solo**
14. Capacidade de troca catiônica
15. Matéria orgânica
16. Reação do solo

Soil Physics?

De Jong van Lier, Q. (Ed.). Física do Solo. Sociedade Brasileira de Ciência do Solo. Viçosa, 2010, pp. 298.

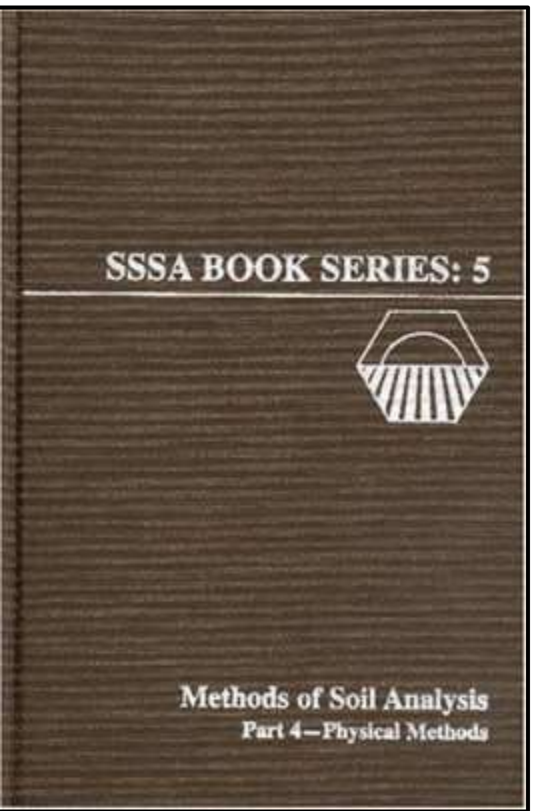


<u>Summary</u>

1. Soil characterization
2. Soil mechanics
3. Soil water
4. Gases in the soil
5. Thermal energy of the soil
6. Solute transport
7. Indicators of soil physical quality
8. Water availability to plants

Soil Physics?

Dane, J.H., Topp, G.C. (Ed.). Methods of Soil Analysis. Part 4 – Physical Methods. SSSA Book Series 5, Madison, 2002, pp. 866.

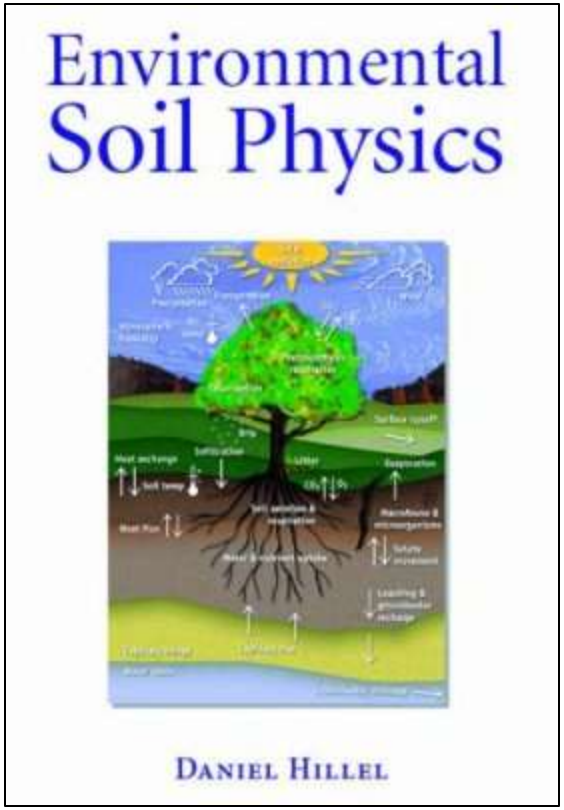


Summary

1. Sampling and statistics
2. The solid phase
   - Bulk density
   - Particle density
   - Porosity
   - Particle size analysis
   - Specific surface area
   - Agregate stability
   - Shear strength
   - Penetrometers
   - Atterberg limits
   - Soil compressibility
3. The soil solution
   - Water content
   - Water potential
   - Water retention and storage
   - Unsaturated water transmission parameters
   - Evaporation from natural surfaces
4. The soil gas phase
5. Soil heat
6. Miscible solute transport
7. Multi fluid flow
8. Soil erosion by water and tillage

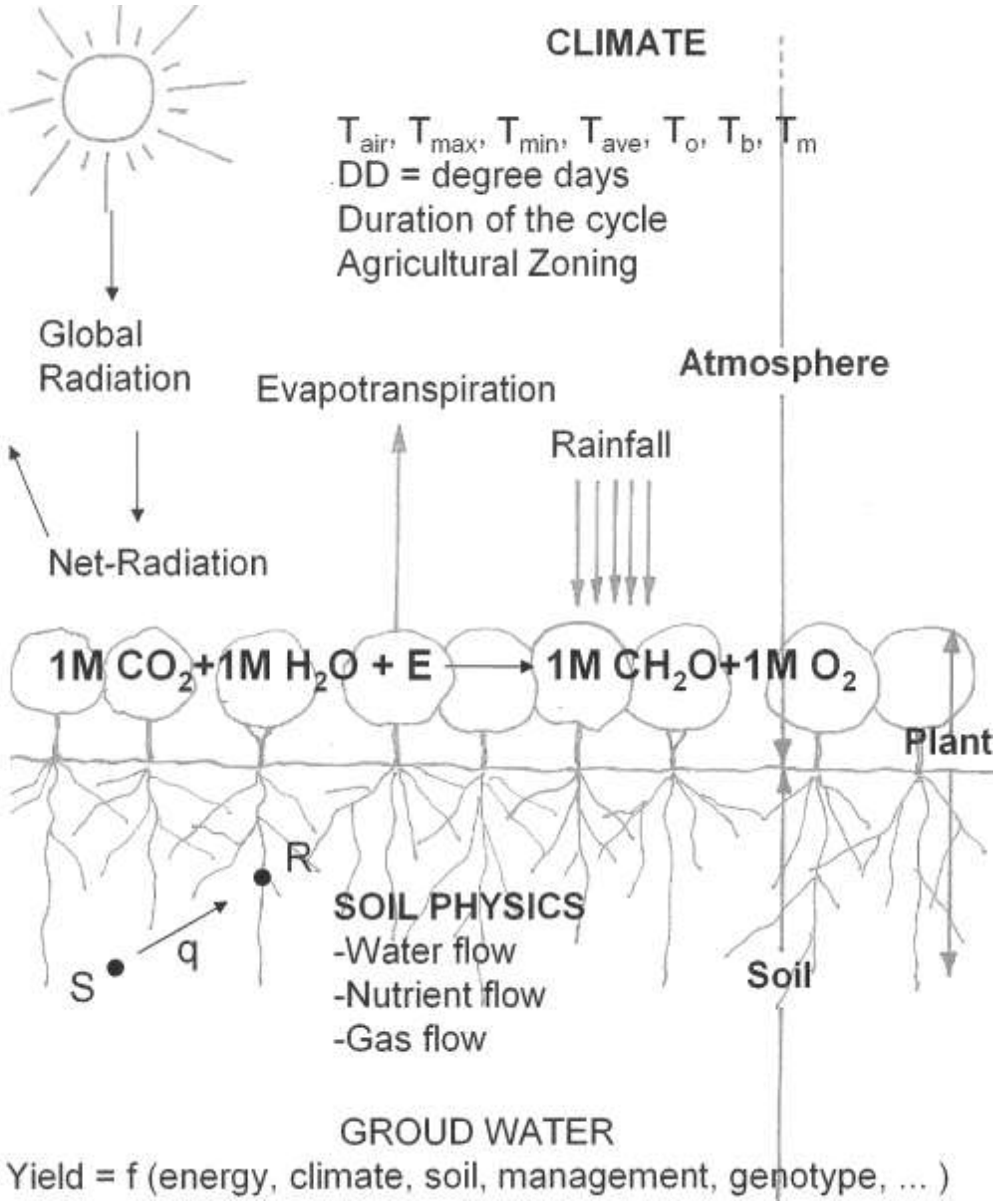
Soil Physics?

Hillel, D. Environmental Soil Physics. Academic Press, New York, 1998, pp. 771.



*"**Física do Solo** é o ramo da Ciência do Solo que trata das propriedades físicas do solo bem como de sua medida, previsão e controle dos processos físicos que nele ocorrem. Da mesma forma que a Física em geral trata das formas e interações entre massa e energia, a Física do Solo trata especificamente do estado e do movimento da matéria, e da transformação e fluxos de energia no solo."*

The Soil-Plant-Atmosphere System in Relation to Crop Production

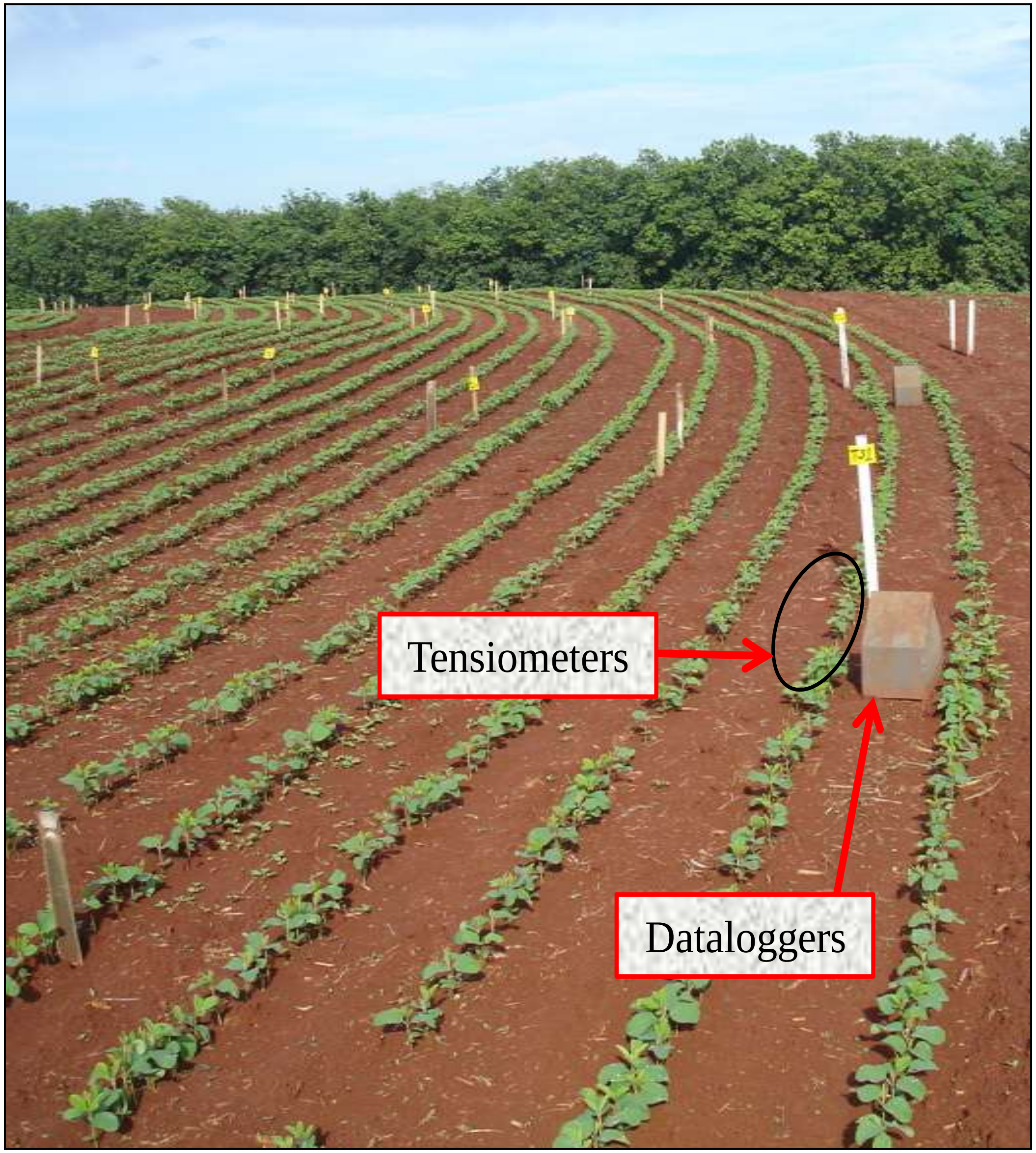


Soil Water Storage Changes Measured in a Soybean Crop in Piracicaba, Brazil

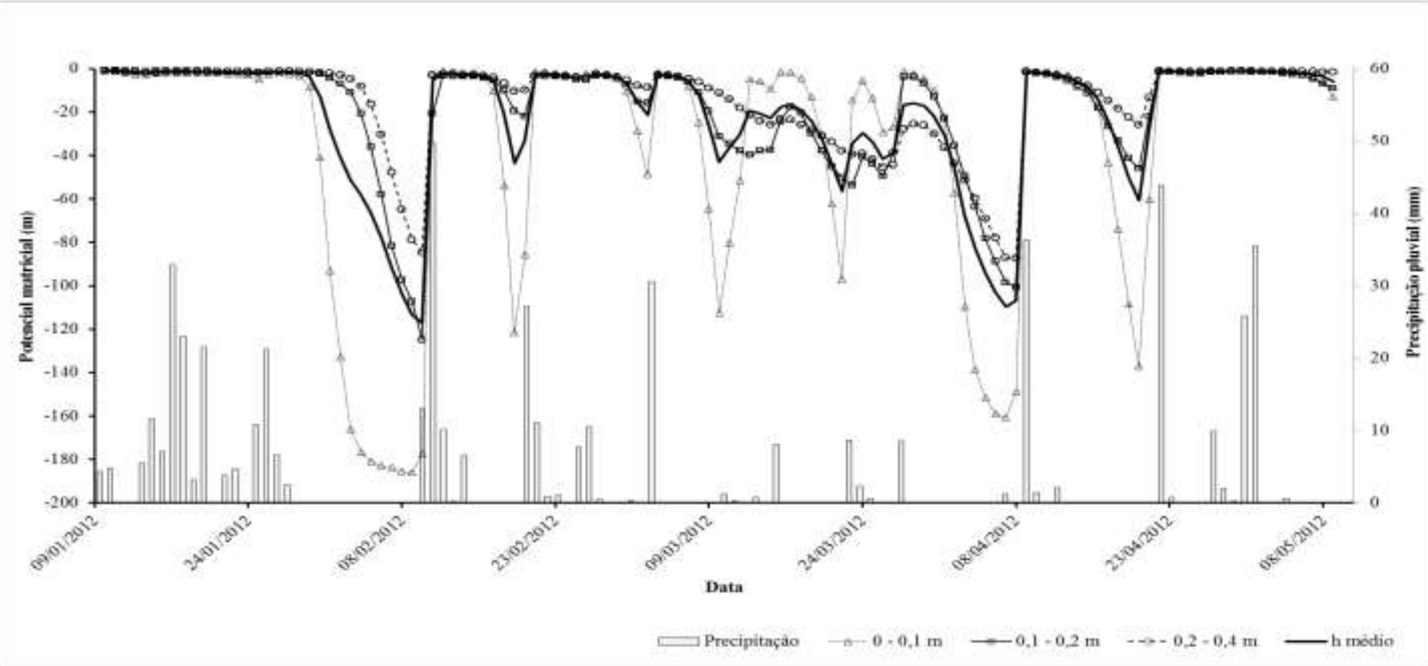
A soybean (*Glycine max* (L.) Merrill) crop was established on an Oxisol in Piracicaba, Brazil, and for management proposed the soil water storage S was monitored during the whole cycle. The novelty of the experiment was the continuous measurement of the soil water matric potential *h* (m) using ***polymer tensiometers***. Readings of *h* were then transformed into Θ through the use of a soil water retention curve, to further calculate water storages.

Polymer Tensiometer
Source: Durigon; de Jong Van Lier (2011)

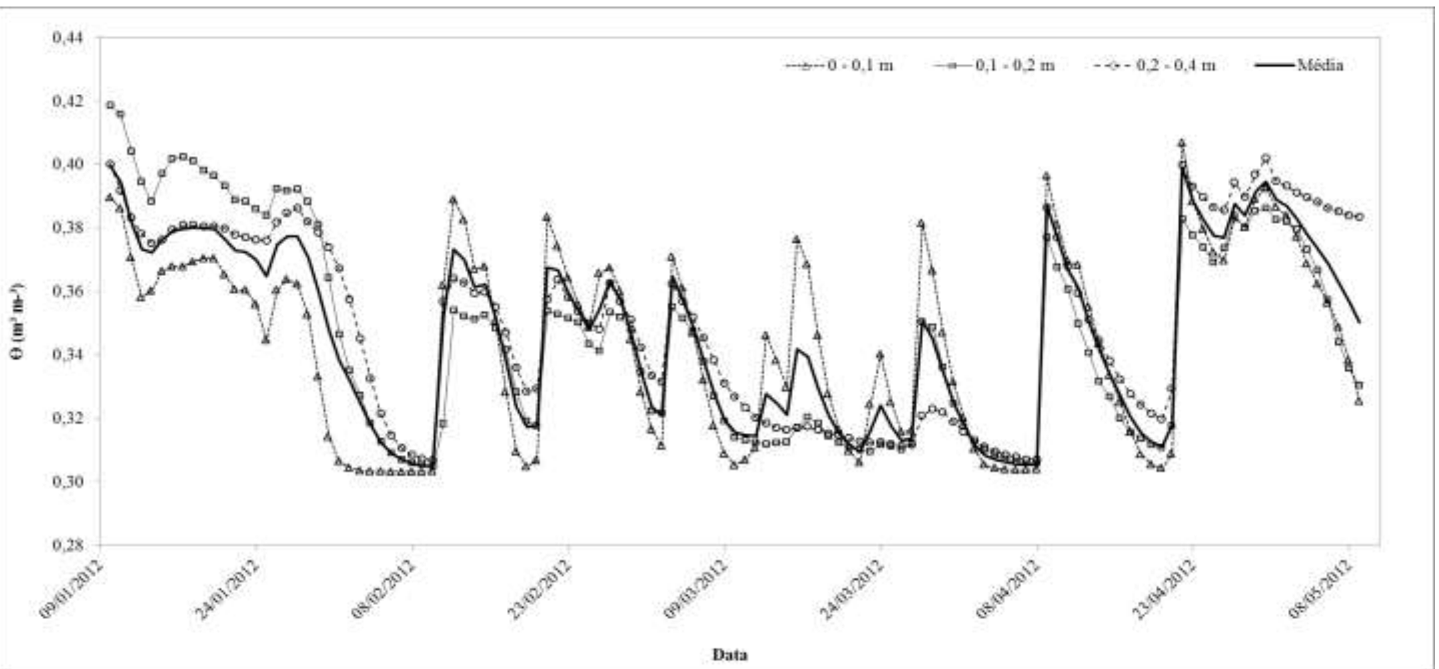
	Polymer Tensiometer	Water-filled Tensiometer
range	-18000 to 0 cm	-800 to 0 cm
resolution	20 cm	0.1 cm
response	seconds	minutes to hours
autologging	yes	some models
maintenance	no	yes
price	€ 1500 - € 3000	€ 20 - € 500



View of the soybean crop at initial growth stage. Piracicaba, 2012.



Matric potential *h* (m) measured by polymer tensiometers and rainfall (mm).



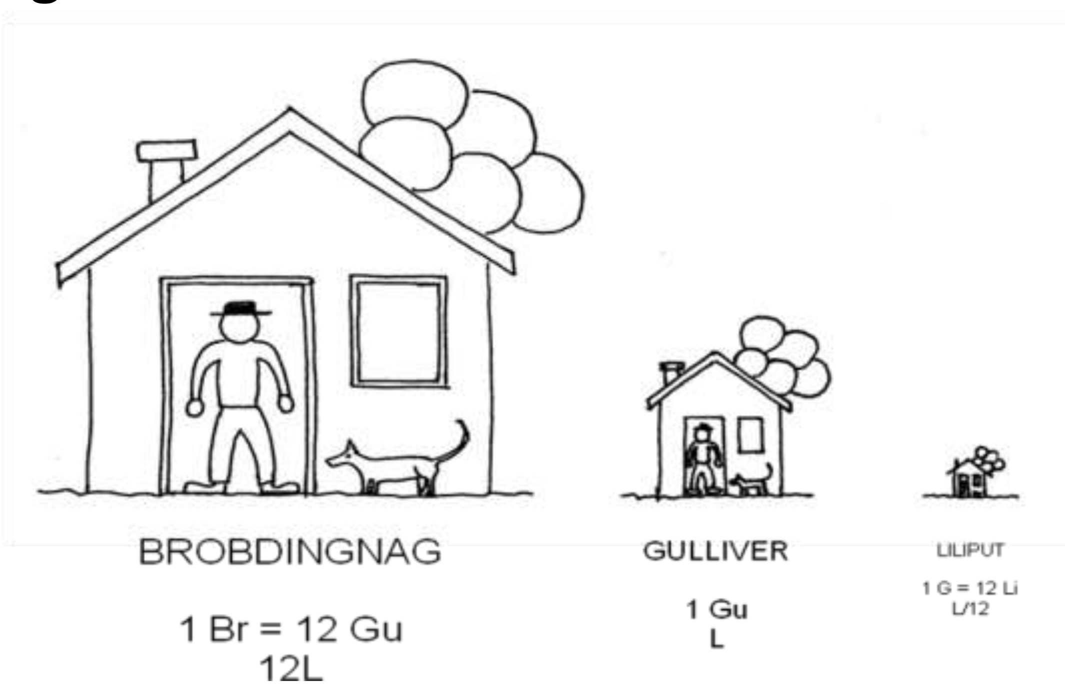
Soil water content θ ($m^3\ m^{-3}$) for the layers 0-0.1 m; 0.1-0.2 m and 0.2-0.4 m and their average.

Scaling and Soil Variability

Dean Swift, in “The Adventures of Gulliver” describes the imaginary voyages of **Lemuel Gulliver** to the kingdoms of **Liliput** and **Brobdingnag**. In these two places life was identical to that of normal persons, their geometric dimensions were, however, different.

In **Liliput**, man, houses, dogs, trees were **twelve times smaller** than in the country of Gulliver, and in **Brobdingnag**, everything was **twelve times taller**.

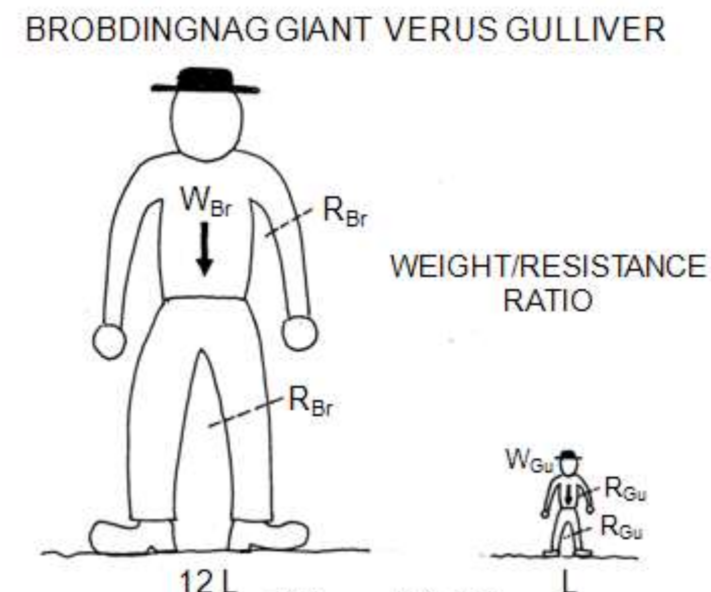
The man of **Liliput** was a geometric model of Gulliver in a scale **12:1**, and that of **Brobdingnag** a model in a scale of **1:12**.



Galileus treated this subject very clearly, using arguments that deny the possibility of the existence of giants of normal aspect. If we wanted to have a giant with the same leg/arm proportions of a normal human, we would have to use a stronger and harder material to make the bones, or we would have to admit a lower resistance in comparison to a man of normal stature.

On the other hand, if the size of the body would be diminished, the resistance would not diminish in the same proportion. The smaller the body, the greater its relative resistance.

In this way, a very small dog could, probably, carry other two or three small dogs of his size on his back; on the other hand, an elephant could not carry even another elephant of his own size!



$$1R_{Br} = 144R_{Gu}$$

$$1W_{Br} = 1728W_{Gu}$$

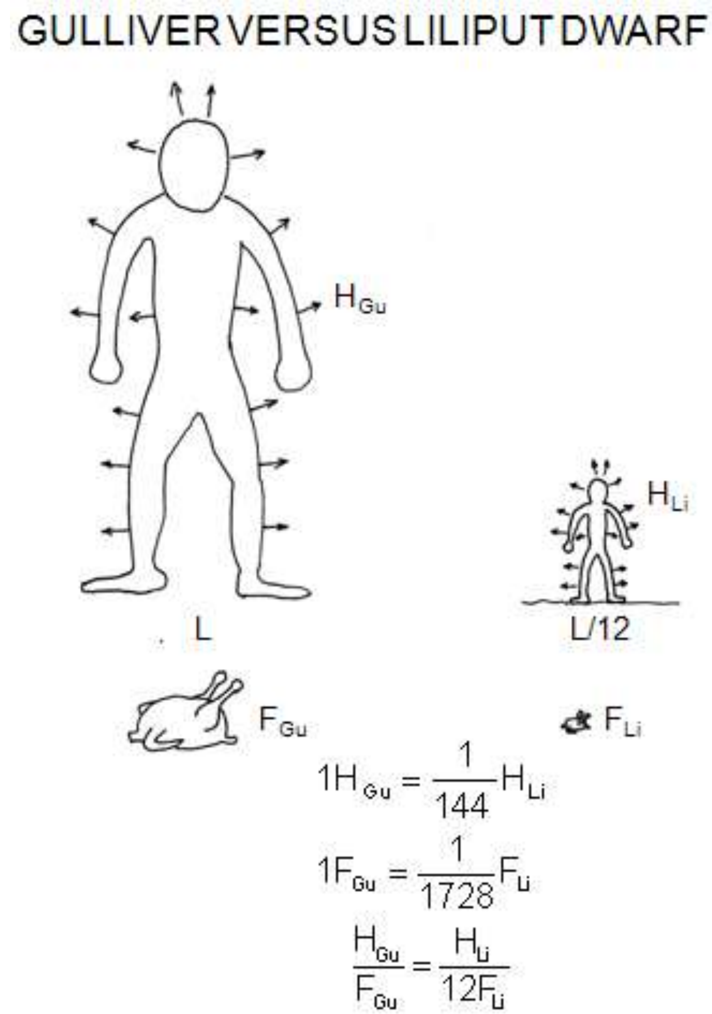
$$\frac{R_{Br}}{W_{Br}} = \frac{R_{Gu}}{12W_{G}}$$

Let´s analyze the problem of the **liliputans**. The heat that a body loses to the environment goes through the skin, being proportional to the area covered by the skin, that is, L^2, considering constant the body temperature and skin characteristics. This energy comes from the ingestion of food. Therefore, the minimum volume of food to be ingested would be proportional to L^3.

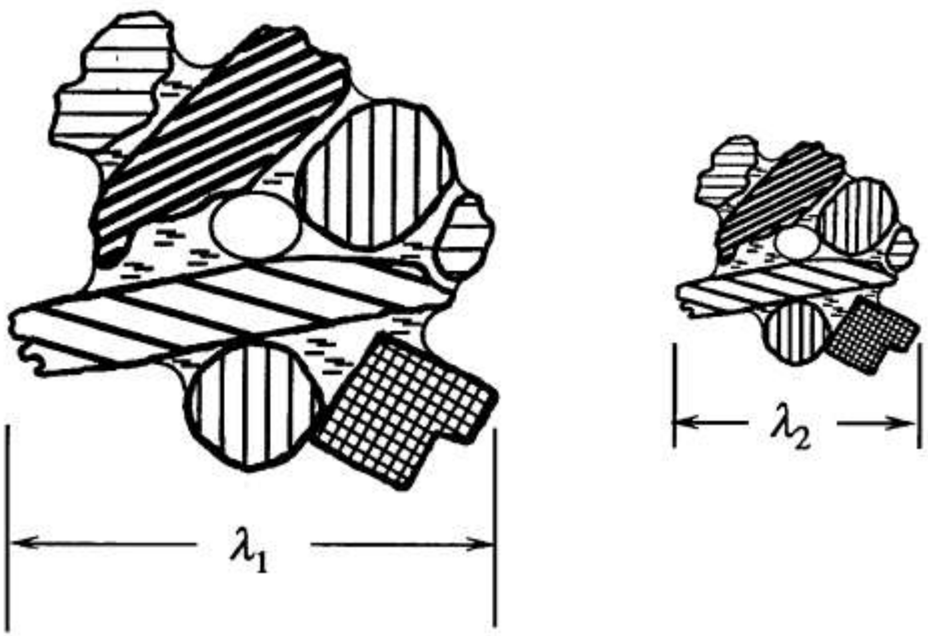
If Gulliver would be happy with a broiler, a bread and a fruit per day, a liliputan would get a $(1/12)^3$ smaller food volume.

But a broiler, a bread, a fruit when reduced to the scale of his world, would be proportional to a surface area $(1/12)^2$ smaller.

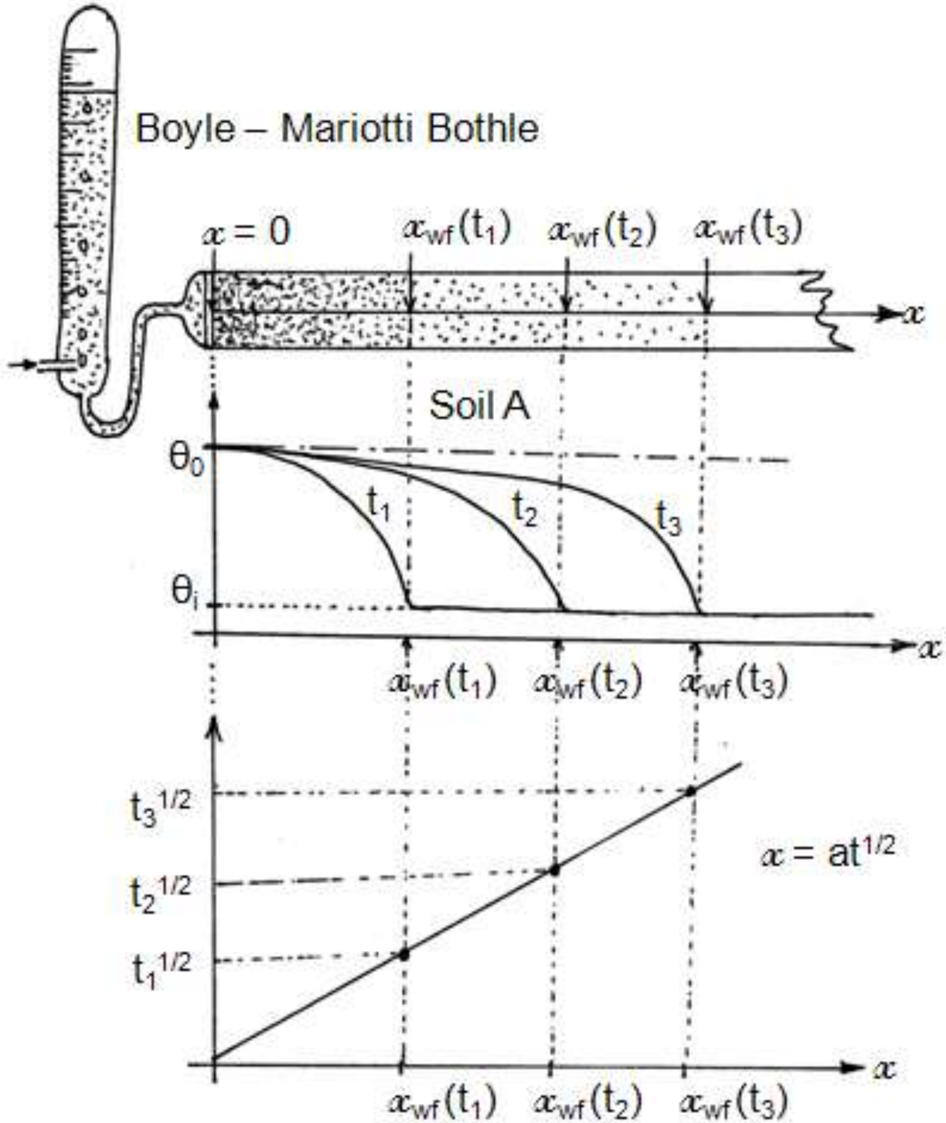
He would, therefore, need twelve broilers, twelve breads and twelve fruits to be as happy as Gulliver.



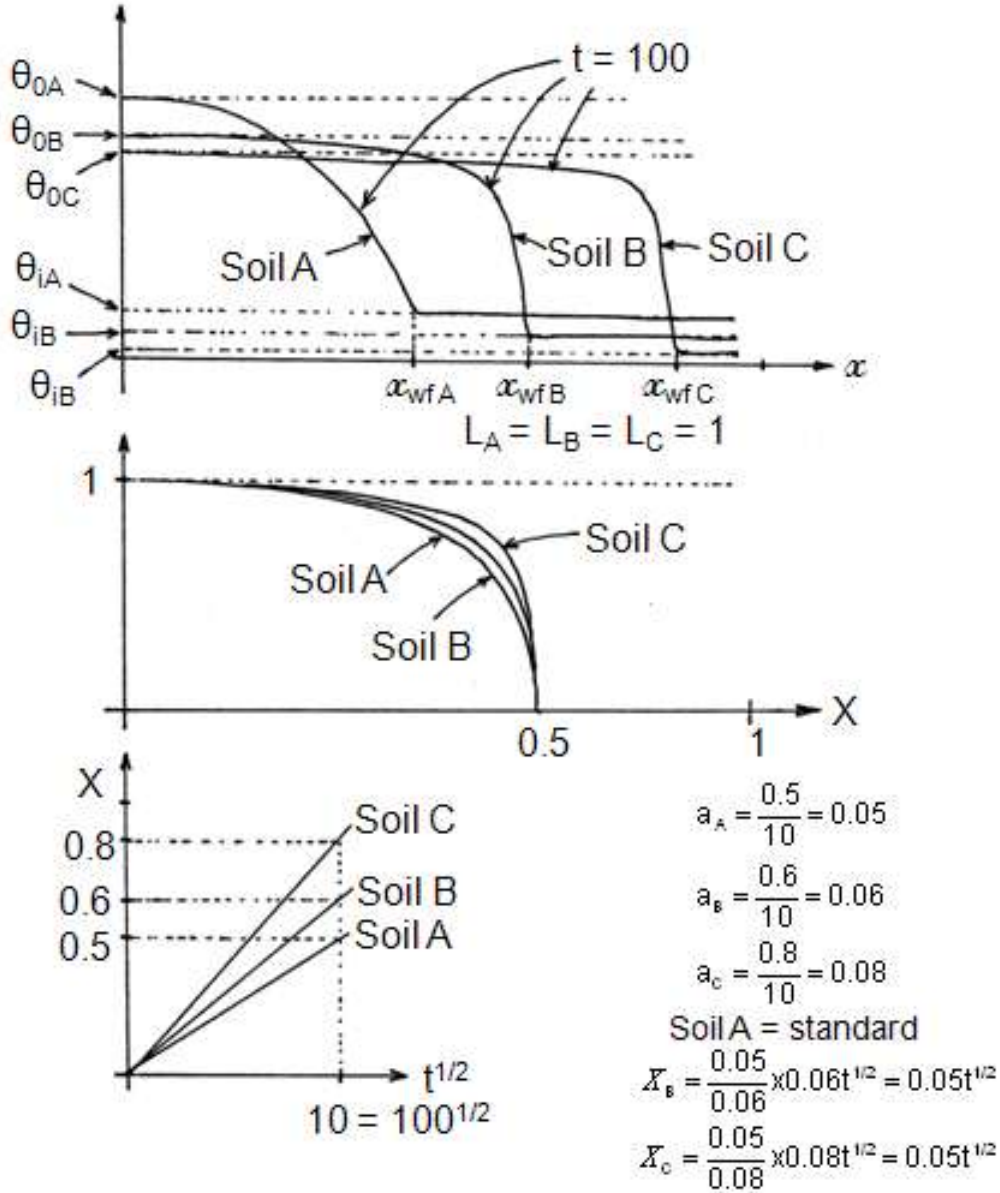
“Scaling”, frequently used in Soil Physics, can be based on similarity concepts and on dimensional analysis. Miller & Miller (1956) were among the first giving the needed emphasis on these important tools through the concept of similar media applied to “capillary flow” of fluids in porous media.



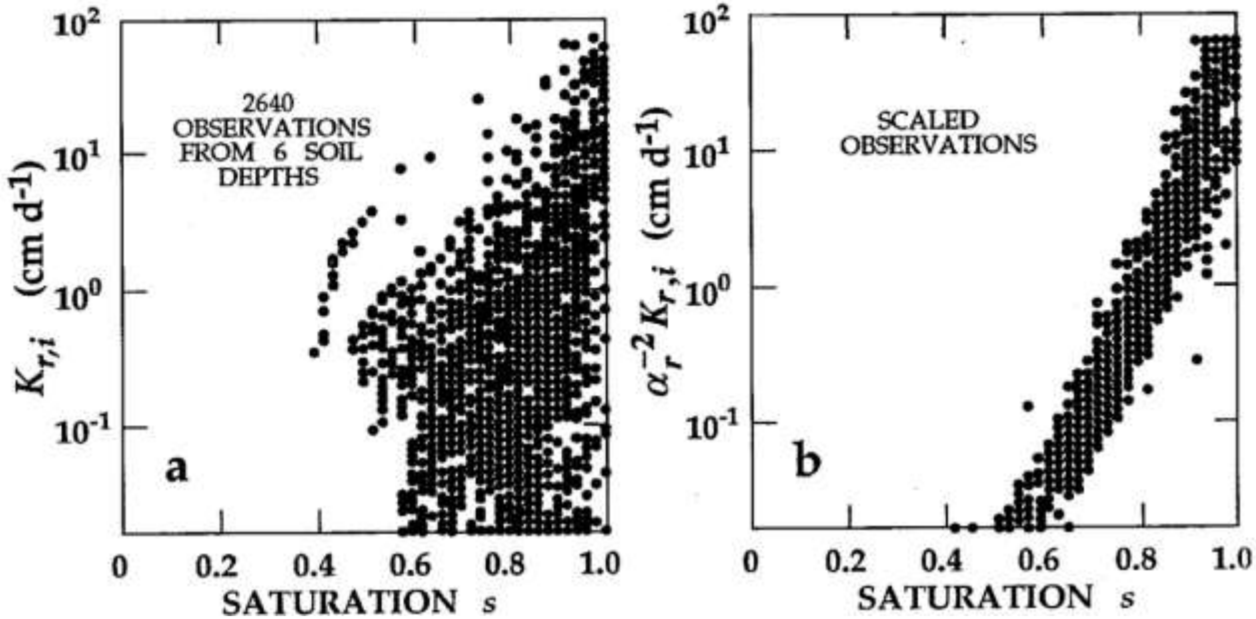
A classical example of similarity in porous media arrangement.



Experimental arrangement to study the horizontal infiltration using transparent acrylic columns for soil A and the advancement of wetting front as a function of the square root of time.



Horizontal infiltration profiles for soils A, B and C, and their scaled profiles.



Left, unscaled hydraulic conductivity data; right, well coalesced scaled data.
Source: Sposito (1998).

State-Space State-Time

Space → transect of observations X_i at positions x_i, spaced by a constant lag h
Time → time series of observations X_i at times t_i, "spaced" by a constant Δt

A water balance time series (Δt = 14 day) from t = 0 to t = 714 days (2 years) in a coffee plantation. The state-time analysis characterizes the state of a system (set of p unobservable variables) at a time t to its state at a time t-j, j = 1, 2, 3, ..., 52, in our study. For j =1, the state-space approach is described as follows (called state equation):

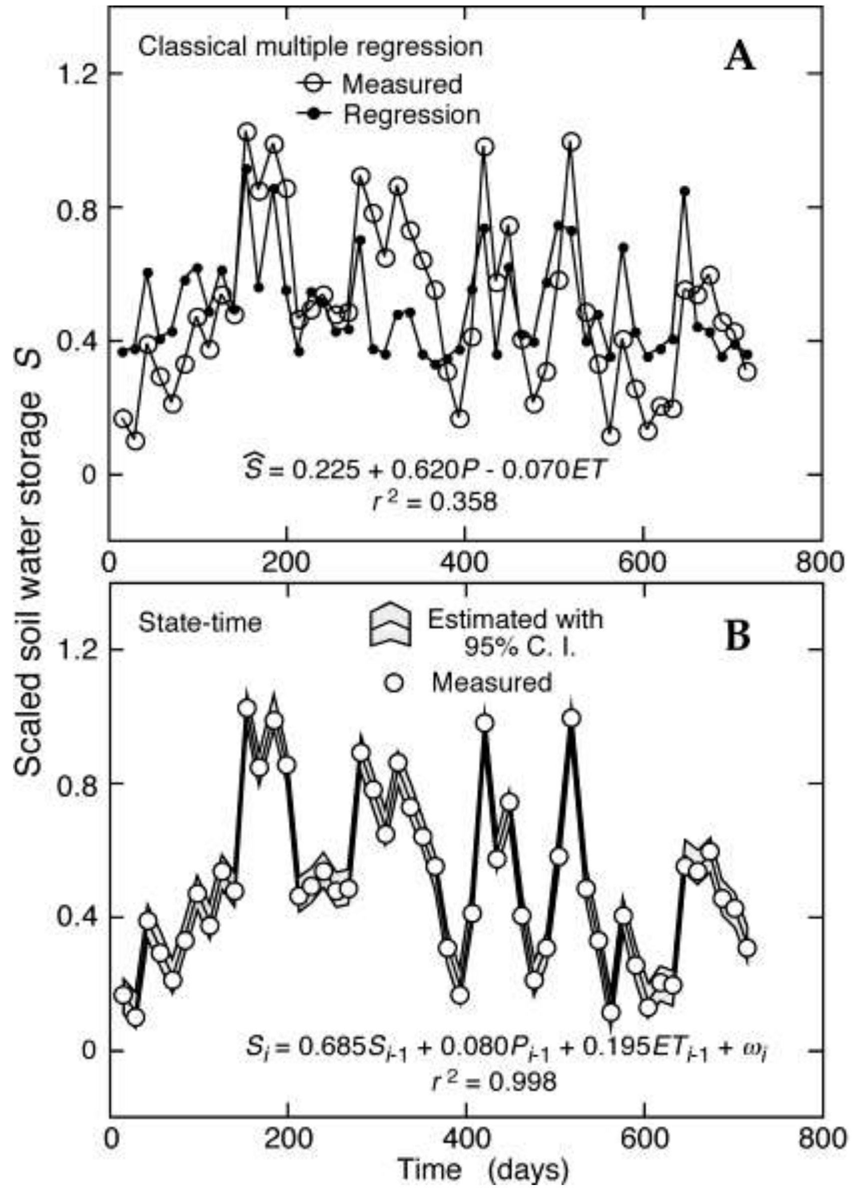
$$X_t = \phi X_{t-1} + \omega_{X_t}$$

X_t and X_{t-1} being the state vector (a set of p unobservable variables); ϕ a p x p matrix of state coefficients, which indicates the measure of the regression; and noises of the system for t = 1, 2, 3,..., j.

$$Y_t = AX_t + \nu_{Y_t}$$

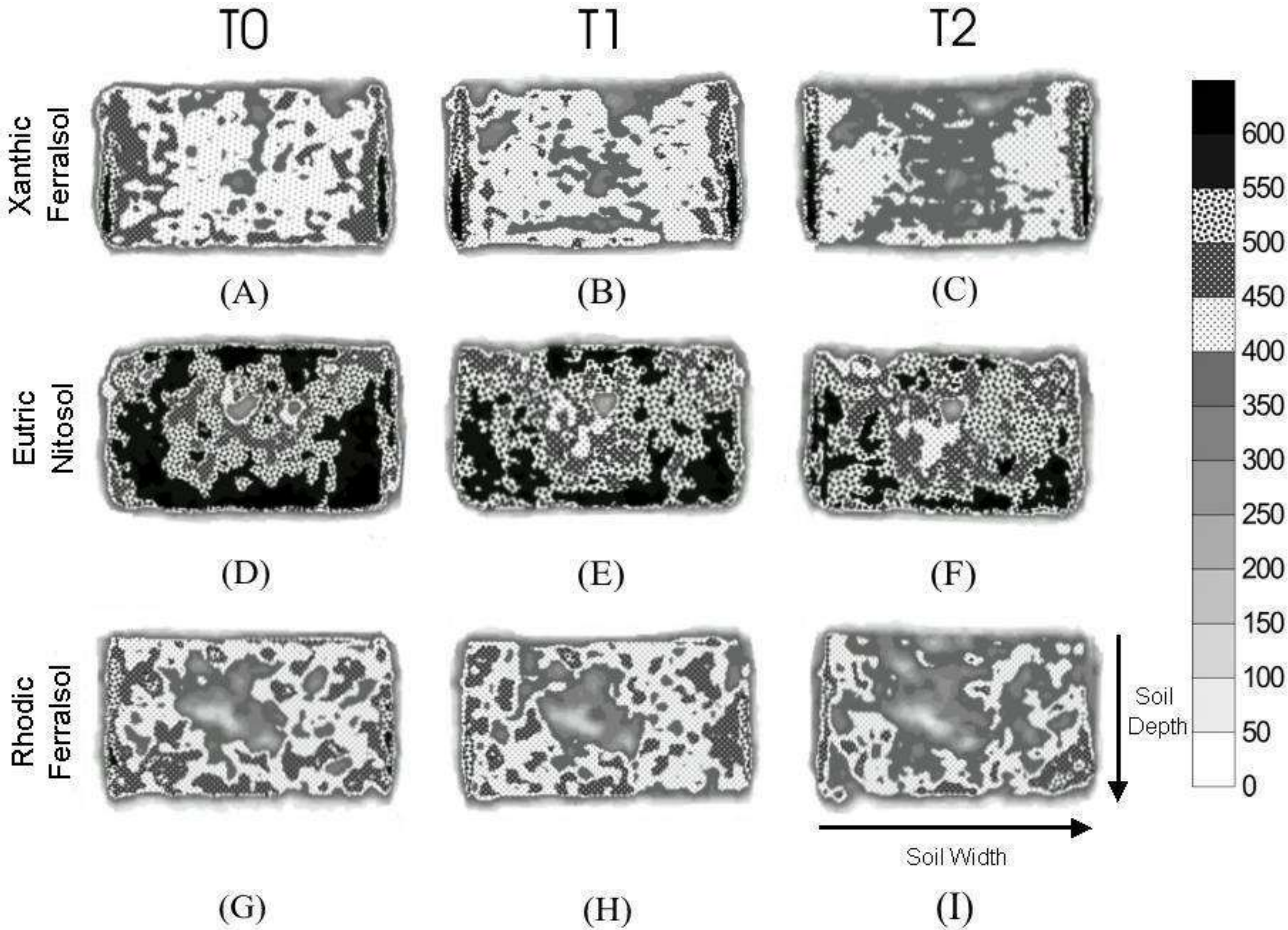
the observation vector Y_t being related to the state vector X_t by an observation matrix A (usually known as, for instance, an identity matrix, p x p) and an observation noise vector.

Timm et al. (2010)



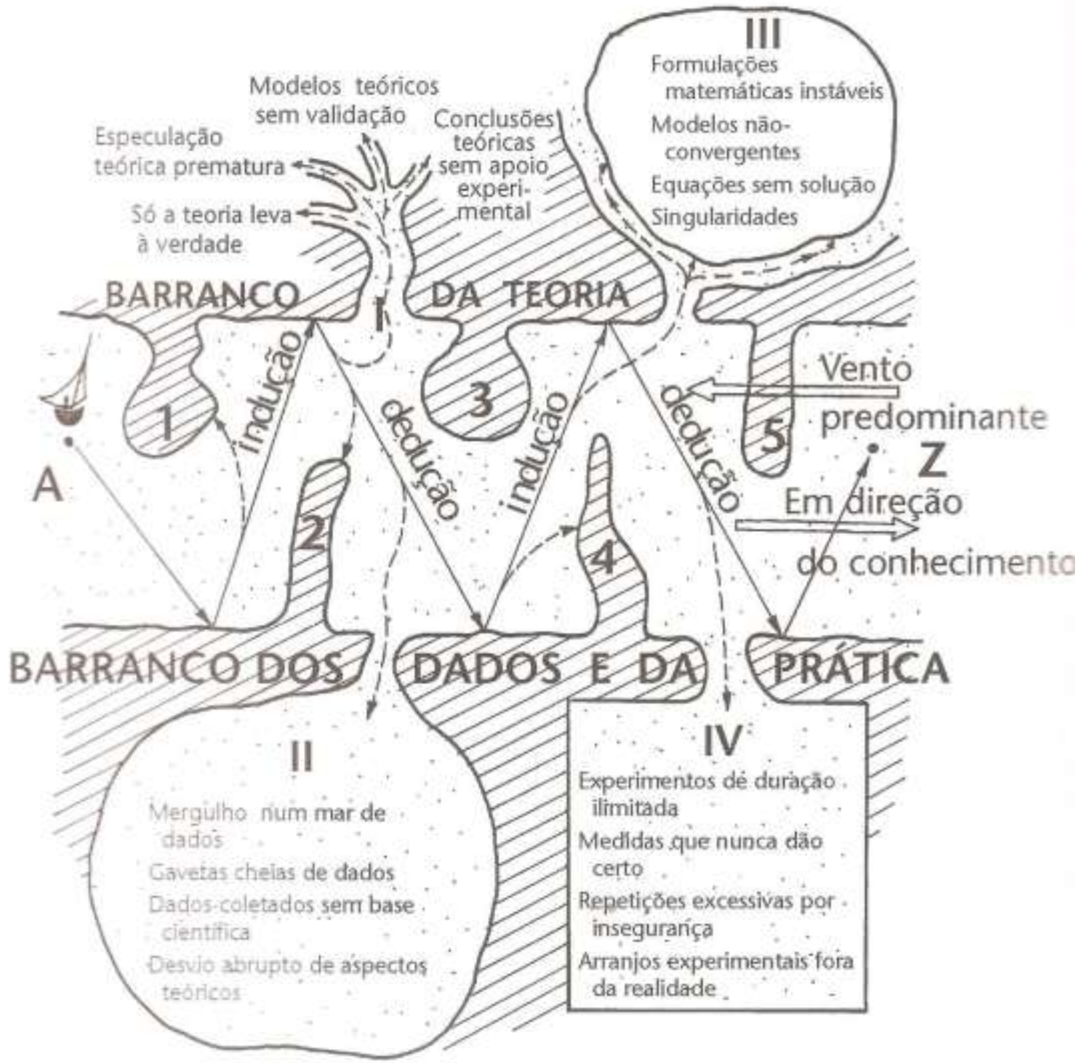
Estimates of soil water storage measured biweekly for 714 days using A. classical multiple regression and B. state-time analysis.

Soil Tomography



- *Kirkham Tree*

Fluxo do Desenvolvimento Científico (Hillel, 1987)



Desvios de Rota: I. Rio dos Diabos; II. Oceano Azul e Profundo; III. A Rocha; IV. Campo do Trabalho Forçado. Barreiras de Percurso: 1. Sabedorias Convencionais; 2. Administração Institucional; 3. Agências Financiadoras; 4. Políticas de Publicação e Revisão por Pares; 5. Comissões de Julgamento, Concursos, Doenças, Barreiras Familiares, Aposentadoria etc.

Obrigado!