PRESENTING, ANALYSING AND COMPARING TWO SOIL MOISTURE REGIME SIMULATION MODELS. APPLICATION TO MOISTURE REGIMES ESTIMATION OF CATALONIA SOILS.

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ABSTRACT

Two main models have been developped for soil moisture regime simulation. The first one was presented by F.Newhall in 1976; the second one was proposed by E.Jarauta in 1989, modifying important aspects of such model: soil profile modelling, infiltration process simulation, evapotranspiration process simulation and Soil Taxonomy criteria application. In this paper we present and analyse both models, and compare their application to soil moisture regime estimation of Catalonia soils. Results obtained are compared to field data. We also present a discussion of the most important aspects to improve in soil moisture regime modelling.

1. INTRODUCTION

Soil surveys rely very heavily on soil classification. The usefulness of a soil survey is a critical component in the way that soil science can be made available to users. However, soil surveys are only valuable if the information they contain can help to solve soil-related problems. Soil surveys often contain information that may appear to be of limited value; alternatively, users may not be able to understand some data included in a soil survey report. The amount of useful information in soil surveys should be increased; this can be done by increasing the total information but also by making more reliable predictions from the data. For the latter, there is a need for accurate prediction of the soil moisture regime, because it plays a key role in the potentials and limitations for land use.

The soil regimes are directely related to the agricultural use of the soil and to crop growth. From soil survey interpretations viewpoint, it is interesting to use soil regimes as classification criteria although soil morphology and genesis must be explained, in many cases, as the result of climates of the past. From a genetic approach to soil study, many criticisms have been made of the use of soil moisture and temperature regimes in soil classification. In general, the main problem with soil moisture regime criteria is getting to know them, because direct measurements of soil moisture are very scarce everywhere. In an attempt to solve this problem, Soil Taxonomy (S.S.S., 1975) proposed to use an accretion and depletion model tested with limited soil moisture data on the Great Plains. The model was developed by F.Newhall (1976), to estimate soil moisture regimes and in spite of the limited amount of information on climate usually available to soil surveyors. Jarauta (1989) pointed out differences between results obtained by Newhall's model application and field data; a new model was also presented whose basic features are exposed in this paper. Our aim in the following is to analyse and compare both models and make a discussion about some open aspects related to soil moisture regimes definition and estimation.

2. BASIC ELEMENTS OF THE F. NEWHALL'S MODEL. APPLICATION AND DISCUSSION.

We present now the basic features of the Newhall's model: it must be said that this model has been used in many countries, but only in very few cases results have been tested against field measurements.
(1) Soil profile modelling.
Homogeneous, isotropic and well-drained soil, represented by a (8,8) real matrix *S* with 200 mm of available water capacity. Rows of this matrix represent different soil horizons; rows 2 and 3 represent the soil moisture control section, *SMCS*. Each element of *S* matrix represents a part of soil wich can have from 0 to 3.125 mm of available water.
(2) Quantity of infiltration water in soil.
All monthly precipitation *MP*, divided in three parts: *MP*/4 in the day 1, *MP* /2 in the day 15 and *MP/4* in the day 16.
(3) Quantity of evapotranspiration water.
Monthly evapotranspiration, *ME*, is computed by the Thornthwaite's formula (1945).
(4) Infiltration model.
Following the rows of the soil matrix *S*. No different soil types are considered.
(5) Evapotranspiration model.
Following the diagonals of the soil matrix *S*, begining by the (1,8) element. No different soil types are considered.
(6) Soil temperature estimation.
Annual mean soil temperature is computed by adding 1.5°C to the annual mean air temperature; mean soil temperatures in winter and in summer are computed by the same way, and reducing the differences by 1/3. A linear interpolation model allows to determine the intervals in wich soil temperature is greater than 5°C and 8°C, respectively.
(7) Soil moisture regime estimation.
Applying the Soil Taxonomy criteria (1975).
(8) Climatic data information.
The model requires the following information: monthly precipitation, mean monthly temperature. It is important have long series of these data, for better estimation.
(9) Model running.
For each month, the state of the *SMCS* is estimated in three days: 1,15,16. In the days 1,15, this state is computed entering into the soil profile the difference $0.25 \cdot MP - 0.5 \cdot ME$ if it is positive or extracting its absolute value from soil if it is negative. In the day 15, the half monthly precipitation is entered into the soil. A linear interpolation model allows us the estimation of the *SMCS* state for the remining days. This process is done along every months of the year and for all years of series of climatic data. Finally, taking into account soil temperature parameters, soil moisture regime estimation is obtained by applying Soil Taxonomy criteria.

In Fig.1(A) is shown application of Newhall's model to soil moisture regime estimation of Catalonia soils (NE of Spain, East Long. from 0°10' to 3°15', North Lat from 40°30' to 42°50'), following Tavernier and Van Wambeke, 1976; representation is done including Catalonia inside a 20x21 matrix; each square represents a uniform part of land, from climate and soil viewpoint. This figure shows that, according to this model, four soil moisture regimes are found in Catalonia: *Udic* in the north, three areas with *Xeric* moisture regime in the north-east, east and south-east along the coast and *Aridic* moisture regime in a part of the west; the rest should correspond to *Ustic* moisture regime. More specifically, application of this model in semi-arid area in the west of Catalonia, produces a *Ustic* soil moisture regime; this estimation does neither agree to the area's crop potential nor to the results of six years of field measurements in that area (Jarauta, 1989).

Discussion of this model is made considering different aspects.

(a) Model of soil profile.

Only a soil profile model is considered by Newhall. Field data (Jarauta, 1989) show that different moisture regimes are founded in neighbouring soils, corresponding to soils with different available water capacity. Different soil matrix models must be considered.

(b) Quantity of infiltration water.

Runoff is not considered by Newhall. Field data (Jarauta, 1989) show that important differences in soil water contents are founded in neighbouring soils having different properties such slope, surface state and water retention capacity. In many areas precipitation has an intensity that implies existence of an important quantity of runoff water, with fewer infiltration than precipitation water. This effect must be considered in a model.

(c) Quantity of evapotranspiration water.

No elements of local climate are considered by Newhall. Field data (Jarauta, 1989) show that soil water in soil as a function of time is different for neighbouring soils with different soil climate characteristics. In soil water balance, elements of local climate must be considered; mainly: relative humidity, wind velocity and insolation.

(d) Infiltration and evapotranspiration models.

No different models in soil infiltration and evapotranspiration processes are considered by Newhall. These soil properties must be considered in a model, as it was shown by Jarauta, 1989.

(e) Soil moisture regime estimation.

Precision of a model must be enough for infiltration and evapotranspiration water simulation. Field data show that Newhall's model presents important differences with field data in soil taxonomy criteria evaluation and soil moisture control section state simulation. Figures 2(A) and 3(A) show these aspects according to field data of a semi-arid zone in north-east of Spain.

FIG.1 Soil moisture regimes estimation of Catalonia soils, by application of Newhall's model (A) and Jarauta's model (B).

(A)

		1	1																
		1	1	1															
		1	1	1	1	1	1	1								1	1	3	
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	2	2
		3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	
		3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	3	3	3
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		3	3	3	3	3	3	3	3	3	3	3	1	1	1	3	3		
		3	3	3	3	3	3	3	3	2	2	3	3	3	3	3			
		3	3	3	3	3	3	3	3	2	2	3	3	3	3				
	4	4	4	4	3	3	3	3	3	2	2	3	3	2					
	4	4	4	3	3	3	3	3	3	3	3	2	2						
	4	3	3	3	3	3	3	3	3	3	2	2							
	3	3	3	3	3	3	3	3	3	3									
	3	3	3	3	3	3	3	3											
	3	3	3	3	3	3	2												
	3	3	3	3	3														
	3	3	3	2															
3	3	3	2																
	3	3	2	2															
		2																	

Soil moisture regimes according Newhall's model
1 = Udic moisture regime
2 = Xeric moisture regime
3 = Ustic moisture regime
4 = Aridic moisture regime

(B)

		3	3																
		3	1	1															
		1	1	1	1	1	1	1								1	2	2	
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
		3	3	3	1	1	1	1	1	1	1	1	1	1	3	2	2	2	
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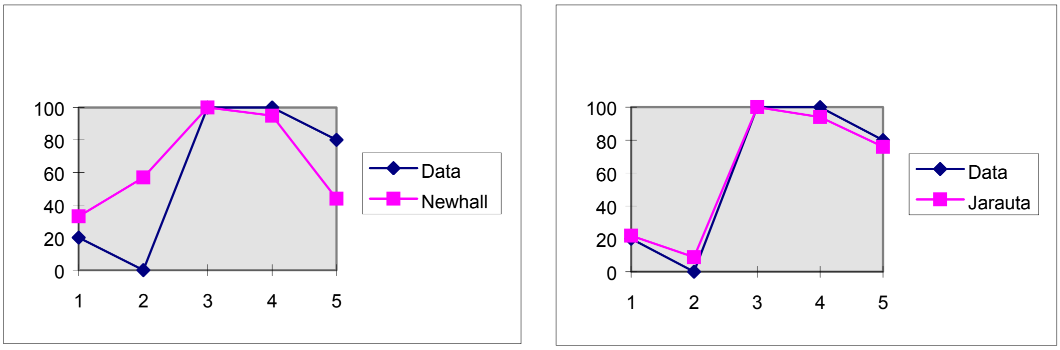
		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
		3	4	2	2	2	2	2	2	2	2	2	2	2	2				
	4	3	4	4	2	2	2	2	2	2	2	2	2	2					
	4	4	3	3	3	2	2	2	2	2	2	2	2						
	4	4	4	3	3	2	2	2	2	2	2	2							
	4	4	4	2	2	2	2	2	2	2									
	2	2	2	4	4	2	2	2											
	2	2	2	4	4	4	2												
	2	2	2	4	4														
	3	3	2	2															
3	3	3	2																
	3	2	2	2															
		2																	

Soil moisture regimes according Jarauta's model
1 = Udic moisture regime
2 = Xeric moisture regime
3 = Ustic moisture regime
4 = Aridic moisture regime

FIG. 2. Soil Taxonomy criteria percentages obtained by Newhall's and Jarauta's models application in a semi-arid zone in Catalonia.

(A) (B)



Crit. 1: Soil moisture control section is dry more than half of the period in wich soil temperature is greater than 5°C.
Crit. 2: Soil moisture control section is moist in some part more than 90 consecutive days in the period in wich soil temperature is greater than 8°C.
Crit. 3: Soil moisture control section is dry in some part more than 90 cumulative days.
Crit. 4: Soil moisture control section is dry in all parts along 45 days or more in the 4 months following the summer solstice.
Crit. 5: Soil moisture control section is moist in all parts along 45 days or more in the 4 months following the winter solstice.

3. BASIC ELEMENTS OF THE E.JARAUTA'S MODEL. APPLICATION AND DISCUSSION.

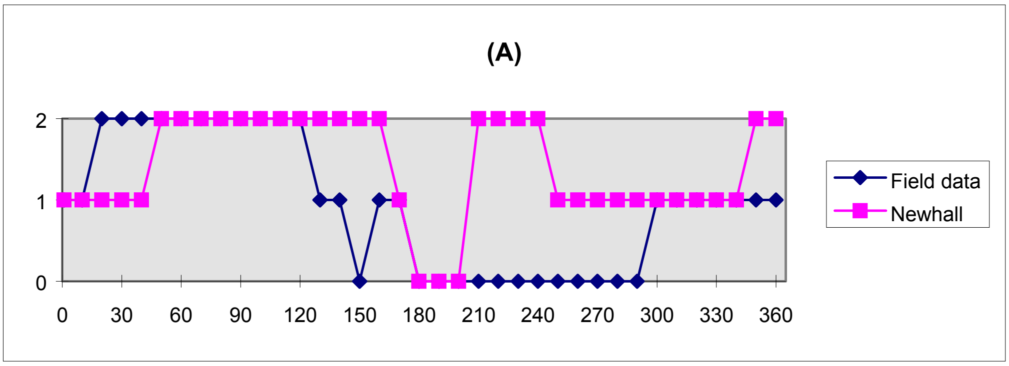
We present now the basic features of the Jarauta's model: it must be said that this model has been tested against field measurements along a six year period in ten benchmark points of Catalonia.
(1) Soil profile modelling.
Homogeneous, isotropic and well-drained soil, represented by a (r,8) real matrix *S,* where $2 \le r \le 8$, depending on soil profile type. Soils from 50 to 200 mm of available water capacity can be modelized. Rows of this matrix represent different soil horizons; rows 2 and 3 represent the soil moisture control section, *SMCS*. Each element of *S* matrix represents a part of soil wich can have from 0 to 3.125 mm of available water.
(2) Quantity of infiltration water in soil.
Dayly and monthly precipitation can be used. A coefficient of surface runoff is considered for effective precipitation consideration.
(3) Quantity of evapotranspiration water.
Evapotranspiration water is computed from Blaney-Cridle formula adapted by Jarauta (1989); it is formulated as a finite-difference equation which computes actual evapotranspiration in the t-day of the month as a function of soil water contents in the day before and potential evapotranspiration of the crop. Thus:

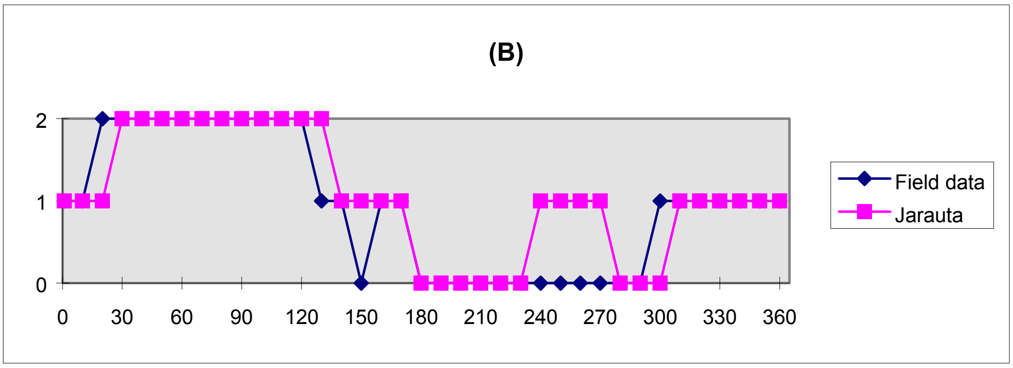
$$E(t) = \lambda.\exp(-\lambda).W(t-1)\,; \quad \lambda = \frac{E_c}{(1-q).W(S_r)}\,; \quad E_c = k_{c.}.E_0 \qquad [1]$$

where $W(t\text{-}1)$ is the soil water contents in the (t-1)-day, E_c is the crop potential evapotranspiration, E_0 is the reference crop potential evapotranspiration, k_c is the crop coefficient, q is the available water fraction and $W(S_r)$ is the available water capacity of soil matrix.

(4) Infiltration model.
Infiltration of water into soil is simulated by a reference sequence of filling, following the elements of soil matrix in each row (horizon), from row 1 to *r*. Different sequences can be defined for different soil types simulation.
(5) Evapotranspiration model.
Evapotranspiration process of water is simulated by an output reference sequence, following the diagonals of the soil matrix, begining in the (1,8) element; different sequences can be defined for different soil types and redistribution simulation.
(6) Soil temperature estimation.
Soil temperature is computed by a linear interpolation model from air average dayly or weekly temperature, depending on available data.
(7) Soil moisture regime estimation.
It is done by applying Soil Taxonomy criteria (1975), modifying some logical equations according to Jarauta, 1989..
(8) Climatic data information.
The model requires the following information: monthly or dayly precipitation, mean monthly or dayly temperature; local climate conditions: relative humidity, insolation and wind velocity; crop coefficients of zone's crops; soil types in the zone.
(9) Model running.
- Precipitation and temperature data are loaded;
- Monthly parameters are computed;

FIG. 3. Comparing evolution of soil moisture control section state with time:
(A) Newhall's model vs. field data. (B) Jarauta's model vs. field data





Soil moisture control section states:
0 = soil moisture control section dry in all parts,
1 = soil moisture control section moist in some part,
2 = soil moisture control section moist in all parts.

- In each day: precipitation is entered into soil, soil water in soil is computed, real evapotranspiration is computed, soil water evapotranspiration is extracted from soil, soil moisture control section state is computed;
- Days in which soil temperature is greater than 5°C are computed;
- Days in which soil temperature is greater than 8°C are computed;
- Soil taxonomy criteria are evaluated;
- Year soil moisture regime is determined;
- Soil moisture regime of series is estimated;
- Computer output is performed.

Fig. 1(B) shows application of this model to soil moisture regime estimation of soils in Catalonia, done with linear interpolation from 30 testing points where model is applied. In this case, *Ustic* moisture regime is found in very few places, as corresponds to its definition. *Xeric* moisture regime is found in major part of area, according to field data and crop observation. Fig. 2(B) shows the comparison of Soil Taxonomy criteria percentages of field data to the output of this model. Fig. 3(B) shows the comparison of soil moisture control section state from field data and estimated to this model in a semi-arid zone.

4. CONCLUSIONS.

1. Soil moisture regimes must be defined according to homogeneous conditions of soils, crops and climate conditions.
2. Logical equations for soil moisture regimes must be reconsidered.
3. Significative differences have been observed between field data and soil moisture regime estimation according to Newhall's model.
4. A better approach for soil moisture regime estimation has been performed according to field data in a semi-arid zone in the north-east of Spain.
5. Geostatistical methods must be applied in soil moisture regime estimation.

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