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Soil moisture distribution over time in a clay loam soil in Kosovo

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Abstract:

Studying the soil moisture distribution over time in a given soil profile is the object of the present study. The way the soil moisture gets distributed over soil profile depends particularly on the soil texture and on the soil suction gradients developed. However, it changes continuously over time for a given soil depth. The method of determining the soil moisture distribution over time is based on the measuring of soil moisture suctions developed and the soil moisture contents in various times, but in a given soil depth (internal drainage method) [7]. The soil depths under investigation are four, starting from 0cm to 60cm, which means that the most important depth of soil profile is considered. Such measurements are supposed to be done over soil profile when the soil water flow is already ceased, in the conditions of preventing the evaporation [1, 7, and 9]. Therefore, to determine the soil moisture distribution over time, a plot of 8m x 6m or 48 m^2 with no plants was set. The tensiometers and the electronic devices for soil moisture content measurements were installed in four soil depths. The plot was previously wetted and covered by a plastic to prevent the evaporation. In this way, it was made sure that the only possibility for water is to move internally, which gave us the opportunity to measure the changes in soil water content and in soil water suction over time. The final result showed that the dependency of soil water suction and soil moisture content over time is a power function (expressed as a semi logarithmic function, basically).

Keywords: soil moisture content • soil moisture suction • tensiometer • unsaturated soil • soil water flow • preventing evaporation • soil texture • internal drainage method

1. Introduction

The best method to determine the distribution of soil moisture over time throughout a given soil profile is the method of internal drainage, which seems to be the simplest and the most accurate method in field conditions. This method is also very well based physically. From the other side, which is very essential for better understanding the importance of this study, the measurement of the soil water distribution in soil in the field conditions is considered to be more accurate comparing with its measurement in the laboratory conditions. It seems unrealistic to measure the soil water distribution by making laboratory determinations on discrete and small samples removed from their natural continuum, particularly when such samples are fragmented or otherwise disturbed [7,4]. Hence, it is necessary to devise and test practical methods for measuring soil water distribution on a macro scale, in situ, as it is done in the present study. The basic result of the study is finding that both, soil water suction and soil water content dependency on time, have a semi logarithmic nature, represented by high coefficients of determination. Also, the study presented here has a specific importance to the application of the theories for predicting the actual processes in field [3, 6], (e.g., processes involved in irrigation, drainage, water conservation, ground water recharge and pollution, infiltration, runoff).

2. Materials and methods

2.1 The method and the devices

Among various methods of determining the soil moisture distribution over time, the internal drainage method seems to be the simplest and the most accurate in the field conditions, namely *in situ*. This method was suggested by Richards and Weeks and later by Hillel [7]. To fulfill the aim of this study, the location chosen was Komoran and the soil taken into consideration is classified as clay loam soil [5]. The period of study was 40 days. The period of time was chosen in summer, when the plant requirements for water are in the maximum values. Basically, the method requires frequent and simultaneous measurements of the soil water suction and of the soil moisture content throughout the soil profile. On this

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base, the respective distributions in time of both, soil suction and soil moisture, are determined. The devices used to measure the soil water suctions in the conditions of an unsaturated soil are tensiometers, while the devices used to measure the soil moisture content are electronic soil moisture measurement devices. To apply this method, an experimental research was undertaken. A plot of the dimensions of 8m x 6m or 48 m^2 with no plants was chosen and the devices were located in the middle of it in order the processes and the measurements not to be affected by the boundaries. Water is then ponded on the surface and the plot was irrigated long enough, so that the entire profile becomes as wet as it can be. The soil, after this, was covered by a sheet of plastic, so as to prevent any water flow across the surface. Before that, four tensiometers and four electronic soil moisture devices were installed within this plot in the four respective depths: 0-15cm, 15-30cm, 30-45cm and 45-60cm. So, one tensiometer and one electronic device for each soil depth. As the internal drainage was proceeding, the measurements of soil water potential (soil water suction) and of soil moisture content throughout the soil profile up to the depth of 60cm were done. The measurements were done over a period of 40 days, but 14 days were picked to make the measurements. The period between each day of measurements was kept constant of three days, which means that the entire period of the experiment was about 40 days.

2.2. Data analysis

The method of measuring of soil water suction and soil moisture content gave us the possibility to get known with the distribution of soil moisture over time throughout the soil profile. This way, the measurements of soil water suction and soil water moisture simultaneously made possible the determination of the functions $H_m=f_1(t)$ and $\theta=f_2(t)$, where H_m is soil water suction, θ is the soil moisture content and t is time. The regression analysis was applied to determine the above mentioned functions.

3. Results and discussions

3.1 The results on the change of soil water suction over time, -dθ/dt

The results taken on the soil water potentials (suctions) measured by tensiometers are presented in the table 1.

Table 1. Soil moisture suction, Hm, (the absolute value of soil water potential, ψ) for four chosen depths over time (days)

days	0-15 cm	15-30 cm	30-45 cm	45-60 cm
	Soil moisture suction, H_m cm	**Soil moisture suction, H_m cm**	**Soil moisture suction,H_m cm**	**Soil moisture suction, H_m cm**
1	20	15	15	10
4	96	76	64	60
7	144	124	104	96
10	196	164	148	136
13	236	204	180	168
16	280	228	212	200
19	308	252	244	228
22	328	272	268	252
25	344	288	284	268
28	354	300	288	268
31	364	312	293	272
34	378	315	301	275
37	389	327	309	295
40	395	340	320	310

The data of the table 1 were also presented graphically in order to get a better physical impression of the function. The color of the lines corresponds with the color in the table 1, which means that a given color in the graph represents the same soil depth as it shown by the same color in the table 1.

Having the data of soil suction over time, the regression analysis became possible. The results of the regression analysis done are given in table 2.

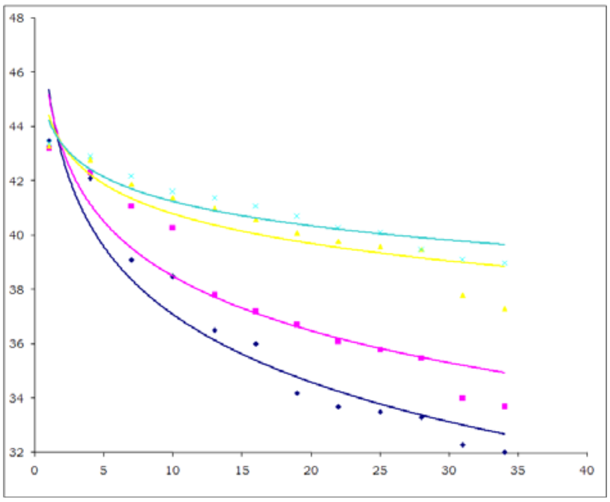

Figure 1. The dependency of soil moisture suction on time, in days, for the four soil depths in consideration.

The colors of the equations and soil depths correspond to the colors of the lines in the figure 1. The equation of slope (first derivate, $H_m'=dH_m/dt$) was also given for each depth.

The function $H_m=f(t)$ found, based on the strength of the determination coefficient, R^2, is of the semi logarithmic type. The graph shows clearly that the slope of each line decreases over time, which means that the soil water suction difference becomes lower over time. Even more important to notice is that the closer to the surface is the soil layer the greater the differences of the soil suction in a given day are. That is why the curve representing the depth 0-15cm is above all other curves and the curve representing the deepest layer is under the rest of other curves. It can be explained with the fact that the water close to the covered surface moves quicker downwardly lowering the water content and consequently, increasing the soil water suction.

Table 2 The regression equations found, which reflect the function of soil suction over time (days) for each depth taken into consideration.

Depth	**Equations $H_m=f(t)$**	**R^2**	**$H_m'=dH_m/dt$**
0-15 cm	$H_m = 113.11 \ln t - 31.8$	0.96	$H_m' = 113.11 \cdot 1/t$
15-30cm	$H_m = 92.23 \ln t - 0.15$	0.96	$H_m' = 92.23 \cdot 1/t$
30-45 cm	$H_m = 93.64 \ln t - 36.53$	0.94	$H_m' = 93.64 \cdot 1/t$
45-60 cm	$H_m = 89.25 \ln t - 38.38$	0.94	$H_m' = 89.25 \cdot 1/t$

3.2 The results on the change of soil water content over time, $-d\theta/dt$

The results of measurements done on the soil water content over time by using the digital devices are presented in the table 3:

The data of the Table 3 are used to build the figure 2. The color of the numbers in the table 3 corresponds to the color of the lines in the graph.

Table 3 The change of soil water content over time in various depths.

Days	**0-15cm**	**15-30cm**	**30-45cm**	**45-60cm**
1	**43.5**	**43.2**	**43.3**	**43.4**
4	**42.1**	**42.3**	**42.8**	**42.9**
7	**39.1**	**41.1**	**41.9**	**42.2**
10	**38.5**	**40.3**	**41.4**	**41.6**
13	**36.5**	**37.8**	**41**	**41.4**
16	**36**	**36.7**	**40.6**	**41.1**
19	**34.2**	**36.2**	**40.1**	**40.7**
22	**33.7**	**36**	**39.8**	**40.3**
25	**33.5**	**35.8**	**39.6**	**40.1**
28	**33.3**	**35.5**	**39**	**39.5**
31	**33**	**34.7**	**38.1**	**39.1**
34	**32.8**	**33.9**	**37.5**	**39**
37	**32.7**	**33.5**	**37**	**39**
40	**32.5**	**33.2**	**36.8**	**38.8**

The color is specific for the depth of soil under consideration. The data of soil water content are given in percentage, on volume basis.

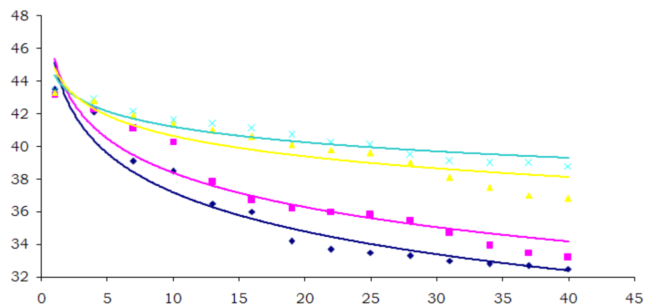

Figure 2 Soil moisture content as a function of time, in four given soil depths

The regression analysis showed that the best shape that fits the relationship between soil water content and time, so the function $\theta=f(t)$, is the semi logarithmic one, which was chosen because the highest coefficient of determination was provided. The results are given in the table 4.

The color is specific for the depth of soil under consideration and corresponds with that one of the figure 4. The data of soil water content are given in percentage, on volume basis. The first derivative .

Table 4 The regression equations belonging the lines in the figure 4.

Depths cm	Equations θ = f(t)	R^2	θ'=-dθ/dt
0-15	**θ=-3.46lnt + 45.2**	**R^2=0.94**	**3.46/t**
15-30	**θ=-3.04lnt + 45.4**	**R^2=0.9**	**3.04/t**
30-45	**θ=-1.82lnt + 44.8**	**R^2=0.81**	**1.82/t**
45-60	**θ=-1.39lnt + 44.4**	**R^2=0.89**	**1.39/t**

equations or the equation of the slope of each line is also given (θ'=-dθ/dt).

Clearly, the situation is inverse comparing with the H_m-time curves. The curve representing the upper layer is under of all other curves, which means that it represents the lowest values of the soil water contents. It gets explained by the fact that the water in the upper layer moves faster downwardly lowering the water content in the top layer faster than any other layer. The deepest layer looses the water very slowly even because of the fact that the water lost in the above layers flows gradually to the next deeper layer or, finally, to the deepest layer under consideration. From another side, the curve representing the upper layer is characterized by the highest slope, which also is explained by the fact that in this layer the water loss is faster than any other one.

Using the equations of the first derivates, or the equation of the slope of the curves per each depth under consideration, the change of soil water content per each day, in every depth, was calculated. The results are given in the table 5.

Table 5 The slope of curves θ=f(days) in various points or the negative of the first derivate -dθ/dt (the change of soil moisture content/day, for each soil depth under consideration)

days	-dθ/dt			
	0-15cm	**15-30cm**	**30-45cm**	**45-60cm**
1	3.46	3.04	1.82	1.39
4	0.86	0.76	0.45	0.35
7	0.49	0.43	0.26	0.2
10	0.346	0.304	0.182	0.139
13	0.266	0.234	0.14	0.107
16	0.216	0.19	0.114	0.087
19	0.182	0.16	0.096	0.073
22	0.157	0.138	0.083	0.063
25	0.138	0.122	0.073	0.056
28	0.124	0.109	0.065	0.05
31	0.112	0.098	0.059	0.045
34	0.102	0.089	0.053	0.041
37	0.093	0.082	0.049	0.038
40	0.086	0.076	0.045	0.035

4. Conclusions

1. The dependency of soil water suction on time, when the evaporation is prevented, is represented by a semi logarithmic curve, which demonstrates that the soil suction values get increased as the time proceeds.
2. The dependency of soil moisture content on time, when the evaporation is prevented, is represented by a semi logarithmic curve, which demonstrates that the soil moisture content values get decreased as the time proceeds.
3. The curve H_m=f(t) representing the upper layer is characterized by the highest slope, which also is explained by the fact that in this layer the water loss is faster than any other one. The curve is situated above all other curves, which means that in the upper layer the greatest values of the soil water suction can be found.
4. The curve θ=f(t) representing the upper layer is characterized by the highest slope, which also is explained by the fact that in this layer the water loss is faster than any other one. The curve is situated under all other curves, which means that in the upper layer the lowest values of the soil moisture content can be found.
5. Both, the $H_m=f_1(t)$ and $θ=f_2(t)$, functions determined in this study can be used to predict the change of soil moisture and soil water suctions over time in the clay loam soil under consideration, [2, 8, 10].

5. References

1. Baver L. D: **"Soil physics",** New York, 1965, 10-29; 124-195.
2. Buckingham E: **"Studies on the movement of soil moisture"**, Bureau of Soils, USDA, Bull. No. 38Washington, DC, 1907, 46.
3. Gjongecaj B: **"Soil – plant relationships"**, university textbook, Agricultural University of Tirana, Tirana, Albania, 2011, 76-88, 96-102.
4. Gjongecaj B: **"Soil Physics"**, university textbook, Agricultural University of Tirana, Tirana, Albania, 2009, 83-95.

5. Gjongecaj B. Nishori A: "**Soil-water relationships**", Prishtina, Kosovo, 2009, 71-81.

6. Hillel D: **"Soil and water "**, from Physiological Ecology, edited by T. T. Kozlowski, Wisconsin, 1971, 108-110, 115-117.

7. Hillel D: "**Introduction to Soil Physics"**, Academic Press, USA, 1982, 107-132.

8. Hillel D: **"Introduction to Environmental Soil Physics "**, Academic Press, Hardbound, USA, 2003, 449.

9. Kirkham D: **"Advanced Soil Physics"**, New York, revised edition. 1984, 534.

10. William A, Jury, Wilford R, Gardner, Walter H, Gardner: **"Soil Physics"**, John Wiley and sons, New York 1991, 87-109.