STUDIA UNIVERSITATIS "VASILE GOLDIŞ" ARAD
SERIA ŞTIINŢE INGINEREŞTI ŞI AGRO-TURISM

November 2014 Vol.9 Iss.2 pp.7-13
http://studia.facultateadeinginerie.ro
"Vasile Goldiş" University Press

"Vasile Goldiş" Western University of Arad

VARIATION INFILTRATION AND DISTRIBUTION OF WATER SPRINKLED IN IARAC FORESTRY NURSERY

Nicuşor Boja[1*]
Florinel Boja[1]
Alin Teuşdea[2]
Maria Isopescu[3]
Constantin Banu[4]

[1] **Department of Forestry and Agrotourism, Faculty of Natural Sciences, Engineering and Informatics**, "Vasile Goldiş" Western University of Arad, Liviu Rebreanu 86, 310426, Arad, Romania
[2] **Faculty of Environmental Protection, University of Oradea**, Gen. Magheru 26, 410396, Oradea, Romania
[3] **Technological High School „Iuliu Moldovan" Arad,** Calea Timişorii,nr.29-31, Arad, Romania
[4] **Faculty of Horticulture and Sylviculture**, Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timişoara, Calea Aradului nr.119, 300645, Timisoara, Romania

Abstract

The purpose of this research is to emphasize the variation of the water infiltration after sprinkler irrigation correlated with the uniformity coefficient (Cristiansen) and the soil granulometry of the experimental field. This correlation is important, because the soil moisture values measured at a certain time frame after irrigation consists in an important parameter for the optimal amount of water supplied per unit area assessments.
The research was carried out in the Iarac forestry nursery in the Iuliu Moldovan Forest District during 2012-2014, on an alluvial soil (the vertical-gleyed subtype). The placement of the sample markets was carried out according to the "divided parcels method" in two repetitions, and the surface of a parcel was 450 m^2. At the time when the measurements were taken, the meteorological conditions were: temperature of 23^o C; wind speed of 1.5 m/s; total nebulosity 3; and relative humidity 47.
The paper work displays the results obtained after the sprinkler irrigation, when we determined the quantity of water spread by the 6 sprinklers on a 15 m-radius, placed on the direction of the cardinal points and values of water infiltration after 24 hours by sprinkler irrigation.
The results show that the optimum irrigation amount depends on irrigation uniformity, and on agronomic and physical properties of soil.

Keywords: sprinkler irrigation, uniformity of sprinkling, water infiltration, soil moisture.

INTRODUCTION

Infiltration is the phenomenon by which water on the ground surface enters the soil in an aeration zone (soil, sediment or permeable rock), followed by a descendent movement that ends in the saturation zone.

Loosely, the infiltration phenomenon has two distinct phases:

- the penetration of water on the ground surface and its entrance in the soil, under the topographic surface;
- the descendent movement with a rather vertical component, in an unsaturated area, from the

* Author to whom all correspondence should de addressed: e-mail: bojanicu@yahoo.com

STUDIA UNIVERSITATIS "VASILE GOLDIŞ" ARAD
SERIA ŞTIINŢE INGINEREŞTI ŞI AGRO-TURISM
November 2014 Vol.9 Iss.2 pp.7-13
http://studia.facultateadeinginerie.ro
"Vasile Goldiş" University Press

"Vasile Goldiş" Western University of Arad

surface of the ground to the first piezometric level, which marks the superior limit of the phreatic water bed.

In the quantitative study of infiltration, two indicators are used: the quantity of water infiltrated in a certain period of time, called accumulated infiltration (infiltration) and the speed at which the water infiltrates in a time unit, called infiltration speed[1].

The soil permeability for water is measured with the aid of some indicators, among which we use the indicator - *the infiltration speed of the water in the soil* - for practical purposes related to the application of the irrigation water. We determine the volume of the water infiltrated in the surface unit and in the time unit[2].

The infiltration speed depends not only on the soil texture, but also on other factors like: the soil structure at the surface, the presence of the soil crusts, the type of coverage of the green soil, the compaction degree and the soil compaction, the content of humidity, the water temperature and the irrigation method[3].

The penetration of the water in the soil, also called infiltration, is of utmost importance for forestry, especially for the process of procurance of saplings in the forestry nurseries[4].

With regards to the influence of the irrigation method on the infiltration speed of the water in the soil, the distinction results from the way in which infiltration occurs: vertically with aspersion and laterally with furrow irrigation[5].

The fluctuation of the infiltration speed is considerable: the coarse soils and the loose soils have the highest values, while the fine soils and compacted soils or the crusted soils at the surface have the lowest values[6].

With the exception of extreme cases, this hydro-physical indicator has values between 1 to 50 mm/h, as it follows: under 10 mm/h for the heavy soils, between 10 and 20 mm/h for the medium soils and above 20 mm/h for the light soils[7].

The values of the infiltration speed are used for the irrigation technique in order to establish the irrigation method, to calculate the technical elements of the watering or to choose the right type of sprinkling device, etc[8].

The infiltration speed at a certain time (instantaneous) is determined as a ratio between the water infiltrated in the soil (as water layer) and the duration of the infiltration[9].

In the case of the vast majority of irrigable soils in the country, we have to deal with the problem of increasing the infiltration speed of the water in the soil so that we could reduce the duration of irrigation. This aspect can be achieved through different means[10].

The determination of the infiltration speed on the irrigated fields must be acquired in very similar conditions to those in which the irrigation is done: the coverage type, the content of humidity, the type of water infiltration in connection with the irrigation method, etc[11, 12, 13].

Measurements of pore characteristics are becoming more and more used to characterize soil structure since they influence numerous functions in soils. One important function of soil is transmission of water, which directly affects plant productivity and the environment. Infiltration of water increases water storage for plants and groundwater recharge and reduces erosion. The rate of infiltration is controlled by the pore size distribution and the continuity of pores or pathways. The relations between soil pore structure induced by tillage and infiltration play an important role in flow characteristics of water and solutes in soil[14].

MATERIAL AND METHODS

The research was carried out in the Iarac forestry nursery (figure 1) in the Iuliu Moldovan Forest District (Arad County Branch) during 2012-2014, on an alluvial soil (the vertical-gleyed subtype). At the time when the measurements were taken, the meteorological conditions were: temperature of 23° C; wind speed of 1.5 m/s; total nebulosity: 3; and relative humidity 47. The placement of the sample markets was carried out according to the "divided parcels method" in two repetitions, and the surface of a parcel was 450 m^2.

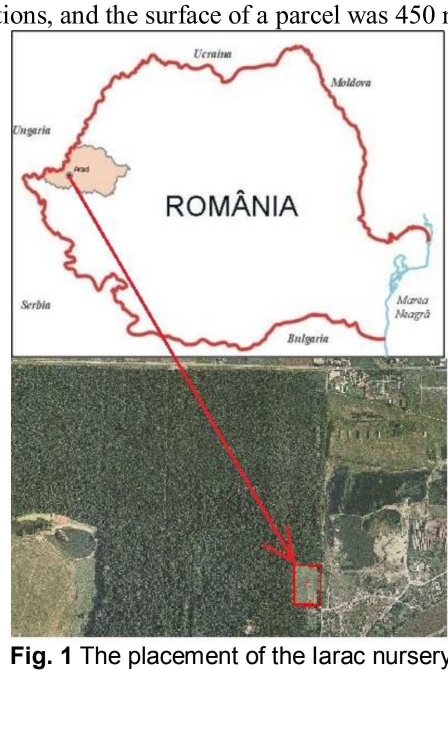

Fig. 1 The placement of the Iarac nursery

The present paper displays the results obtained after the sprinkler irrigation, when we determined the quantity of water spread by the 6 sprinklers on a 15 m-radius, placed on the direction of the cardinal points and values of water infiltration after 24 hours by sprinkler irrigation.

Thus, we established two surfaces for the sampling of the observational data, in a rectangular form, with a 450 m^2 (30 x 15 m) surface, among which one was the witness sample –the un-irrigated soil, and the other surface suffered successive modifications through the sprinkler irrigation. At each surface, we sampled 60 primary data, placed on the direction of the cardinal points (N, S, E, W) for each of the six sprinklers henceforth abbreviated (A1…A6)[15].

In order to assess the impact of the irrigation through sprinkling on the water quantity in the soil, we had to determine the soil moisture at a 24-hour interval after the irrigation. The determination of the soil humidity was effectuated in the same points used for the determination of the sprinkling uniformity, but at a different depth (0-10 cm, 10-20 cm, 20-30 cm).

In order to determine the quantity of water in the soil which had been distributed by the sprinkling device, we effectuated soil profiles at a 30-cm depth, each and every meter, on two diagonals (the cardinal points: N, S, E, W), until a 15-m distance, for all the sprinkling devices included in the experiments. The gathered information appears in tables 4-6.

For the expedite determination of the soil moisture, we used a digital thermometer, Blumat Digital, which is an accurate tool for the measurement of the level of soil moisture, both for the inside and the outside, and for all the types of soils, even for the claylike fields.

As the water consumption of the saplings is concerned, it is necessary to be in the know of the quantity of water existent in the soil layer[11], because it constitutes the water reserve and it is expressed in m^3/ha or in t/ha.

Knowing the soil moisture is of utmost importance for the orientation of the water reserve in the soil which is at the disposal of the saplings, for the establishment of the optimal moment of execution of the soil works and the determination of the moment and norm of watering.

Radial basis function interpolation

Radial basis function (RBF) interpolation consists in finding the coefficients, $\lambda = (\lambda_1,...,\lambda_n)$, for a base of radial functions and the coefficients, $c = (c_1,...,c_l)$, for a set of fitting polynomial, $p = \{p_1,...,p_l\}$, so that this interpolation function $s(x)$ defined below[16]

$$s(x) = p(x) + \sum_{i=1}^{n} \lambda_i \cdot \phi(|x - x_i|) \ , \ x \in R^n$$

has to pass through the values of definition

$$s(x_i) = y_i \ , \ i = \overline{1,n} \ \text{ and } \ \sum_{j=1}^{n} \lambda_j \cdot p(x_j) = 0 \ ,$$

where $(x_i ; y_i)$ are the coordinates of N known points.

The thin plate radial function, $\phi(r) = r^2 \cdot \ln(r)$, was chosen for the studied case. These conditions, under the matrix form, can be written the following form[17]

$$\begin{pmatrix} R & P \\ P^T & 0 \end{pmatrix} \begin{pmatrix} \lambda \\ c \end{pmatrix} = \begin{pmatrix} Y \\ 0 \end{pmatrix}$$

where we have: $R_{i,j} = \phi(|x_i - x_j|)$, $P_{i,l} = p_l(x_i)$, $Y_i = y_i$, $i, j = \overline{1,n}$, $l = \overline{1,m}$. The generated equations system has the solution given by[15, 18, 19]

$$c = \left[(P^T \cdot R^{-1} \cdot P)^{-1} \right] \cdot (P^T \cdot R^{-1} \cdot Y) \ ,$$
$$\lambda = (R^{-1} \cdot Y) - (R^{-1} \cdot P) \cdot [(P^T \cdot R^{-1} \cdot P)^{-1} \cdot (P^T \cdot R^{-1} \cdot Y)]$$

In order to find out the granulometric structure of the soil from the parcels included in the experiment, we firstly determined their granulometry fractionally. This is strictly necessary because of the rapports existent between the granulometric fractions and other physical-mechanical properties. The coarse-grained part of the soil particles were determined through sieving, while the fine parts (dust, clay) trough sedimentation. The attempts were done in the Agro-Pedological Laboratory from the Department of Agriculture from Arad.

RESULTS AND DISCUSSION

1. Granulometric analysis

The knowledge about the granulometric composition of a soil is extremely important because on one hand, it is in a direct connection with the water infiltration, and on the other hand, together with other constituents, it offers the soil better or worse biological valences.

Table 1. Average values of the granulometric analysis at different depths of prelevation

Depth of prelevation of the sample	Sand		Dust		Clay
	Coarse	Fine	I	II	
(cm)	(%)				
0-10	1.6	36.8	13.2	23.8	21.8
10-20	1.7	37.1	13.8	23.1	23.8
20-30	2.2	38.8	14.5	22.5	25.2
Average per profile	**1.8**	**37.6**	**13.8**	**23.1**	**23.6**

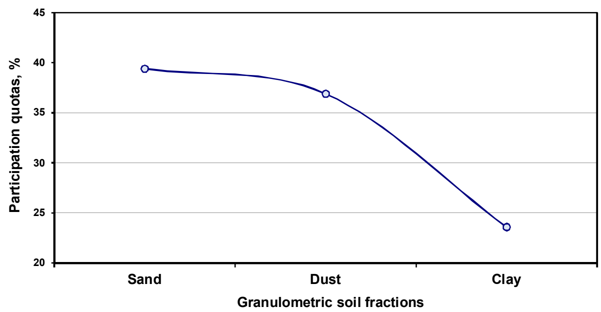

Fig 2. Granulometric curve analysis of the nursery soil

From the analysis of the values gathered from the participation quotas of the granulometric fractions (figure 2), we infer some interesting differences, as it follows:

- The soil presents a relatively close mixture, but in different proportions from the three granulometric fractions (table 1), as it follows: sand 39,4%, dust 36,9% and clay 23,6%;
- The sand fraction (coarse and fine) is predominant (39,4%), with a heavy weight of fine sand (37,6%);
- In the case of the granulometric component of dust, the ratios change in the sense that the highest percentage belongs to the dust II (0,01-0,002 mm) 23,1 %, and the lowest one is dust I (0,02-0,01 mm) 13,8 %.
- The participation quotas of the clay granulometric fraction are the lowest, 23,6 %, occupying a medial position between the other two;

The determination of the soil granulometry is essential so that we could refer to the quantity of water that infiltrates after 24h from the irrigation with sprinkling.

2. Water Infiltration

The results gathered appear in tables 2-5 for the average values of the quantity of water stored in the soil at a distance from the sprinkling device, at the sample depth with the purpose of emphasizing the variation of the soil humidity after the irrigation (figure 3).

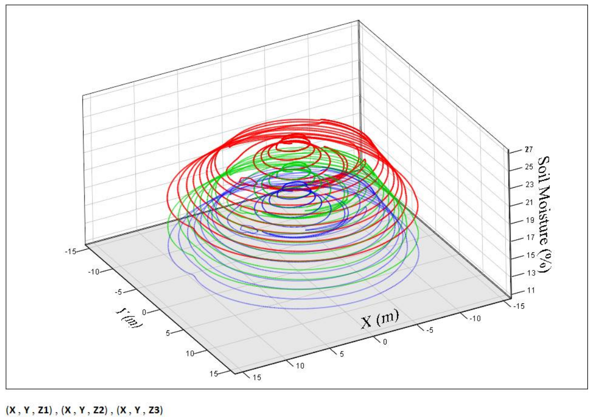

Figure 3. Variation of average values of the soil moisture for three sampling depths
(red: 0-10 cm; green: 10-20 cm; blue: 20-30 cm)

We can draw the following conclusions after analysing the data in tables 2-5, which gather average values of the soil moisture recorded at the cardinal points, at certain distances from the sprinkling device and at the sample depth:

- The largest quantity of water accumulated in the soil after the irrigation is recorded at a 0-10-cm depth;
- High values of soil moisture in the 0-10-cm blanket are recorded until a 10-m distance from the sprinkling device (humidity above 20%);
- Normal values of soil moisture in the 10-20-cm blanket are recorded until a 6-m distance from the sprinkling device, because at greater distances we inferred oscillations of humidity;
- The soil moisture determined at a 20-30-cm depth presents quite sizeable variations, dependent on the distance of determination from the sprinkling device; these variations are due to the relatively short amount of time of the water infiltration from the irrigation.

STUDIA UNIVERSITATIS "VASILE GOLDIŞ" ARAD
SERIA ŞTIINŢE INGINEREŞTI ŞI AGRO-TURISM
November 2014 Vol.9 Iss.2 pp.7-13
http://studia.facultateadeinginerie.ro
"Vasile Goldiş" University Press

"Vasile Goldiş" Western University of Arad

Table 2. Average values of the soil moisture on the direction of the cardinal points

Depth (cm) \ Cardinal points	North	East	South	West
10	22.27	21.68	21.61	21.53
20	19.24	18.65	18.58	18.49
30	17.21	16.61	16.54	16.46

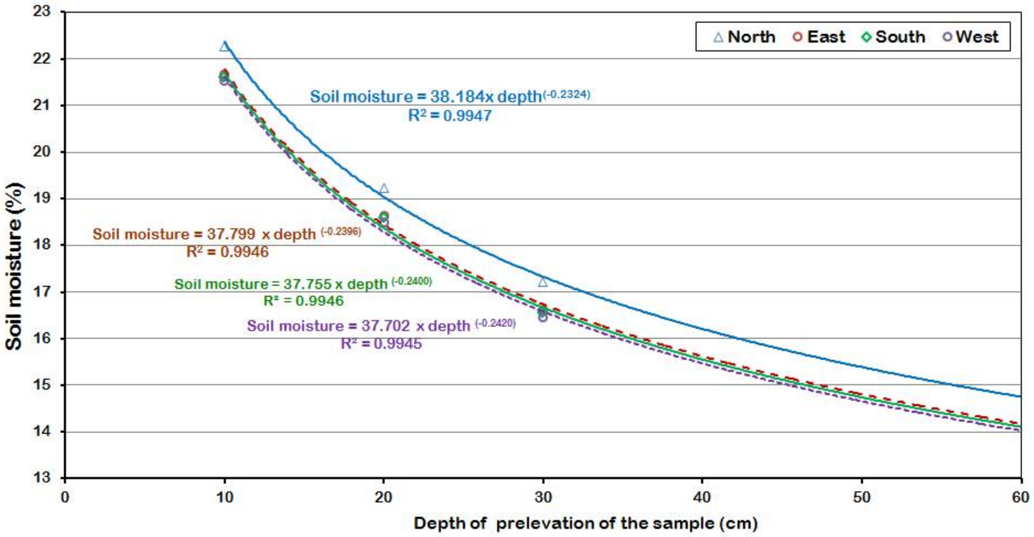

Fig 4. Variation of average values of the soil moisture on the direction of the cardinal points

In order to synthetize more efficiently the data and to describe more accurately the intrinsic characteristics of the sample, we proceeded to the statistical processing with the aid of the KyPlot (Kyplot Version 5.0.2, http://www.kyplot.software.informer.com)program[20].

Without insisting on all the interesting aspects contained as informational messages in the values of the statistical indicators, we have to point out, though, that the average values of humidity are very close at the level of distances from the sprinkling device, especially in the case of the sample depth.

We can also notice the values of the coefficient of variation of the geometric means, which are below 1, for both determinations, which indicates a severe homogeneity of sampled data.

Table 3. Variance of some statistical indexes of the average values of the soil moisture in connection with the cardinal points on 0-10 cm depth

Statistical indexes \ Cardinal points	North	East	South	West
Mean	22.27	21.68	21.61	21.53
S.E.M. (Average standard error)	0.60	0.67	0.57	0.54
Standard deviation	2.34	2.61	2.19	2.08
Coefficient of variation	0.10	0.12	0.10	0.10
Minimum	18.57	18.45	18.53	18.60
Maximum	25.83	25.33	25.22	25.73
The number of feature values (N)	15	15	15	15
Skewness	-0.46	-0.04	-0.15	0.37
Curtosis	-1.14	-1.64	-1.34	-0.59
Mean Deviation	2.12	2.52	2.05	1.74
Median	23.45	21.97	22.55	21.77
Range	7.26	6.88	6.69	7.13
Confidence Level (0,95)	1.29	1.45	1.22	1.15

November 2014 Vol.9 Iss.2 pp.7-13
http://studia.facultateadeinginerie.ro
"Vasile Goldiş" University Press

Statistical indexes \ Cardinal points	North	East	South	West
Lower Confidence Limit	21.67	21.01	21.04	20.99
Upper Confidence Limit	22.88	22.36	22.18	22.06

Table 4. Variance of some statistical indexes of the average values of the soil moisture in connection with the cardinal points on 10-20 cm depth

Statistical indexes \ Cardinal points	North	East	South	West
Mean	19.24	18.65	18.58	18.49
S.E.M. (Average standard error)	0.60	0.67	0.57	0.54
Standard deviation	2.34	2.61	2.19	2.08
Coefficient of variation	0.12	0.14	0.12	0.11
Minimum	15.53	15.42	15.50	15.57
Maximum	22.80	22.30	22.18	22.70
The number of feature values (N)	15	15	15	15
Skewness	-0.46	-0.03	-0.15	0.38
Curtosis	-1.14	-1.64	-1.34	-0.59
Mean Deviation	2.12	2.52	2.05	1.74
Median	20.42	18.93	19.52	18.73
Range	7.27	6.88	6.68	7.13
Confidence Level (0,95)	1.29	1.45	1.21	1.15
Lower Confidence Limit	18.64	17.97	18.01	17.96
Upper Confidence Limit	19.85	19.32	19.14	19.03

Table 5. Variance of some statistical indexes of the average values of the soil moisture in connection with the cardinal points on 20-30 cm depth

Statistical indexes \ Cardinal points	North	East	South	West
Mean	17.21	16.61	16.54	16.46
S.E.M. (Average standard error)	0.60	0.67	0.57	0.54
Standard deviation	2.34	2.61	2.19	2.08
Coefficient of variation	0.14	0.16	0.13	0.13
Minimum	13.50	13.38	13.47	13.53
Maximum	20.77	20.27	20.15	20.67
The number of feature values (N)	15	15	15	15
Skewness	-0.46	-0.03	-0.15	0.38
Curtosis	-1.14	-1.64	-1.34	-0.59
Mean Deviation	2.12	2.52	2.05	1.74
Median	18.38	16.90	17.48	16.70
Range	7.27	6.89	6.68	7.14
Confidence Level (0,95)	1.30	1.45	1.21	1.15
Lower Confidence Limit	16.60	15.94	15.98	15.92
Upper Confidence Limit	17.81	17.29	17.11	17.00

CONCLUSIONS

From the analysis of the values gathered from the participation quotas of the granulometric fractions, we infer some interesting differences: the soil presents a relatively close mixture, but in different proportions from the three granulometric fractions, as it follows: sand 39.4%, dust 36.9% and clay 23.6%.

Values of the Christiansen coefficient of uniformity determined for the six sprinklers according to the cardinal points indicates a very good uniformity (Cu > 75%).

Values of the Pernes coefficient of uniformity grouped according to the distance to sprinkler indicates a medium uniformity (50% > Cu < 75%) up to a distance of 10 m from sprinkler.

The average value of soil moisture for the six sprinklers and all cardinal points measured in the 0-10 cm depth is 21.77 %. The average value of soil moisture for the six sprinklers and all cardinal points measured in the 10-20 cm depth is 18,74 %. The average value of soil moisture for the six sprinklers and all cardinal points measured in the 20-30 cm depth is 16,71 %.

Christiansen uniformity coefficient high values (Cu > 75%) resulted from the research analysis. This indicates very good sprinkler water distribution uniformity. Furthermore, as reflected by high soil moisture values measured after 24 hours from irrigation. Thus, in order to achieve an efficient management of water resources in the area, we recommend reducing the dispersed water flow up to 15%.

REFERENCES

E. CAZACU: Irrigations. Ceres Publ. House, Bucharest, 1989.

I. S. VLAD: Irrigation of Cultures. Ceres Publ. House, Bucharest, 1982.

I. PLESA, V. BURCHIU: Exploitation of the Systems for Territorial Improvements. Ceres Publ. House, Bucharest, 1986.

I. POPESCU, S. POPESCU: Mechnization of Sylvical Works. Publ. House of the University of Transylvania, Brasov, 2000.

N. GRUMEZEA, C. KLEPS: Irrigation Installations in Romania. Ceres Publ. House, Bucharest, 2005.

St. TRIFU: Mechanization, Irrigation of Landscaped Land. Ceres Publ. House, Bucharest, 1973.

M. NEDELCU: Current State Regarding the Construction of Installations for Irrigation. Brasov, 2004.

V. I. SISESTI: Irrigated Cultures. Didactical Publ. House, Bucharest, 1971.

S. MIHAI: Contributions to the Study of the Work Indices Carried Out by the Sprinkling Installation from the Central Forestry Nursery Gaest. J Forest, (7), 24 (1970).

N. C. SABAU, M. SANDOR, C. DOMUTA, A. C. TEUSDEA, R. BREJEA, Cr. DOMUTA: Verification of Conditions for Irrigation Water Application in Drainage Experimental Field in Avram Iancu, the Bihor County (Sub-irrigation) with DrainVSubIR Program. J Environ Prot Ecol, **12** (4A), 2322 (2011).

K. DONEVA: Effect of Irrigation of Crops on Soil Thermal Properties. J Environ Prot Ecol, **11** (2), 562 (2010).

Y. KIRKOVA: Irrigation Regime Effect on Soil and Plants. J Environ Prot Ecol, **11** (2), 577 (2010).

E. KUKALI, E. KONGJIKA, M. KASMI: Influence of Irrigation on Olive and Grape Culture. J Environ Prot Ecol, **13** (2A), 925 (2012).

M. Kutı´lek: Soil hydraulic properties as related to soil structure. Soil Till. Res. **79**, 175 (2004).

N. BOJA, F. BOJA, A. TEUSDEA, C. MAIOR, P. A. DARAU: Research Regarding the Uniformity of Sprinkler Irrigation, J Environ Prot Ecol, **14** (4), 1661 (2013).

A. BOER; M. S. SCHOOT, H. BIJL,: Mesh deformation based on Radial Basis Function Interpolation, Computers & Structure. Fourth MIT Conference on Computational Fluid and Solid Mechanics, Vol. 85, Issues 11-14, 2007, 784-795.

J. C. Carr, R. K. Beatson, B. C. McCallum, W. R. Fright, T. J. McLennan, T. J. Mitchell: Smooth surface reconstruction from noisy range data, ACM GRAPHITE, Melbourne, Australia, 2003, 119-126.

T. Modog; A. C. Teusdea; V. S. Negrau; D. Gombos; Sparse Time Series Interpolation Of Dam Displacements; 0430-0431, Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Published by DAAAM International, Vienna, Austria 2010, 02-18.

Prada, Marcela; Teusdea, Alin Cristian; Fetea, Ioana & Suba, Stefan: Radial Basis Function Interpolation Of Non-Matching Grids Surfaces For Volume Calculation; Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium, Published by DAAAM International, Vienna, Austria 2009, 1043-1044.

http://www.kyplot.software.informer.com