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Research article

Determination of the physical and hydrodynamic parameters of the Degueche Oasis soil (Southern Tunisia): approach to precision and quality

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Abstract

Land degradation and progressive loss of agricultural soil fertility are two dynamic challenges threatening the sustainability of agricultural production, and the economic security of agro-based countries. Hence, a fruitful investment in irrigated lands relies on a critical assessment of soil proprieties and hydrodynamic function, and their relative impacts on soil water dynamics. In this context, the present study investigates the spatial distribution of these parameters and their likely consequences on the oases agro-systems of Menchia Oasis parcels (SW Tunisia) given their socio-economic and environmental relevance to the region.
In this study, this oasis was divided in twelve plots according to Sectoral Center for Agricultural Vocational Training in palm date culture. The granulometric analysis indicates that sandy fraction that represents about 60% of the analyzed samples. The soils have different physio-chemical proprieties with alkaline pH with a means of 7.5±0.2 and a moderate salinity with a means of 2.5±0.2 g.l^{-1} and variable hydraulic characteristics according to the obtained results from the application of MUNTZ method.
The findings coupled with field investigations indicate that the productivity of these agro-systems is closely related to irrigation water quality and soil proprieties on the one hand and on the dynamic balance soil-water regulated by the appropriate irrigation and drainage techniques on the other hand. Modeling of the evolution of these proprieties are crucial for the prediction of drought and desertification phenomena in Saharan Oases.

Key words: Double ring, Infiltration, Hydrodynamics, Oasis soil, Physical properties. Tozeur-Tunisia.

1. Introduction

Desertification is a dynamic issue affecting large part of arid and semi-arid countries and threatening the sustainability of the agro-systems without appropriate measures of adaptation and management (Liu et al. 2018). Different projects have been implemented to combat land degradation and to secure sustainable agricultural production in various regions all over the world. These programs rely principally on field observation and they are often coupled with modeling system used to predict the evolution of the environment under natural and anthropogenic constraints. Rehabilitation and prevention measures are variables depending according to climate, geomorphologic, and socio-economic features of the regions and differ from local to regional and national scales.
In hot dry areas, oases reveal increasing economic and environmental values as they represent the most

adopted systems to harsh climate conditions, and they represent the principal activity for local residents. Thus, various actions have taken place to prevent the degradation of these agro-systems such as the shelterbelts have been planted around and within the oasis areas in order to protect the cropland against damage from sandstorms and dry thermal winds originating in deserts. Previous works have indicated, however, that the preservation of oases agro-systems from land degradation issues relies principally on the monitoring of the fragile water-soil balance along soil profile. This equilibrium is closely related to soil proprieties (physical, bio-physical, chemical, hydrodynamic…), irrigation water quality (salinity, alkalinity, hardness…) and farming practices (irrigation technique, water requirements, drainage…).

In fact, according to previous studies, climate change, economic development, water scarcity and management of agricultural lands are the key parameters influencing prevention or expansion of desertification processes (Yang et al., 2000; King et al., 2006; Bradly and Weil, 2008; Govil et al., 2018). These factors are inter-linked and result in a complex nexus difficult to control in a sustainable way without careful small-scale studies of these hierarchical influences on desertification process.

Southern Tunisia is one of the most known areas for its oases landscape located across four governorates of Tozeur, Kebili, Gabes and Gafsa. Given the low non-agricultural employment, the desert outfits of these areas and the harsh climate conditions, these agro-systems know a continuous expansion from a total area of about 16,720 ha in 1973 to more than 41,700 ha, so about 9% and 0.8% of the total irrigated land and the country's agricultural area, respectively (OSS, 2018). Besides to their economic and environmental values, these oases have religious and cultural dimensions for local population. Thus individual, institutional, and governmental efforts have been made to preserve theses lands from degradation and to secure sustainable agricultural development.

In this context, this study was conducted in El Manechia-Degueche oasis in southwestern Tunisia where these agro-systems along the border of Chotts depressions and the dunes of the oriental erg create a net contrast with the desert outfits of the region. In these regions, the sustainable development of oasis is the main way to guarantee the livelihood of the local population. Thus, the assessment of different factors influencing directly and (or) indirectly the agricultural production is of paramount importance. Correspondingly, the present paper discusses the effects of water infiltration on the implementation of appropriate irrigation system using a modeling tool that significantly reduces the time and cost of infiltration measurement in field (Mudiare and Adewumi, 2000). The fruitful estimation results depend on the careful examination of soil proprieties and irrigation water quality. Indeed, the estimation of physical and hydrodynamic parameters of the oasis soil is a very delicate step in the use of models (and the results that can be expected depend strongly on them), thus controlling the quantity of water used for irrigation. Consequently, this paper attempts, firstly, to characterize, physico-chemical and hydrodynamic parameters of the Degueche oasis soil and secondly to evaluate their impacts on soil-water balance, on soil fertility and land productivity.

2. Material and methods

2.1. Field site characteristics

This study was carried out in an area of El Manechia Oasis located in southern sector of Degueche33°59'28.27''N, 8°14'16.44''E. An incline of slope varying from gentle to moderate, the average of which is about 7%. The oasis climate is upper saharan fresh, hot in summer and mild in winter. Rainfall is low and erratic with an annual average of 186 mm. Under the influence of Saharan winds, the summer temperature can reach 42.5 °C in August and falls to reach 5 °C in winter in December and January. The winds blow between December and April are cold, dry, and carrying sand. The soils of the oasis are gypsum, according to WRB classification; it can be classified as Gypsisol. The oasis has a vegetation cover composed of three tiers; the top tier consists of the dominant tree species in the oasis, the date palm (*Phoenix dactylifera* L.), about 45 varieties have been recorded. The middle tier comprises fruit trees including Pomegranate (*Punicagranatum* L.), apricot (*Prunusarmeniaca*), figs (*Ficuscarica),* and grapes (*Vitis.* spp*).* The bottom tier comprises horticultural plants such as carrots (*Daucuscarota*), onion (*Allium cepa*) and alfalfa (*Medicago sativa*). The vegetation cover is concentrated in the middle of the oasis near to water resources while outside the oasis in the desert side, scarce or no vegetation cover can be found (Figure1).

The parcel of this study composed by 12 plots with is different by their agriculture practices.

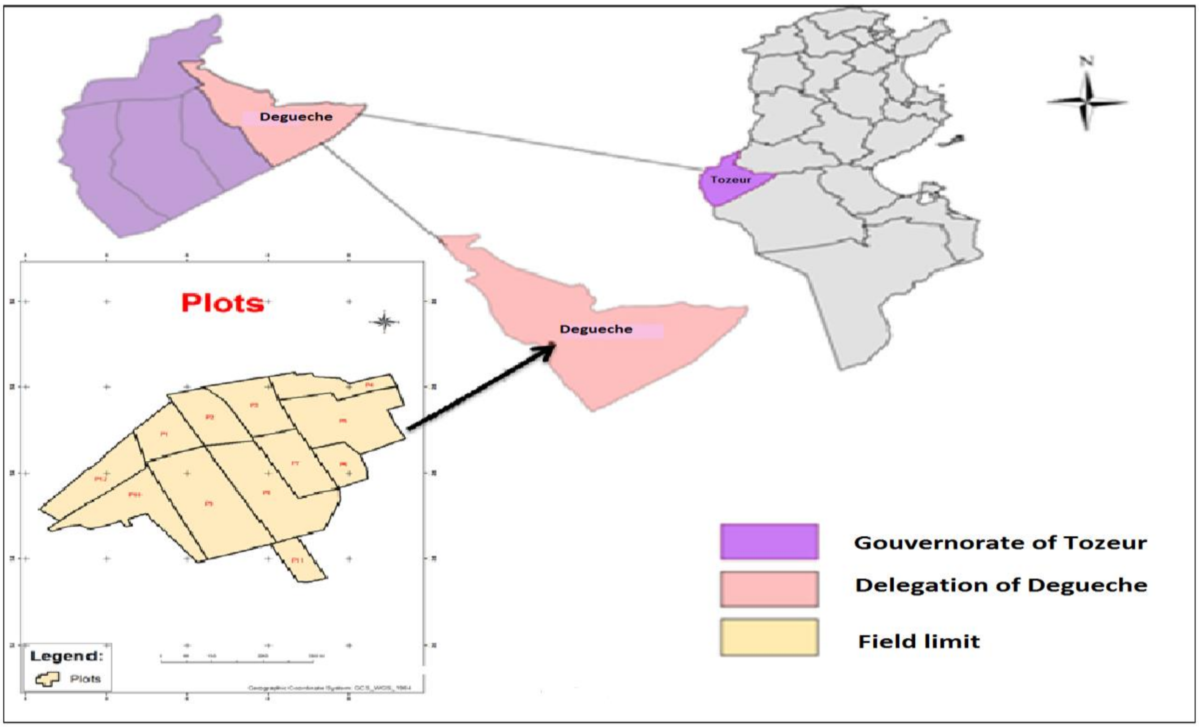


Fig. 1. Map of the Manechia Degueche

2.2. Soil analysis

Physico-chemical characterization of the soil: Soil samples were taken from the different plots of the EL Manechia Oasis. The depth of the soil pits varies from 60 to 90cm, in order to determine the physico-chemical proprieties such as grain size, pH, electrical conductivity, field capacity, wilting point, and statured water content.

Particle size analysis: The distribution of the soil particle size was determined using the method described by (Schvartz, Christian, Muller, Jean-Charles 2005). The granulometric analysis was carried out the Robinson pipette method valid only for soils with a gypsum percentage in the range of 10% to 12%. Samples were collected from tree horizons (0-30, 30-60, 60-90 of depth) for different study plots of the El Manechia oasis. The replicates positions were designed with respect to the palm tree.

→ *Measurement of the bulk density of the soil:*, the bulk density of the soil taken from four plots is determined by the roll method using undisturbed and fresh samples knowing the constant dry weight of the samples at 105°C and the volume of the sampling rolls used (Gee, Bauder, and Klute 1986).

2.3. Hydrodynamic soil properties

The assessment of water content at field capacity (θCC) and water content wilting point (θpf) was conducted for the sampled soils. To experimentally evaluate the water contents θCC and θpf, a range of samples were taken from tree depths of 30 cm, 60 cm, 90 cm for tree points for which plots in the study area.

In fact, the concept of “field capacity” poses serious difficulties when it comes to translating it into matrix potential value. The permanent wilting point is the water state of the soil from which plants can no longer draw water and wither irreversibly. It is matched by the value of pF 4,2 i.e.Ψ = - 15 MPa (Cresswell et al., 2006). In this study two Richards pots of 1 bar and 15bar were used (PF-meter set with ceramic plat, basic standard set).

2.4. Water infiltration into the soil

In order to characterize the variability of soil infiltration in an oasis in southern Tunisia, a first campaign of infiltration measurement, using the double ring method or the Muntz method, was carried out in the El Manechia. The Müntz method used in this study was described by (Colombani et al. 1972). It relies on the principle of measure of the evolution of the infiltration over time of a water slide under constant load, infiltrating vertically into the soil. In this study, several measurements were carried out to define the characteristics of water transfers in the soils of this region. On this 33 ha oasis, 12 infiltration tests were carried out during the month of April. The infiltration rate of each plot is measured either immediately after the irrigation of the plots or after 24 or 48 hours of irrigation. The double ring infiltration device had the following geometry external ring (or guard ring) with a diameter of 60 cm and inner ring with a diameter of 30cm (Figure 2).

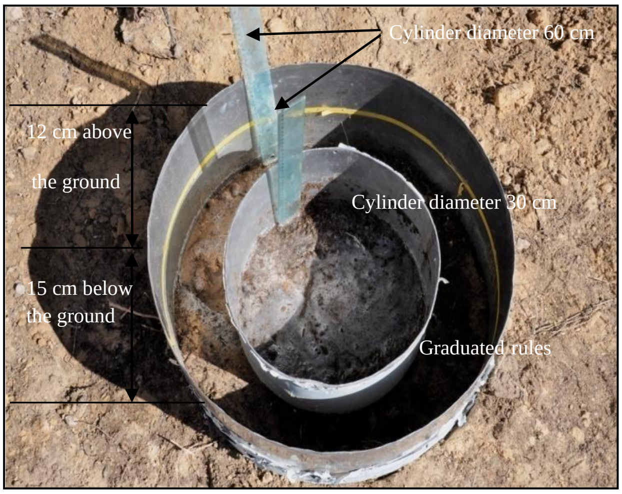


Fig. 2. *In situ* measurement device Müntz method.

2.4. Data analysis

Despite the presence of a high number of infiltration models, there are very popular empirical models (Ruth Uloma et al., 2014). In this study we used the empirical Kostiakov infiltration model (Kostiakov 1932) derived from data observed under real or laboratory conditions. The Kostiakov infiltration was determined according to the following equation:

$$I = Kt^{\alpha} \qquad (1)$$

Where I = Cumulative infiltration rate

t = Elapsed time

α and κ are the empirical constants, where K' 0 and 0‹α‹1, site-specific, dependent on different parameters, and site-specific dependent on different parameters (Uloma et al., 2014).

A plot of log I against log t gives a line whose slope gives the value of α, while the interception gives the value of log K. The value of K was obtained from the anti-log K;

$$\kappa = 10^{\log\kappa} \qquad (2)$$

3. Results and discussion

3.1. Chemical characteristics of different study sites

Table 1 show that the pH value of soils for all the plots of the study sites was generally alkaline. In the surface layer (0-30 cm), the high mean value of pH was 8.39±0.2. In all sites the pH increase with depth to achieve a maximum of 8.43±0.3 in lower layer (60-90 cm) , the pH results were predictable as they attributed to the highly salt contents encrusted in soil layers stem from the gypsum crust, irrigation with saline water and rising of the ground watertable (Boulbaba et al., 2012).The high pH values could be explained by an upcoming of water from already saline aquifers (2.2 g/l) of which all of oases are irrigated from. The pH values for the same region were reported in previous literature and were in agreement with other researches findings (Bouksila et al., 2013; Rejili et al., 2012).

The soil salinity is significantly affected to soil electric conductivity, the soil salinity in different study sites (table1) increase with depth to achieve 1.83±0.3 $g.l^{-1}$ in deeper layer (60-90 cm) from 1.61±0.2 $g.l^{-1}$ in surface layer (0-30 cm) this can be explained that the soils are usually affected by soil surface crusting given the high evaporation rate and the excess of irrigation water which reduces significantly infiltration, hampers germination of seeds and reduces root aeration and water availability.

These results agreed with results obtained by Karbout et al., (2020). Thus, knowledge detailed examination of the physical and chemical properties of the surface soil crust are essential important to predict and mitigate it's their likely negative side effects on soil-water balance and on sustainable land productivity. In fact, (Cresswell et al., 2006) found that the soil salinization significantly affected the development of regional economies and agriculture mainly by accelerating desertification.

This phenomenon has a strong ability to inhibit the crops growth, hindering agricultural development, and reducing soil quality (Xiao and Huang, 2016). Salinization has been one of the main problems for all coastal areas of the world generally due to inundation from sea level rise (Dasgupta et al., 2014). Soil salinity in the study area is associated with various biophysical factors, for instance, the amount of water available for agriculture will drop eventually because of high evaporation rates and decline in groundwater recharge, which will pose significant challenges to the agricultural sector both for the rain-fed and irrigated agriculture as in oasis agrosystems. It is expected that the oasis agrosystems should experience a warming of

1.1°C by 2030, and 2.1° C by 2050 (Verner, 2013). Date production is expected to be severely affected as a result of this change, the areas where date palm grows may become unsuitable to support an economic production of the crop (Shabani et al., 2012). Climate change is predicted to reduce the growing period of the plants and thus date cultivation is subjected to change to attain higher crop production, farmers are thus need to consider tolerant varieties to drought and best management practices to adapt to these effects (Cuculeanu et al., 2002).

Moreover, the oases are under the influence of Saharan winds. The strong hot winds of sirocco blow in the spring and summer seasons and causing the erosion of the fertile soils from the oases lands and the breaking of the date palms branches (Labiadh et al., 2013). (Verner, 2013) related the invasion of the sand dunes into the oasis's areas to the scarce vegetation cover in surrounding rangelands. Vegetation cover can act as wind breakers and help to stabilize the soil against the erosion. Soil erosion is believed to be a direct driver for loss of soil productivity in arid and semi-arid areas through depletion of soil nutrients stocks (Larney et al., 1998).

Unlike water erosion, wind erosion has a strong influence on removing the fine nutrient rich particles over large surfaces of land, while water erosion occurs to specific surfaces where the water flow runs, thus only the vulnerable soil is detached and eroded. Due to wind erosion mechanism, the soil becomes more coarse in texture and lacks to organic matter contents which ultimately result in soil productivity decline of the affected area (Gregorich et al., 1998). Wind also has a mechanical influence on the plants, for example, strong winds can damage the plant's parts by breaking the stems and branches or entirely cause plant falling or expose the plants' roots to air (Cleugh et al., 1998). In addition, the variation in lands topography in arid and semi-arid regions contributes to vulnerability of these lands to wind and water erosion (Breshears et al., 2009).

3.2. Physical characteristics of different study sites

3.2.1. Grain size distribution

The distribution of the fractions relative to different grain size of the sampled soil is given by Table 2. The sand represents the major part; the percentage varies between 86.75% and 74.75%, the coarse sand is the most dominated in our simples than the fine sand, the loam, and the clay represents a very small percentage in the texture soil composition. The domination of coarse sand in the different plots is the characteristic of texture soils of oases system in Tozeur region (Karbout et al,. 2018; Bousnina and Mhiri, 1998).

3.2.2. Bulk density

The bulk density of the soil reflects the overall compaction state of the material and, indirectly, the total porosity. When the value of bulk density is high, the soil does not contain pores necessary for root growth, water capacity is reduced and fluid circulation slows down (Alongo and Kombele, 2013).

Bulk density, unlike other physical parameters, is sensitive to anthropogenic actions (Boyer and Boyer, 1982).According on the results presented in Figure 3, the measured bulk density of the analyzed samples is greater at depth than at surface. It varies between 1.4 and 1.48 g/cm^3. Found that the apparent density of the horizons of cultivated soils was between 0.9 and 1.8 g/cm^3 and those values below this range characterized organic layers and volcanic ash. Soil bulk density values from different plots are well within this range of 1.51-1.7 g/cm^3). It is also less than 1,7 g/cm^3, so the soil is not permanently compacted and does not require any improvement (Maitre and Pasquier, 2014).

The results showed some contradiction assuming that bulk density increases with high level of soil salinity and soil compaction (Shakir and Razzaq, 2002). However, a possible explanation is that changes in soil swelling due to changes in water content and the time of sampling might have influenced the bulk density values. However, the overall means of bulk density were in comparable to other observations found in the literature under similar soil conditions in southern Tunisia (Belaid et al., 2012; Bouksila et al., 2008).

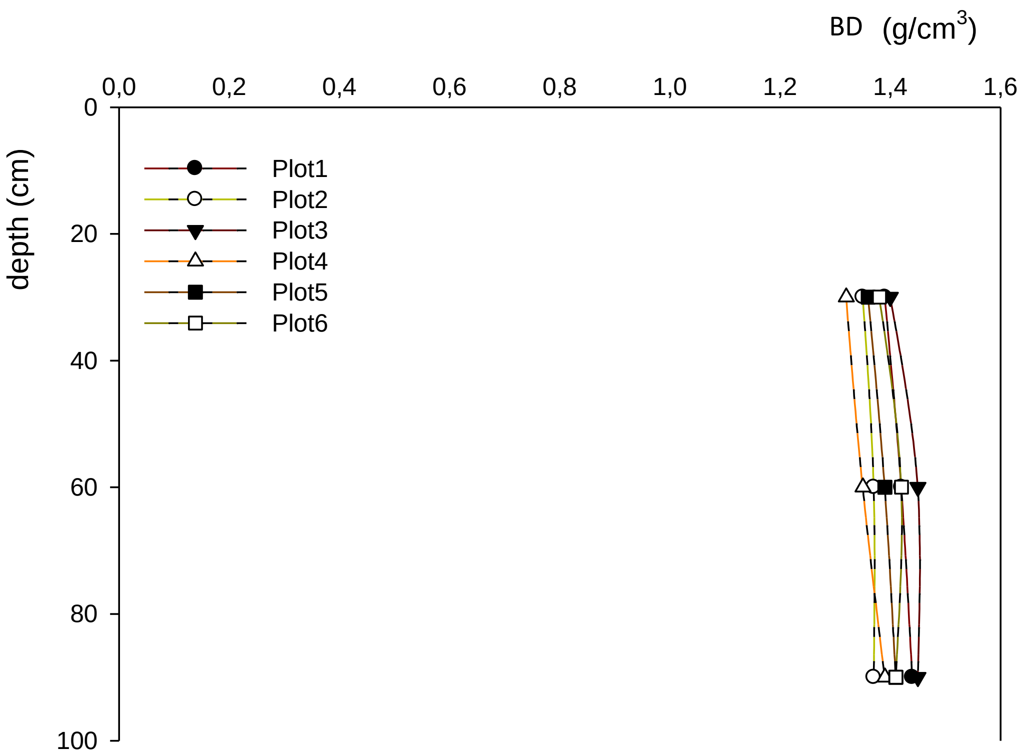
3.2. Water content

The obtained results from the assessment of water content values from field capacity (θcc) and wilting point (θpf) are presented in Table 3. The field capacity value (θcc) range between 7.40±0.17% and 14.79±0.53% in the surface layer (0-30cm), in the deeper layer (60-90cm) this value is variants between 5.52±0.55% and 12.59±0.08%.

For the moisture content at the wilting point (θpf), the value achieves a maximum of 8.59±0.11% in the surface layer (0-30cm), this value generally increases with depth to variant between 2.29±0.46% and10.44±0.27% in deeper layer (60-90cm).

Table 1. Chemical characteristics of soils simples in different plots on different depths

Plot	Soil depth (cm)	pH	Salinity ($g.l^{-1}$)	Electrical conductivity ($dS.cm^{-1}$)
	0-30	8.01±0.2[a]	1.58±0.1[a]	2.20±0.2[a]
1	30-60	8.11±0.3[a]	1.47±0.1[b]	2.11±0.1[b]
	30-90	8.12±0.1[a]	1.45±0.2[b]	2.09±0.3[b]
	0-30	8.10±0.1[a]	1.56±0.2[a]	2.23±0.1[a]
2	30-60	8.12±0.1[a]	1.47±0.1[b]	2.10±0.2[b]
	30-90	8.08±0.3[a]	1.48±0.1[b]	2.12±0.2[b]
	0-30	7.94±0.2[a]	1.58±0.3[a]	2.26±0.3[a]
3	30-60	7.96±0.3[a]	1.53±0.1[a]	2.19±0.1[a]
	30-90	7.97±0.2[a]	1.49±0.1[b]	2.13±0.1[b]
	0-30	7.92±0.3[a]	1.58±0.2[a]	2.27±0.2[a]
4	30-60	7.96±0.2[a]	1.51±0.1[b]	2.17±0.1[b]
	30-90	7.95±0.3[a]	1.47±0.1[ab]	2.11±0.2[b]
	0-30	7.93±0.2[a]	1.54±0.2[a]	2.20±0.1[a]
5	30-60	7.85±0.3[a]	1.62±0.1[b]	2.32±0.1[b]
	30-90	7.95±0.1[a]	1.63±0.1[b]	2.33±0.2[b]
	0-30	7.90±0.4[a]	1.61±0.2[a]	2.30±0.3[a]
6	30-60	7.89±0.1[a]	1.64±0.3[b]	2.35±0.2[b]
	30-90	7.97±0.1[a]	1.63±0.3[b]	2.34±0.2[b]
	0-30	7.95±0.2[a]	1.54±0.1[a]	2.21±0.1[a]
7	30-60	7.90±0.2[a]	1.61±0.3[b]	2.31±0.1[b]
	30-90	8.12±0.3[a]	1.57±0.3[a]	2.25±0.2[a]
	0-30	7.95±0.1[a]	1.50±0.1[a]	2.15±0.2[a]
8	30-60	7.96±0.1[a]	1.56±0.2[b]	2.24±0.1[b]
	30-90	7.98±0.1[a]	1.57±0.2[b]	2.25±0.3[b]
	0-30	7.98±0.2[a]	1.54±0.3[a]	2.20±0.2[a]
9	30-60	7.99±0.3[a]	1.51±0.1[a]	2.16±0.1[a]
	30-90	8.10±0.2[a]	1.57±0.1[b]	2.25±0.2[b]
	0-30	7.96±0.2[a]	1.47±0.3[a]	2.10±0.1[a]
10	30-60	7.98±0.3[a]	1.49±0.2[a]	2.14±0.1[a]
	30-90	8.04±0.3[a]	1.57±0.3[b]	2.25±0.1[b]
	0-30	8.39±0.2[a]	0.70±0.1[a]	1.004±0.2[a]
11	30-60	8.40±0.1[a]	0.95±0.1[a]	1.36±0.1[a]
	30-90	8.41±0.4[a]	1.83±0.1[b]	2.62±0.2[b]
	0-30	8.35±0.2[a]	1.61±0.2[a]	2.31±0.1[a]
12	30-60	8.40±0.1[a]	1.54±0.1[b]	2.21±0.2[b]
	30-90	8.43±0.2[a]	1.83±0.1[c]	2.62±0.2[c]



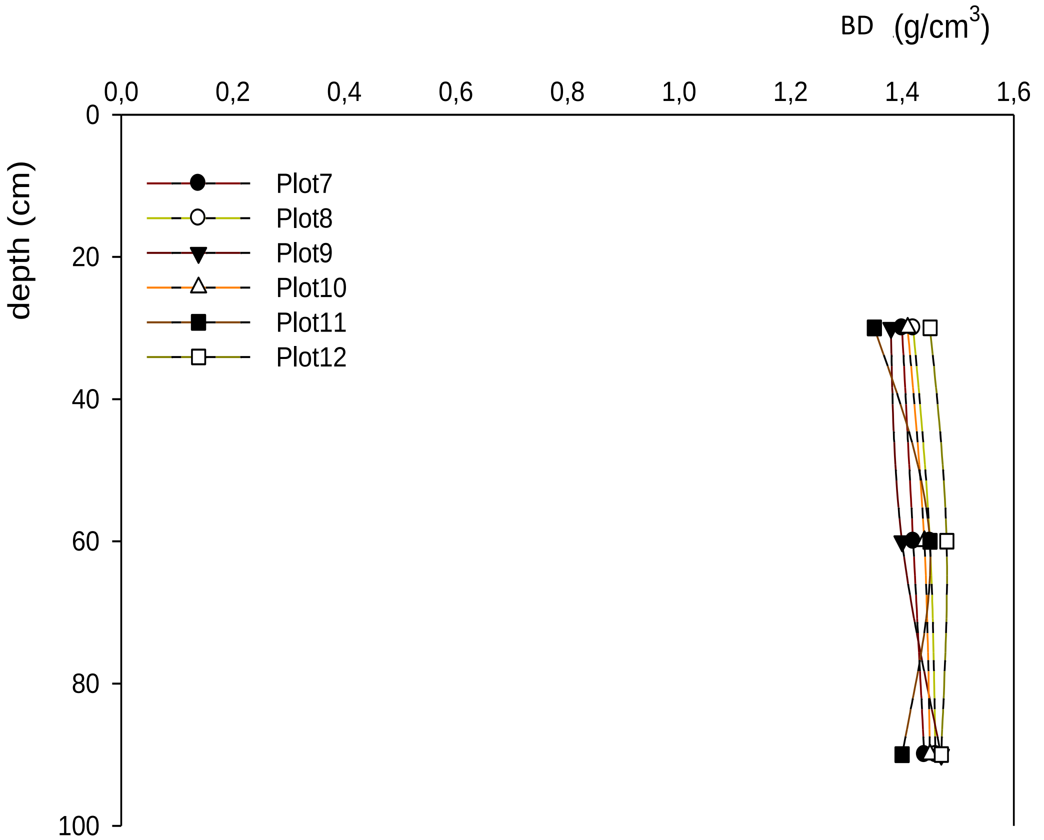


Fig. 3. Bulk density (BD) in different study plots

Table 2. Grain size distribution in different study plots

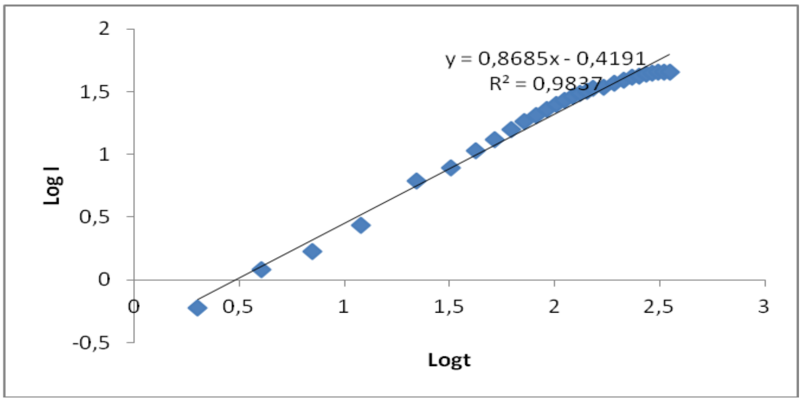
Plot	Soil depth (cm)	Clay (%)	Fine silt (%)	Coarse silt (%)	Fine sand (%)	Coarse Sand (%)
1	0-30	3	1	6	15	75
	30-60	5	2	8	35	50
	60-90	2	2	9	25	62
2	0-30	1	1	3	22	73
	30-60	3	2	4	51	40
	60-90	4	1	3	37	55
3	0-30	2	3	2	26	67
	30-60	5	2	5	53	35
	60-90	4	4	5	28	59
4	0-30	2	1	7	20	70
	30-60	3	2	5	30	60
	60-90	6	1	3	36	54
5	0-30	5	1	4	10	80
	30-60	5	1	3	19	72
	60-90	6	2	4	38	50
6	0-30	4	2	1	12	81
	30-60	5	1	1	25	68
	60-90	4	2	1	10	83
7	0-30	3	1	1	25	70
	30-60	4	2	3	35	56
	60-90	3	1	2	34	60
8	0-30	5	0	1	10	84
	30-60	6	2	2	37	53
	60-90	9	1	2	32	56
9	0-30	3	0	1	13	83
	30-60	5	2	3	23	60
	60-90	4	1	2	14	79
10	0-30	6	3	6	21	64
	30-60	4	0	5	21	70
	60-90	3	0	2	10	85
11	0-30	6	5	4	25	60
	30-60	8	4	1	30	57
	60-90	5	3	1	12	79
12	0-30	2	3	2	13	80
	30-60	7	3	4	32	54
	60-90	4	2	1	11	82

Table 3. Water content

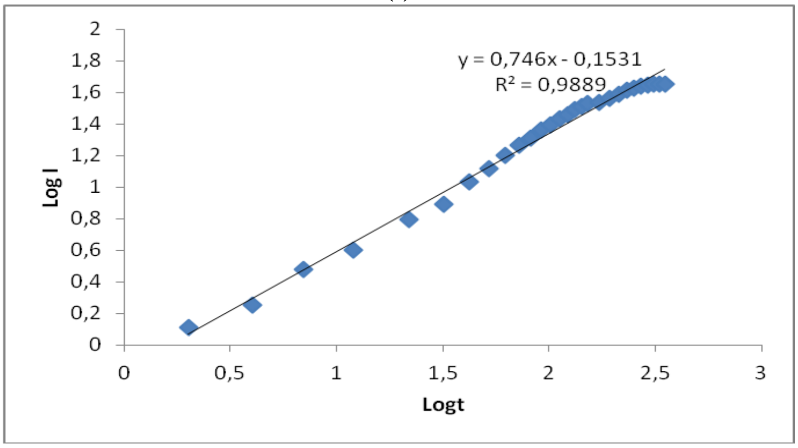
Plot	Soil depth (cm)	Ѳcc (%)	Ѳpf (%)
1	0-30	8.05±0.07[a]	3.64±0.22[a]
	30-60	8.54±0.06[a]	3.54±0.10[a]
	60-90	12.59±0.08[a]	2.29±0.46[a]
2	0-30	9.74±0.07[a]	4.65±0.05[a]
	30-60	9.48±0.09[a]	4.86±0.05[a]
	60-90	12.09±0.11[a]	2.43±0.60[a]
3	0-30	8.17±0.04[a]	3.46±0.13[a]
	30-60	6.21±0.26[a]	3.07±0.29[a]
	60-90	5.52±0.55[a]	10.44±0.27[a]
4	0-30	7.91±0.08[a]	4.70±0.07[a]
	30-60	15.34±0.21[a]	11.25±0.13[a]
	60-90	10.69±0.10[a]	4.41±0.10[a]
5	0-30	7.40±0.17[a]	8.59±0.11[a]
	30-60	7.15±0.11[a]	3.74±0.06[a]
	60-90	10.77±0.09[a]	8.57±0.12[a]
6	0-30	9.28±0.04[a]	6.40±0.16[a]
	30-60	11.70±0.23[a]	9.45±0.33[a]
	60-90	11.53±0.05[a]	5.51±0.16[a]
7	0-30	10.80±0.07[a]	4.32±0.10[a]
	30-60	10.57±0.07[a]	4.00±0.05[a]
	60-90	9.55±0.07[a]	8.06±0.31[a]
8	0-30	14.79±0.53[a]	6.08±0.16[a]
	30-60	12.08±0.24[a]	7.88±0.33[a]
	60-90	10.11±0.14[a]	5.65±0.05[a]
9	0-30	7.28±0.06[a]	4.74±0.09[a]
	30-60	7.20±0.17[a]	3.17±0.16[a]
	60-90	9.33±0.02[a]	8.79±0.12[a]
10	0-30	9.81±0.02[a]	4.50±0.03[a]
	30-60	10.02±0.13[a]	4.18±0.12[a]
	60-90	10.20±0.15[a]	4.15±0.13[b]
11	0-30	10.11±0.05[a]	6.02±0.01[a]
	30-60	12.05±0.11[a]	5.12±0.10[a]
	60-90	11.05±0.14[a]	5.96±0.11[a]
12	0-30	9.31±0.02[a]	5.10±0.02[a]
	30-60	11.10±0.21[a]	4.16±0.11[a]
	60-90	12.07±0.20[a]	5.23±0.21[a]

Table 4. Infiltration parameters determined by the two methods for different plots

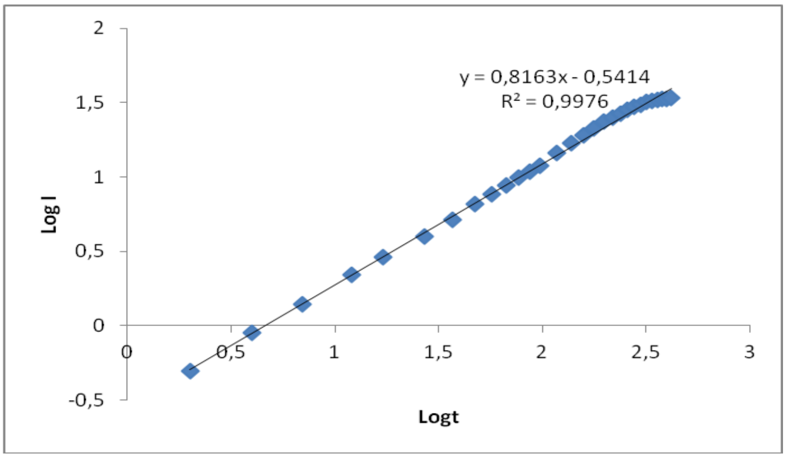
Study sites	Kostiakov Method		
	k	α	$Z = \kappa t^{\alpha}$
1	2.624	0.868	$Z=2.6t^{0.86}$
2	1.422	0.746	$Z=1.2t^{0.74}$
3	3.475	0.816	$Z=3.4t^{0.81}$
4	3.605	0.821	$Z=3.6t^{0.82}$
5	3.0199	0.745	$Z=3.01t^{0.74}$
6	3.475	0.771	$Z=3.47t^{0.77}$
7	1.458	0.726	$Z=1.45t^{0.72}$
8	2.123	0.791	$Z=2.12t^{0.79}$
9	9.120	0.716	$Z=9.12t^{0.71}$
10	7.870	0.739	$Z=7.87t^{0.73}$
11	3.451	0.76	$Z=3.45t^{0.76}$
12	3.614	0.75	$Z=3.61t^{0.75}$



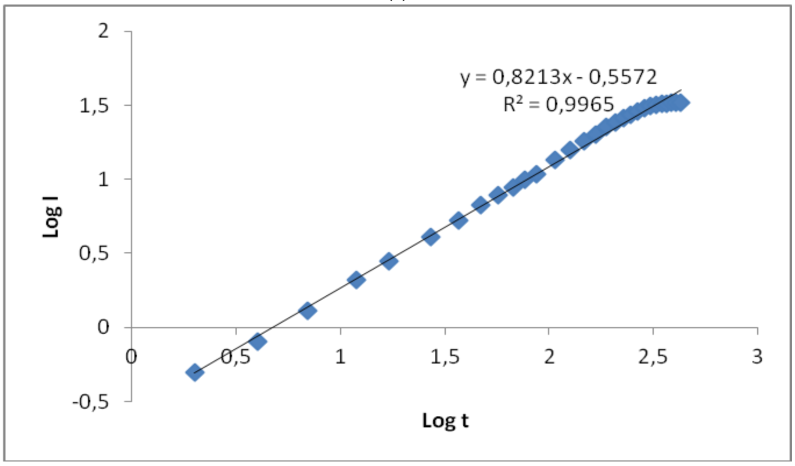
(a)



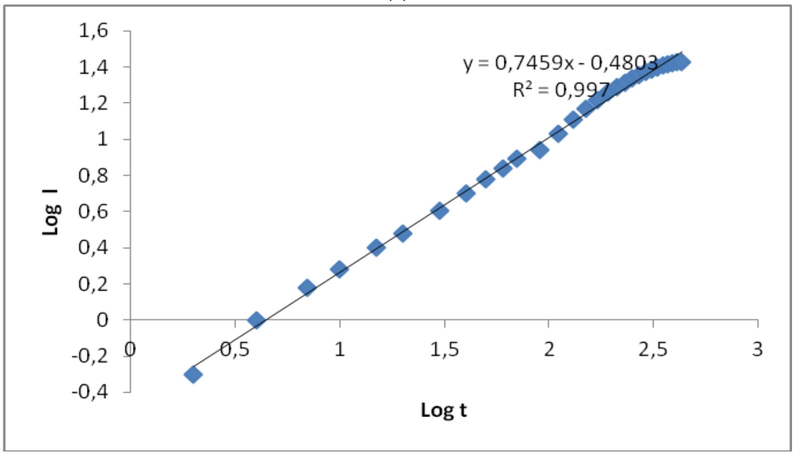
(b)


y = 0,8163x - 0,5414
R² = 0,9976
Log I
Logt
2
1,5
1
0,5
0
-0,5
0
0,5
1
1,5
2
2,5
3

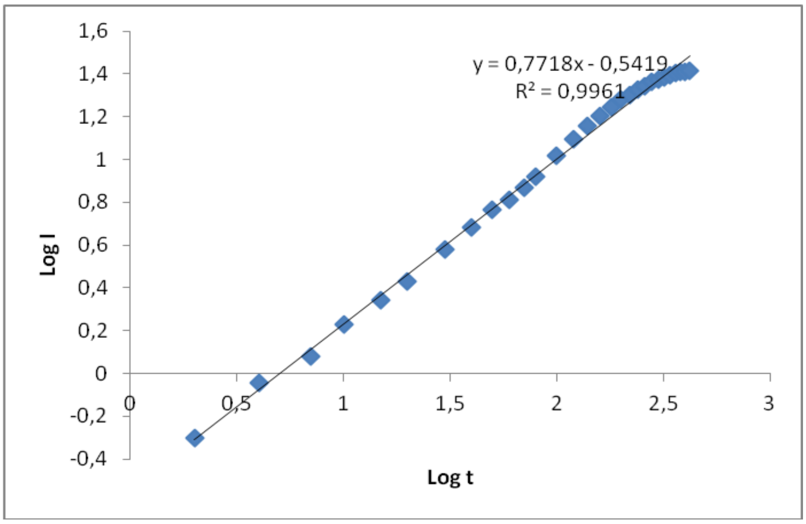
(c)


y = 0,8213x - 0,5572
R² = 0,9965
Log I
Log t
2
1,5
1
0,5
0
-0,5
0
0,5
1
1,5
2
2,5
3

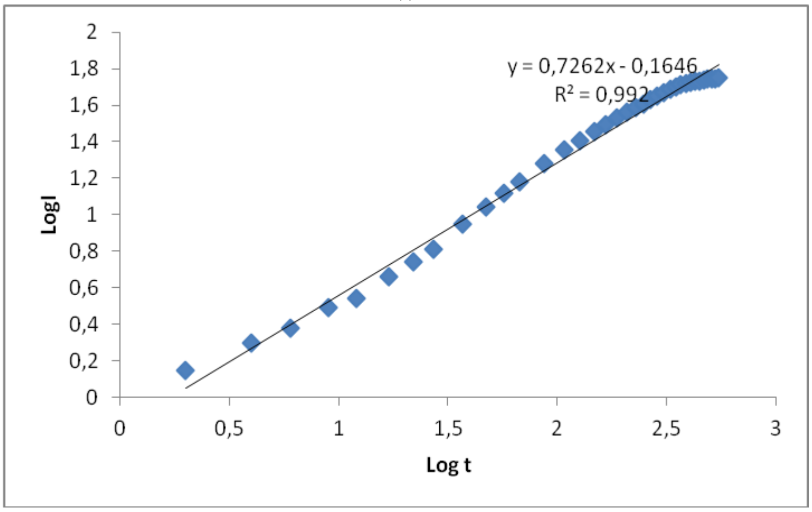
(d)


y = 0,7459x - 0,4803
R² = 0,997
Log I
Log t
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
0
0,5
1
1,5
2
2,5
3

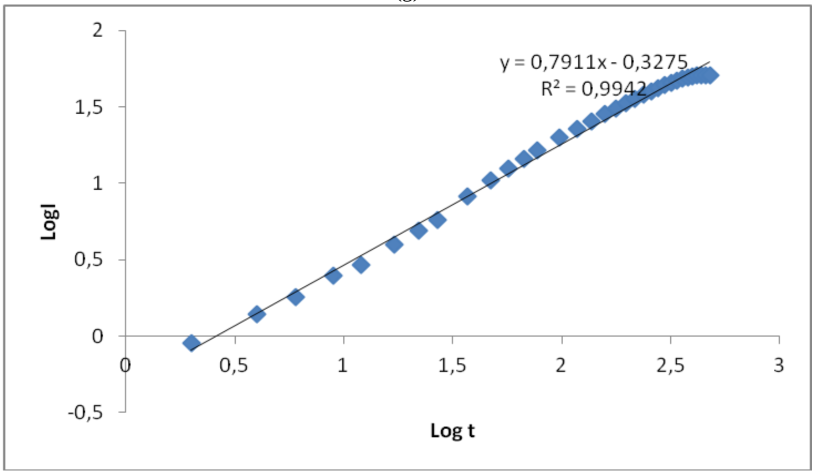
(e)


1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
Log I
0
0,5
1
1,5
2
2,5
3
Log t
y = 0,7718x - 0,5419
R² = 0,9961

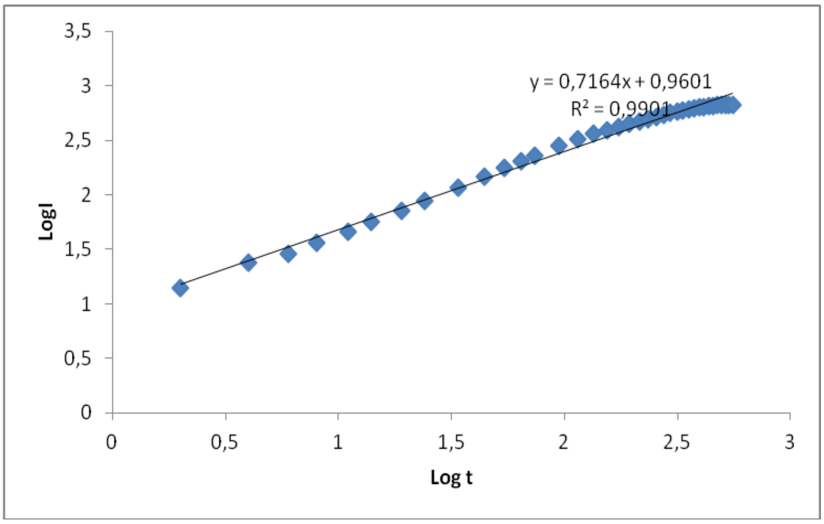
(f)


2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
LogI
0
0,5
1
1,5
2
2,5
3
Log t
y = 0,7262x - 0,1646
R² = 0,992

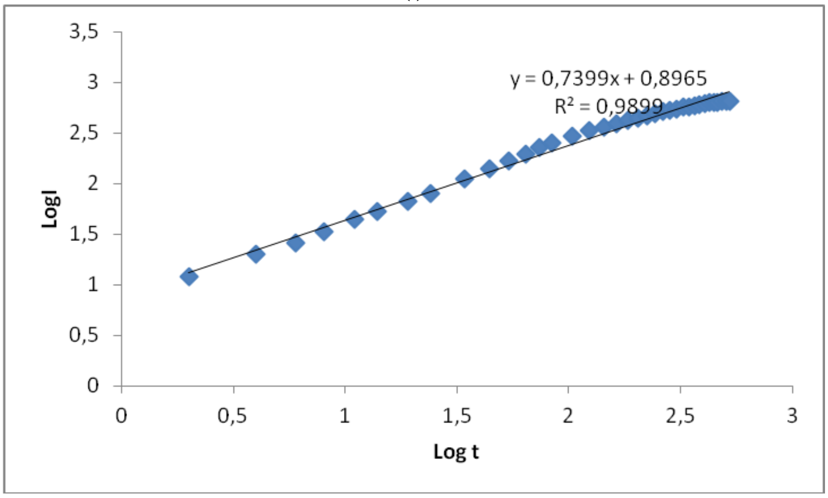
(g)


2
1,5
1
0,5
0
-0,5
LogI
0
0,5
1
1,5
2
2,5
3
Log t
y = 0,7911x - 0,3275
R² = 0,9942

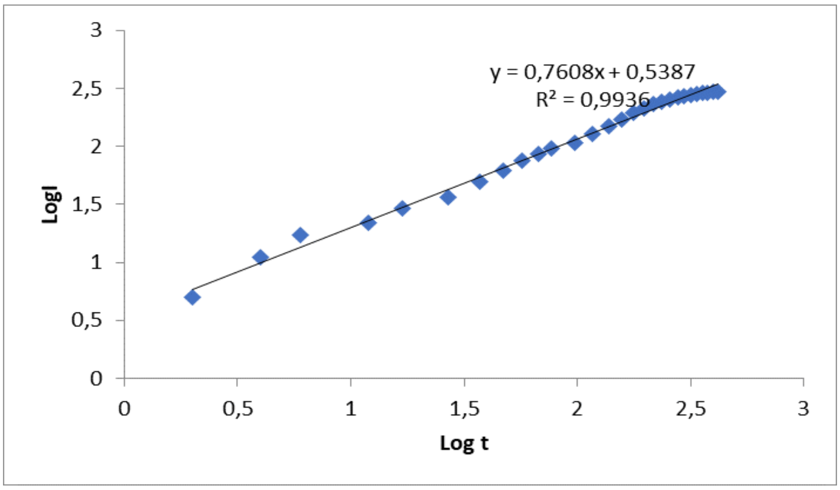
(h)


y = 0,7164x + 0,9601
R² = 0,9901
LogI
Log t

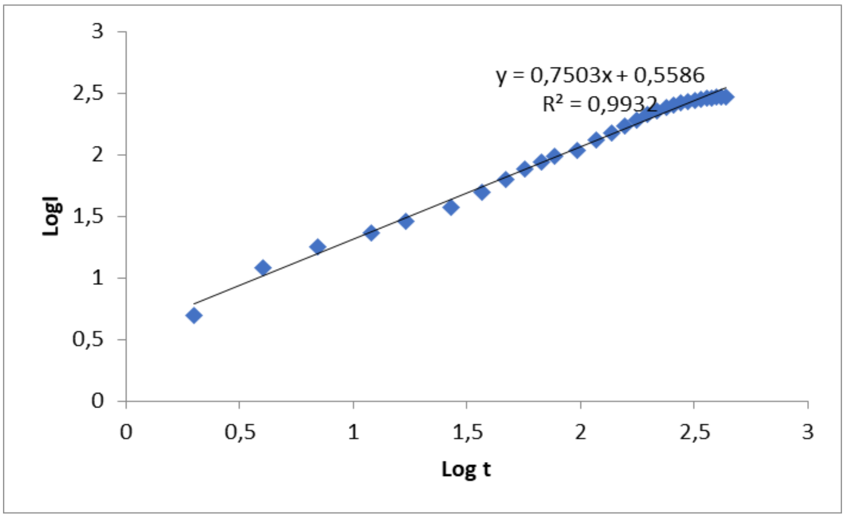
(i)


y = 0,7399x + 0,8965
R² = 0,9899
LogI
Log t

(j)


y = 0,7608x + 0,5387
R² = 0,9936
LogI
Log t

(k)



(l)

Fig. 4. Kostiakov infiltration curve for different plots:
(a) Plot1; (b) plot2; (c) plot3; (d) plot 4; (e) plot 5; (f) plot 6; (g) plot 7; (h) plot 8; (i) plot 9; (j) plot10; (k) plot11; (l) plot12

The low values of wilting point(θpf) and the field capacity value (θcc) is due to the dominant sandy texture in the different plots of our study site, for instance, soil aggregates could be found at all (Kotzé et al., 2013). The amount of plant-available water in relation to air-filled porosity at field capacity is often used to assess soil physical fertility (Peverill et al., 1999). The effect of soil texture on the WHC of soil is generally assumed to be positive, but the structural types and forms of particle in soil responsible for this effect and synergistic behavior with other soil properties are not well understood (Krulletal, 2004). Hence oasis soils texture may help to increase water storage and water use efficiency in these extremely water limited agrosystems, but precautions have to be arranged that any additional gain in water is not immediately lost through evaporation.

3.3. Hydrodynamic analysis of soil

Referring to Table 4 and Figure 4 summarizing the Kostiakov parameters (K and α) and the equations obtained for the various locations, 'k' ranged from 1,422 to 9,120. 'α' varied from place to place and ranged from 0,716 to 0,868. The infiltration equations estimated in this study were: $2.6t^{0.86}$, $1.2t^{0.74}$, $3.4t^{0.81}$, $3.6t^{0.82}$, $3.01t^{0.74}$, $3.47t^{0.77}$, $1.45t^{0.72}$, $2.12t^{0.79}$, $9.12t^{0.71}$, $7.87t^{0.73}$, $3.45t^{0.76}$, $3.61t^{0.75}$. .

A log I plot with log t gave the Kostiakov linear curves to evaluate the infiltration parameters. The slopes of these curves gave the values of 'α', while the values of 'K' were obtained from the anti-log of K according to equation (3).

For the two plots (1,2) and (7,8) there is a slight difference at the beginning of the curves, while the other plots are almost confused. The curves varied according to the variation in soil infiltration rate determined by the specific properties of the soil. Although the twelve plots have almost the same soil texture, different other factors can interact to cause a significant difference in soil infiltration rates. The majority of soil and water characteristics that affect infiltration rates are as follows : initial moisture content, surface condition, texture, hydraulic conductivity of the soil, porosity, degree of swelling of soil colloids, duration of irrigation or rain (Saxton and Rawls, 2006).The infiltration parameters obtained were positive (0.868,0.746, 0..816, 0.821, 0.745, 0.771, 0.726, 0.791, 0.716, 0.739, 0.76, 0.75) indicating that the soils were unsaturated at the time of the year during which the experiments were conducted.

4. Conclusion

The evaluation of the physical and hydrodynamic parameters of the soils of twelve plots in Degueche and the application of modeling was very effective in the estimation of soil infiltration parameters and might save time and reduce field measurement costs. The determination of physical parameters of the oasis soil (textures, bulk density, ϴcc, ϴpf,.) and the use of the kostiakov model to obtain water infiltration parameters and soil equations could be used to simulate the infiltration of these soils, thus saving time and cost of field measurements. The simulated infiltration could also help soil water management as well as conservative water resource practices in the region.

The findings coupled with field investigations indicate that the productivity of these agro-systems is closely related to irrigation water quality and soil proprieties on the one hand and on the dynamic balance soil-water regulated by the appropriate irrigation and drainage techniques on the other hand. The modeling of the evolution of these proprieties are crucial for the prediction of drought and desertification phenomena in Saharan Oases.

Conflict of interest

The authors declare that they have no conflict of interest.

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