Statistical methods to study soil infiltration rate in Kharga Oasis, Egypt.

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Introduction

Agricultural expansion in the Kahrga oasis, located in the western desert of Egypt (Fig. 1), strongly depends on irrigation. Hence, the infiltration rate is a key parameter for further development. In this study, we use principle component and multiple regression analyses to study the soil infiltration rate in Kharga Oasis.

Fig. 1. Location of the study area.

Methodology

The soil infiltration rate (IR) was measured using a double ring infiltrometer (Fig. 2) at 20 m intervals in a 120 m by 120 m plot, i.e., 6 rows by 6 columns or 36 sampling sites in total. The rate of water entering the soil from the inner ring was recorded versus time and IR (m/d) was determined when steady state was obtained.

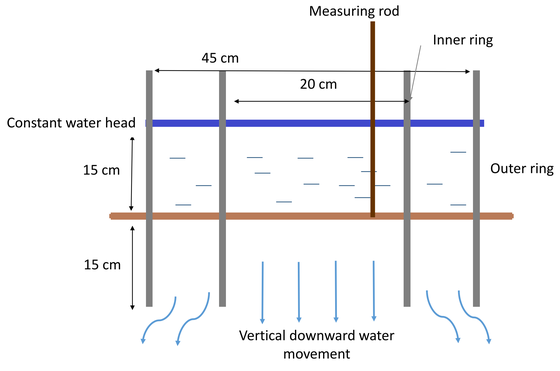

Fig. 2. Double ring infiltrometer setup used to measure IR.

At the same time and locations, soil samples were collected and analysed in the laboratory for hydraulic conductivity (K /m d^{-1}), texture (silt and clay fractions /%), carbonate content (CAR /kg kg^{-1}), sodium adsorption ratio (SAR), pH, electric conductivity (EC /S m^{-1}), water saturation (WP/ m^3 m^{-3}), field capacity (FC /m^3 m^{-3}), wilting point (WP /m^3 m^{-3}), and bulk density (BD/ kg m^{-3}).

Results

Statistical analysis shows that the infiltration rate is log-normally distributed (Fig. 3) as proven by the Kolmogorov-Smirnov test.

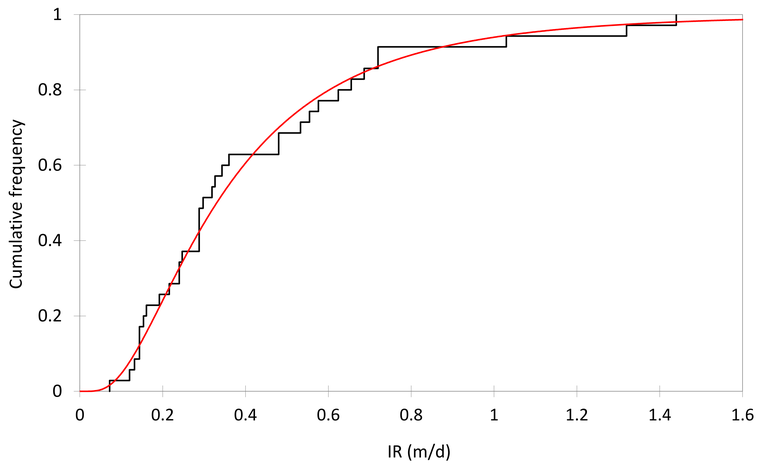

Fig. 3. Observed (black line) and fitted (red line) cumulative distribution of IR.

Principle component (PC) analysis is used to determine interrelationships between the soil parameters. Only the first two PCs are important (Fig. 4). PC1 represents soil structure as it is strongly related to WP, FC, WS and BD, while PC2 represents the soil texture as it is predominantly determined by CAR, silt and clay. The plot of factor loadings (Fig. 4) reveals that log(IR) is strongly positively linked to log(K) and BD, and negatively to WS, FC, WP, CAR and silt.

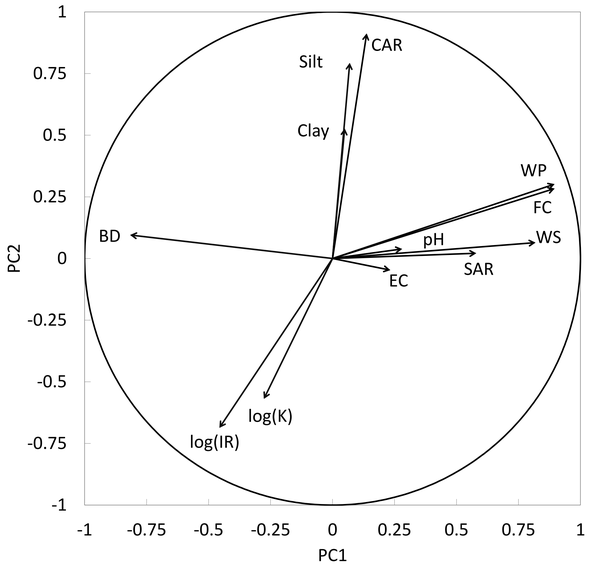

Fig. 4. Pot of PC factor loadings of all soil variables.

Multiple linear regression of $\log_{10}$(IR) shows that the most relevant factor to predict IR is $\log_{10}$(K) followed by CAR and clay fraction (Table 1), while all other soil parameters can be ignored. $\log_{10}$(K) is able to predict 30% of the variation of $\log_{10}$(IR) as experienced in the field observations, CAR can predict only 5% of the variation and the clay fraction another 5%. The most accurate equation to predict IR is given by:

$$\log_{10}(IR) = -0.2 + 0.11 \log_{10}(K) - 3.3\ CAR + 0.02\ Clay$$

60% of the variation of IR encountered in the field remains unaccounted for, and must be attributed to sampling and observation errors and most likely to natural randomness and heterogeneity of soil properties.

Table 1. Results of multiple linear regression analysis

N°	Variable	Coeff.	Stand. Dev.	Beta	t-stat	p-level
1	log(K)	0.17	0.04	0.55	3.8	0
	Intercept	-0.22				
	R^2 = 0.30	F = 14				0.001
2	log(K)	0.12	0.05	0.4	2.3	0.03
	CAR	-2	1.3	-0.3	-1.5	0.15
	Intercept	-0.05				
	R^2 = 0.35	F = 9				0.001
3	log(K)	0.11	0.05	0.4	2.0	0.05
	CAR	-3.3	1.6	-0.4	-2.0	0.17
	Clay	0.02	0.013	0.2	1.4	0.26
	Intercept	-0.2				
	R^2 = 0.40	F = 7				0.002

Conclusions

Soil infiltration rate is log-normally distributed. Principle component analysis shows that the soil infiltration rate is determined by soil structure and soil texture, where the soil structure is represented by related parameters as WP, FC, WS and BD and the soil texture by CAR, silt and clay. In addition log(IR) is strongly linked to log(K). Multiple linear regression analysis shows that only 40% of the variation in the infiltration rate can be predicted using hydraulic conductivity, soil carbonate content and clay content, while the rest of the variation remains unexplained.