Distributed large-scale unsaturated soil properties of a semi-arid area of Kairouan plain (Tunisia)

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ABSTRACT

Water resource management is a major issue in semi-arid regions, especially where irrigated agriculture is dominant for soils with highly variable clay content. Indeed, topsoil clay content has a significant importance on infiltration and evaporation processes and therefore in the estimate of the water crop requirement. Thus at large-, i.e. regional- scale, it is necessary to develop tools for topsoil clay content mapping using remotely sensed data. In this paper we present a method to estimate wilting point, field capacity volumetric water content and saturated hydraulic conductivity of the Kairouan plain (680 km^2), central Tunisia (North Africa), characterized by a semi-arid climate. The estimation of soil hydraulic properties was carried out by using three different methods at local scale. The first one is based on the Beerkan Estimation of Soil Transfer parameters (BEST) method, which provides local estimate of unsaturated soil hydraulic properties from a single-ring infiltration test. BEST results are obtained over six different topsoil texture classes along the Kairouan plain. Saturated hydraulic conductivity is high on both coarse textured and on some of the fine textured soils due to shrinkage cracking-macropore soil structure. The second method based on evaporation tests on different test plots, consists on analyzing soil moisture profile changes during the dry down periods. It allows defining the variation interval for both field capacity and welting point. These two first methods are compared to different pedotransfer functions (PTFs) used to estimate soil hydraulic properties as function of easy to measure parameters (i.e. dry bulk density, sand, silt and clay contents, organic matter and water retention). PTFs seek to establish statistical relationships between soil properties and water retention curve parameters and hydraulic conductivity. Statistical results show that Wösten (1999) PTF function is the most adapted for the studied region. It has the lowest RMSE values and provides the best modelling. This PTF will be used to map both wilting point and field capacity soil-water contents, which can be used to compute water crop requirements through Soil-Vegetation-Atmosphere models. This PTF is particularly interesting and easy to use with topsoil clay content map, which is illustrated for data obtained from a time series of Landsat TM5 data.

METHODOLOGY

Beerkan method (BEST) (Braud et al., 2005; Lassabatère et al., 2009)

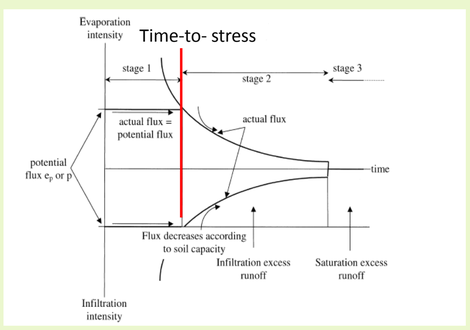
- To estimate soil hydrodynamic properties , the BEST method was used over main soil texture classes. The BEST method is a simple three-dimensional infiltration test under positive head conditions, made in cylinders of diameter ranging from 5 to 20 cm.
- These tests provide cumulative infiltration as a function of time.
- Measurements of particle size, initial and final water content and dry bulk density are also required.
- Derivation of shape parameters of the retention curve. Five fractions must be extracted from the analyzed soil samples.
- Optimization of normalization parameters : hydraulic conductivity and air entry pressure obtained from the expression of sorptivity . These parameters depend on soil structure.

Infiltration tests with the Beerkan method

Evaporation tests (Boulet et al., 2009)

- The evaporation test consists on analyzing dry down periods over bare soils after a rainfall event and to detect the time-to-stress.
- A modeled Time-to-stress is calculated for all interstorm periods for which a reduction in evaporation due to water shortage is observed using a range of realistic hydraulic parameter values.
- To detect Time-to-stress we used the albedo data, soil moisture and soil temperature

Evaporation stages and time-to-stress detection



Pedotransfer functions

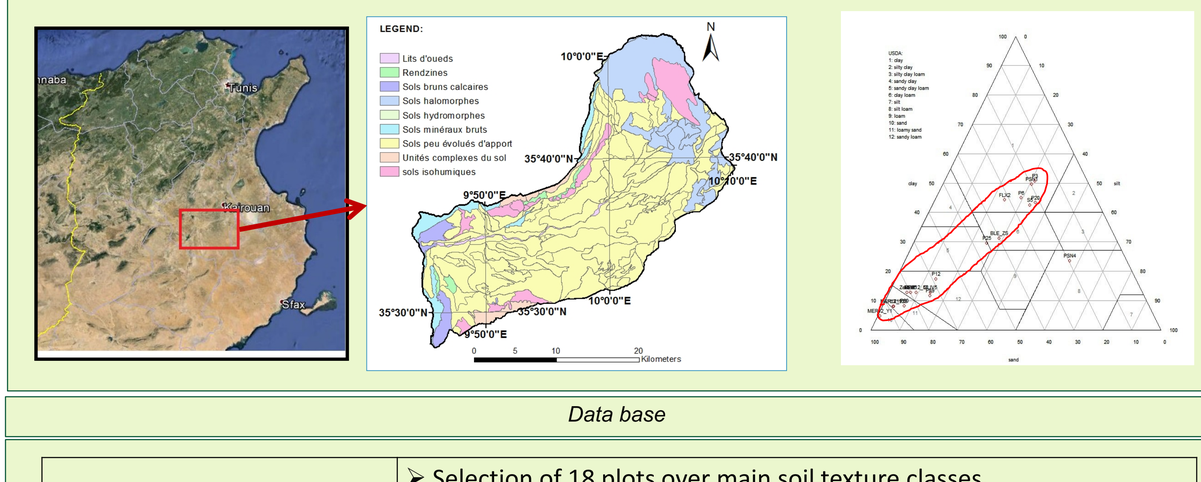
- Pedotransfer functions seek to establish statistical relationships between available soil properties (bulk density, particle size, organic matter content) and the parameters of the retention curve and the hydraulic conductivity .
- Several pedotransfer functions has been used (campbell,1985; Wosten,1997; Wosten,1999 and Saxton et al., 1986)

Analysis of dry down periods by the detection of the time-to-stress parameter to complete extracted information from infiltration tests and to select the adapted pedotransfer function

STUDY SITE AND DATA BASE

- The Kairouan plain is located in central of Tunisia (North Africa).
- The site is mostly flat.
- Climate: semi-arid with limited water resources.
- The dominant major soil group is fluvisols (SOTWIS Tunisia, 2010)
- The clay content is ranging from 50 to 700 g/kg

Study area location and Distribution of 18 analyzed soil samples over the Kairouan plain across the USDA soil triangle texture



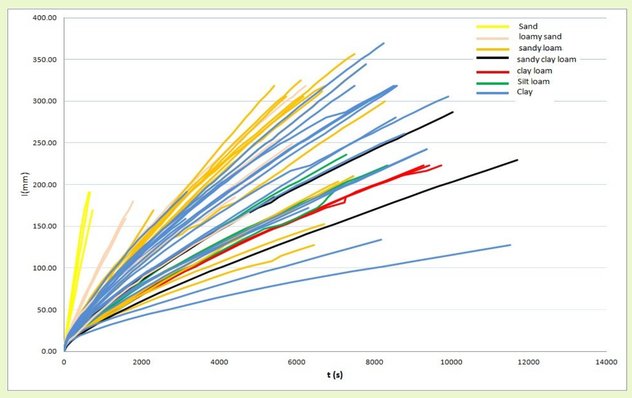
Data base

Ground measurements	➢ Selection of 18 plots over main soil texture classes. ➢ 55 infiltration tests were done by using the BEST method. ➢ Soil moisture measurements were carried out on 10 fields.
Remote sensing data	➢ Landsat TM5 data (2009) ➢ ASAR/ENVISAT radar data

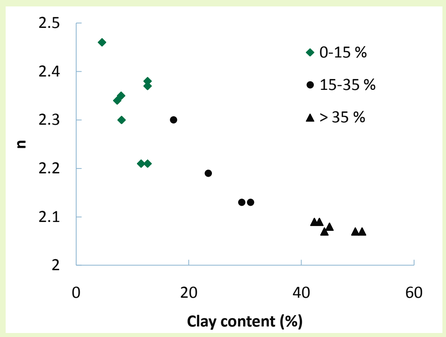
RESULTS

Hydrodynamic soil properties (BEST)

Cumulative infiltration as function of time and as texture soil classes

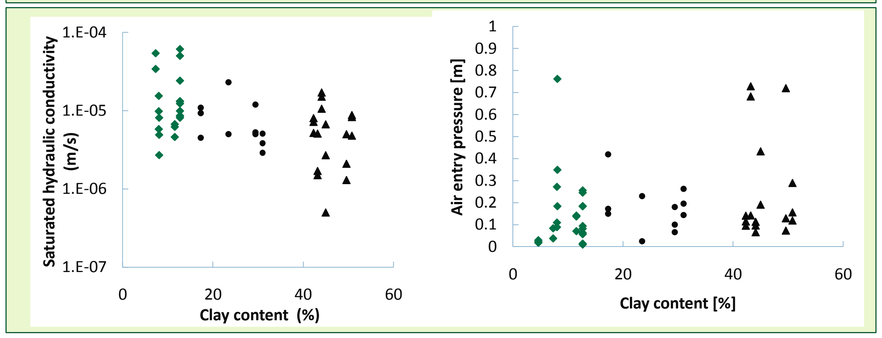


Shape parameter "n"



- « n » decreases with high values of clay content

Parameter of normalization: Ks and hg



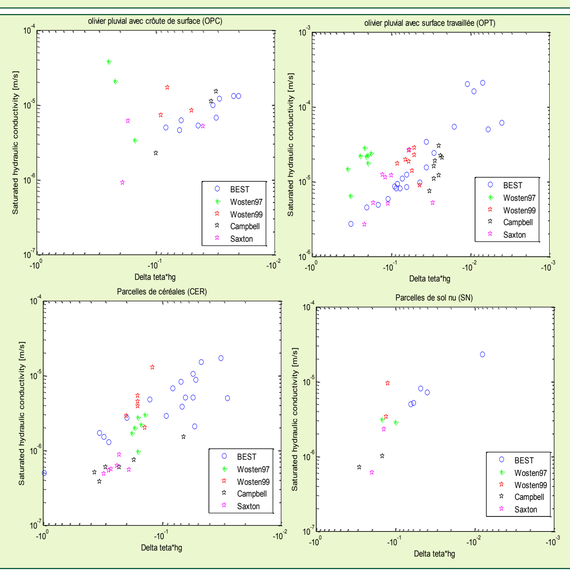
When analyzing saturated hydraulic conductivity for different clay content values, we can classify the Ks values into 03 classes :

- Clay content ranging from 0 to 15 % for sandy soils with a high infiltration rate.
- Clay content between 15 and 35 % for loamy soils.
- Clay content above 35 % for clayey soils with a low infiltration rate.

- **for high values of hydraulic saturated conductivity low values of air entry pressure were observed**

Comparison between BEST and pedotransfer functions

Saturated hydraulic conductivity as function of air pressure entry



- To compare BEST to pedotransfer functions we used statistical indicators like RMSE, Nash coefficient and CRM.
- For sandy soils (Pluvial olives): Wosten 1999 pedotransfer function estimates "ks" and "hg" with low RMSE values.
- For clayey soils Campbell and Wosten 1999 estimate "ks" and "hg" with low RMSE values.
- Campbell and Wosten 1999 are well adapted to estimate saturated hydraulic conductivity "ks" and air entry pressure for our study area. These pedotransfer functions depend on texture (clay content) and on structure (bulk density)

Conclusions

- The BEST method was used to derive soil properties. It's easy to implement and cheap.
- Wosten (1999) and Campbell (1985) are the most adapted pedotransfer functions for our study area. They can be applied on clay content map to map soil properties.
- We have to analyze dry down periods and to observe the time-to-stress parameter by using albedo data, temperature and soil mois[illegible]

Acknowledgments

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