*Water Science and Engineering*, 2014, 7(4): 351-362
doi:10.3882/j.issn.1674-2370.2014.04.001

http://www.waterjournal.cn
e-mail: wse2008@vip.163.com

# A simplified dynamic method for field capacity estimation and its parameter analysis

Zhen-tao CONG*, Hua-fang LÜ, Guang-heng NI

*Department of Hydraulic Engineering, Tsinghua University, Beijing 100084, P. R. China*

**Abstract:** This paper presents a simplified dynamic method based on the definition of field capacity. Two soil hydraulic characteristics models, the Brooks-Corey (BC) model and the van Genuchten (vG) model, and four soil data groups were used in this study. The relative drainage rate, which is a unique parameter and independent of the soil type in the simplified dynamic method, was analyzed using the pressure-based method with a matric potential of −1/3 bar and the flux-based method with a drainage flux of 0.005 cm/d. As a result, the relative drainage rate of the simplified dynamic method was determined to be 3% per day. This was verified by the similar field capacity results estimated with the three methods for most soils suitable for cultivating plants. In addition, the drainage time calculated with the simplified dynamic method was two to three days, which agrees with the classical definition of field capacity. We recommend the simplified dynamic method with a relative drainage rate of 3% per day due to its simple application and clearly physically-based concept.

**Key words:** *field capacity; simplified dynamic method; pressure-based method; flux-based method; soil water; HYDRUS*

## 1 Introduction

Field capacity is widely used as an important concept and parameter in irrigation management, hydrological modeling, and ecohydrological studies. In irrigation management, the field capacity represents available soil water content, and irrigation depth is adjusted so that the soil water content can reach its field capacity (Brouwer et al. 1989). In hydrological modeling, the field capacity is an important parameter for simulating infiltration and evapotranspiration (Singh 1995). For example, in the SWAT catchment model, percolation occurs when the water content of soil layers exceeds the field capacity (Neitsch et al. 2005). In ecohydrological studies on water-controlled ecosystems, the field capacity is often used as a reference value triggering the control of soil water over plant water uptake (Rodríguez-Iturbe and Porporato 2004).

The field capacity has been defined in various ways. According to the classical definition given by Veihmeyer and Hendrickson (1931), the field capacity is the amount of water held in

This work was supported by the National Natural Science Foundation of China (Grants No. 51179083 and 91225302).

*Corresponding author (e-mail: *congzht@tsinghua.edu.cn*)

Received Nov. 11, 2013; accepted Jun. 14, 2014

soil after excess water has drained away, and the rate of water downward movement has materially decreased, which usually takes place within two to three days after a rain event or irrigation in pervious soils of uniform structure and texture. Although this definition is conceptually intuitive and sound, it does not provide a quantitative measure with respect to the time when excess water has drained away and when the rate of water downward movement has materially decreased after free drainage is negligible (Hillel 1998).

Quantitative measurement is indispensable for estimating the field capacity in experiments, and typically involves wetting a covered soil profile and waiting for drainage to cease (Twarakavi et al. 2009). Such measurement can measure a matric potential or a drainage flux that represents the field capacity status. The pressure-based method was introduced by Richards and Weaver (1944) to estimate the field capacity with the soil water content at a matric potential of −1/3 bar (equivalent to −33 kPa and −348 cm of water column) based on their laboratory experiments. The choice of −1/3 bar was confirmed in a later study by Colman (1947), and it has been widely adopted in modern hydrology (Dingman 1994; Hillel 1998). The field capacity defined through the matric potential varies with the soil texture, depending on the soil water retention characteristics. Romano and Santini (2002) suggested the use of a matric potential of −100 cm of water column for sandy soils, −350 cm of water column for medium-textured soils, and −500 cm of water column for clayey soils, to reflect their different water retention characteristics. On the other hand, the flux-based method proposed by Nachabe (1998) estimates the field capacity with the soil water content at a free drainage flux of 0.005 cm/d, which is two orders of magnitude lower than the average potential evapotranspiration. In Nachabe (1998), it was assumed that the water content was uniform within a given soil horizon after a period of infiltration and remained that way during drainage, meaning that water flow occurred solely in response to the gravity, and the free drainage flux was equal to the unsaturated soil hydraulic conductivity. This assumption is reasonable according to the definition of field capacity with free drainage at the bottom, and it is easily verified with the HYDRUS-1D model. This approach is equivalent to determining the soil water content at a given unsaturated hydraulic conductivity based on the unsaturated hydraulic conductivity model. The field capacity defined based on the drainage flux also varies with the soil texture. For example, Meyer and Gee (1999) suggested estimating the field capacity with the soil water content at a free drainage flux of 0.001 cm/d for sand and 0.01 cm/d for clay, and Sun and Yang (2013) took the value of 0.01 cm/d of the drainage flux.

These two static methods, i.e., the pressure-based method and the flux-based method, are straightforward and simple. However, they are inadequate for characterizing the dynamic process of water drainage from soils after wetting events and accounting for the influence of other important factors, such as the soil thickness, on the estimated field capacity. The dynamic method, on the other hand, estimates the field capacity by simulating the soil water dynamics after wetting events. The boundary conditions used in the dynamic method are free drainage at the bottom and zero flux at the top, which are consistent with the field capacity definitions. In Zacharias and Bohne (2008), the soil water dynamics after a wetting event in a