



PTFs for predicting LLWR from various soil attributes including cementing agents

Mohammad Reza Neyshabouri^{a,*}, Zahra Kazemi^a, Shahin Oustan^a, Mohammad Moghaddam^b

^a Soil Sci. Dept., Univ. of Tabriz, 51666 Tabriz, Iran

^b Agron. and Plant Breeding of Tabriz, 51666 Tabriz, Iran

ARTICLE INFO

Article history:

Received 31 May 2013

Received in revised form 4 February 2014

Accepted 14 February 2014

Available online 11 March 2014

Keywords:

Cementing agents

Soil resistance curve

Water retention curve

Moisture coefficients

ABSTRACT

Least limiting water range (LLWR), the range of soil water content at which plant growth is least limited by water potential, soil aeration or soil mechanical resistance is routinely calculated from water release curve (WRC) and soil resistance curve (SRC). There is no enough information about the effect of various soil attributes including cementing agents (metal oxides, carbonates and organic carbon) on LLWR. The present study evaluates the effect of several soil characters, including cementing agents, texture, sodium adsorption ratio (SAR), bulk density (D_b) and cation exchange capacity (CEC) on LLWR and develops proper pedotransfer functions (PTF) for its prediction. Disturbed and undisturbed samples of 32 soils with wide range of properties were collected from Ahar, Horand and Tabriz regions, northwest of Iran. Undisturbed soil samples were equilibrated to matric pressures of 0.001, 0.004 MPa in hanging columns and of 0.01, 0.03, 0.1, 0.5, 1.5 MPa in pressure plate and the equivalent water contents were measured gravimetrically. Penetration resistance of each sample at the mentioned matric pressures was measured by a hand cone penetrometer. Soil water contents at field moisture capacity (θ_{fc}) and permanent wilting point (θ_{wp}) (matric pressures of 0.01 and 1.5 MPa, respectively) were predicted using WRC; water content at 2 MPa penetration resistance (θ_{sr}) was estimated from SRC. Water content at 10% air filled porosity (θ_{afp}) was taken as $\theta_s - 0.1$ and LLWR computed from the above moisture coefficients. The relative influence of soil characters, as independent variables on the moisture coefficients (θ_{afp} , θ_{fc} , θ_{sr} , θ_{wp}) and on LLWR was evaluated separately using multiple linear stepwise regression and then appropriate pedotransfer functions were developed to predict LLWR. The relative influences of soil attributes on the moisture coefficients and on LLWR were not similar. Clay content, bulk density (D_b) and ammonium oxalate extractable iron produced considerable effects on LLWR. Grouping the examined soil samples according to D_b or clay content led to more accurate prediction of LLWR ($R^2 = 0.86$ and 0.76 , respectively) than forcing all samples in a single group ($R^2 = 0.31$). In samples with $D_b \geq 1.4 \text{ Mg/m}^3$, citrate-bicarbonate-dithionate extractable aluminum, as cementing agent, turned to be the second most influential soil attribute (after clay) on LLWR while the latter was not affected by calcium carbonate equivalent. Even though SAR significantly ($P < 0.01$) affected both θ_{wp} and θ_{fc} , its net effect on LLWR was insignificant.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Least limiting water range (LLWR), the range of the soil water content at which plant growth is least limited in relation to water potential, aeration and mechanical resistance of the soil, has received a great attention during the last two decades (Fidalski et al., 2010; Lapen et al., 2004). Moreover, LLWR has been proposed as an indicator of soil productivity (Benjamin et al., 2003) and as a soil structural quality index (Olibone et al., 2010; Tormena et al., 1999) for the assessment of various management decisions at the field scale (Kay et al., 2006). LLWR is based on the concept introduced by Letey (1985). A large value of LLWR implies that soil is more resistant to the environmental stresses such as water shortage, soil aeration limitation and soil mechanical resistance. A small LLWR implies that plants grown in a

given soil may be more vulnerable to the imposed adverse conditions, and this soil may have a low productivity.

LLWR is calculated from four moisture coefficients (θ_{afp} , θ_{fc} , θ_{sr} and θ_{wp}), where θ_{afp} or θ_{fc} is assumed to be the upper limit of the available soil moisture to plants depending on either aeration or rapid drainage restricts the moisture availability. θ_{sr} or θ_{wp} is presumably the lower limit depending on either soil water potential or soil mechanical resistance creates restriction to water uptake. For calculation of LLWR, it is necessary to determine the relations between water potential (Ψ), soil mechanical resistance and soil aeration with θ . The relation between θ and Ψ is water retention curve (WRC) that can be described by several models. At high water contents Van Genuchten (1980) model seems more appropriate. Other WRC models such as those of Kosugi (1994) and Groenevelt and Grant (2004) may fit the experimental data well in a wide range of water potentials. da Silva et al. (1994) proposed a power-form function for WRC with including D_b as an important variable affecting θ and Ψ relation.

* Corresponding author. Tel.: +98 91410106502; fax: +98 4113356006.

E-mail address: neyshmr@hotmail.com (M.R. Neyshabouri).

Soil mechanical resistance (SR) is also generally affected by θ and D_b . The relation between SR as a dependent variable and θ and D_b as independent variables has been recognized as soil mechanical resistance curve (SRC) by Busscher (1990). The θ_{sr} is considered water content at 2 MPa penetration resistance beyond that root growth is practically ceased. It may be predicted from SRC. Soil aeration condition could also be described as a function of air filled porosity; an adverse relation between air filled porosity and water content is expected.

There is little information about the effects of soil properties and management practices on LLWR (Kay et al., 2006). As mentioned earlier, several PTFs have been proposed to predict WRC and SRC from bulk density (D_b), organic carbon (OC) and clay content (%C) using multiple regression models (da Silva et al., 1994; Fidalski et al., 2010). The effect of other soil attributes and management practices on LLWR has not been fully investigated. Van den Berg et al. (1997) and Özdemir et al. (2000), for example, reported appreciable effects of cementing agents [citrate-bicarbonate-dithionite extractable iron and aluminum (Fe_d and Al_d) and calcium carbonate equivalent (CCE)] on available water capacity which conceptually is similar to LLWR. Therefore, it is expected that LLWR may also be affected by the above variables, specially, via their influence on SRC. Determining to what extent those variables may affect LLWR would be useful in terms of its implementation in the management practices influencing plant and soil behavior at the field scale. The objectives of the present study are evaluating the relative significance of various soil attributes including cementing agents on θ_{afp} , θ_{fc} , θ_{sr} , θ_{wp} and LLWR, and to develop pedotransfer functions for their prediction from pertinent soil properties.

2. Materials and methods

2.1. Soil sampling and measurements

The study area is located around Ahar, Horand and Tabriz cities (east Azerbaijan, Iran). Parent material, land use and climate of the sites from

Table 1
Parent material, land use and climate for the locations of the examined soils.

Soil no.	Parent material	Land use	Climate
1	Hydrothermally altered zone	Range land	Semi arid
2	Hydrothermally altered zone	Range land	Semi arid
3	Latite-ingnimberite	Uncultivated	Semi arid
4	Latite-andesite	Range land	Semi arid
5	Latite-ingnimberite	Range land	Semi arid
6	Latite-andesite	Range land	Semi arid
7	Latite-ingnimberite	Range land	Semi arid
8	Gabbro-pyroxenite	Range land	Semi arid
9	Monzolitite-granite-apelite	Range land	Semi arid
10	Latite-ingnimberite	Range land	Semi arid
11	Latite-ingnimberite	Range land	Semi arid
12	Latite-ingnimberite	Range land	Semi arid
13	Pyroxene-andesite	Range land	Semi humid
14	Pysroxene-andesite	Range land	Semi humid
15	Pysroxene-andesite	Range land	Semi humid
16	Pysroxene-andesite	Forest	Semi humid
17	Sandstone	Range land	Semi humid
18	Sandstone	Forest	Semi humid
19	Sandstone	Range land	Semi humid
20	Sandstone	Range land	Semi humid
21	Sandstone	Range land	Semi humid
22	Sandstone	Range land	Semi humid
23	Marly limestone	Forest	Semi humid
24	Marly limestone	Uncultivated	Semi humid
25	Sandstone	Range land	Semi humid
26	Sandstone	Range land	Semi humid
27	Sandstone	Range land	Semi humid
28	Marly limestone	Range land	Semi humid
29	Silt conglomerate	Range land	Semi humid
30	Silty shale	Range land	Semi humid
31	Tuff conglomerate	Farm	Semi arid
32	Tuff conglomerate	Horticulture	Semi arid

Table 2

Physico-chemical properties and their statistics for the examined soils.

Property	Maximum	Minimum	Mean	CV (%)
Mn_o (mg kg ⁻¹) ^a	1065.5	36.0	307.1	94.27
Al_d (mg kg ⁻¹) ^b	867.0	167.0	510.1	40.54
Fe_o (mg kg ⁻¹) ^c	3357.4	289.8	1184.5	76.05
Fe_d (mg kg ⁻¹) ^d	11166.8	2557.6	5146.1	44.0
D_b (Mg m ⁻³) ^e	1.6	1.1	1.3	9.6
SAR (mmol _c l ⁻¹) ^{-1/2f}	8.9	0.1	1.2	90.2
CEC (cmol _c kg ⁻¹) ^g	74.4	8.9	26.6	51.8
OC (%) ^h	4.1	0	1.7	63.2
CCE (%) ⁱ	30.4	2.5	1.7	53.4
Clay (%) ^j	34.3	7.1	20.5	35.8

^a Mn_o and ^c Fe_o = ammonium oxalate extractable manganese and iron respectively; ^b Al_d and ^d Fe_d = citrate-bicarbonate-dithionite extractable aluminum and iron, respectively; ^e D_b = bulk density; ^fSAR = sodium adsorption ratio; ^gCEC = cation exchangeable capacity; ^hOC = organic carbon; ⁱCCE = calcium carbonate equivalent; ^jClay = clay percent.

where the examined soils were collected are listed in Table 1. All sites are located at semi-arid to semi-humid region but with various parent materials and land uses (farm, forest, horticulture, range land and uncultivated).

Undisturbed samples from 32 soils (0–5 cm layer in five or six replicates, totally 188 samples) were gathered using sampling cylinders with 5.6 cm diameter and 4.0 cm height. Bulk densities (D_b) were determined from these cores (Grossman and Reinsch, 2002). Disturbed samples from the same depth were also taken to determine soil properties including texture (Gee and Or, 2002), organic carbon (OC) (Nelson and Sommers, 1996), calcium carbonate equivalent (CCE) (Nelson, 1982), sodium adsorption ratio (SAR) (Rhoades, 1996), cation exchange capacity (CEC) (Rhoades, 1982), citrate-bicarbonate-dithionite extractable iron and aluminum (Fe_d and Al_d) (Courchesne and Turmel, 2007) and ammonium oxalate extractable iron and manganese (Fe_o and Mn_o) (McKeague and Day, 1966). Among the mentioned properties only the effects of D_b , OC and clay content on LLWR have been investigated (da Silva and Kay, 1997; Fidalski et al., 2010). The other soil attributes and their rules on LLWR have almost remained untouched and therefore, we included those attributes in our investigation.

2.2. Determination of WRC and SRC

Water retention curve was characterized by measurement of soil water contents after saturation of the undisturbed core samples by 0.01 M CaCl₂ solution and then equilibrating to the matric pressures of 0.001, 0.004 MPa in hanging column and to 0.01, 0.03, 0.1 MPa in pressure plate apparatus (da Silva and Kay, 1997). We used that solution instead of deionized water to prevent soil swelling or dispersion upon saturation (Klute, 1986).

The soil mechanical resistances at those matric pressures were directly measured in core samples by a hand cone¹ penetrometer. In each core only one penetration measurement was allowed. The SR measurement at 0.5 and 1.5 MPa was performed in a slightly different way. The moisture contents at the two potentials ($\theta_{0.5}$ and $\theta_{1.5}$) were obtained in disturbed samples prepared from the fine earth (<2 mm) inside rubber ring with 2.56 cm diameter and 1 cm height that was placed in the pressure plate apparatus. After determining $\theta_{0.5}$ and $\theta_{1.5}$, the undisturbed samples were exposed to the atmosphere in laboratory conditions and allowed to evaporate much of their moisture until approaching the pre-determined weight equivalent to about $\theta_{0.5}$ and $\theta_{1.5}$. This was detected by knowing the pre-measured air-dried weight of each sample and by regularly weighting the samples after letting the evaporation to occur from the soil cores for a given period of time. At this step, in order to obtain uniform moisture throughout the cores, they were wrapped in plastic sheet and stored for a week. It was

¹ Hand penetrometer for top layers, type IB.

Download English Version:

<https://daneshyari.com/en/article/6408864>

Download Persian Version:

<https://daneshyari.com/article/6408864>

[Daneshyari.com](https://daneshyari.com)