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APPLIED ASPECTS OF PEDOTRANSFER MODELLING IN THE SOIL PHYSICS

Purpose. To consider some examples of pedotransfer models use. **Methods.** Statistics, mathematical modeling. **Results**. On the basis of mass experimental material which is available in a database «Soil properties of Ukraine» are developed linear and nonlinear pedotransfer models for the description of equilibrium bulk of density, soil-hydrological constants and structure. As base parameters in models data of humus contents and physical clay are used. **Conclusions.**Various applied aspects of pedotransfer modelling mainly in the soil physics are proved, which, we hope, will promote popularization of this perspective direction.

Key words: pedotransfer model, soil property, soil physics

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ПРИКЛАДНІ АСПЕКТИ ПЕДОТРАНСФЕРНОГО МОДЕЛЮВАННЯ У ФІЗИЦІ ГРУНТІВ

Мета. Розглянути деякі приклади використання педотрансферніх моделей. **Методи.** Статистичний, математичне моделювання. **Результати.** На підставі масового експериментаьного матеріалу, наявного в базі даних «Властивості ґрунтів України» розроблені лінійні й нелінійні педотрансферні моделі для опису рівноважної щільності будови, ґрунтово-гідрологічних констант і структурного складу. Як базові показники в моделях використано дані вмісту гумусу й фізичної глини. **Висновки.** Обґрунтовано різні прикладні аспекти педотрансферного моделювання головним чином у фізиці грунтів, що, сподіваємося, буде сприяти популяризації цього перспективного напрямку.

Ключові слова: педотрансферна модель, властивості грунтів, фізика грунтів

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ПРИКЛАДНЫЕ АСПЕКТЫ ПЕДОТРАНСФЕРНОГО МОДЕЛИРОВАНИЯ В ФИЗИКЕ ПОЧВ

Цель. Рассмотреть некоторые примеры использования педотрансферних моделей, которые, надеемся, будут содействовать популяризации этого перспективного направления. **Методы.** Статистический, математическое моделирование. **Результаты.** На основании массового экспериментаьного материала, имеющегося в базе данных «Свойства почв Украины» разработаны линейные и нелинейные педотрансферные модели для описания равновесной плотности сложения, почвенно-гидрологических констант и структурного состава. В качестве базовых показателей в моделях использованы данные содержания гумуса и физической глины. **Выводы.** Обоснованы различные прикладные аспекты педотрансферного моделирования главным образом в физике почв, что, как мы надеемся, будет способствовать популяризации этого перспективного направления.

Ключевые слова: педотрансыерная модель, свойства почв, физика почв

Introduction

History of pedotransfer models development and their applied aspects are widely described in the literature (E.V.Shein, etc., 2006). Pedotransfer models allow to determine soil properties, using for this purpose others which will be measured easier and are cheapier to obtain. J. Bouma (1989) – one of active adherents of application of models, wrote, that it is - «transfer of data we have, in data we need». As base in models data of texture, bulk of density, the contents of organic substance more often are used. With their help we can count soil-hydrological constants, physico-mechanical and technological properties, migration of a moisture and substances, estimate opportunities of soils to form micro- and a macrostructure.

Realization of pedotransfer modelling tasks and development of new types of models will allow to develop a direction in the soil science, connected with forecasting, various types of estimations and, finally, management.

The purpose of article is to consider some examples of use of pedotransfer models which, we hope, will promote popularization of this perspective direction.

Technique and objects of modelling

Models describing macrostructure, equilibrium bulk of density and soil-hydrological constants, and as base parameters - data of texture and the contents of humus, available in a database «Soil Properties of Ukraine» are used. The base is created in laboratory of soil geoecophysics of National Scientific Centre «O.N. Sokolovsky Institute for Soil Science and Agrochemistry Research (T.M. Laktionova, etc., 2012). From a database the indices of physical clay and humus contents (base parameters) and the contents of agronomical useful fraction of structure in the size of 10-0,25 mm, its water-stability, bulk of density, humidity steady wilting of plants, the least moisture capacity and a range of an active moisture (functional parameters) arable layer of soil have been taken. All initial information on base and functional parameters has been systematized depending on the humus contents and concerning the basic classes of texture (tab. 1 and 2). Unfortunately, it was not possible to use the important factor of formation of water-physical properties - a saturation colloid complex by calcium. However, to our opinion, such loss was not so important, as the majority of arable soil in the Ukraine (except for soil of Polesye) are developing on loesses and loesslike loams and the contents of calcium in them differs not so considerably. For this reason we considered minor variability of this parameter in

Table 1

Average values of soil water-physical properties depending on the contents of humus

Parameters	**The humus contents, %**																	
	<1,5		*1,5-2,0*		*2,0-2,5*		*2,5-3,0*		*3,0-3,5*		*3,5-4,0*		*4,0-4,5*		*4,5-5,0*		*>5,0*	
	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*
Equilibrium bulk of density, gr/cm^3	1,50	317	1,37	62	1,35	65	1,30	56	1,29	58	1,24	49	1,23	35	1,18	29	1,06	88
Humidity steady wilting of the plants, %	8,5	139	9,6	54	9,7	66	9,4	69	10,6	48	10,8	55	10,7	76	11,3	61	12,6	164
The least moisture capacity, %	20,1	80	23,4	9	25,9	13	28,6	11	25,6	4	28,2	4	30,6	2	33,6	1	29,4	2
Range of the active moisture, %	11,6	79	14,2	9	17,4	13	17,9	10	16,4	4	15,5	4	20,3	2	19,8	1	15,9	2
The contents of physical clay (<0,01мм), %	34,7	656	44,2	187	46,7	192	47,1	172	50,2	153	52,2	170	55,7	156	54,4	140	55,6	329
The contents of macroaggregates 0, 25-10 мм (dry sifting), %	43,6	26	61,8	11	57,3	23	57,6	47	61,1	55	56,1	75	60,7	38	63,2	15	79,8	39
The contents} of waterproof aggregates > 0,25 mm, %	52,3	29	46,8	12	46,2	28	47,0	55	42,2	63	41,1	86	51,4	56	60,4	39	67,4	120

X – average value of sample, n – number of dates in sample

Table 2

Average values of soil water-physical properties on classes [1] of texture

Parameters	Classes of soil texturев																	
	1		*2*		*3*		*4*		*5*		*6*		*7*		*8*		*9*	
	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$	*n*
Equilibrium bulk of density, gr/cm^3	5,9	22	8,7	147	17,5	307	26,0	483	39,4	1172	52,1	1268	59,3	1093	66,8	921	83,5	57
Humidity steady wilting of the plants, %	1,67	27	1,64	127	1,53	281	1,39	343	1,35	869	1,34	809	1,33	674	1,34	509	1,32	40
The least moisture capacity, %	1,5	22	1,9	65	3,7	217	7,0	232	9,5	680	11,5	693	13,4	583	13,7	461	16,4	35
Range of the active moisture, %	10,8	17	11,2	45	16,2	178	21,9	197	23,8	736	26,1	626	26,6	520	27,1	433	32,6	31
The contents of physical clay (<0,01мм), %	9,8	11	9,8	38	12,9	164	15,0	189	14,8	578	14,9	603	13,6	502	13,4	422	15,9	30
The contents of macroaggregates 0, 25-10 мм (dry sifting), %	–	–	–	–	–	–	52,3	53	59,1	363	64,4	495	63,6	398	67,7	166	39,4	8
The contents} of waterproof aggregates > 0,25 mm, %	–	–	–	–	–	–	45,1	52	45,4	359	50,5	494	52,2	396	54,9	164	46,0	8

[1] 1 – sandy; 2 – clay-sandy; 3 – loamy sand; 4 – light loamy; 5 – middle loamy; 6 – heavy loamy; 7 – light clay; 8 – middle clay; 9 – heavy clay.

soils of the country. However, given remark does not touch of podsolised soils, process of podsolisation in which (especially under condition of an average and strong degree) is accompanied by noticiable descending migration of calcium and deterioration of soil water-physical properties.

Data have been processed with the purpose to obtain 1 and 2-factorial linear and quadratic pedotrasfer models. Their reliability has been checked up by means of factor of determination and other standard estimations. Data processing was executed by O. N. Bigun.

Results of researches

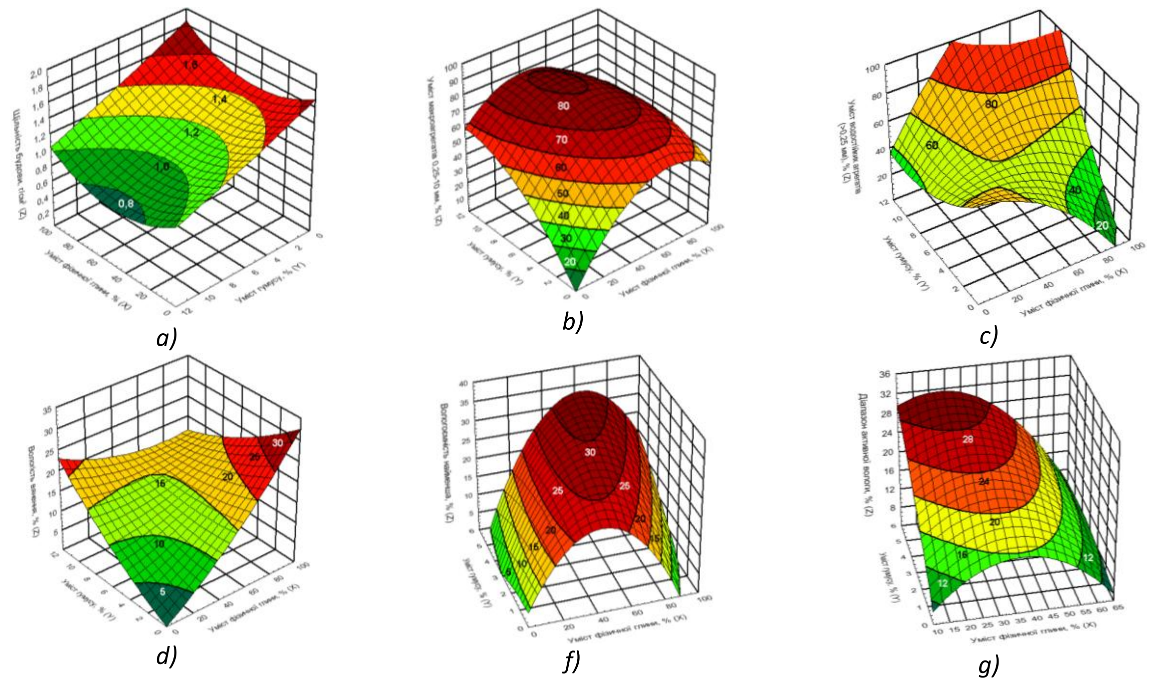
Mathematical data processing has allowed to receive models of a linear and quadratic kind. More reliable have appeared models for bulk of density and soil-hydrological constants (humidity steady wilting of plants – HW and the least moisture capacity – MC), less reliable (however authentic, considering mainly significant sizes of samples) – for other functional parameters. Linear models were simplier and more clear, but a little less correct (tab. 3). Pedotransfer models of a quadratic kind for definition physical and water-physical properties of soil on contents of humus and physical clay are shown on fig.1.

Pedotrahsfer models can have various application. For example, we can use them for functional parameters forecasting with base parameters variations. It is known, that approximately for 50 years the average humus contents in arable soils of the country has decreased from 3,5 down to 3,1 %, or on 0,008 % in a year (V. O. Grerov ets., 2011). If the level of land tenure will be kept at a present level in 50 years the equilibrium soil bulk of density will increase on 0,1 gr/cm³ and it will mean falling productivity on 6 t/hectares a year (according to normative estimations of influence of density for a crop –

Table 3

Pedotransfer model of linear and quadratic kind and their statistical estimations

Functional parameters	**Factor of determination**	**The standard error**	**Fisher's Criterion**
Linear model			
Equilibrium bulk of density, gr/cm³	Z = 1, 5606-0,0011* x-0,0664*y		
	0,58	**0,14**	**(2,662)=464,57**
Agronomical useful aggregates in the size of 0,25-10 mm, %	Z = 35,8572+0,3937*x+3,4445*y		
	0,17	**18,10**	**(2,246)=25,024**
Waterproof aggregates > 0,25 mm, %	Z = 43,151+0,0262*x+3,4798*y		
	0,15	**15,79**	**(2,245)=21,437**
HW, %	Z =1,257+0,2362* x-0,0698*y		
	0,65	**3,41**	**(2,177)=166,54**
MC, %	Z = 8,1692+0,3347*x+1,1114*y		
	0,78	**3,89**	**(2,64)=111,38**
Range of the active moisture, %	Z = 12, 5779-0,0054*x+1,5942*y		
	0,43	**2,58**	**(2,13)=4,8319**
Квадратическая модель			
Equilibrium bulk of density, gr/cm³	Z = 1, 6929-0,0103* x-0,0645*y+0,0001*x²- -0,0001*x*y+0,0006*y²		
	0,63	**0,13**	**(5,659)=223,62**
Agronomical useful aggregates in the size of 0,25-10 mm, %	Z = -0,7335+1,5621*x+9,5318* y-0,0113*x²- -0,0478*x* y-0,391*y²		
	0,20	**17,86**	**(5,243)=12,234**
Waterproof aggregates > 0,25 mm, %	Z = 72, 8434-0,1096* x-7,1738* y- 0,0077*x²++0,1619*x*y+0,3427*y²		
	0,22	**15,23**	**(5,242)=13,474**
HW, %	Z = 0,0945+0,2192*x+1,2117*y+0,0011*x²- -0,0323*x*y+0,0566*y²		
	0,67	**3,35**	**(5,174)=71,181**
MC, %	Z = 3,8882+0,8719* x-0,2831*y- -0,0103*x²+0,0724*x* y-0,2917*y²		
	0,84	**3,36**	**(5,61)=64,669**
Range of the active moisture, %	Z = -1,3202+0,9216*x+5,4379* y-0,0126*x²- -0,0581*x* y-0,1768*y²		
	0,64	**2,33**	**(5,10)=3,5269**
Note: x – physical clay contents, %; y – humus contents, %.			



a) bulk of density;
b) the contents of macroaggregates of 0,25-10 mm;
c) the contents of waterproof aggregates > 0,25 mm;)
d) humidity steady wilting of plants;
f) the least moisture capacity;
g) a range of an active moisture

Fig. 1 –Pedotransfer models of a quadratic kind for definition physical and water-physical properties of soil under the contents of the humus and physical clay

A. G. Bondarev, etc., 1987), or in total measurement annual loss will make nearby 100 thousand tons of grain (on the area of cultivation of grain crops nearby 20 million in hectares).

Pedotransfer models are suitable for an estimation of soil physical properties for territories where water-physical properties did not investigate earlier. This question for Polesye where it is much less than measurements of water-physical properties, than in Forest-Steppe and Steppe is especially actual.

Pedotransfer models can be of special importance for irrigated agriculture at definition of the least moisture capacity - key parameter for calculation of irrigation norms - instead of bulk definition of this characteristic by a field method which are filled in. We shall notice, that this method is not used for production/manufacture, and necessary parameters are taken from reference books/directories. Without special risk to be mistaken we shall tell, that it is one of the reasons of overirrigation and, as consequence, the important development of processes secondary solontzization and solinization during irrigation.

Precisely also pedontransfer models are perspective for definition of other important soil-hydrological constant - humidity steady wilting of plants. The direct method of measurement of this characteristic by means of vegetative miniatures is used seldom, and calculation under the maximal characteristic by its multiplication to factor 1,34 as has shown A.G.Dojarenko (1963), is not exact, as disregards very different ability of cultures to acquire difficultly accessible moisture. For this reason it is possible to approve, that today actually there are no experimental data about real quantity of an inaccessible moisture in soils. We can think, that pedotransfer calculation HW will significantly improve the current situation.

Pedotransfer estimations of soil water-physical properties can appear useful at decoding the remote information, especially considering that circumstance, that humus and physical clay are estimated at the analysis of space pictures already enough reliably. It will allow to specify significantly an available spatial information on a condition of soil physical properties.

Table 4

Pedotransfer function

The name of function	Base characteristics	The purpose of modelling
Aggregation	Texture, a parity of granulometric elements, the humus contents, bulk of density, quantity and structure exchange cations	Laws of processes, an estimation of factors which render or do not affect process, characteristic parameters
Deaggregation	Same + system of agriculture	Laws of degradation of structure
Soil-hydrological properties	Texture, a parity of granulometric elements, structure, bulk of density, the contents of humus	The estimation of migration of a soil moisture, characteristic parameters
Physical, physical - mechanical and technological properties	Texture, structure, humidity, anthropogenous loadings	The forecast of propensity of soil to deformation, formation of structure at tillage, strength characteristics, agridemands to designing and operation of machine-tractor units and soil-cultivating cars

Still an example: for revealing territories where displays of physical degradation take place. The reason for last one is more often the loss of humus and decrease in soil ability to form agronomical useful structure. Calculation by means of models can be a simple way of revealing so-called «hot spots» – places where dispersion is more often shown overcompaction, lumpiness, and, probably, wind erosion.

Prospects of pedotransfer models in monitoring are absolutely obvious at etalonization display parameters of a soil condition depending on local values of base parameters. Revealings of a trend of the same display parameters.

Eventually, under condition of the further regionization checks of reliability of model can find application in the control of a soil condition at long-term rent of the lands, specification of cost of the land area under condition of its sale and in general for more effective and objective conducting market transformations.

In tab. 4 we have tried to systematize available and possible pedotransfer functions. Naturally greatest attention has been given to functions which are capable to estimate physical properties, including physical degradation.

Conclusions

Using the mass experimental material which is available in a database «Soil properties of Ukraine», we have developed models, base parameters in which are the humus contents and physical clay, and transfering functions are soil-hydrological constants and structure. Perspective applied aspects of pedotransfer modelling in the soil physics are described.

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