

Institute of Nuclear Research and Nuclear Energy–BAS, Sofia, Bulgaria



South-West University, Faculty of Natural Sciences and Mathematics, Geography, Ecology and Environment Protection Department, 66 Ivan Michailov str., 2700 Blagoevgrad, Bulgaria

DEVELOPING A SIMULATION MODEL FOR ENVIRONMENT CONDITIONS MONITORING AND AGRICULTURAL PRODUCTION MANAGEMENT BY USING GIS OF SAMOKOV SOIL RESOURCES

By Boyko Kolev & Maria Shishmanova



### Introduction

•The possibility for maximum yield realization is connected with crops structure, soil cultivations and agricultural land use improving as well as by renders an account of climatic conditions and effective soil water content variations.

•The simulation procedure for soil hydro-physical properties determination was realized by using soil particle size distribution data only. This is a good start position for develop a calculation algorithm for soil water content dynamic monitoring. Kolev, 1994 realized this for the first time for Bulgarian soils, with developed in his Ph.D. thesis universal model.

The meteorological conditions could be modeling by using a simulation model, which was also suggested by Kolev, 1994 in his Ph.D. thesis.

•The following research considers the described physical and hydrophysical properties for two different soil types - Alluvial and Alluvial-Meadow soils and Deluvial and deluvial-meadow, sandy and loamy, mainly stony for the region of the Samokov valley.

#### The main aims of the study are:

•To demonstrate a simulation procedure for soil hydro-physical properties determination by using the created soil particle size distribution database only.

•To demonstrate how useful is the developed model for monitoring environment conditions and agricultural production management.

#### Materials and methods

•The Samokov area is situated around 60 km from Sofia. It is surrounded by the three mountains - Rila, Plana and Sredna Gora Mountains and has an elevation from 630 to 1400 m. The soils are cinnamonic forest and brown forest soils and are not fertile. At the foot of the mountain Deluvial and Deluvial-Meadow soils are presented. In the valley of the Iskar river and its feeders can be described some regions with the more generous Alluvial and Alluvial-Meadow soils. This paper is concentrated on two of the typical for the region soil types - Alluvial and Alluvial-Meadow and Deluvial and Deluvial-Meadow soils.

•The climate is moderate continental. The mean annual air temperature is between 7-8 °C, and it going down to about 6 °C for the places with evaluation above 1000 m. The sum of air temperature is about 2300 °C with very high fluctuation. The temperature conditions are suitable for potato, flax, meadow and pastures.

•The method offered by Kolev converts the Russian classification of the soils by their particle size distribution, which was used in Bulgaria, into their USDA classification. Here is used the integral curved line of the particle size distribution and the approximation is calculated after the regression model. This is shown in Kolev et al, 2006 where also is calculated the hydrophysical properties of the soils. The same approach is also used for the determination of the hydraulic conductivity (k). •Experimentally values for soil water content at field capacity (*SMfc* 33 kPa) were obtained by the method of flooded plots (Kachinsky, 1965), soil water content at wilting point (*SMw* 1.50 MPa) after Dolgov, 1948, maximal hygroscopic water content (SMmhwc 1.70 MPa) after Kachinsky, 1965, soil bulk density (BD -  $\rho_b$  g/cm<sup>3</sup>) was assessed after Kachinsky, 1965 and soil particle density (SD -  $\rho_s$  g/cm<sup>3</sup>) was determined trough pycnometrical measurements (Klute, 1986). Total porosity (SM0 0 Pa) was calculated by:

$$SMO = 1 - \rho_b / \rho_s$$
 (1)

•The effective soil water content *Tpwc* (m<sup>3</sup>/ha<sup>3</sup>), which have an important meaning for the regulation of the water amount in the soils, is determined by:

$$T_{pwc} = 100 * h * \alpha * (SM_{fc} - SM_{w})$$
 (2)

•where:

• $\alpha$  is the soil bulk density (g/cm<sup>3</sup>)

- •*h* is the soil depth (m)
- •SMfc water content at field capacity (%)
- •SMw water content at permanent wilting point (%)

The method offered by Kolev converts the Russian classification of the soils by their particle size distribution, which was used in Bulgaria, into their USDA classification. Here is used the integral curved line of the particle size distribution and the approximation is calculated after the regression model. These is shown by Kolev et al, 2006 where also is calculated the hydrophysical properties of the soils. The same approach is also used for the determination of the hydraulic conductivity (k). The calculated soil constants for two soils are presented on Fig. 1 and Fig. 2.

Die kar per peet Agent peet Agent peet geben gebe     A Routh of an analysis     A Routh of analysis <th< th=""><th>an and the</th><th>and deal</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></th<>	an and the	and deal												
No.     L     M     H     D     P     O     #     Saturation       8     200     100     100     100     1100     Saturation	101 101	900 (00) (11) (10) (11)	н гуни 2,5° Х - Н /	R R Den Den D		x - 63 , 512	1 11 <b>1</b> 01 01 0	10% + ]+ ( <b>b</b> +	⊕. ƥ.			1000	and the	# ×
Image: Construint     State	K	L	M	н	0 P	0	#	1 2 4	100					3
9 11.00 10.00 <td< th=""><th>4 <u>D(0.01</u> 6 <u>60</u> 6 <u>83</u> 7 <u>83</u> 8 <u>34</u></th><th>3#5 100 100 100 100</th><th></th><th></th><th>Кумулативна</th><th>крива на</th><th>механи</th><th>Netural</th><th>Selter Or ) Selter S</th><th>i 👞 sa nda Clav La</th><th>[H.R. )</th><th>a Seed [2</th><th>-</th><th>Get Suit Tope Constants</th></td<>	4 <u>D(0.01</u> 6 <u>60</u> 6 <u>83</u> 7 <u>83</u> 8 <u>34</u>	3#5 100 100 100 100			Кумулативна	крива на	механи	Netural	Selter Or ) Selter S	i 👞 sa nda Clav La	[H.R. )	a Seed [2	-	Get Suit Tope Constants
11 39 Geni Piner 4s: a a a b b a   13 1 Sand 7700 100 100 0.000 114 50.11   14 Sand 100 0.000 175 50 0.000 0.144 50.11   15 Sand 100 0.000 100 0.000 0.144 50.11   15 Sand 100 0.000 100 0.000 0.144 50.11   16 Sand 100 0.000 100 0.000 100 0.000 100   16 Sand 100 0.000 100 0.000 100 0.000 100 0.000 100   16 Sand 100 0.000 100 100 0.000 100 100 100   10 Sand 100 0.000 100 100 100 100 100   10 Sand 100 0.000 100 100 100 100 100   10 Sand 100 0.000 100 100 100 100 100   10 Sand 100 100 100 100 100 100	9 11,06	100			kell cervitants									
13 1. Samed 1. Samed 0.0000 1.75 50 0.13 0.0000 12.44 10.57   14 Samed 2.1 James 0.459 0.0000 1.75 50 0.13 0.0000 12.44 10.57   16 Same 0.2.2 1.0 0.459 0.0007 1200 13.5 16.4 0.0209 12.75 13.5   16 Outp 7.2 1.0 <td>11</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>Genality</td> <td>Tines:</td> <td>1.94</td> <td></td> <td></td> <td>191.0</td> <td></td> <td></td>	11						Genality	Tines:	1.94			191.0		
14 Same (P)(1)   15 Same (Same)   16 Same (Same)   17 Same (Same)   18 Same (Same)   19 Same (Same)   10 Same (Same)   11 Same (Same)   12 Same)   13 Same)   14 Same)   15 Same)   16 Same)   17 Same)   18 Same)   19 Same)   22 Same)   10 Same)   11 Same)   12 Same)   13 Same)   14 Same)   14 Same)   15 Same)   16 Same)   17 Same)   18	13				E-Savd	1872	0.0200	175	-	10.9	0.0500	11.44	30.31	
10 Oby 7/2   10 Oby 7/2   10 10   10 10   10 10   10 10   10 10   10 10   10 10   10 10   10 10   10 10   10 10   10 10   10 10   11 10   10 10   11 10   11 10   12 10   13 10   14 10   15 10   16 10   17 11   18 10   10 10   11 10   12 10   12 10   13 10   14 10    15 10   16 10   17 11   18 10   19 10   10 10   10 10   11 10   11 10   10 10   10	14 Sand	29,01			2 Loany Save	6.459	8.8550	200	28.5	16.4	6.0340	19-20	11.00	
0.0 0.0 0.00	16 Clay	7.0			3. Sandy Livers	8.504	0.0237	290	11.0	365	0.00+0	12.52	9.36	
19 10 1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.	10				6.181240	8.309	0.0129	.300	4.5	47.3	0.0000	14.40	6.32	
10 1 + 5 tenth Carp Lane 6.427 0.000 200 213 30.4 0.0270 11.02 14.01 14.01   22 1 1 1 1 1 1 1.10 1.	19				A town	8.500	0.0100	300	5.8	194	8.823	11.23	3.47	
22     -1     1     R. Bry Greinam     0.475     0.010     170     1.3     340     0.027     4.11     1.18       23	20				6. Sent-Cay Lown	6.422	0.0096	000	23.8	10.4	0.0702	19.00	14.91	
22     8. Decision:     0.446     0.000     500     0.00     1.00     0.70       22     70     1.00     0.00     0.00     0.00     1.00     0.70     0.70       27     71.19     0.00     0.00     0.00     1.0     0.20     0.70     0.70     0.70     0.70       20     0.00     0.00     0.00     0.00     1.0     0.20     0.70	22			1	1.My Gelaim	0.875	0.0105	679	1.8	36-8	0.6137	8.13	3.38	
26) a. Light Clay: a. 4412 0.0005 300 1.5 8.4.a 6.3.7 2.7.9   27) m 119 10. Marcy Clay: 6.3.07 5.0.000 100 4.5 3.5.2 8.9.40 3.00 8.00   20 30 2.5.0 1.0.0 100 6.000 101 6.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 0.2.2 +.56 5.0.000 101 101 101 101 101 101 101 101 101 101	28				8. Day Loans	0.445	0.0018	300	0,00	1.89	0.0249	4.75	0.76	
21 11.9 10.36 (Day) 6.540 6.005 10 6.3 5.9 5.00 5.00   30 20 30 1.0 mary Olar 6.540 6.005 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 6.002 10 0.22 4.86 0.002 10 0.22 4.86 0.002 10 0.22 4.86 0.002 10 0.22 4.86 0.002 10 0.22 4.86 0.002 10 0.22 4.86 0.002 10 0.22 4.86 0.002 10 <	20				R. Light Clev	6.401	0.0005	300	2.8	35.4	8.0474	15.74	1.14	-
301     11.0many Olive     0.540     0.0002     00     0.222     4.06     0.0000     1.01     0.0000	27 n 219				10.58y Clay	6.807	1.0045	50	1.3	38.2	8.0480	2.14	1.60	
20     20:001     3-45     100     110       31     20:1     100     100     110     110       32     20:0     100     100     100     110       35     20:0     100     100     100     110       35     20:0     100     100     100     110       36:0     40:0     100     100     100     100       40:0     40:0     100     100     100     100     100	20	_			EL Many Cher	0.540	6.0042	80	0.42	4.05	0.0380	1.85	8,18	-
31 31 100 K0 400 - ・ + (Sheet)/Sheet2/Sheet3/ - ・ + 1 Apthese - 、 、 、 」 ○ 副 	29 TCD.01	1.145	-											
We w (Seet / Seet / Seet / Seet ) / Rear & Aphan / 、 、 」 〇 副 And	31 2.1	100		K)										- 0.0
Ren 1 Aphan / Y 口口图	· · · + 1.54	eet1/Shee	12/9 wet	5/										21
Fiely A Cavi	lame la A	pringes -	10	0日.										100 B
	Analy	and the second		-										evel .

Fig. 1. The calculated soil constants for Alluvial soils.

(MM) -0-001 I	2.1.101	10.0	144 100	M N	0	F He	0   gd	R • IgN	-	1		v w
13 19 17 122	53 53 92 7,00	11.9 11.9 14.6 11.06	100 100 100	Fell canalization	9%	Lana -	Tite.			AL.		
	-	-		1.5ed	0.364	0.0288	178		10.9	0.0000	22.44	30.33
ngd 2	Eg%			2.10my Serd	6.439	0.0330	200	26.8	16.4	0.0000	18.00	17.00
30100	옷감			3.Sertylaen	6.50+	0.0207	290	12.8	28-8	3.4240	17.57	8.31
HOUTON .	37 62			4.581.000	5.509	0.011	300	6.5	47.5	0.0200	24,40	5.32
30103	20,39			5.1000	0.503	0.0190	308	5.0	14.4	8.0071	11.73	3.97
30103	8,90			6.5mb/Cletion:	1011	0.00%	220	23.8	22.6	0.1253	18.05	16.51
0000	-700			2.58y Clay Lines	0.475	0.0575	170	1.8	34.0	0.4231	8.15	1.18
-				8. Our Lives	2.441	0.0050	306	LW.	1.09	8.8246	4.00	6.76
1	Sand	13.24		B-Inde Cler	0.453	0.0085	380	31	ILA	8.0174	81.74	4.94
0	Clay	2,1		HL SHy Cher	0.907	0.0000	- 10	1.2	28.2	0.0+00	1.00	8/80
	-			11. Heavy Class	6.540	0.0042	85	8.22	4.56	0.0300	1.15	8.15
3 3 69890 5 5 6	8.90 7.00 7.1 5.0 Sand San Clay	79.61 13.24 7.3		6. Senty Christen 7. Sky Christen 8. Onr Lean 9. July: Christen 16. Sky Christ 15. Sky Christ 15. Heavy Christ	1031 6.415 6.445 6.461 6.907 6.546	0.00% 0.05% 0.00% 0.00% 0.00%	200 170 200 200 300 300 80	23.5 1.8 5.9 3.1 1.3 5.22	22.6 36.0 1.49 92.6 23.7 4.06	0.2253 0.8237 0.8246 0.0174 0.0400 0.0300	23.05 8.15 8.19 81.79 81.79 81.79 81.79 81.99	16.5 1.1 0.7 0.8 0.8 0.8

Fig. 2. The calculated soil constants for Deluvial soils.

#### The General view of the object is shown on Fig. 3.



Fig. 3. General view of the object.

# Results and discussion

•Fig. 4 show the water and hydro-physical properties, which here are already included in the attribute table of soils in GIS.



Fig. 4. Adding of SMO, SMfc, SMwp, KO, BD, SD and Tpwc into the attrubute table for the two soils.

•Total porosity SM0 (cm<sup>3</sup>/cm<sup>3</sup>) and effective water resources Tpwc (m<sup>3</sup>/ha<sup>3</sup>) by (1) and (2) are calculated with GIS software ArcView 3.3 (function Calculate). The final results are presented on Fig. 5 and Fig. 6 for Alluvial and Alluvial-Meadow soils and Deluvial and Deluvial-Meadow soils, respectively.





Fig. 5. The final results for Alluvial and Alluvial-Meadow soils.

Fig. 6. The final results for Deluvial and Deluvial-Meadow soils.

Tez_beobal - M	icrosoft Word											
54 Edit Yew C C III III III IIII A Normal + Bold	Insert Figmat Tools Tab a a a a a a a a a a a a a a a a a a a	le ∰ndow B ≪Tiknie D B Z U 1				] 100% €≓   □ •	• 🗇 . 🛃 • 🛆 •			Type a	ponition for help	• ×
L	(+2+++++++){-++++++++++++++++++++++++++++	2211-3111	4 - 1 - 5 - 1	· 5 · 1 · 7 ·	1-8-1-9	+ i + 10 + i	11 - 1 + 12 +	1 + 13 + 1 + 14			81	
5	,	21500										
7		-Sol typ										
		Clay	7 10	58 13		od 79.65		Get Sol Type	1			
		P.414	and the state	New Yorks								
7	Contractorer	208.09	pe: Sandy C	THAT FORM				Constants				
	Soil constants									2		
		5M0	Gama	Fimax	Ko	1	Atta	50	A			
1	1. Sand:	1524	0.0288	175	50	10,9	0.0500	21.44	30.33			
	2. Loamy Sand:	0.439	0.0330	200	26.5	16.4	0.0396	19.20	17.80			
	3. Sandy Loam:	0.504	0.0207	290	12.0	26.5	0.0248	17.57	9.36			
-	4. SR Loan:	0.509	0.0185	300	6.5	47.3	0.0200	14.46	5.32			10
	S. LOAMS	0.503	0.0180	300	5.0	14.9	0.0231	11.73	3.97			
2	6. Sandy Clay Loa	mi 0.432	0.0096	200	23.5	33.6	0.0353	19.05	16.51			
÷.	7. Sity Clay Loan	0.475	0.0105	170	1.8	36.0	0.0237	6.15	1.18			
3	8. Clay Loam:	0.445	0.0058	300	0.98	1.69	0.0248	4.70	0.76			
÷	9. Light Clay:	0,453	0.0085	300	3.5	\$5.6	0.0174	10.74	2.94			-
÷.	10. Sity Clay:	0.507	0.0065	50	1.3	20.2	0.0480	3.98	0.60			
	11. Heavy Clay:	0.540	0.0042	80	0.22	4.86	0.0380	1.90	0.15			
è.												
1												
2												•
-												•
Page 2 Sec 1								OK	1 0	ncel		11
Histart	Dizdana	Tren berbel - I	inneed.	(A) Horney	At PowerPower		Sed.			1000	C > 600	10:02

Fig. 7. The results for Alluvial and Alluvial-Meadow soils after simulation model using.

🖲 rez_beobal - Microsoft Word	
Elle Edit Yiew Insert Format Iools Table Window Help aA x² ×₂ √α	Type a question for help 🔸 🗙
🛃 Normal + Bold • Times New Roman • 12 • 🖪 / 世 副 書 書 圖 語 • 註 語 課 部 • 🖉 • 🛆 •	•
L	·13 · 1 · 14 · 1 · 15 · 1 · △ · 1 · 17 · 1 · 18 ·
🖞 Soil	
- Soil type	
Clay 7 % Silt 13.35 % Sand 79.65 % G	et Soil Type
m Soil type: Sandy Clay Loam	
SM - soil	moisture = 0.402822
Parameters K-hydri	aulic conductivity = 0.005595 ivity = 1.28665
Soil's matric suction: 500 sm Ep - ove	ration = 16.7/2640 rall efficiency factor = 0.396000
ل التحقيق التحق التحقيق التحقيق	illary rise = 272.700012
Potential evaporation rate(Eo): 0.5 sm T/Tm - r	eduction in transpiration under stress :
Water table depth (zt) : 450 sm CropGro	up1 = 0.200000 up2 = 0.280000
w CropGro	up3 = 0.380000 up4 = 0.480000
	ups = 0.550000
Ime(t): j 27 h	OK
Ed - field application efficiency factor	
EF - Field canal efficiency factor	
Blocks larger than 20ha	
Ei - conveyance efficiency factor	
÷	•
	Exit
Draw 🔹 😓 AutoShapes * 🔨 🔪 🖸 😂 🛃 🞲 🖳 🧟 💁 - 🚣 - 🚍 🚍 🚍 🚰 -	
Page 2 Sec 1 2/2 At 2,5 cm Ln 1 Col 1 REC TRK EXT OVR English (U.S 🕰	
🐉 Start 🕞 Durdana 👜 rez_beobal - Microsof 🖪 Microsoft PowerPoint 🔒 Soil	🧷 😨 😨 🏺 🤇 🛱 😵 🔂 US 16:12

Fig. 8. The results for Alluvial and Alluvial-Meadow soils after first simulation.

💌 rez_beobal - Microsoft Word			- 8 X								
File Edit View Insert Format Iools Table Window Help 🖓 ײ ×₂ √ α		Type a question for	help 🔸 🗙								
I D 😅 🖬 🔒 🝓 🤮 🖪 🖤 🕹 🖻 🛍 🍼 🔛 - 🗠 - 🍓 🗷 🗔 🏢 🛃	) 🕵 ¶ 100% 🔹 🖸	2 .									
A Normal + Bold • Times New Roman • 12 • B I U ≣ ≣ ≣ II • 1	目信律日・名	· • <u>A</u> • •	_								
L 1-2+1+1+X+1+1+2+1+3+1+4+1+5+1+6+1+7+1+	8 • • • 9 • • • 10 • • • 11 •	····12····13····14····15····△····17····18·									
T Soil											
Soil type	Soil type										
Clay 7 % Silt 13.35	Clay 7 % Silt 13.35 % Sand 79.65 % Get Soil Type										
Soil type: Sandy Clay Loam		Soil 🛛									
Parameters		SM - soil moisture = 0.402822 K - bydraulis conductivity = 0.005595									
Soil's matric suction:	500 sm	S - sorptivity = 1.286665 IM - infiltration = 16.772640									
Depth of the root zone(RD):	100 sm	Ep - overall efficiency factor = 0.352000 Ea - actual rate of evaporation = 0.150597 CD - actilization = 0.222 720012									
Potential evaporation rate(Eo):	0.5 sm	CR - capillary rise = 272.700012 T/Tm - reduction in transpiration under stress :									
Water table depth (zt) :	450 sm	CropGroup1 = 0.20000 CropGroup2 = 0.280000	-1								
Leaf Area Index (LAI):	3	CropGroup3 = 0.380000 CropGroup4 = 0.480000									
Time(t):	24 h	CropGroup5 = 0.550000									
도 유 Ed - field application efficiency fac	tor	OK									
Surface methods	▼ Sandy soils										
Ef - field canal efficiency factor											
Blocks up to 20ha	Lined or piped	ed 🔄									
Ei - conveyance efficiency factor											
Effective management, project	s of 3000-7000ha and areas	as of 70-300ha 💌	-								
			± 0								
S Calculate		Exit	*								
	7 <b>a</b>										
Page 2 Sec 1 2/2 At 2,5 cm Ln 1 Col 1 REC TRK EXT OVR End	lish (U.S <b>D3</b>										
🔀 start 🖻 Durdana 👜 rez_beobal - Microsof 🔃 Microsoft F	owerPoint 🏭 Soil	2 🕫 🕄 🗘 😼 🖸	US 16:16								

Fig. 9. The results for Alluvial and Alluvial-Meadow soils after second simulation.

## Conclusions

•The approach suggested by Kolev, 1994 for calculating SMfc, SMwp, K0 and calculating Tpwc and the values of total porosity (*SM0*) by using GIS software, gives more quality and quantity information of the studied soil.

- •To demonstrate how useful is the developed model for monitoring environment conditions and agricultural production management.
- •It is obvious that GISoSR with that information will improve the information using.
- •Of course such kind of study should continue with different Bulgarian soil types.

# **Acknowledgements**

The authors expressed their gratitude to Damian Michalev, Nevena Miteva and Dimitar Jivkov from Soil Resources Agency – Sofia and Associated Professor Dr Penka Kastreva from South-West University of Blagoevgrad for their cooperation in realization of this scientific study.

# Thank for your attention!

