DEPARTMENT OF ENVIRONMENTAL IMPROVEMENT
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CALIBRATION OF TDR FOR MOISTURE CONTENT MONITORING IN MOORSH LAYER

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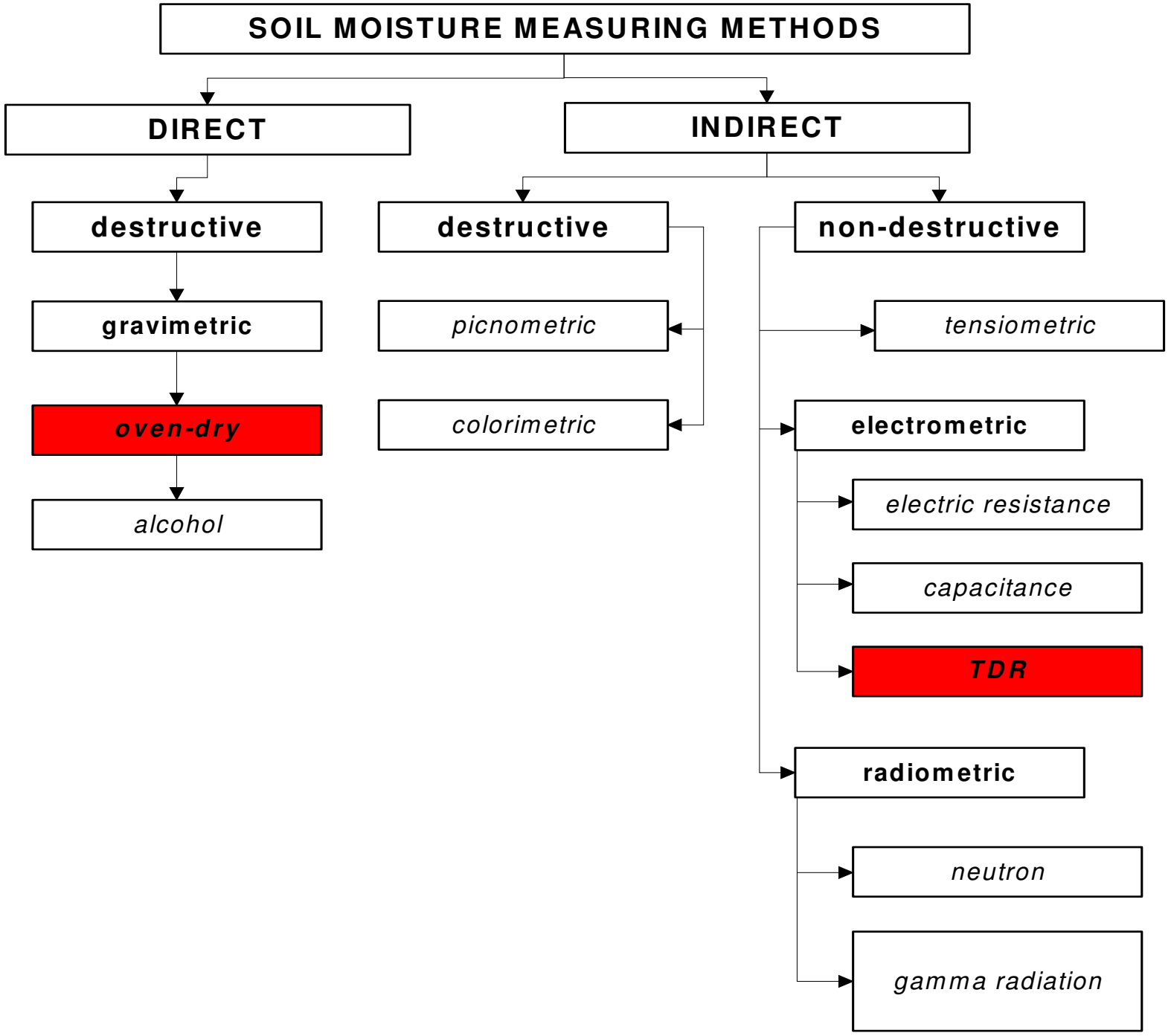
FEN SOILS IN POLAND

METHODS OF SOIL MOISTURE MEASUREMENT



TIME DOMAIN REFLECTOMETRY (TDR)

Theoretical principles

The propagation velocity of a plane wave can be written (Kronig, 1959) as:

$$\nu = \frac{C}{\sqrt{K_a}} \qquad (1)$$

where:

- ν - propagation velocity of electromagnetic wave [m s^{-1}],
- C - speed of light [= 3 10^8 m s^{-1}],
- K_a - dielectric constant of the medium [-].

Propagation velocity of electromagnetic wave (ν) can be presented as:

$$\nu = \frac{L}{\Delta t_s} \qquad (2)$$

where:

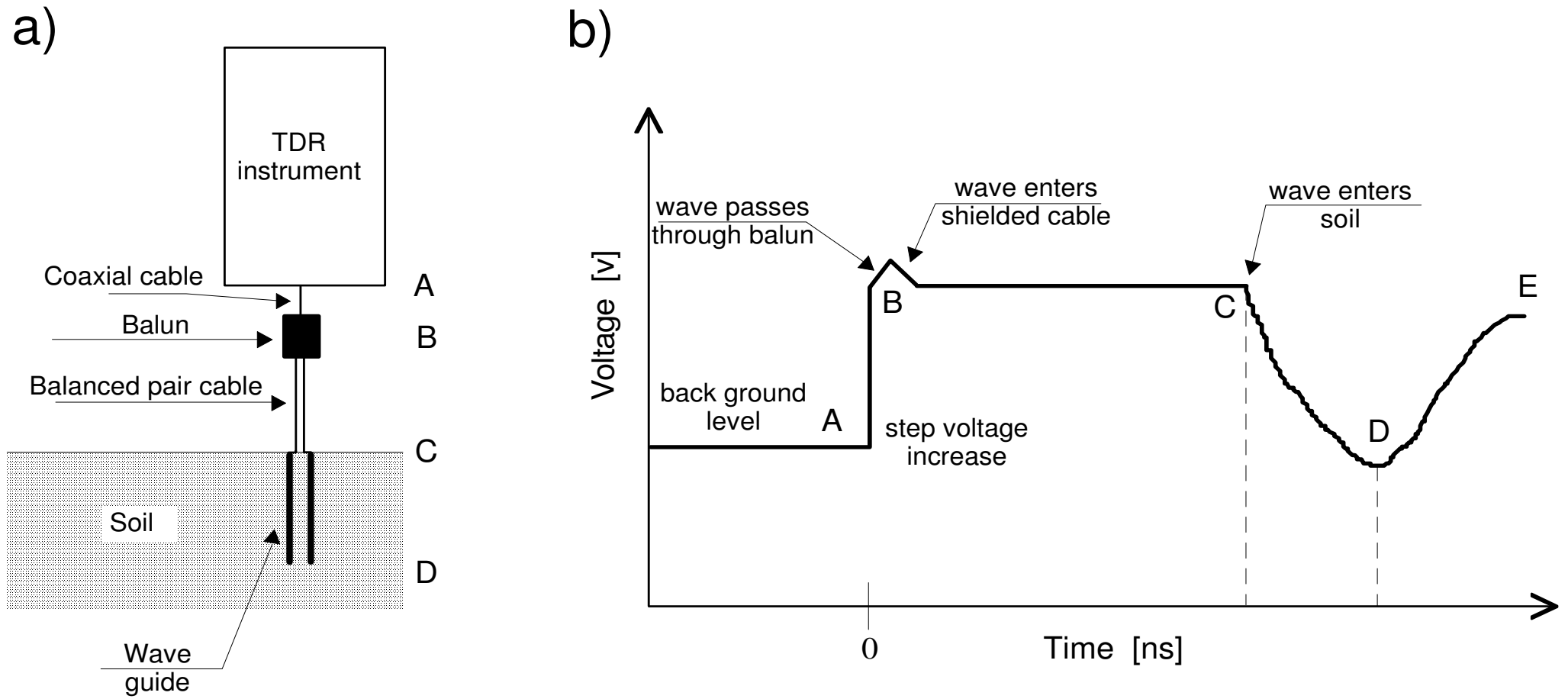
- L - linear distance the wave travels along the transmission line wave guide equal to **2l** (because the wave travels to the end of the wave guide of the length **l** and back) [m],
- Δt_s - time required for the wave to travel distance **2l** [s].

From the comparison of equations (1) and (2) the dielectric constant can be calculated:

$$K_a = \left(\frac{C \Delta t_s}{2l} \right)^2 \qquad (3)$$

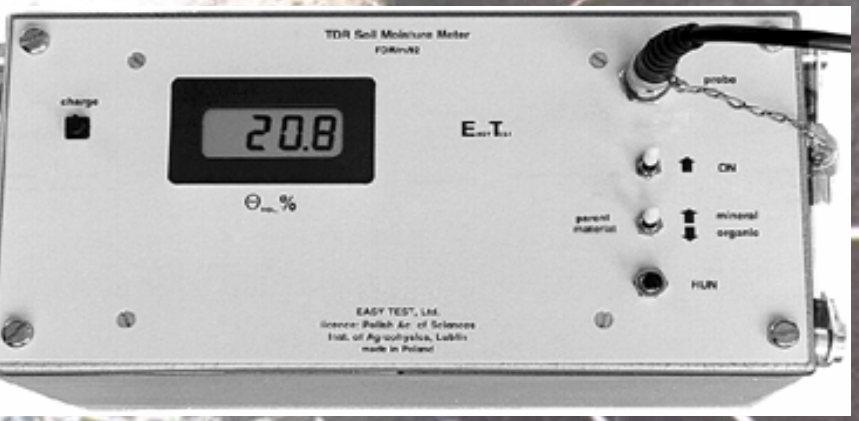
water K_a=81; air K_a=1; solids K_a=5-8

TIME DOMAIN REFLECTOMETRY (TDR)



Schematic diagram of TDR system (a) and TDR output showing voltage as a function of time (b) (Cassel i in., 1994)

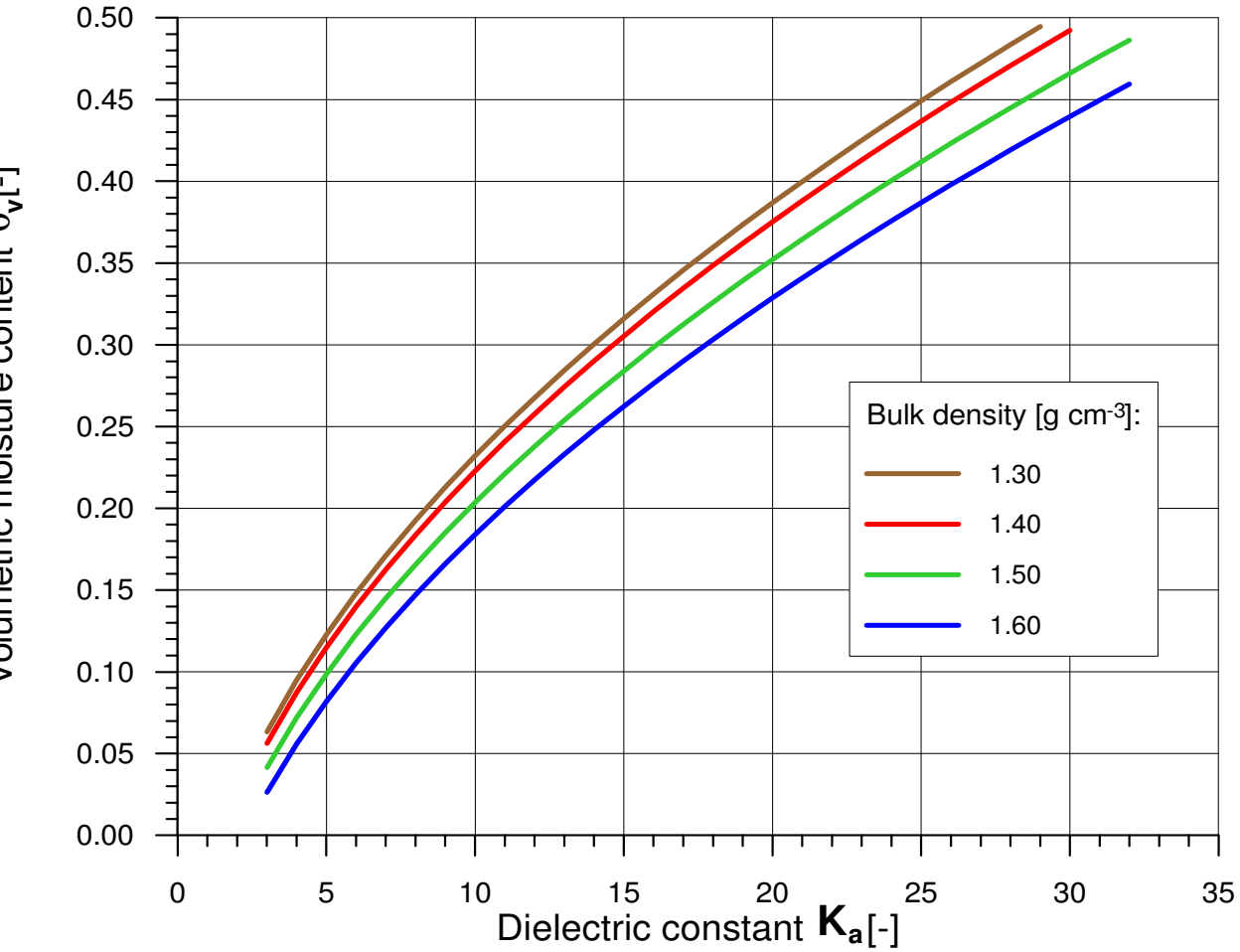
SOIL MOISTURE CONTENT MEASUREMENTS



TDR CALIBRATION

Equation [Topp et al (1980)]:

$$\theta_v = \left(-530 + 292K_a - 5.5K_a^2 + 0.043K_a^3\right)10^{-4}$$



Equation [Malicki et al (1996)]:

$$\theta_v = \frac{\sqrt{K_a} - 0.819 - 0.168\rho_b - 0.159\rho_b^2}{7.17 + 1.18\rho_b}$$

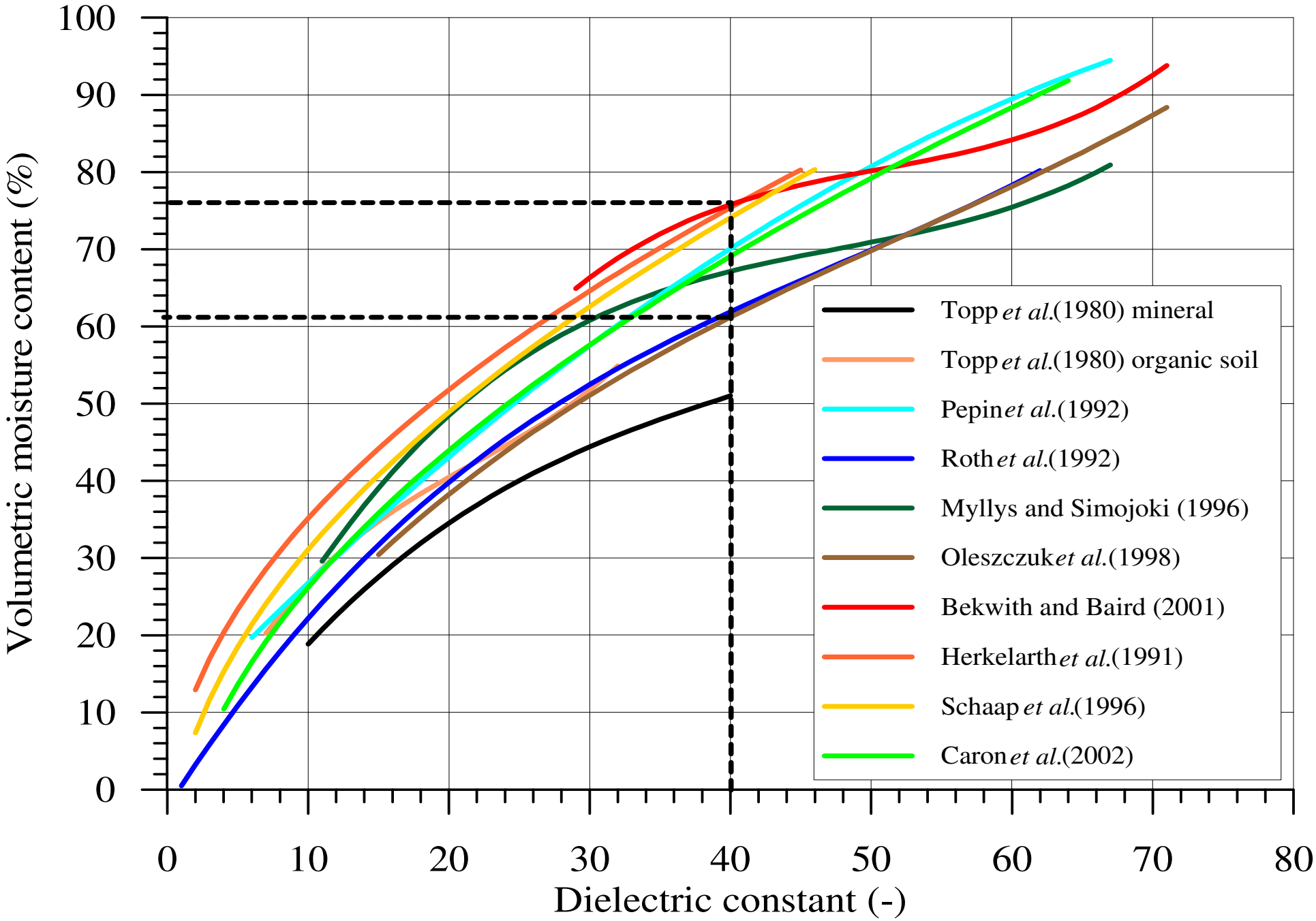
where:

ρ_b – **bulk density [g cm^{-3}],**

θ_v – **volumetric moisture content [-]**

K_a – **dielectric constant [-].**

CALIBRATION CURVES FOR ORGANIC SOILS & ORGANIC MATERIALS



PHYSICAL PROPERTIES OF MOORSH

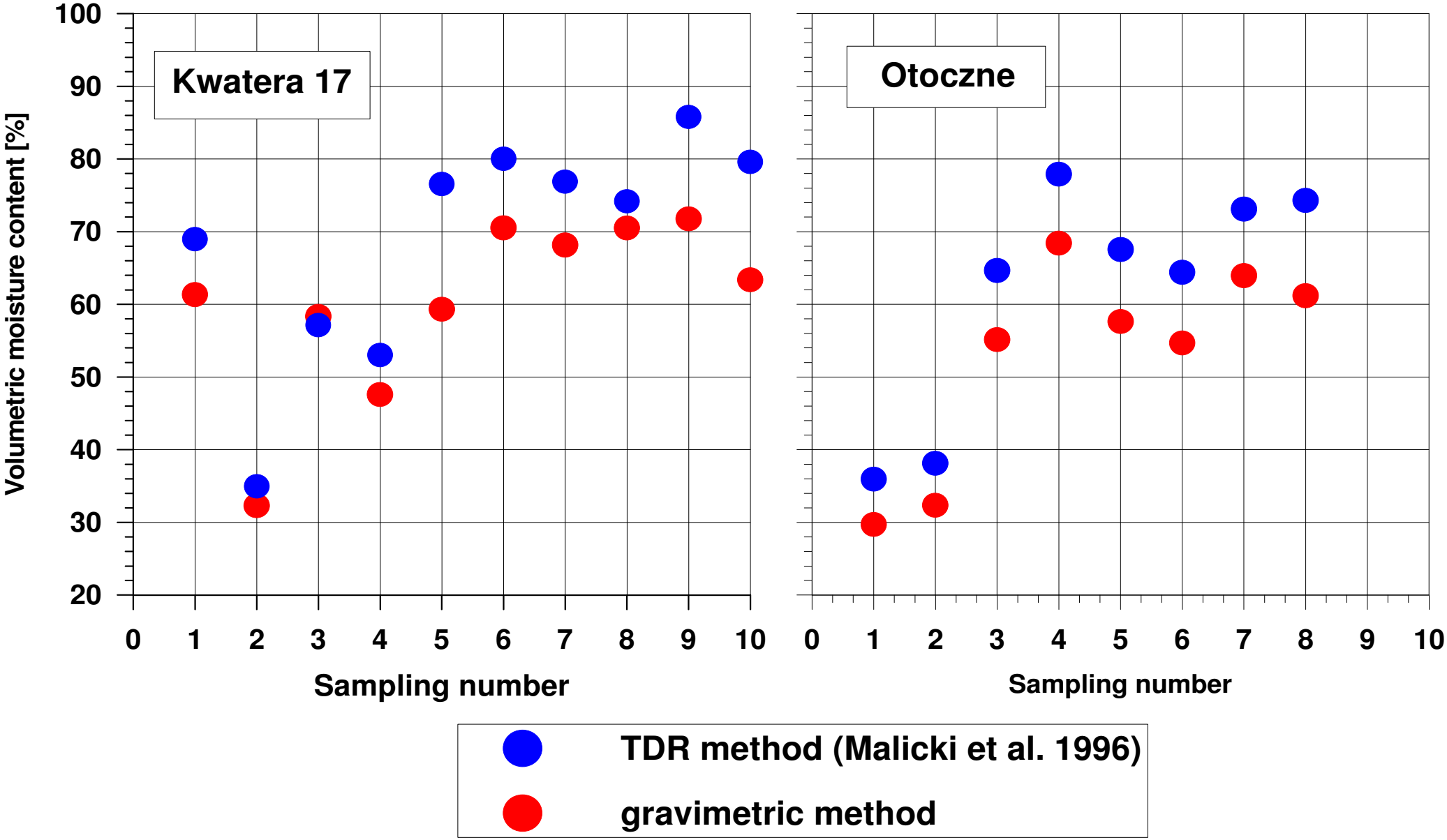
Moorsh type	Ash content [% a.s.m.]	Bulk density [kg m^{-3}]	Porosity [m^3 m^{-3}]	Saturated moisture content [m^3 m^{-3}]
Peaty (M_3)	16.7	192.0	0.884	0.861
Humic (M_2)	16.3	232.0	0.860	0.824
Grainy (M_1)	17.6	302.0	0.819	0.779

PEAT

MOORSH

COMPARISON OF MEASURED MOISTURE CONTENTS IN MOORSH LAYERS

Depth 10 cm



OBJECTIVES

- to calibrate TDR method for moorsh layers in the laboratory
- to validate of the obtained calibration equation against measured field data

MATERIALS

Physical properties of considered moorsh layers from Biebrza river valley

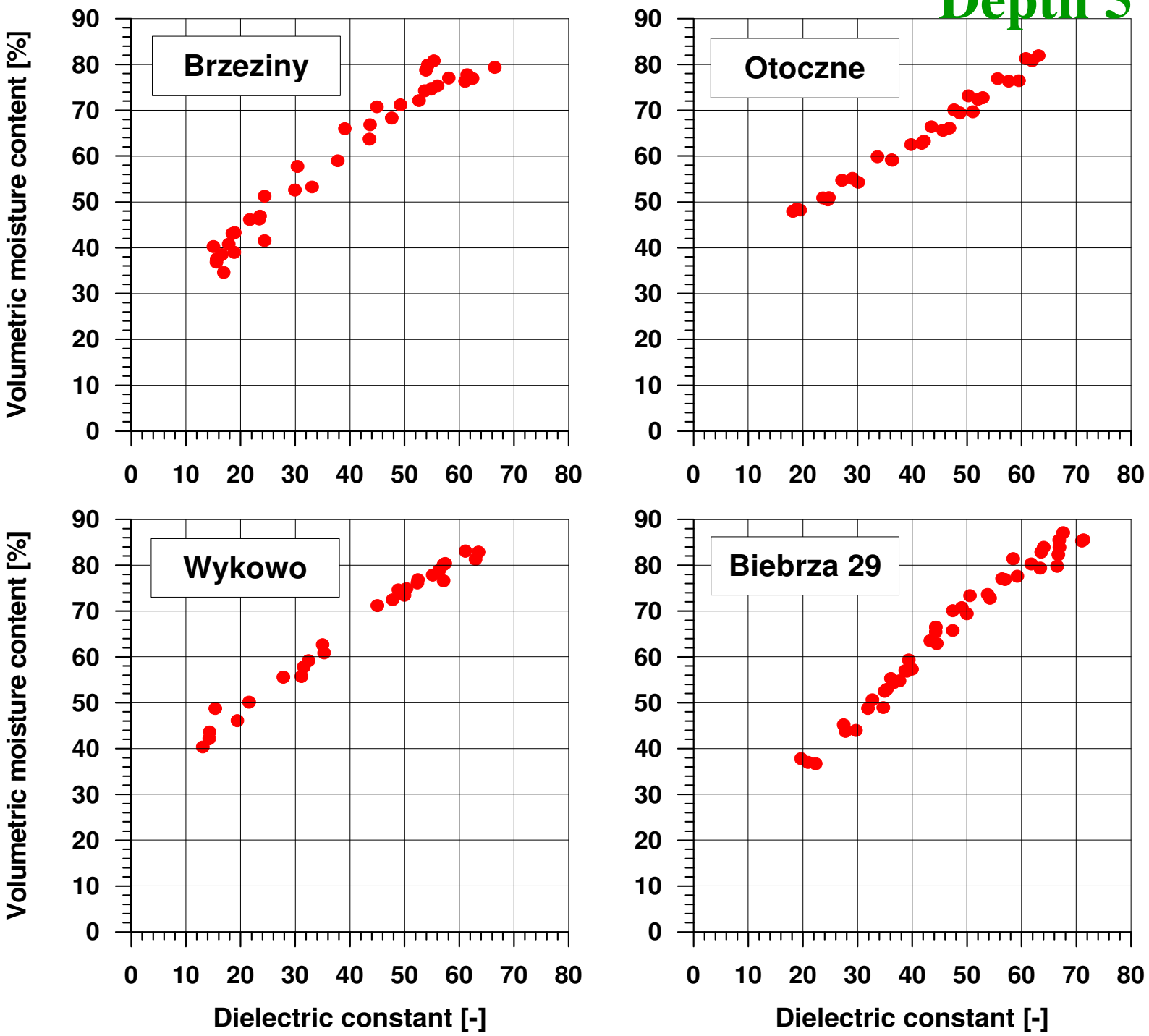
Soil profile	Depth [cm]	Bulk density [g cm^{-3}]	Particle density [g cm^{-3}]	Porosity [%]	Ash content [% a.d.m]
Otoczne	5-15	0.298	1.601	81.4	20.5
		0.309	1.601	80.7	20.5
		0.316	1.601	80.3	20.5
	15-25	0.149	1.518	90.2	16.4
		0.155	1.518	89.7	16.4
		0.166	1.518	89.1	16.4
Brzeziny	5-15	0.226	1.317	82.8	13.9
		0.185	1.317	85.9	13.9
		0.222	1.317	83.1	13.9
	25-35	0.180	1.263	85.7	9.2
		0.177	1.263	86.0	9.2
		0.188	1.263	85.1	9.2
Wykowo	5-15	0.350	1.649	78.7	16.0
		0.374	1.649	77.2	16.0
	15-25	0.266	1.656	83.9	15.3
		0.269	1.656	83.7	15.3
		0.271	1.656	83.6	15.3
Biebrza 29	5-15	0.240	1.466	83.7	17.7
		0.215	1.466	85.3	17.7
		0.236	1.466	83.8	17.7
Kwatera 17	5-15	0.223	1.525	85.3	17.9
		0.255	1.525	83.2	17.9

EXPERIMENTAL SET-UP

SOIL SAMPLES AND TDR PROBES

MEASURED DATA

Depth 5 -15 cm



CALIBRATION OF TDR FOR MOORSH LAYERS

$$\sqrt{K_a} = a + b\theta_V$$

where:

$\sqrt{K_a}$ - refractive index; a – intercept; b - slope; θ_V - moisture content ($cm^3\,cm^{-3}$)

Soil profile	Depth [cm]	a	b	Bulk density [g cm^{-3}]	Ash content [% a.d.m]
Otoczne	5-15	0.317	9.612	0.298	20.5
		0.284	9.582	0.309	20.5
		0.182	9.514	0.316	20.5
	15-25	3.675	5.026	0.149	16.4
		4.498	4.261	0.155	16.4
		3.837	5.287	0.166	16.4
Brzeziny	5-15	0.238	9.773	0.226	13.9
		1.109	8.436	0.185	13.9
		0.693	8.602	0.222	13.9
	25-35	1.005	8.710	0.180	9.2
		1.721	7.866	0.177	9.2
		0.895	8.333	0.188	9.2
Wykowo	5-15	0.142	9.479	0.350	16.0
		0.159	9.230	0.374	16.0
	15-25	0.532	9.255	0.266	15.3
		0.535	9.033	0.269	15.3
		0.158	9.300	0.271	15.3
Biebrza 29	5-15	2.109	7.081	0.240	17.7
		2.227	7.127	0.215	17.7
		1.746	7.593	0.236	17.7
Kwatera 17	5-15	1.136	7.714	0.223	16.4
		0.503	8.928	0.255	16.4

RELATIONSHIPS BETWEEN THE EQUATION PARAMETERS AND MOORSH PROPERTIES

$$\sqrt{K_a} = a + b\theta_v$$

$$\sqrt{a} = -2.104 + 0.474\rho_b^{-1} + 0.062\,AC$$

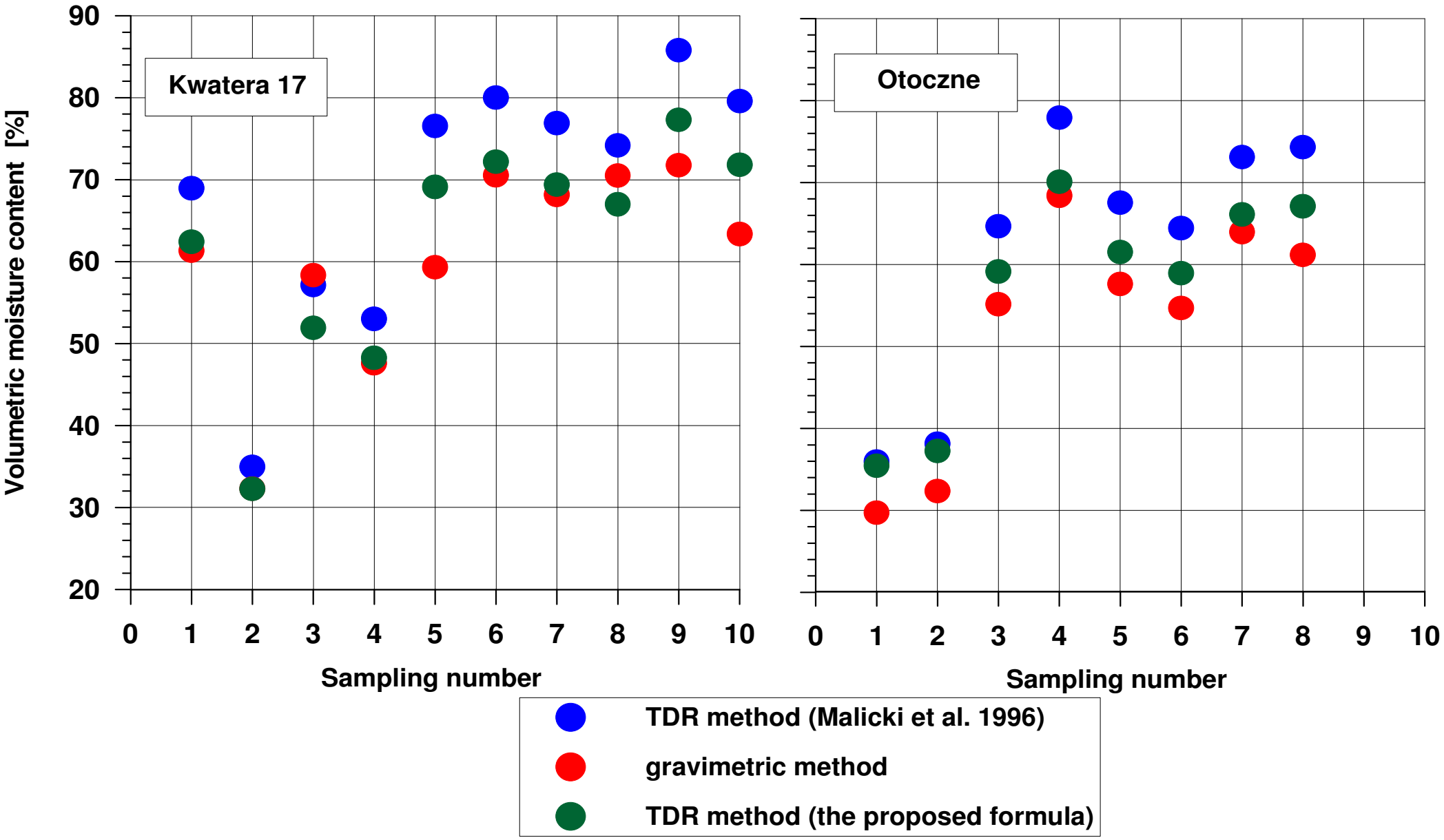
$$b = 17.731 - 1.373\rho_b^{-1} - 0.219\,AC$$

$$\theta_V = \frac{\sqrt{K_a} - (-2.104 + 0.474\rho_b^{-1} + 0.062\,AC)^2}{(17.731 - 1.373\rho_b^{-1} - 0.219\,AC)}$$

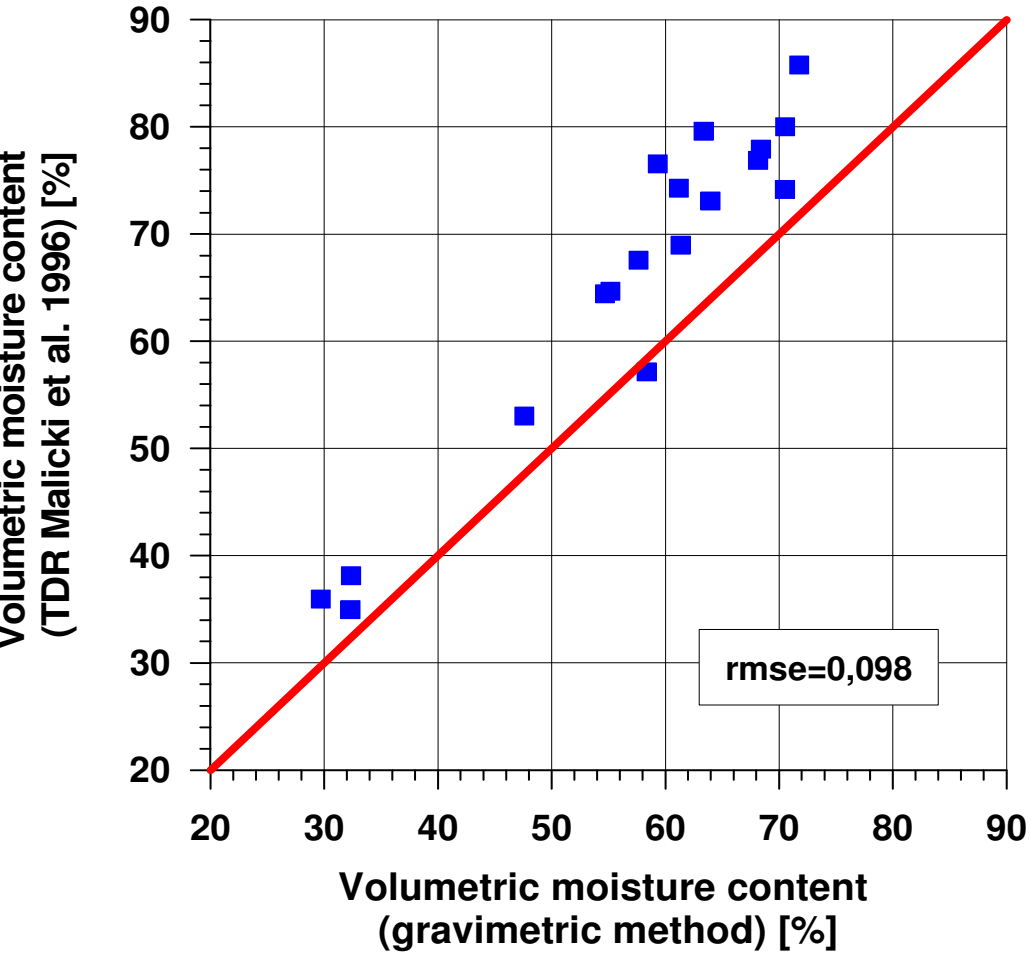
$\sqrt{K_a}$ – refractive index (-),
b – slope,
ρ_b – soil bulk density (g cm^{-3}),
a – intercept,
θ_v – volumetric moisture content (cm^3 cm^{-3}),
AC - ash content (% a.d.m.).

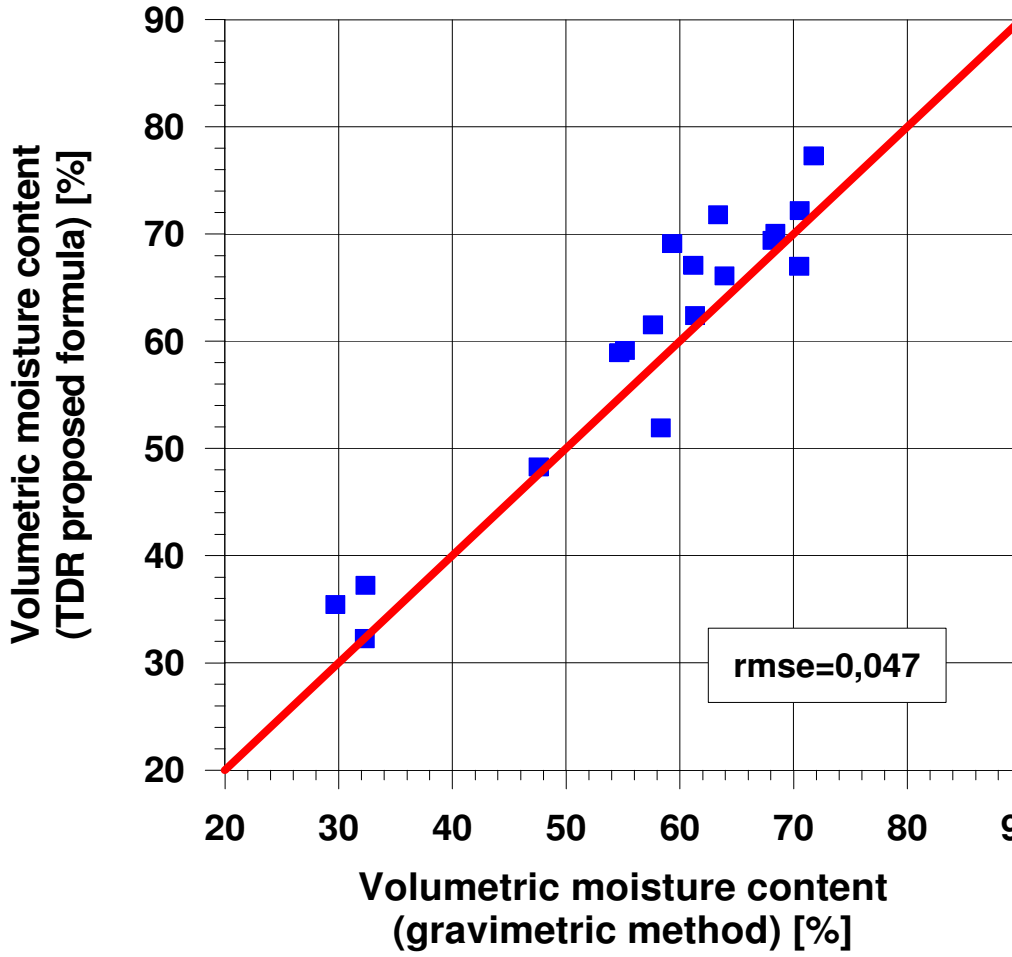
COMPARISON OF MEASURED MOISTURE CONTENTS IN MOORSH LAYERS

Depth 10 cm



COMPARISON OF TDR WITH GRAVIMETRIC MEASUREMENTS OF MOISTURE CONTENTS IN MOORSH LAYERS





CONCLUSIONS

1. **The measurements performed on undisturbed moorsh samples from Biebrza river valley allowed to formulate the TDR calibration equation relating dielectric constant with moisture content.**

2. **The relationship between dielectric constant and moisture content in considered range of moorsh layers can be represented by square-root equation and it was proven, that the values of intercept *a* and slope *b* parameters in this equation are strongly depended on bulk density and ash content.**

3. **The proposed calibration equation relating moisture content with dielectric constant, bulk density and ash content for TDR moisture measurements in moorsh deposits from Biebrza river valley gives better prediction than equation previously proposed by Malicki et al. (1996).**