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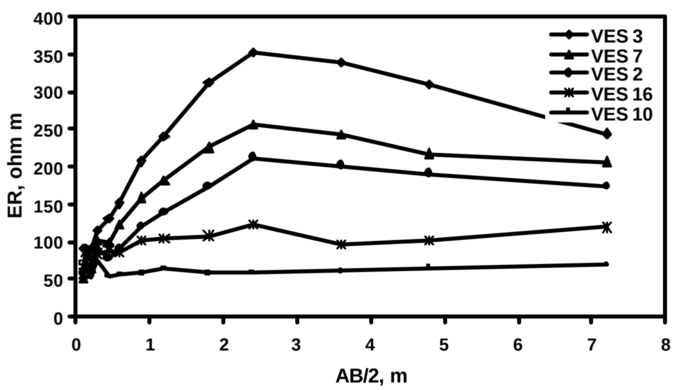
Evaluation of soil stone content with electrical geophysical methods to aid orchard planning

Establishments of orchards and vineyards are long-term and money-intensive, but highly pay-off projects. This study allowed developing procedure for incorporating geophysical survey data into recommendations of usage skeletal soils under orchards. Geophysical methods of electrical resistivity, such as **VES and four-electrode profiling** provided the information about spatial distributions of stones in skeletal soils. The resistivity of rocks or stones is much higher (about 10^4-10^{12} ohm m) than the resistivity of soil horizons with any texture. Therefore, high resistivity will indicate the presence of stones in soil profiles.

Study was conducted on skeletal soils (Paleoxerolls and Lithic Xerorthents) formed on carbonate-cemented marine deposit, limestone, or pebbles of alluvial origin in western part of Crimea Peninsula, Ukraine. The stone content varied from 2 to 90% of fragments coarse than 2 mm by volume and stony layers occurred in soil profiles at the depth as shallow as 12 cm.

The measured VES profiles were used to approximately evaluate the depth and arrangement of the stony layers in the soils. Most of the soils in the study area were well characterized by a three-layer VES profile. The top layer (I) had the smallest stone content (0.22-0.41 cm^3 cm^{-3}) with electrical resistivity about 80 ohmm. The middle layer (II) had the highest stone content (>50 cm^3 cm^{-3}) and electrical resistivity as high as 450 ohm m. The bottom layer (III) was not always presented in soil profiles. In some profiles layer III was outlined as having lower resistivity (40-200 ohm m) than layer II, which indicates a decrease in stone content in the bottom layer compared with layer II.



The approximate stone content of soil profiles was evaluated by observing VES profiles, thus, the stone content in the soil profiles decreases in a row of VES 3-7-2-16-10. We developed a rough scale for evaluation of stone contents in Crimea soils. Note, that the values may be different for other soils/regions.

Stone content by volume	Electrical resistivity
——— % ———	——— ohm m ———
<5	**<50**
5-20	**50-80**
20-40	**80-120**
40-60	**120-150**
60-80	**150-250**
>80 (slightly eroded rocks)	**>250 (1000-3000)**

During the study and collaboration with scientists from Nikitskii Arboretum, Yalta and Crimea Institution of Irrigated Orchards, Eupatoria, **three soil properties** were found to be essential for estimation of soil potential productivity for usage under orchards. These properties are **stone**

content in the **layers of 0-50 cm, 50-100 cm, and >100 cm**; the **depth to impermeable rock**; and the **depth of the A horizon**. We developed a practical guideline for estimation of soil productivity from the stone content and depth to the rock for some typical fruit trees.

Culture	Stone content in layers 0-50 cm	50-100 cm	>100 cm	Depth to rock	Potential productivity
Pear	**<10**	**<20**	**<30**	**>160**	**100**
	10-25	**20-35**	**30-45**	**140-160**	**75-100**
	25-35	**35-40**	**45-60**	**120-140**	**75-50**
Apple	**<15**	**<30**	**<50**	**>145**	**100**
	15-25	**30-45**	**50-60**	**120-145**	**75-100**
	25-40	**45-50**	**60-75**	**100-120**	**75-50**
Peach	**<25**	**<45**	**<55**	**>120**	**100**
	25-35	**45-55**	**55-65**	**100-120**	**75-100**
	35-55	**55-65**	**65-75**	**80-100**	**50-75**
Apricot	**<20**	**<25**	**<40**	**>130**	**100**
	20-30	**25-35**	**40-50**	**110-130**	**75-100**
	30-40	**35-45**	**50-65**	**90-110**	**50-75**
Cherry	**<15**	**<25**	**<40**	**>140**	**100**
	15-25	**24-35**	**40-50**	**120-140**	**75-100**
	25-35	**35-45**	**50-60**	**100-120**	**50-75**
Plum	**<15**	**<25**	**<50**	**>130**	**100**
	15-25	**25-35**	**50-60**	**120-130**	**75-100**
	25-35	**35-45**	**60-70**	**100-120**	**50-75**
Almond	**<25**	**<45**	**<65**	**>110**	**100**
	25-40	**50-60**	**70-80**	**100-110**	**75-100**
	40-50	**60-70**	**80-90**	**80-100**	**50-75**
Walnut	**<20**	**<30**	**<50**	**>100**	**100**
	20-30	**30-40**	**50-70**	**90-100**	**75-100**
	30-40	**40-60**	**70-90**	**80-90**	**50-75**

Let us demonstrate how to evaluate the possible productivity of orchard on a particular soil using the VES measurements and Tables. Soils with VES 2, 16, and 10 do not have a contact with an impermeable rock within 240 cm, since the resistivity is less than 250 ohm m for all the AB/2. VES 7 and 3 reach value of 250 ohm m at the AB/2 equal 240 and 90 cm, respectively. Through the VES interpretation or using the recalculation coefficient 0.323 obtained for the studied soils we can estimate that the depth to the rock is 240 x 0.323 = 77.5 cm for VES 7 and 90 x 0.323 = 29.1 cm for VES 3. These two soils are too shallow to be used under any of the orchard cultures. The soils with VES 2, 16, and 10 can be evaluated for the stone content in the characteristic layers of 0-50, 50-100, and >100 cm. These depths can be approximated with AB/2 <180, 180-360, and >360 cm. VES 10 has electrical resistivity of about 50 ohm m through the profile, which represents about 8-10 % of stone content. The soil can be used for growing of any fruit culture. Soil with VES 16 has resistivity about 100 ohm m, therefore, about 20-40% of stones uniformly distributed in the profile. Referencing to Table, this soil can ensure 100% productivity for peach, almond, or walnut orchards.

Thus, vertical electrical sounding is a useful method for evaluation of stone content in skeletal soils. The measured electrical resistivity profiles were used to estimate stone contents of the different layers in soil profiles. Key soil properties, such as stone contents in characteristic layers of 0-50, 50-100, and >100 cm as well as the depth to rock were estimated. **To further increase the efficacy of the estimation, the extend mapping of an area can be conducted on selected characteristic distances AB/2 equal to 90, 180, and 360 cm with four-electrode probe or NEP.**