Dynamic soil probing for rapid assessment of soil health and ecosystem function

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Abstract. This paper examines the use of dynamic soil penetration probing was evaluated as a rapid method for assessing soil health by linking physical properties with biological functionality. Analysis of anthropogenically transformed soils conducted at the Moscow State University Meteorological Observatory showed a direct correlation between soil penetration resistance and key biological constraints. Compacted upper soil layers (0–2 m) containing anthropogenic inclusions were identified as significant barriers to root growth, microbial habitats, and gas exchange, directly disrupting nutrient cycling and water balance regulation. The results demonstrate the potential of the method for rapid mapping of soil profiles, predicting the risks of arable land degradation, and predicting environmental stress. This approach facilitates the development of sustainable land management strategies aimed at enhancing soil biodiversity, ecosystem resilience, and agricultural sustainability under anthropogenic pressure.

1 Introduction

Studying the structure of the soil strata is important for predicting soil thermal regimes, assessing landscape stability, and assessing anthropogenic impacts. The dynamic probing method is widely used in engineering geology due to its speed and portability, but its educational potential for training geographers and soil scientists remains underestimated [1-5]. This research was conducted as part of a study examining the influence of snow and vegetation cover on soil thermal regimes. Two boreholes were drilled at the meteorological observatory site: one in the natural cover zone and one in an area with artificially removed vegetation. The resulting cores served as a standard for verifying the probing data.

2 Materials and methods

The study site was the Moscow State University meteorological observatory (55°42' N, 37°31' E), characterized by technogenically transformed soils on moraine deposits from the Moscow glaciation.

The probing technique involved the use of a portable probe with a conical tip (20 mm diameter, 60° angle) and a 10 kg hammer, which was dropped from a height of 50 cm.

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The number of hammer blows required to penetrate the probe for every 10 centimeters of depth was recorded (Figure 1).

Fig. 1. Conducting a lesson with students on studying the structure of the soil layer at the site of the Moscow State University meteorological observatory using the impact penetrating probe method.

3 Results

Specifically, during the study, the probe was driven to a depth of up to 3 meters. During the first two meters, approximately eight hammer blows were required for every 10 cm of penetration, while slightly fewer blows were required during the third meter (Figure 2).

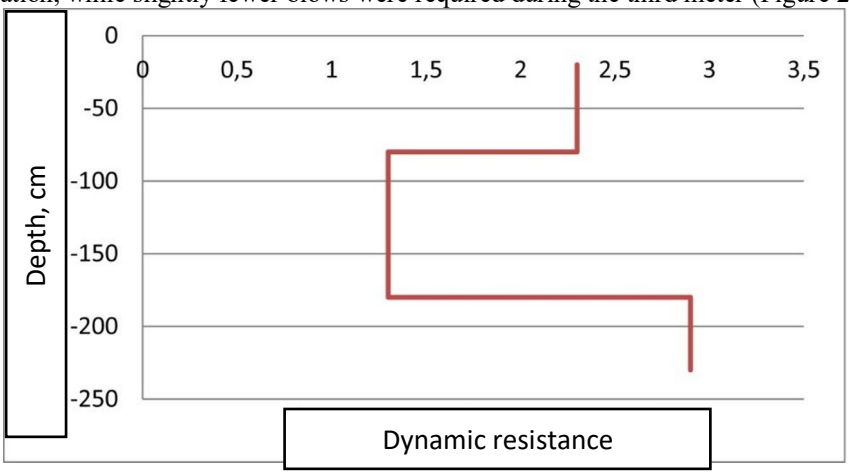

Fig. 2 Change in dynamic soil resistance with depth

This is consistent with the results of a study of core samples collected during drilling at the meteorological site (Table 1). For example, Table 1 shows that the first eighty centimeters

consist of mantle loam with inclusions of man-made sediments. The next horizon, up to two meters of excavated rock, consisted of less dense mantle sediments with inclusions of man-made sediments. The beginning of the third meter of excavated soil consisted of denser mantle sediments with inclusions of moraine sediments.

Table 1. A borehole at the Moscow State University Meteorological Observatory

Depth, m	Diagnostics	Description
0-0.24	Sod and humus horizon	Moldy odor, coarse texture, abundant roots, uniform brownish-gray color. Effervescence with 10% HCl is weak and fragmentary (fine soil).
0.24-0.37	Humus horizon with a technogenic one at the lower boundary	Effervesces at 10% HCl at the lower limit of inclusions. Inclusions: coal, brick
0.37-0.52	Man-made horizon	A turbated horizon based on mantle loam. Large inclusions (stones), coals. Fragments stained with humus, signs of structure (nuts, prisms). Effervesces in 10% HCl over rare carbonate inclusions.
0.52-0.63	Man-made horizon	In general, it doesn't effervesce
0.62-0.83	Man-made horizon	Large inclusions of brick, etc. in mixed cover loam, does not effervesce from HCl 10%
0.83-0.99		Effervesces from 10% HCl with inclusions
1.08-1.34	Cg,f	Covering loam, grayish-brown with nodules and concretions
1.49-1.65	Same	Less blue tones in the coloring
2.13-2.23	Moscow Moraine	At the upper boundary of the core is yellow sand with fine silicate gravel. Below is red-brick sandy loam.
2.23	Moscow Moraine	Doesn't effervesce with 10% HCl. Brick-red color. Sandy heavy loam/clay? Inclusions – silicate grit, dark crushed rock – basalt?
2.4-2.61	Moscow Moraine	Brick-red color. Sandy heavy loam/clay? Inclusions: silicate grit. Does not effervescent with 10% HCl.
3.00-3.84	Soil: Moscow/Dnieper? Moraine	A reddish-dark brown loam with a large amount of carbonate gravel. Due to inclusions and dispersed carbonates, it is not very plastic. It effervesces violently with 10% HCl.
6m	Soil, Dnieper moraine	Reddish-dark-brown loam with a large amount of carbonate gravel. Effervescent with 10% HCl.
7.91-8.03	Soil, Dnieper moraine	Brown – the color of milk chocolate, plastic with whitish sparse grains, fragmentary effervescence with inclusions
9.2-		More plastic, impregnated with carbonates, effervesces evenly and intensively
9.36-9.63	Paleosoil?	The horizon has a “spring earth” scent. It is unevenly colored. Darker spots with a gray undertone are visible against the overall reddish-brown background. Carbonate neoplasms in the form of pseudomycelium are present.
9.98-10.13	Paleosoil?	The horizon is structured—a nutty texture, with dark films on the edges of structural units. Reminiscent of a textural carbonate horizon. Rounded inclusions of carbonate composition.

10.80	Soil, Dnieper moraine	Reddish-dark-brown loam with a large amount of carbonate gravel. Effervescent with 10% HCl.
11.92-12.04	Soil, Dnieper moraine, within the capillary fringe of the waterlogged horizon	Brownish in color. Pale yellow tint and redox features (rusty and bluish spots, nodules and concretions of iron and manganese). Effervescence is moderately intense, primarily in large inclusions; fine earth and small inclusions are less intense.
14.3	Soil, Dnieper moraine, flooded	Very plastic, heavy, and wetter than the bulk of the samples. Carbonate nodules (new formations resulting from uniform, long-term flooding of carbonate rock) are observed.

4 Conclusions

The conducted training demonstrated the high efficiency of the impact probing method. Comparison with drilling data confirmed its applicability for rapid assessment of soil lithology in anthropogenically transformed areas.

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