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GENESIS AND GEOGRAPHY OF SOILS

Application of Cluster and Discriminant Analyses to Diagnose Lithological Heterogeneity of the Parent Material according to Its Particle-Size Distribution

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Abstract—Particle-size distribution in soddy-podzolic and light gray forest soils of the Botanical Garden of Kazan Federal University has been studied. The cluster analysis of data on the samples from genetic soil horizons attests to the lithological heterogeneity of the profiles of all the studied soils. It is probable that they are developed from the two-layered sediments with the upper colluvial layer underlain by the alluvial layer. According to the discriminant analysis, the major contribution to the discrimination of colluvial and alluvial layers is that of the fraction >0.25 mm. The results of canonical analysis show that there is only one significant discriminant function that separates alluvial and colluvial sediments on the investigated territory. The discriminant function correlates with the contents of fractions 0.05–0.01, 0.25–0.05, and >0.25 mm. Classification functions making it possible to distinguish between alluvial and colluvial sediments have been calculated. Statistical assessment of particle-size distribution data obtained for the plow horizons on ten plowed fields within the garden indicates that this horizon is formed from colluvial sediments. We conclude that the contents of separate fractions and their ratios cannot be used as a universal criterion of the lithological heterogeneity. However, adequate combination of the cluster and discriminant analyses makes it possible to give a comprehensive assessment of the lithology of soil samples from data on the contents of sand and silt fractions, which considerably increases the information value and reliability of the results.

Keywords: soil texture, multivariate statistical analysis, lithological heterogeneity, classification functions, Luvisols

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INTRODUCTION

The profile method developed by V.V. Dokuchaev is based on the examination of full soil profiles, including the parent material, with further comparison of the investigated properties and their characteristics [1, 13]. The application of this method allows us to trace the changes in the soil material under the impact of soil formation. However, the realization of this approach is only possible in the case of a simple soil profile consisting of the genetic horizons developed from the homogenous parent material [17, 18, 28]. According to B.G. Rozanov "during the analysis of soil profiles developed on loose parent materials... we cannot definitely judge the nature of the underlying horizons, i.e., to distinguish between C and D horizons. The separation of the C horizon is almost always open to argument" [12, p. 59]. The assessment of the initial lithological homogeneity (or heterogeneity) of the parent material cannot be based exceptionally on the results of soil morphological studies in the field. It requires an objective assessment based on laboratory analyses of the soil samples.

To diagnose the initial vertical heterogeneity of soil profiles, researchers usually apply the results of micromorphological [18], particle-size distribution [23–25, 32], mineralogical [17, 25, 27, 29], and elemental analyses. Among mineralogical data, the ratios of minerals resistant to weathering in different horizons are often examined, e.g., the zircon/rutile/tourmaline ratios [25]. In order to assess the lithological heterogeneity on the basis of data on the bulk elemental composition, the ratios of some characteristic elements are considered, e.g., the titanium/zirconium ratio [10, 22, 27, 31], the zirconium/yttrium ration [10, 22], etc. The results obtained with the use of the data of mineralogical and elemental analyses are considered to be most reliable in the assessments of lithological heterogeneity of the soil profiles. However, these methods are vary laborious and require certain pretreatments of the samples [10]. In this context, the use of particle-size distribution data on the fine earth material seems to be promising. In some cases, this method may be sufficient to diagnose the lithological heterogeneity of the initial parent material.