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## SPATIAL VARIABILITY OF SOIL ELECTRICAL RESISTIVITY WITHIN PEDOGENIC HORIZONS UNDER COASTAL INFLUENCE

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### Abstract

The aim of this study was to investigate the spatial variability of soil electrical resistivity within pedogenic horizons under coastal conditions and to evaluate its relationship with soil genesis, morphological features, and physicochemical properties.

The research was conducted within the coastal ecological monitoring zone of Lake Baikal, in near-shore areas characterized by periodic water level fluctuations, active sediment redistribution, and variable moisture regimes. Field investigations were carried out during the vegetation period.

Field studies were performed using standard pedological approaches. Representative soil profiles (burzems, stratozems, and lithozems) were described according to WRB (2022) guidelines, and samples were collected from each genetic horizon. Soil electrical resistivity ( $\rho$ ) was measured using the LandMapper-03 device following electrophysical methods. Laboratory analyses included determination of moisture content, humus, particle-size distribution, and pH. A new indicator, the Pedogenetic Resistivity Index (PRI), was proposed to evaluate the relative contribution of resistivity in relation to humus and clay content. Statistical analysis included descriptive statistics, correlation analysis, one-way ANOVA, and the Kruskal–Wallis test.

The results revealed significant vertical and spatial variability of electrical resistivity across soil types and horizons. Burzem soils showed a gradual increase in resistivity with depth, while stratozem soils exhibited non-monotonic, layered patterns reflecting lithological heterogeneity. Lithozem soils demonstrated the highest variability due to weak profile development and strong lithological control. PRI values effectively reflected pedogenetic differentiation, with lower values in humus-rich horizons and higher values in deeper layers. Statistical tests did not confirm significant differences among soil types ( $p > 0.05$ ), although a clear tendency toward differentiation was observed.

Soil electrical resistivity is a reliable integrative indicator of soil heterogeneity and pedogenetic differentiation under coastal conditions. The proposed PRI index enhances the interpretation of electrophysical data; however, its application requires an integrated approach combining morphological, physicochemical, and geophysical analyses.

**Keywords:** soil electrical resistivity, Pedogenetic Resistivity Index (PRI), coastal soils, spatial variability, soil heterogeneity, pedogenic horizons, lithological control, soil profile differentiation

### Introduction

Soil electrical resistivity has emerged as an effective integrative indicator reflecting the combined influence of soil physical, chemical, and structural properties. As a non-destructive and

sensitive parameter, it has been increasingly used in soil science to characterize spatial heterogeneity, diagnose soil conditions, and interpret pedogenic processes. Electrical resistivity is primarily controlled by soil moisture content, pore structure, texture, salinity, and temperature, but its behavior within soil profiles is often governed by complex interactions among these factors.

In recent years, increasing attention has been given to the application of electrical resistivity measurements for studying vertical soil differentiation and identifying genetic horizons. Variations in resistivity within soil profiles can reveal transitions between horizons, reflecting differences in humus accumulation, mineral composition, bulk density, and degree of weathering. However, the relationship between electrical resistivity and individual soil properties is not always linear or uniform, particularly under heterogeneous environmental conditions.

Coastal landscapes represent a specific pedoecological environment where soil formation is influenced by a combination of hydrological, geomorphological, and climatic factors. Fluctuating moisture regimes, periodic wetting and drying, sediment deposition, and the influence of surface and groundwater dynamics contribute to the development of complex soil profiles. These conditions often result in pronounced spatial variability of soil properties, including electrical resistivity, both horizontally and vertically.

Despite the growing body of research, the interpretation of electrical resistivity in terms of soil genesis and horizon differentiation remains challenging. In many cases, resistivity patterns cannot be explained solely by traditional soil parameters such as moisture or granulometric composition. Instead, they reflect the integrated effect of multiple pedogenic processes, including organic matter transformation, mineral weathering, structural evolution, and anthropogenic or pyrogenic influences.

The study of electrical resistivity within pedogenic horizons under coastal influence is therefore essential for improving our understanding of soil formation mechanisms and for refining the use of geophysical methods in soil science. In particular, identifying consistent patterns of resistivity distribution across different soil types can provide valuable insights into the genetic structure of soils and their functional properties.

The aim of this study is to investigate the spatial variability of soil electrical resistivity within pedogenic horizons in a coastal monitoring zone and to assess its relationship with soil morphological features and genesis. Special attention is given to comparing resistivity patterns across different soil types and interpreting their variability in the context of pedogenic processes.

It is hypothesized that soil electrical resistivity exhibits systematic spatial variability within pedogenic horizons under coastal influence, reflecting the combined effects of soil-forming processes, morphological differentiation, and environmental factors. This variability is expected to correspond to the genetic structure of soil profiles rather than being controlled by a single factor such as moisture or texture.

### **Literature review**

Soil electrical resistivity (ER) and electrical conductivity (EC) are widely recognized as integrative indicators reflecting the combined influence of soil moisture, temperature, porosity, texture, and ionic composition [1]. Unlike individual soil parameters, electrical properties provide a cumulative response to multiple soil-forming factors, making them particularly valuable for studying soil heterogeneity and pedogenic processes. Recent studies emphasize that the interpretation of electrical properties should be based on a complex, multi-factor approach rather than simplified linear relationships [18, 4].

The theoretical foundations of soil electrophysical properties have been extensively developed in classical and modern studies. Pozdnyakov outlined the methodological basis for applying electrophysical methods in soil investigations, highlighting their sensitivity to structural and moisture-related changes [15]. Earlier, Pozdnyakov and Gulaliyev demonstrated that soil electrical properties vary significantly depending on soil type, granulometric composition, and environmental conditions, emphasizing their diagnostic potential in soil science [16].

Temperature is another key factor influencing soil electrical behavior. Gulaliyev showed that specific electrical conductivity of soils is strongly dependent on temperature, which affects ion mobility and water–solid interactions [10]. These findings confirm that electrical properties should be interpreted in relation to both thermal and hydrological regimes, particularly in environments characterized by seasonal variability. In recent years, geophysical methods such as electrical resistivity tomography (ERT) have significantly expanded the possibilities for studying soil profile structure and spatial variability. ERT-based approaches allow for high-resolution analysis of subsurface heterogeneity and have been successfully applied to monitor soil moisture dynamics and structural differentiation [2,7,8].

These methods are particularly useful in identifying vertical contrasts within soil profiles and detecting transitions between genetic horizons. Modern research increasingly demonstrates that electrical resistivity can be used to identify pedogenic horizons and lithological discontinuities. Variations in resistivity are often associated with changes in soil structure, density, mineral composition, and degree of weathering [6, 22]. However, these relationships are not always straightforward, as resistivity reflects the combined influence of multiple interacting factors rather than a single dominant variable. The relationship between electrical properties and soil trophic status has also been investigated using electrophysical methods. In agricultural systems, soil electrical conductivity has also been increasingly applied for site-specific nitrogen management and precision fertilization strategies [17]. Buzuk proposed an approach based on exponential regression and moisture correction, demonstrating that accurate interpretation of electrical data requires accounting for non-linear dependencies and environmental variability [5]. This approach further supports the idea that soil electrical properties are governed by complex interactions rather than simple linear models. Spatial variability of soil electrical properties is strongly influenced by landscape position, microrelief, and hydrological conditions. Recent evidence from arid urban soils also indicates that episodic waterlogging significantly modifies hydropedogenic pathways and spatial redistribution of soil moisture, resulting in pronounced electrophysical contrasts within soil profiles [3]. Studies have shown that microtopography plays a significant role in pedogenesis, affecting moisture redistribution and soil development processes [12]. Similar pedogenetic contrasts between slope and basin positions have also been reported in recent geomorphologically controlled soil studies [23]. Coastal environments, in particular, exhibit high spatial heterogeneity due to fluctuating moisture regimes, sediment deposition, and groundwater influence [10, 19]. Similar variability patterns have also been reported in irrigated agricultural systems, where ERT-based observations revealed substantial temporal changes in soil moisture distribution [13].

Within the Baikal region, electrophysical methods have been successfully applied for soil diagnostics in ecological monitoring zones. Vashukevich et al. demonstrated that electrical resistivity reflects internal soil heterogeneity and can be effectively used for monitoring soil conditions and profile differentiation [20]. Their work highlighted the importance of integrating geophysical measurements with pedological observations. Recent studies further confirm the importance of combining electrophysical methods with classical soil analysis. Advances in sensor-based and spectroscopic detection systems further expand the applicability of soil electrical conductivity measurements in modern digital soil diagnostics [21]. Kozlova and Gulaliyev showed that electrical resistivity, when interpreted together with morphological and physicochemical properties, provides a reliable basis for diagnosing soil transformation under agropedogenesis [11]. Their results indicate that resistivity patterns are closely linked to humus content, granulometric composition, and iron forms, although these relationships vary across soil types. Overall, the current state of research indicates that soil electrical resistivity is a powerful tool for analyzing spatial variability and soil profile structure. Recent imaging-based studies further confirm the applicability of resistivity methods for quantitative assessment of soil water content variability at field scale [14]. However, its interpretation remains complex due to the multicausal nature of controlling factors, including moisture, temperature, lithology, and pedogenic processes. Despite

significant advances, there is still a lack of studies that explicitly examine the spatial variability of electrical resistivity within pedogenic horizons under coastal influence while integrating morphological, genetic, and environmental factors.

### **Materials and methods**

The study was conducted within the coastal ecological monitoring zone of Lake Baikal, specifically in near-shore areas characterized by periodic water level fluctuations, active sediment redistribution, and variable moisture regimes. These conditions create a highly heterogeneous pedogenic environment formed under the influence of hydrodynamic processes, lithological variability, and surface runoff.

The investigated soils include burzems, lithozems, and stratified soils (stratosems), which represent different stages and conditions of soil formation within the coastal landscape.

Field investigations were carried out using standard pedological methods. Representative soil profiles were selected, and soil samples were collected separately from each genetic horizon.

Soil electrical resistivity ( $\rho$ , Ohm·m) was measured using the LandMapper-03 device based on electrophysical principles. Measurements were conducted following the methodological approaches of Pozdnyakov [15] and Pozdnyakov and Gulaliyev [16]. Soil samples were prepared to preserve their natural structure, moisture conditions were standardized, and electrode contact stability was ensured.

In addition, selected soil physicochemical properties, including moisture content, particle-size distribution, humus content, and soil pH, were determined under laboratory conditions.

Statistical data processing included descriptive statistics (mean, standard deviation, and coefficient of variation, CV%) and correlation analysis.

In this study, a new indicator — the Pedogenetic Resistivity Index (PRI) — was introduced:

$$PRI = \frac{\rho}{Humus + Clay_{<0.01}}$$

This index expresses the relative variation of electrical resistivity in relation to soil organic matter and fine particle fraction and is used as an integrative indicator of pedogenetic differentiation.

To assess differences in PRI among soil types, one-way ANOVA and the non-parametric Kruskal–Wallis test were applied.

### **Results**

The results of the study indicate that soils formed under coastal conditions exhibit significant spatial variability in electrical resistivity ( $\rho$ ), both vertically within soil profiles and across different soil types. This variability is closely associated with the differentiation of genetic horizons and reflects the complex influence of soil-forming processes.

In burzem soils (section 9), the vertical distribution of electrical resistivity shows a relatively consistent pattern (Table 1). In the upper O and AY horizons, resistivity values range from 773 to 775 Ohm·m, while in the deeper horizons, these values increase to 969–1112 Ohm·m. This increase can be attributed to the decrease in humus content and the compaction of soil structure with depth.

Correlation analysis revealed that electrical resistivity is negatively correlated with humus content ( $r = -0.737$ ) and positively correlated with coarse particle fractions ( $r = 0.856$ ), confirming the significant role of soil structure and granulometric composition in controlling electrical properties.

**Table 1. Electrical resistivity and physicochemical properties of burzem soil (Section 9)**

Horizon	Depth (cm)	$\rho$ (Ohm·m)	Humus (%)	pH	Clay <0.001 mm (%)	Clay <0.01 mm (%)
O	2–7	773.8	14.5	4.9	14	23
AY	7–13	775.2	6.6	5.3	26	20
BM	13–30	969.3	4.5	5.2	20	36
C	30–40	922.1	3.4	5.2	18	23
	40–50	1112.0	2.8	5.2	17	36

*Note. Correlation coefficients (r):  $\rho$ –Humus =  $-0.737$ ;  $\rho$ –pH =  $0.07$ ;  $\rho$ –Clay (<0.001 mm) =  $-0.234$ ;  $\rho$ –Clay (<0.01 mm) =  $0.856$ .*

In the second burzem soil profile (section 7), the distribution of electrical resistivity exhibits a more pronounced and heterogeneous pattern (Table 2). In the upper horizon (4–9 cm), resistivity is relatively low ( $\rho = 345$  Ohm·m), whereas within the 10–50 cm interval, it increases sharply to 1185–1248 Ohm·m. In deeper layers, resistivity decreases again and stabilizes within the range of 840–870 Ohm·m.

Such variability reflects structural heterogeneity within the soil profile and indicates the presence of different stages of pedogenic development. Correlation analysis also shows a negative relationship between electrical resistivity and humus content ( $r = -0.7167$ ), as well as a weak negative correlation with fine particle fractions.

**Table 2. Electrical resistivity and physicochemical properties of burzem soil (Section 7)**

Horizon	Depth (cm)	$\rho$ (Ohm·m)	Humus (%)	pH	Clay <0.001 mm (%)	Clay <0.01 mm (%)
AY	4–9	345.1	8.6	5.4	13	32
	10–20	1185.0	2.6	5.7	11	30
BM	20–30	1243.0	1.7	5.8	8	20
	30–40	1189.0	2.1	5.7	7	18
	40–50	1248.0	1.4	5.6	11	27
C	50–60	845.7	1.3	5.9	10	21
	60–70	841.3	1.3	6.0	10	24
	>85	873.3	0.9	6.0	9	24

*Note. Correlation coefficients (r):  $\rho$ –Humus =  $-0.7167$ ;  $\rho$ –pH =  $0.208$ ;  $\rho$ –Clay (<0.001 mm) =  $-0.6405$ ;  $\rho$ –Clay (<0.01 mm) =  $-0.460$ .*

In stratossem soils (section 6), the distribution of electrical resistivity exhibits a non-monotonic and layered pattern (Table 3). Resistivity values vary within a wide range of 301–1007 Ohm·m, showing pronounced differences across genetic horizons. Maximum values (~1007 Ohm·m) are observed at a depth of 25–45 cm (AC horizon), whereas minimum values (~301 Ohm·m) occur at 110–115 cm.

This variability can be explained by the presence of sedimentary layers and buried soil horizons. Correlation analysis indicates that relationships between electrical resistivity and soil properties in this soil type are weaker and less stable compared to other soil types.

**Table 3. Electrical resistivity and physicochemical properties of stratossem soil (Section 6)**

Horizon	Depth (cm)	$\rho$ (Ohm·m)	Humus (%)	pH	Clay <0.001 mm (%)	Clay <0.01 mm (%)
RU	1–4	625.4	10.5	5.7	8	18
	4–9	887.4	15.8	5.5	11	25
	9–15	905.2	10.5	5.5	11	27
{A}	15–25	659.9	3.1	5.5	11	24
{AC}	25–45	1007.0	1.4	5.6	9	20
{C}	75–105	525.3	0.7	6.5	13	23
{A}	105–110	370.1	3.8	6.6	21	39
	110–115	301.0	2.2	6.5	14	31
{C}	115–130	740.5	0.7	6.4	11	25
	130–152	802.7	0.5	6.8	18	36

*Note.* Correlation coefficients ( $r$ ):  $\rho$ -Humus = 0.296;  $\rho$ -pH = -0.578;  $\rho$ -Clay (<0.001 mm) = -0.500;  $\rho$ -Clay (<0.01 mm) = -0.413.

In lithozem soils, the distribution of electrical resistivity is strongly dependent on the degree of soil profile development and lithological characteristics. In section 4 (Table 4A), resistivity values are relatively low, ranging from 279 to 456 Ohm·m. Correlation analysis shows a strong positive relationship between electrical resistivity and humus content ( $r = 0.9797$ ), while a strong negative relationship is observed with fine particle fractions. This indicates that electrical properties are closely related to soil water retention capacity and dispersive composition.

**Table 4. Electrical resistivity and physicochemical properties of lithozem soil (Section 4)**

Horizon	Depth (cm)	$\rho$ (Ohm·m)	Humus (%)	pH	Clay <0.001 mm (%)	Clay <0.01 mm (%)
AY	2–18	456.2	8.1	5.4	18	28
C	18–27	279.7	2.9	5.3	26	41
	27–38	284.6	1.7	5.3	23	38

*Note.* Correlation coefficients ( $r$ ):  $\rho$ -Humus = 0.9797;  $\rho$ -pH = 0.9997;  $\rho$ -Clay (<0.001 mm) = -0.9373;  $\rho$ -Clay (<0.01 mm) = -0.9805.

In section 3 (Table 5), electrical resistivity increases sharply and varies within a wide range of 453–1282 Ohm·m. The highest values are recorded in the parent material (R horizon). This pattern can be explained by the weakly developed soil profile and the influence of dense lithological material. Correlation analysis indicates a strong negative relationship between electrical resistivity and both humus content and fine particle fractions.

**Table 5. Electrical resistivity and physicochemical properties of lithozem soil (Section 3)**

Horizon	Depth (cm)	$\rho$ (Ohm·m)	Humus (%)	pH	Clay <0.001 mm (%)	Clay <0.01 mm (%)
AY	4–10	453.3	5.0	5.4	18	28
C	10–20	1113.0	1.2	5.4	17	27
	20–40	902.4	0.9	5.4	16	26
R	>40	1282.0	0.5	5.4	16	25

*Note.* Correlation coefficients ( $r$ ):  $\rho$ -Humus = -0.9234;  $\rho$ -Clay (<0.001 mm) = -0.7709;  $\rho$ -Clay (<0.01 mm) = -0.8199.

Overall, the obtained results indicate that soil electrical resistivity is not controlled by a single factor but is governed by the combined influence of moisture, humus content, granulometric composition, structural organization, and lithological characteristics. The differences in resistivity distribution among soil types confirm that this parameter serves as an integrative indicator reflecting soil genesis and profile differentiation.

Statistical analysis of the Pedogenetic Resistivity Index (PRI) revealed that the observed differences among soil types are not statistically significant at the 5% significance level. According to the results of one-way ANOVA, the differences are not statistically significant ( $p = 0.0999$ ). Similarly, the non-parametric Kruskal–Wallis test confirmed the absence of statistically significant differences ( $p = 0.1069$ ).

However, despite the lack of statistical significance, the results indicate a clear tendency toward differentiation among soil types. This pattern can be explained by high within-group variability, as reflected by elevated coefficients of variation (CV), and by pronounced lithological heterogeneity, particularly in lithozem soils.

The distribution of PRI across soil types is presented in Figure 2. The boxplot demonstrates that burzem soils are characterized by higher median values and relatively stable distributions, indicating a more uniform and gradually developed pedogenetic structure. In contrast, stratossem soils exhibit a narrower interquartile range but include several outliers, reflecting local heterogeneity associated with layered sedimentary structures. Lithozem soils show the highest variability, with a wide interquartile range and extended whiskers, indicating strong heterogeneity and the dominant influence of lithological control.

Thus, the PRI index effectively reflects not only the differentiation of genetic horizons but also the degree of internal heterogeneity within soil profiles.

### **Discussion**

The results of this study demonstrate that the vertical distribution of soil electrical resistivity under coastal conditions directly reflects the genetic structure of soil profiles and follows different patterns across soil types.

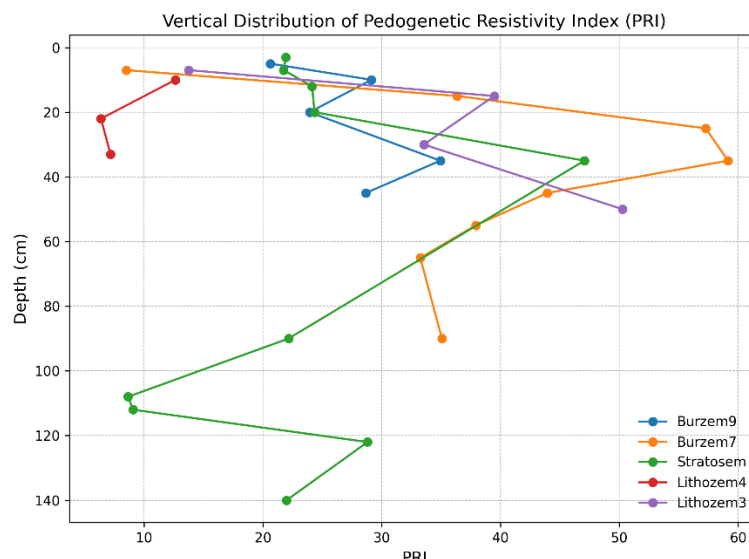
In burzem soils, the consistent increase in resistivity with depth ( $773 \rightarrow 1112 \text{ Ohm}\cdot\text{m}$ ) corresponds to a decrease in humus content and compaction of soil structure. These findings confirm the sensitivity of soil electrophysical properties to structural and moisture changes, as reported by Pozdnyakov [15] and Pozdnyakov and Gulaliyev [16].

In stratossem soils, the observed non-monotonic distribution of resistivity ( $301\text{--}1007 \text{ Ohm}\cdot\text{m}$ ) is associated with their lithologically heterogeneous structure. This feature indicates the presence of lithological discontinuities within the soil profile and is consistent with the findings of Cheng et al. [6] and Waroszewski et al. [22].

In lithozem soils, the sharp variation in resistivity ( $279 \rightarrow 1282 \text{ Ohm}\cdot\text{m}$ ) can be explained by the weak development of the soil profile and the dominant influence of parent material. These results highlight the key role of lithological control in coastal landscapes [10, 19].

Correlation analysis shows that relationships between electrical resistivity and soil properties vary depending on soil type and do not exhibit a universal pattern. This confirms the multi-factor nature of electrical resistivity and emphasizes the importance of non-linear approaches in its interpretation [5].

The application of the Pedogenetic Resistivity Index (PRI) further clarifies these patterns. As shown in Figure 1, PRI values vary in accordance with genetic horizons within the soil profile, clearly reflecting pedogenetic differentiation.



**Figure 1.** Vertical distribution of the Pedogenetic Resistivity Index (PRI) in burzem, stratossem, and lithozem soils, reflecting pedogenetic differentiation and lithological control within soil profiles.

The results of PRI calculations indicate that in upper humus-rich horizons, PRI values are relatively low (6–20), which is associated with higher humus and clay content. In contrast, in deeper horizons, particularly in layers under lithological control, PRI values increase significantly, reaching 40–60.

In burzem soils, the increase of PRI values with depth reflects a classical pattern of soil profile development. In stratossem soils, however, PRI exhibits irregular variation, indicating lithological heterogeneity. In lithozem soils, the highest PRI values are observed in the parent material zone.

The mean values of PRI and the coefficient of variation (CV%) for different soil types are presented in Tables 6 and 7.

**Cədvəl 6. Mean PRI and coefficient of variation (CV%) for soil profiles**

Soil type	Mean PRI	SD	CV (%)
Burzem (section 9)	27.46	5.46	19.88
Burzem (section 7)	38.93	15.82	40.63
Stratossem	22.99	10.65	46.31
Lithozem (section 4)	8.73	3.41	39.11
Lithozem (section 3)	34.26	15.33	44.75

As shown in Table 6, burzem soils (section 9) are characterized by low variability of PRI (CV = 19.88%), indicating a relatively homogeneous profile structure. In contrast, burzem soils (section 7) and stratossem soils exhibit higher CV values, reflecting structural and lithological heterogeneity.

The aggregated results presented in Table 7 indicate that lithozem soils show the highest variability (CV = 75.22%), confirming that they represent the most lithologically heterogeneous soil type.

Overall, the PRI index serves as an effective diagnostic indicator that reflects not only the differentiation between genetic horizons but also the degree of structural heterogeneity within soil profiles.

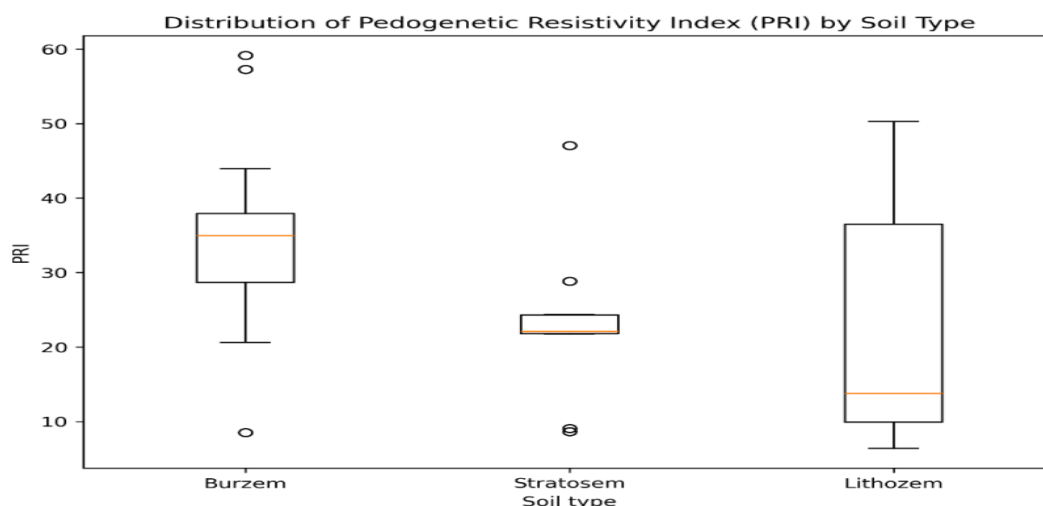
**Cədvəl 7. Aggregated statistics of PRI for soil types**

Soil type	Mean PRI	SD	CV (%)
Burzem (overall)	34.52	13.77	39.89
Stratosem (overall)	22.99	10.65	46.31
Lithozem (overall)	23.32	17.54	75.22

Statistical analysis further supports this interpretation. Both one-way ANOVA ( $p = 0.0999$ ) and the Kruskal–Wallis test ( $p = 0.1069$ ) indicate that differences in PRI values among soil types are not statistically significant at the 5% level. However, the observed variability suggests a clear tendency toward differentiation between soil types.

This pattern can be attributed to relatively high within-group variability and limited sample size, particularly in lithozem and stratosem soils. The elevated coefficients of variation (CV) confirm that intra-profile heterogeneity plays a dominant role in PRI distribution and may mask statistically significant differences between soil types.

The boxplot (Figure 2) further supports these findings, showing that lithozem soils exhibit the highest variability in PRI, while burzem soils display a more stable and uniform distribution.



**Figure 2.** Distribution of Pedogenetic Resistivity Index (PRI) across soil types. The boxplot illustrates median values, interquartile range, and variability of PRI in burzem, stratosem, and lithozem soils.

The boxplot analysis confirms that the variability of PRI differs substantially among soil types. The relatively compact distribution observed in burzem soils suggests more uniform pedogenetic development. In contrast, stratosem soils exhibit localized deviations, likely associated with lithological discontinuities and buried horizons. Lithozem soils show the highest variability, which is consistent with their weak profile development and strong dependence on parent material.

The presence of outliers in the PRI distribution further highlights the influence of local pedogenic and lithological heterogeneity. These extreme values may correspond to horizons with abrupt changes in moisture content, texture, or structural organization, particularly in stratified and weakly developed soils.

### Conclusion

The study demonstrates that soil electrical resistivity is a reliable integrative indicator of pedogenetic differentiation under coastal conditions and exhibits pronounced spatial variability within soil profiles. This variability is controlled not by a single factor but by the combined influence of moisture, humus content, structural organization, granulometric composition, and

lithological characteristics.

Burzem soils show a gradual increase in resistivity with depth, reflecting classical profile differentiation, whereas stratossem soils exhibit non-monotonic, layered patterns associated with sedimentary heterogeneity. In lithozem soils, resistivity is primarily controlled by parent material and the degree of profile development.

The proposed Pedogenetic Resistivity Index (PRI) effectively captures both vertical differentiation and internal heterogeneity of soils. Although statistical tests did not confirm significant differences among soil types, the observed patterns indicate a clear tendency toward differentiation governed by pedogenetic and lithological factors.

Overall, soil electrical resistivity can be considered a robust diagnostic parameter for assessing soil heterogeneity; however, its interpretation requires an integrated approach combining morphological, physicochemical, and geophysical data.

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## SAHİL TƏSİRİ ALTINDA PEDOGENETİK HORIZONTLAR DAXİLİNDƏ TORPAĞIN ELEKTRİK MÜQAVİMƏTİNİN MƏKAN DƏYİŞKƏNLIYI

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### Xülasə

Tədqiqatın məqsədi sahil şəraitində pedogenetik horizontlar daxilində torpağın elektrik müqavimətinin məkan dəyişkənliyini öyrənmək və onun torpaq genezisi, morfoloji xüsusiyyətlər və fiziki-kimyəvi göstəricilərlə əlaqəsini qiymətləndirmək olmuşdur.

Tədqiqat Baykal gölünün sahil ekoloji monitorinq zonasında, su səviyyəsinin dövrü dəyişməsi, aktiv çöküntü yığılması və dəyişkən rütubət rejimi ilə səciyyələnən sahilyanı ərazilərdə aparılmışdır. Çöl tədqiqatları vegetasiya dövründə həyata keçirilmişdir.

Çöl işləri standart torpaqşünaslıq metodları əsasında aparılmışdır. Reprezentativ torpaq profilləri (burözəmlər, stratozəmlər və litosemlər) WRB (2022) təsnifatına uyğun təsvir edilmiş və hər genetik horizontdan nümunələr götürülmüşdür. Torpağın elektrik müqaviməti ( $\rho$ ) LandMapper-03 cihazı vasitəsilə elektrofiziki metodlara əsasən ölçülmüşdür. Laborator analizlər çərçivəsində rütubət, humus miqdarı, qranulometrik tərkib və pH müəyyən edilmişdir. Elektrik müqavimətinin humus və gil fraksiyası ilə qarşılıqlı təsirini qiymətləndirmək üçün yeni göstərici — Pedogenetik Müqavimət İndeksi (PRI) təklif edilmişdir. Statistik təhlilə təsviri statistika, korrelyasiya analizi, birləşdirilmiş dispersiya təhlili (ANOVA) və Kruskal–Wallis qeyri-parametrik testi daxil edilmişdir.

Nəticələr göstərmişdir ki, torpağın elektrik müqaviməti müxtəlif torpaq tipləri və genetik horizontlar üzrə əhəmiyyətli şaquli və məkan dəyişkənliyi nümayiş etdirir. Burözem torpaqlarda

müqavimətin dərinlik üzrə tədricən artması müşahidə olunduğu halda, stratozemlərdə litoloji heterogenliyi əks etdirən qeyri-monoton və laylı paylanma müşahidə olunur. Litosem torpaqlar isə zəif inkişaf etmiş profil və ana süxurun dominant təsiri ilə əlaqədar ən yüksək dəyişkənlik göstərir. PRI göstəricisi pedogenetik diferensiasiyayı effektiv şəkildə əks etdirir: humusla zəngin horizontlarda aşağı, daha dərin qatlarda isə yüksək qiymətlər qeydə alınmışdır. Statistik testlər torpaq tipləri arasında əhəmiyyətli fərqləri təsdiqləməyə də ( $p > 0.05$ ), diferensiasiya meyli müşahidə edilmişdir.

Torpağın elektrik müqaviməti sahil şəraitində torpaq heterogenliyinin və pedogenetik diferensiasiyanın qiymətləndirilməsi üçün etibarlı inteqral göstərici hesab oluna bilər. Təklif olunan PRI indeksi elektrofiziki məlumatların interpretasiyasını genişləndirir, lakin onun tətbiqi morfoloji, fiziki-kimyəvi və geofiziki məlumatların inteqrasiyasına əsaslanan kompleks yanaşma tələb edir.

**Açar sözlər:** torpağın elektrik müqaviməti, Pedogenetik Müqavimət İndeksi (PRI), sahil torpaqları, məkan dəyişkənliyi, torpaq heterogenliyi, pedogenetik horizontlar, litoloji nəzarət, torpaq profilinin diferensiasiyası

## ПРОСТРАНСТВЕННАЯ ИЗМЕНЧИВОСТЬ ЭЛЕКТРИЧЕСКОГО СОПРОТИВЛЕНИЯ ПОЧВ В ПЕДОГЕНЕТИЧЕСКИХ ГОРИЗОНТАХ В УСЛОВИЯХ ПРИБРЕЖНОГО ВЛИЯНИЯ

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### Аннотация

Целью данного исследования являлось изучение пространственной изменчивости электрического сопротивления почв в пределах педогенетических горизонтов в прибрежных условиях, а также оценка его взаимосвязи с генезисом почв, морфологическими признаками и физико-химическими свойствами.

Исследование проводилось в прибрежной зоне экологического мониторинга озера Байкал, в прибрежных участках, характеризующихся периодическими колебаниями уровня воды, активным перераспределением осадков и изменчивым режимом увлажнения. Полевые исследования выполнялись в вегетационный период.

Полевые работы проводились с использованием стандартных почвоведческих методов. Репрезентативные почвенные разрезы (бурозёмы, литозёмы и стратифицированные почвы — стратозёмы) описывались в соответствии с рекомендациями WRB (2022), а образцы отбирались из каждого генетического горизонта. Электрическое сопротивление почвы ( $\rho$ ) измерялось с использованием прибора LandMapper-03 на основе электрофизических методов. Лабораторные анализы включали определение влажности, содержания гумуса, гранулометрического состава и pH. В работе предложен новый показатель — индекс педогенетического сопротивления (Pedogenetic Resistivity Index, PRI), позволяющий оценить относительное значение сопротивления с учётом содержания гумуса и глинистых частиц. Статистическая обработка включала описательную статистику, корреляционный анализ, дисперсионный анализ (ANOVA) и непараметрический критерий Краскела–Уоллиса.

Результаты показали значительную вертикальную и пространственную изменчивость электрического сопротивления в различных типах почв и горизонтах. В бурозёмах наблюдается постепенное увеличение сопротивления с глубиной, тогда как стратозёмы характеризуются немонотонным, слоистым распределением, отражающим литологическую неоднородность. Литозёмы демонстрируют наибольшую изменчивость, обусловленную слабым развитием

профиля и доминирующим влиянием материнской породы. Значения PRI эффективно отражают педогенетическую дифференциацию: более низкие значения характерны для гумусированных горизонтов, тогда как более высокие — для глубоких слоёв. Статистические тесты не выявили значимых различий между типами почв ( $p > 0,05$ ), однако наблюдается тенденция к их дифференциации.

Электрическое сопротивление почв является надёжным интегральным показателем почвенной неоднородности и педогенетической дифференциации в прибрежных условиях. Предложенный индекс PRI расширяет возможности интерпретации электрофизических данных, однако его применение требует комплексного подхода с учётом морфологических, физико-химических и геофизических характеристик почв.

**Ключевые слова:** Электрическое сопротивление почвы, индекс педогенетического сопротивления (PRI), прибрежные почвы, пространственная изменчивость, почвенная неоднородность, педогенетические горизонты, литологический контроль, дифференциация почвенного профиля

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