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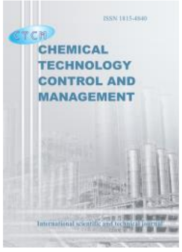

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THE MORPHOLOGY ANALYSIS OF SOIL IN REMOTE SENSING IMAGE PROCESSING

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Abstract. *This article analyzed various techniques used in satellite image processing to analyze soil morphology. Analysis of soil morphology using satellite imagery plays a crucial role in soil science research, Land Management, and environmental monitoring. It provides an economical and efficient means of studying large-scale soil variability, providing information on land sustainable use, resource management and soil conservation decisions.*
Keywords: *remote sensing, pattern, soil, identification, morphology, classification, kuboid, prizma, plita.*

Annotatsiya. *Ushbu maqolada tuproq morfologiyasini tahlil qilish uchun sun'iy yo'ldosh tasvirlarini qayta ishlashda qo'llaniladigan turli usullar tahlil qilingan. Sun'iy yo'ldosh tasvirlari yordamida tuproq morfologiyasini tahlil qilish tuproqshunoslikni tadqiq qilish, yerni boshqarish va atrof-muhit monitoringida hal qiluvchi rol o'ynaydi. U tuproqning keng ko'lamli o'zgaruvchanligini o'rganish, yerdan barqaror foydalanish, resurslarni boshqarish va tuproqni muhofaza qilish bo'yicha qarorlar to'g'risida ma'lumot berishning iqtisodiy va samarali vositasini taqdim etadi.*
Tayanch so'zlar: *masofadan zondlash, naqsh, spiral, identifikatsiya, morfologiya, tasnif, kuboid, prizma, plita.*

Аннотация. *В данной статье проанализированы различные методы, используемые при обработке спутниковых изображений для анализа морфологии почвы. Анализ морфологии почвы с использованием спутниковых снимков играет решающую роль в почвоведческих исследованиях, землеустройстве и мониторинге окружающей среды. Он обеспечивает экономичное и эффективное средство изучения крупномасштабной изменчивости почв, предоставляя информацию об устойчивом использовании земель, управлении ресурсами и решениях по сохранению почв.*
Ключевые слова: *дистанционное зондирование, узор, спираль, идентификация, морфология, классификация, кубоид, призма, плита.*

Introduction

Identification of emblems based on precedents for object identification in remote sensing images is one of the important tasks in the field of remote sensing and computer vision. It consists in the development of a method for automatic object identification in remote sensing images using crocodile detection methods.

Remote sensing has become an important tool for collecting information about the Earth's surface and has many applications in areas such as environmental monitoring, agriculture and urban planning. However, the large size and complexity of remote sensing images makes it difficult to manually identify the object. Therefore, automated methods for detecting an object in remote sensing images will be necessary [1].

In the process of development, the soil acquires a number of external features that distinguish it from the rocks. In it, genetic horizons are released, new substances and compounds are formed. Morphological signs are external signs of the soil, which are used in assessing the direction of the soil formation process [2]. The main morphological features of the soil: 1) the structure of the soil profile, 2) the power of the soil and its horizons, 3) structure, 4) granulometric composition, 5) addition, 6) humidity, 7) coloring, 8) neoplasms and inclusions, 9) the nature of the transition to the underlying horizon and the shape of the border [3].

The development and evolution of the soil lead to the appearance in it of layers that are located on top of each other and differ in a number of signs, such as structure, color, mechanical composition, orientation of biological processes. Such layers are called soil horizons, and the set of soil horizons forms a soil profile in the form of a vertical sequence of genetic horizons specific to each soil. Young underdeveloped soils are very thin, close to the original rock, and the horizons in it do not form. During the development of the soil, the number of Horizons increases. In well-developed soil, three main horizons (a, b, c) can be distinguished, which has a specificity due to the nature of the soil-forming processes [5].

Solution method

The main thing in soil research is to understand the nature, properties, development and the role of soils as part of landscapes and ecosystems. The main condition for understanding this object of research is the availability of reliable information about soil morphology and other characteristics obtained during the study and description of the soil in the field. It is important to make a careful description of the soil, as it serves as the basis for soil classification and land assessment, as well as for describing the genesis and ecological functions of the soil. The correct description of the soil and the information about the genesis of the soil obtained from it are also powerful tools for planning and interpreting expensive laboratory studies. This can prevent sampling errors.

Soil morphology analysis in the processing of satellite images involves studying the physical characteristics and patterns of soil on the Earth’s surface using remotely sensed data. Here are some methods commonly used in this process:

1. Spectral Indices: Spectral indices are derived from satellite images by combining different bands to highlight specific soil properties. For soil morphology analysis, indices like Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and Enhanced Vegetation Index (EVI) can be utilized to identify variations in vegetation cover, which can indicate different soil types.

2. Texture Analysis: Texture refers to the arrangement of soil particles and influences various soil properties. Texture analysis can be performed by applying image processing techniques on satellite images. This involves segmenting the image into different regions based on texture, such as using algorithms like k-means clustering or Gaussian mixture models. These segments can provide insights into variations in soil texture across the landscape.

3. Supervised Classification: Supervised classification is a technique where a training dataset with known soil classes is used to classify pixels in satellite images. The training dataset consists of sample points with corresponding soil type information. Various classification algorithms, such as Maximum Likelihood Classification, Support Vector Machines (SVM), or Random Forests, can be applied to classify the pixels based on their spectral properties and assigned soil types.

4. Unsupervised Classification: Unsupervised classification is used to identify clusters or patterns within satellite images without any prior knowledge of soil classes. This technique groups of pixels based on their spectral similarity using algorithms like k-means or hierarchical clustering. The resulting clusters can then be examined to identify potential soil types or patterns.

5. Image Fusion: Soil morphology analysis can benefit from fusing multiple satellite images or different data sources, such as multispectral, hyperspectral, or radar images. Image fusion techniques combine the complementary information from different sources to enhance the discrimination and

identification of soil properties. Fusion methods like Principal Component Analysis (PCA) or Intensity-Hue-Saturation (IHS) transformation can be applied to integrate and analyze the data.

6. Change Detection: Change detection techniques compare satellite images captured at different time intervals to identify temporal changes in soil morphology. By differencing or thresholding the images, changes in soil properties such as erosion, deposition, or land-use conversion can be detected and quantified. Change detection can provide valuable insights into soil dynamics and their impact on the landscape.

By the nature of the ratio of soil horizons [4]:

• Young soils have a primitive profile, in which only a few upper centimeters of soil are affected by soil formation.

• The underdeveloped profile is typical for soils of steep slopes or on massively crystalline rocks, the thickness of horizons is small.

• The normal profile is characteristic of mature soils on flat conditions, contains a complete set of genetic horizons.

• A poorly differentiated profile is inherent in soils developing on poor rocks (quartz sands, ancient weathering crusts); horizons are poorly expressed, transitions are gradual.

• Eroded soils usually have a disturbed profile, in which the upper part of the profile is destroyed.

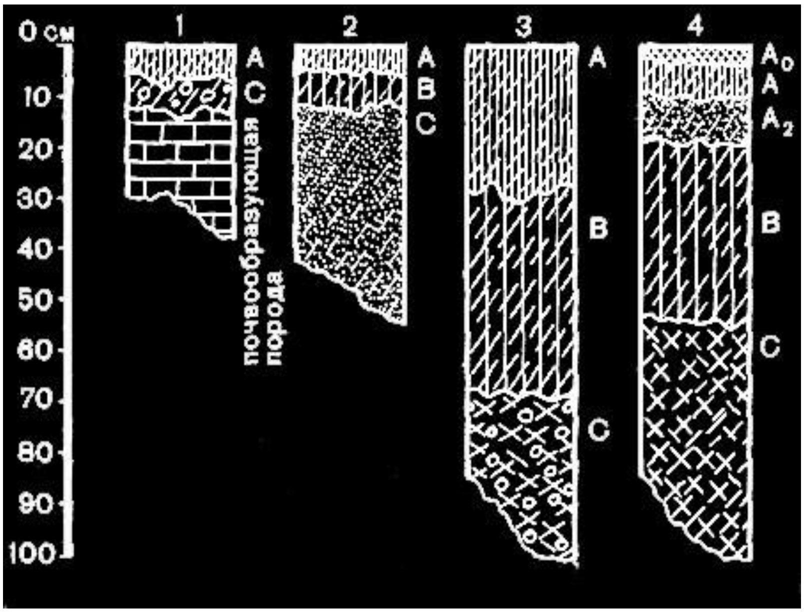

Figure 1. ***Scheme of soil structure at various stages of development.***

This figure cites poorly developed soil in hard rocks 1, poorly developed soil in loose sandy rocks 2, developed soil under steppe vegetation 3, developed soils under forest vegetation 4 The thickness of the soil is its vertical extent, measured from the surface of the day of the rock, which is weakly affected by soil formation processes. Soil thickness varies on average from 50-150 CM. According to the horizons present in the soil and their vertical thickness, it is possible to specialise in the nature of soil-forming processes and the presence of certain substances in the soil. The A1 layer horizon has a nutrient-rich soil, showing the development of the process of accumulation of substances and the process of attenuation. The presence of a clear eluvial horizon A2 in the soil profile is associated with an intensive selection process [6].

According to The Shape of the soil elements, there are three main types of soil horizons:

• cuboid, structural elements develop evenly along the three mutually perpendicular axes. The main types of this type of structure (by size) are: blocky, collected, nutty and granular;

- prism-shaped, structural elements are mainly developed along the vertical axis. The main types are columnar, columnar and prismatic;
- plate-shaped, structural elements are mostly located along two horizontal axes and are shortened in a vertical direction. The main types are tiled and thong-shaped.

Table 1.

Granulometric element classification (According to N.A. Kachinsky).

Particle diameter, mm	Name of elements (particle size fractions)	Class
>3 3-1	stones, gravel;	Soil skeleton
1-0,5 0,5-0,25 0,25-0,05 0,05-0,01	big sand medium sand fine sand fine dust	Physical sand
0,01-0,005 0,005-0,001 < 0 001 < 0 0001	dust: medium, fine dust; Silt Including colloids	Physical clay

Results and Discussion

Optimal control is called such a set of control actions, which, under given constraints, provides the most advantageous value of a certain quantitative indicator - the optimality criterion that characterizes the effectiveness of the functioning of the controlled object. As a control action, consider watering. The water consumption deficit of agricultural crops is determined in millimeters of water layer or in cubic meters per 1 ha (1mm = 10m3/ha). The amount of the deficit for the τ day can be determined by the equation [7]:

$$D_\tau = E_\tau - (P_\tau - \Delta P_\tau) - W_\tau^g \quad (1)$$

where E_τ - total evaporation from the field (water consumption), consisting of transpiration of plants and evaporation from the soil, mm; P_τ - the amount of precipitation, ΔP_τ - their loss for surface runoff and filtration, mm; W_τ^g - capillary inflow of close groundwater, mm.

The main criterion that is used in irrigation management is the dynamics of soil moisture reserves in the layer of maximum concentration of the roots of the culture, called the active soil layer. The moisture reserve in it, mm, is calculated by the formula:

$$W = 10h^{(a)}\overline{\gamma}\overline{\beta} \quad (2)$$

where $h^{(a)}$- active soil layer, m; $\overline{\gamma}$ - average soil density for the layer, t/m^3; $\overline{\beta}$ - average soil moisture, % by weight of dry soil.

The main technological criterion for irrigation management is the dynamics of the moisture content in the active soil layer. By the amount of $h^{(a)}$ a number of factors affect. The most important is the morphology and structure of the root system, which depend on the type and phase of plant development and change under the influence of the feeding area, density and porosity of the soil, the depth of soil moisture by precipitation and irrigation at the beginning of the growing season, the depth of groundwater and their mineralization, weather conditions.

The calculated active layer is not the maximum depth of root penetration, but the depth of the upper most active part of the root systems of plants. Due to the inability to accurately determine it, they resort to expert assessments.

The change in the moisture reserve in the active layer during the day is equal to:

$$\Delta W_\tau = W_{\tau-1} + (P_\tau - \Delta P_\tau) + W_\tau + m_\tau + E_\tau \quad (3)$$

where, $W_{\tau-1}$ - moisture reserve at the end of the previous and the beginning of the day τ, *mm;* W_τ - the same at the end τ-th days, mm; m_τ - the net irrigation rate, which is entered into the calculation if watering was carried out on the day of τ, mm.

The lower limit of the range of optimal soil moisture for plants in the layer $h^{(a)}$ is the critical humidity $\beta^{(ch)}$ and the corresponding critical moisture reserve $W^{(cmr)}$. At $\beta_\tau \leq \beta^{(ch)}$ and $W_\tau \leq W^{(cmr)}$ plants slow down growth and reduce productivity. The upper limit of this range is some maximum humidity β_{max} and moisture reserve W_{max}, when the soil is moistened above which excess moisture is lost to runoff and filtration and can cause soil erosion, leaching of plant nutrients, groundwater replenishment and other negative effects on land fertility. In practice, W_{max} is usually taken as moisture reserves $W^{(HB)}$, corresponding to the highs moisture capacity $\beta^{(HB)}$. Subject to the considered restrictions, the maximum irrigation norm m_max, mm, should not exceed the values of the difference $W_{max} - W_{min} = W^{(HB)} - W^{(ch)}$ or, taking into account their values:

$$m_{max} = 10h^{(a)}\overline{\gamma}(\beta^{HB} - \beta^{ch}) \quad (4)$$

The choice of the target function of optimal irrigation management depends on the level of provision of irrigation with the necessary resources - water, productivity of irrigation equipment, labor. With sufficient resources, the objective function is to maintain moisture reserves of the active soil layer within the boundaries of the optimal range:

$$W_{max} \geq W_\tau > W_{min} \text{ or } W^{HB} \geq W_\tau > W^{ch} \quad (5)$$

what ensures minimization of water losses and optimal water supply of plants.

The granulometric composition of soils is the content of elementary particles of various sizes. Soil type is a group of soils that develops in the same type of conjugate biological, climatic and hydrological conditions and is characterized by a vivid manifestation of the main process of soil formation in possible combination with other processes.

It is not possible to determine the size of each particle that is part of the soil. In laboratory conditions, they are limited to determining the fraction of particles of a certain size within the established limits, which are called fractions of granulometric composition. These parameters characterize the severity of the soil profile and give grounds to judge the soil-forming processes.

Table 2

Granulometric composition of soil (According to N.A. Kachinsky).

Physical clay content (%)	Physical sand content (%)	Classes of soils by granutometric composition
0-5	100-95	Super Sandy
5-10	95-90	Medium Sandy
10-15	90-85	Light sand
15-20	85-80	Sand
20-30	80-70	Light clay
30-40	70-60	Medium clay
40-50	60-50	Extremely muddy
50-65	50-35	Light clay
65-80	35-20	Middle clay
>80	<20	Extremely muddy

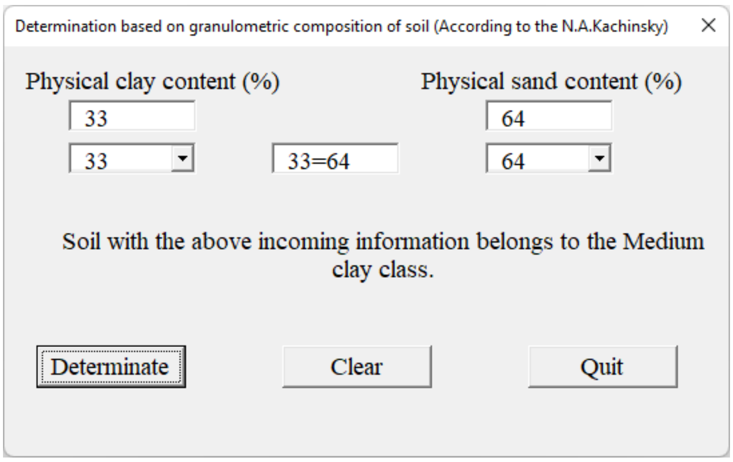

Figure 2. ***Software result.***

Incoming data on granulometric composition of soils are given. Based on this information, VBA (Visual Basic for Application) was designed in the programming language. Using a ready-made software tool, it will be possible to determine which class the soil belongs to based on the optional given input data. The figure below included optional input data (physical clay content 33%, physical sand content 64%). As a result, the software tool adopted these parameters and found that the soil belongs to the medium clayey class.

Conclusion

In conclusion, soil morphology analysis through the processing of satellite images offers valuable insight into the physical characteristics and patterns of soil across large areas. By leveraging remote sensing data, researchers and land managers can gain a better understanding of soil variability, soil types, and the dynamics of soil-related processes. Various methods can be employed in the analysis, including spectral indices, texture analysis, supervised and unsupervised classification, image fusion, and change detection. These techniques allow for the identification of soil properties such as vegetation cover, texture variations, and temporal changes in soil morphology. The integration of multiple data sources and the application of advanced image processing algorithms enhance the accuracy and effectiveness of soil analysis [8, 9].

However, it is important to note that soil morphology analysis using satellite images should be validated and calibrated using ground truth data. Field measurements and other ground-based surveys are crucial for ensuring the accuracy and reliability of the satellite-based analysis results. Overall, soil morphology analysis using satellite images plays a significant role in supporting soil science research, land management decisions, and environmental monitoring. It provides a cost-effective and efficient means of studying large-scale soil variability and helps inform strategies for sustainable land use, resource management, and soil conservation efforts.

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