Method of remote determination of humus content in soils of grape agrocenoses in southern regions of Russia

I Yu Grishin¹, R R Timirgaleeva¹,², V V Likhovskoy³ and I A Vasylyk³

¹ Lomonosov Moscow State University, GSP-1, Leninskie Gory, Moscow, 119991, Russia
² Institute of Economics and Management of the Humanities and Pedagogic Academy, 14, Khalturina Street, Yalta, 298635, Russia
³ Federal State Budget Scientific Institution All-Russian National Research Institute of Viticulture and Winemaking Magarach of the RAS, 31, Kirova Street, Yalta, 298600, Russia

E-mail: igugri@gmail.com

Abstract. The article discusses methods for analyzing soil fertility in grape agrocenoses based on determining the value of the humus content by remote methods based on the analysis of spectral characteristics of soils. The study was carried out using laboratory photography with a digital camera and satellite multispectral equipment. It is shown that the considered methods for determining the humus content in the soil are highly accurate, which makes it possible to apply them to create an automated system for monitoring the state of soils.

1. Introduction
Monitoring the state of agrocenoses using remote observation methods allows you to quickly obtain reliable information about their condition over large areas [1]. Of course, various types of agrocenoses require taking into account the peculiarities of their chemical, physical and biological composition. One of the most difficult species for remote monitoring is grape agrocenoses, since they are represented, first of all, by perennial vegetation and soils with a special composition necessary for obtaining good yields with specified (or desired) properties, for example, sugar content. These circumstances require the creation of new information technologies and systems for monitoring and processing information about the state of grape agrocenoses, which would allow both assessing their current state and making certain predictions for managing soil quality.

An analysis of existing publications and the results of research works by domestic scientists [2-6] and foreign researchers [7-11] allows us to summarize that the direction of restoring the fertility of various types of agrocenoses, as well as their conservation, is actively developing. There are also publications devoted to the remote assessment of the state of soils and vineyards.

In recent decades, Moscow State University named after M.V. Lomonosov, as well as at the Space Research Institute of the Russian Academy of Sciences, technologies, methods and algorithms have been developed that make it possible to efficiently work with data coming from orbiting satellites to solve fundamental and applied problems of processing remote sensing results [12].

The use of remote sensing methods for assessing the state of terroir in viticulture is considered in [13], in which methods of object image analysis, space-time analysis, hyper spectral analysis and topoclimatology were developed.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd
It should be noted that in the available publications there are no comprehensive studies aimed at identifying and substantiating significant factors (indicators) that determine the most important characteristics of grape agrocenoses and their fertility based on data obtained remotely, both in laboratories or directly in the field, as well as by satellite information in the conditions of the southern regions of Russia.

2. Materials and methods

The need to monitor the state of soils in grape agrocenoses arises due to the intensive use of lands to obtain high yields, which leads to their degradation and a decrease in fertility. Therefore, it is desirable to conduct such monitoring continuously, or at a sufficiently high frequency, observing the main indicators of the dynamics of chemical substances, the main indicators of fertility, and the intensity of pollution due to increased anthropogenic load.

In the overwhelming majority of cases, the most important complex indicator of soil fertility is the content of organic matter in it and its qualitative state. It is known that the properties, composition and amount of organic matter determine the biological indicators of soil fertility. Humus is the main representative (85-90% of the total) taken together of substances that make up organic matter. Humic compounds are dark-colored high-molecular compounds with a complex chemical structure. Soil types differ in the content of humus, in the amount and ratio of humic acids and fulvic acids, which significantly affects their reflectivity in various ranges of electromagnetic waves.

The most important morphological feature of the soil is its color, which depends on the chemical composition and, above all, on the humus content. There are a sufficient number of publications devoted to the development and study of methods for assessing the state of the vegetation cover using remote sensing methods, however, they are oriented towards application in laboratory conditions and have a high computational complexity for use in real information systems for monitoring soil quality.

Therefore, in this work, an attempt is made to develop the foundations of a methodology for assessing the humus content of grape agrocenoses in the southern regions of Russia. At the same time, the assessment of humus content was carried out both in laboratory conditions and on the basis of a space spectrozonal survey.

The objects of research at the first stage were the soils of grape agrocenoses in the southern regions of Russia. Soil characteristics and geographic data are shown in table 1.

In each case, samples were taken from a depth of 5-15 centimeters. The analysis of the humus content in the laboratory was carried out according to Tyurin in accordance with GOST 26213-91. Soils. Methods for the determination of organic matter.

The spectral characteristics of the studied soils were determined on the basis of the multispectral imaging equipment MSS (spectral range is 460-860 nm) of the Kanopus-V satellite (the survey time is synchronized with the time of soil sampling, archived data were used), as well as in laboratory conditions using a digital camera Canon DS126181. The focal length of the camera lens was 55 mm, the resolution was 4272x2848 pixels, the spectral range of the matrix was 400-780 nm.

For decryption, from 22 polygon areas, 4 areas were selected, which at the time of sampling and satellite imagery were not occupied by vegetation, and there was no atmospheric interference for satellite images.

Analysis of the data from the archives of meteorological stations showed that the surface layers of the soil of all four studied areas were in an air-dry state. This circumstance made it possible to disregard the effect of soil moisture on its color during deciphering and subsequent analysis.

When preparing soil samples for photography in a laboratory, the soil samples were dried to an air-dry state, they were ground to a size of 0.2-0.25 mm.

For the photography, artificial lighting was used. In this case, the power supply was stabilized with a supply voltage accuracy of 220V ± 1%. We placed the soil sample in a glass cuvette, compacted it, and also aligned it. A reference white sample was placed side by side and was subsequently used to correct the white balance in preparation for shooting and image processing.
Table 1. Characteristics of plots and soils.

| Sample No. | Farm, plot Description | Soil type |
|------------|------------------------|-----------|
| 1          | Blagodatnogye, "Zolotaya Balka" |
|            | The relief is a wavy plain; humus (layer 0-20 cm) - 1.2%, parent breed - deluvium; salinity - no; soil pH - 6.9; P$_2$O$_5$ - 1.4 mg / 100 g of soil; K$_2$O - 17.5 mg / 100 g of soil; Ca asset. - 19.4 mg / 100 g. |
| 2          | with. Vilino, mother Kober |
|            | Relief - lowering; humus - 65 cm; parent breed - deluvium; boiling HCl - from the surface; salinity - no; humus - 1.55%; pH - 8.0; P$_2$O$_5$ - 0.9 mg / 100 g of soil; K$_2$O - 20.1 mg / 100 g of soil; Ca active - 14.5 mg / 100 g. |
| 3          | with. Vilino, AK "Magarach" |
|            | The humus content is 2.5%. pH - 8.1 units. The bulk density of the soil is 1.29-1.33 g / cm$^3$. |
| 4          | Agrofirm "Chernomoret" |
|            | The humus layer is 80-90 cm. The humus content is 3.5%. |

The images obtained during shooting in RAW (digital camera) and GeoTIFF (satellite images) were processed for subsequent analysis using the SIPS software package, as well as Photoshop CS6, which allow determining the average brightness value in spectral channels (R, G, B) ... To increase the reliability, the images were obtained by an automatic series of 5 images, and then averaged. The spectral coefficients were calculated relative to the brightness of the standard, their averaged values are shown in table 2.

3. Results and Discussion

The analysis of the results obtained as a result of the experiment, it is advisable to carry out both the results of laboratory shooting with a digital camera and the results of remote sensing from a satellite.

From the analysis of table 2, it can be concluded that, according to the results of laboratory studies, the highest brightness value is observed in the red range (R), the lowest - in the blue range (B). Comparative results are shown in figure 1.

The analysis of the results of statistical processing of laboratory survey data suggests that the greatest correlation is observed between the humus content (G) and the brightness of the red channel of the digital image, the value of the correlation coefficient was $r = -0.93$. Thus, the R channel is the most informative for monitoring the level of humus in the soil.

Table 2. Spectral characteristics of soils.

| Sample No. | R  | G  | B  | Humus content, % |
|------------|----|----|----|------------------|
| 1          | 75.6 | 65.1 | 51.2 | 1.2              |
| 4          | 76.1 | 67.3 | 53.6 | 1.55             |
| 3          | 64.3 | 52.9 | 42.1 | 2.5              |
| 2          | 62.9 | 56.8 | 45.7 | 3.5              |
For a more convenient assessment of the soil humus content, an analytical expression (regression equation) was obtained for the dependence of the humus content in the soil on the brightness level of the channel R:

\[ G = -0.136R + 11.651. \]  

(1)

In this case, \( r^2 = 0.87 \), which indicates a high level of correlation, the standard error is \( m = 2.6 \). The values of \( G \), calculated from the R level in accordance with expression (1), are shown in figure 2.

In addition, satellite images of the analyzed areas were obtained from the Kanopus-V satellite, multispectral equipment (figure 3).

With satellite images, a similar list of works related to the preliminary processing of photographic images and statistical processing of the results was carried out. In this case, the following regression dependence was obtained (2):

\[ G = -0.011R + 9.21. \]  

(2)

In this case, the statistical indicators of the obtained regression dependence are as follows: \( r^2 = 0.79 \), which indicates a sufficiently high level of correlation, the standard error is \( m = 4.7 \), which allows us to assert a fairly good approximation of the real results obtained by the regression (figure 4).
Figure 3. Satellite images of the analyzed areas (a - sample 1, b - samples 2-4).

Figure 4. Regression equation (satellite images).

From the analysis of the results obtained, it follows that the error in the value of the humus content does not exceed 20% (for laboratory images - 8.5%), which indicates the possibility of the considered remote monitoring.

It should be noted that the work presents only the first results of remote monitoring of the fertility of grape agrocenoses. In the future, it is planned to break more landfills for sampling and remote diagnostics. To determine the spectral properties of soils, it is planned to use a mobile spectrometer, which makes it possible to carry out measurements directly in the field, while planning such measurements based on preliminary forecasts of monitoring specified territories by the required satellites, as well as weather forecasts. It is possible that more reliable results can be obtained with the use of images with hyperspectral satellite equipment, which will make it possible to single out narrower, most informative parts of the spectrum.
4. Conclusion
As a result of the research carried out, it can be concluded that space and laboratory methods for measuring the spectral reflectance of soils are sufficiently effective for analyzing their fertility by remotely determining the humus content in them.

A method has been developed for using a modern digital camera to determine the humus content in the soil. It is shown that the accuracy of determining the indicated value practically corresponds to analytical methods. However, it should be noted that it is important to perform random measurements directly in the field, which is possible when using mobile spectrometers. It is shown that to determine the value of soil humus content in the southern regions of Russia, it is advisable to use the spectrum of the red channel of a digital camera photograph.

The use of a similar technique for processing and interpreting satellite images also makes it possible to determine the humus content in the soil with sufficient accuracy. At the same time, this monitoring method should be considered the most important, since it requires less labor for continuous monitoring of the state of the soil cover of grape agrocenoses and can be used as the basis for automatic monitoring of soil quality.

In the course of further research, it is advisable to switch from multispectral monitoring methods to hyperspectral, which can improve the accuracy and quality of monitoring.

Acknowledgments
The reported study was funded by RFBR, project number 20-016-00220.

References
[1] Grishin I Yu and Timirgaleeva R R 2020 Remote sensing: The method of GIS application for monitoring the state of soils. E3S Web of Conferences 175 06009
[2] Blokhina S Yu 2018 Application of remote sensing in precision agriculture. Bulletin of the Russian agricultural science 5 10-16
[3] Ergina E I 2012 Dynamics of thermodynamic properties and energy reserves in humus of soils of the Crimean peninsula. Geopolitics and ecogeodynamics of regions 8(1–2) 62–72
[4] Kiryushin V I 2013 The problem of minimizing soil cultivation: development prospects and research objectives. Agriculture 7 3-6
[5] Kozubenko I S and Savin I Yu 2017 Satellite data in the management of the agro-industrial complex of the region. Bulletin of Russian Agricultural Science 5 9–11
[6] Kulik K N and Koshelev A V 2017 Methodological framework for agroforestry assessment of protective forest plantations based on remote monitoring data. Forestry journal 3 107–114
[7] Elbasiony H 2018 Assessment of Environmental Sensitivity to Desertification, Soil Quality and Sustainability in An Area of The North Nile Delta, Egypt. J. Soil. Sci.. 58(4) 399-415
[8] Chervan’ A 2018 The assessment of resource potential of agro-landscapes with use of geo-information systems on the basis of soil cover structure. The Proceedings of the 10thInternational Soil Science Congress on “Environment and Soil Resources Conservation” 19
[9] Bonfante A, Terribile F, and Bouma J 2019 Refining physical aspects of soil quality and soil health when exploring the effects of soil degradation and climate change on biomass production: an Italian case study. SOIL 5 1-14
[10] Braun V J and Mirzabaev A 2016 Land Use Change and Economics of Land Degradation in the Baltic Region. Baltic Region 8(3) 33-44
[11] Glinushkin A P, Kudeyarov V N, Sokolov M S, Zinchenko V E and Chernenko V V 2018 Nature-Similar Technologies of the Biogeosystem Techniquein Solvinga Global Social and Environmental Problem. Biogeosystem Technique 5(2) 164-196
[12] Lupyan E A, Savorskiy V P, Shokin Yu I, Aleksanin A I, Nazirov R R, Nedoluzhko I V and Panova O Yu 2012 Modern approaches and technologies for organizing work with Earth remote sensing data for solving scientific problems. Modern problems of remote sensing of
[13] Hall A 2018 Remote Sensing Application for Viticultural Terroir Analysis. *Elements* **14**(3) 185-190