Technologies

AIRBORNE HYPERSPECTRAL IMAGERY AND FIELD SURVEY DATA FOR PRECISION FARMING

Airborne hyperspectral data are very promising for high-resolution mapping of vegetation characteristics. The study examines the vegetation indices as a tool of such mapping and the process of choosing the most representative indices to get the crops characteristics at the Menkovo experimental station (southern Leningrad Region). Accuracy of determining the characteristics from airborne data was estimated using the ground spectroradiometry data and laboratory analyses of samples from experimental plots.

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Precision farming is the concept of the agricultural land treatment, based on the existence of inhomogeneities within one field, which require differentiated fertilizing, herbiciding, and other agricultural activities. Introduction of precision farming leads to economic and environmental benefits. To implement such a technology, operational and highly detailed cartographic materials of acceptable accuracy are required.

Application of remote sensing data is a method of regular assessment of the crop lands condition on a large area at a time. Hyperspectral data have very high spectral resolution (usually 1-3 nm) and quite a broad spectral range (usually including visible and near-infrared bands) and therefore have an advantage over multispectral ones in terms of identification of materials and their characteristics. This is exactly the purpose of mapping for precision farming needs. Imagery from low-flying aircraft and UAVs ensures high spatial detail.

The question of how to obtain information useful for precision farming based on hyperspectral imagery data has been addressed by many researchers worldwide. Soil conditions, green phytomass of plants, their biochemical parameters and status were evaluated in the studies of various authors. However, for each combination of natural conditions, soil and crops it is required to empirically seek for the most accurate and specific calculation tools. Technical features of the data used should be taken into account as well.

The study area is located in the southern part of the Leningrad Region, within the area of the active agricultural development of the fertile calcareous soils. These are the two test fields of the Menkovo experimental station of the Agrophysical R&D Institute. On June 26, 2014, joint efforts of our team and specialists from St-Petersburg branch of CJSC "Luch" Design Bureau, CJSC "Reagent", the Agrophysical R&D Institute and the Mozhaisky Aerospace Military Academy helped conducting ground-based measurements and aerial hyperspectral imaging of experimental plots with spring wheat at the tillering stage and with winter wheat at the heading stage. A series of experiments was being conducted at these plots applying herbicides and introducing various doses of nitrogen fertilizers at selected test areas.

Vegetation indices were selected as a way of getting various vegetation characteristics. They represent the relationship of spectral characteristics (typically of spectral brightness coefficients) on two or more wavelengths. As spectral characteristics of plants are determined by the internal structure of a leaf and the contents of pigments, the combination of spectral brightness coefficients at different wavelengths (as a rule, in the near infrared, red and green parts of the spectrum) allow to comprehensively assess the biophysical and biochemical characteristics of plants.

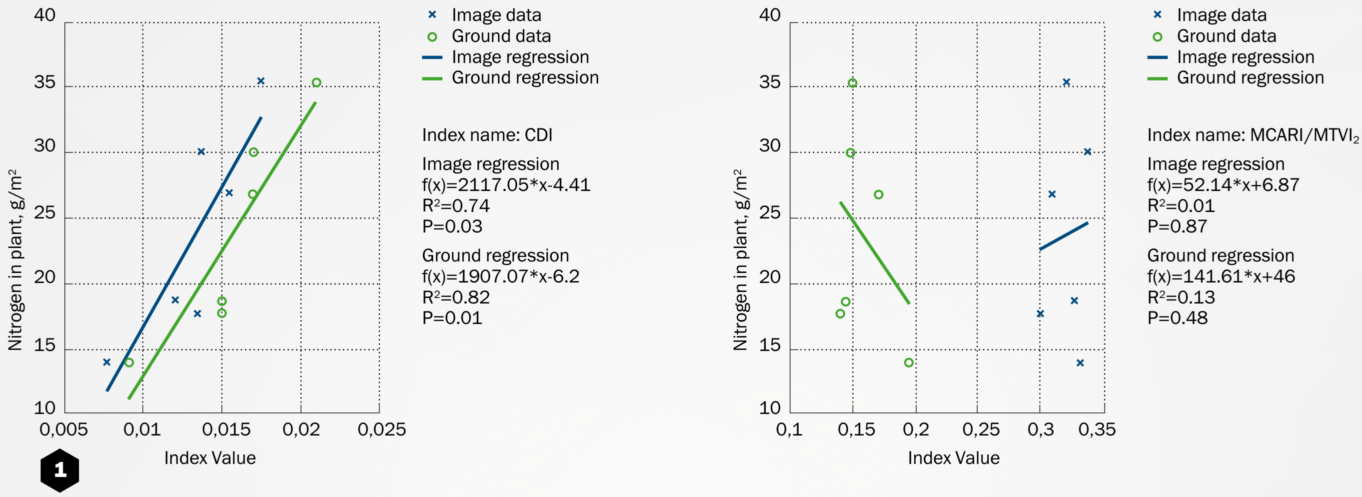

Fig. 1. Examples of regression analysis complex graphs for the nitrogen content indices. The left graph shows the good relationship between index values based on airborne (blue line) and ground (green line) spectral data and the content of nitrogen in plants according to laboratory analyses data. On the right graph there is no meaningful communication between them

According to the results of an extensive analysis of research literature, 28 vegetation indices in four thematic groups were selected, on the basis of results of the quality assessment in source literature, on frequency of use by other authors, and associated with the relevant laboratory data: general greenness (associated with the volume of green phytomass); the contents of pigments (anthocyanins, carotenoids, chlorophylls a and b); nitrogen content in plants; humidity of plants.

Selected indices were calculated for 19 test grounds based on spectral signatures from a hyperspectral airborne image and ground-based spectrometric measurements. After that both types of index measures were subjected to joint regression and statistical analysis with the relevant laboratory-defined characteristics of plants. It is important that all data were obtained in one day and had statistically significant volumes (20-25 measurements) for each individual test area. Using integrated graphics in "index measure — absolute values of a laboratory indicator" medium for airborne and ground data, a drop-out of 2/3 indices, which did not demonstrate the existence of significant correlation, was carried out (fig. 1). Graphical criteria were the tilt and the proximity of the regression lines, as well as the quality of reference points description by them (magnitude of residual regression errors).

The second and final stage of the selection process was based on regressions and statistics calculation between the index measures of ground and airborne data (they were supposed to be very close), as well as the magnitude of residual regression index of airborne data with laboratory data (they were supposed to be minimal).

As a result, five most representative indices for the conditions being studied were found (Table 1), enabling to evaluate the vegetation characteristics with the following maximum errors (relative to the range of the absolute value: content of anthocyanins — 10%, of carotenoids — 15%, of chlorophyll b — 10%, of nitrogen — 20-30%, depending on the phenological phase, the amount of green phytomass — 15%. It was also shown that when the airborne hyperspectral equipment of CJSC "Reagent" was used, the moisture content in plants can be estimated with a very low accuracy, because there are no

Table 1. The most representative vegetation indices for the study area (Rnnn is the spectral brightness coefficient at the wavelength of nnn nm)

Index name	*Formulae*	*Reference*
Anthocyanins content	ARI750=1/R550 - 1/R750	Gitelson et al., 2001
Carotenoids content	PSRI= (R680-R500)/R750	Merzlyak et al., 1999
Chlorophyll content b	PSSRb=R800/R635	Blackburn, 1998
Nitrogen content	CDI=(R736-R735) *R980/R720	Bao et al., 2013
Green phytomass number	MTCI=(R760-R720)/(R720-R670)	Dash et al., 2004

Nitrogen content in wheat at earing stage

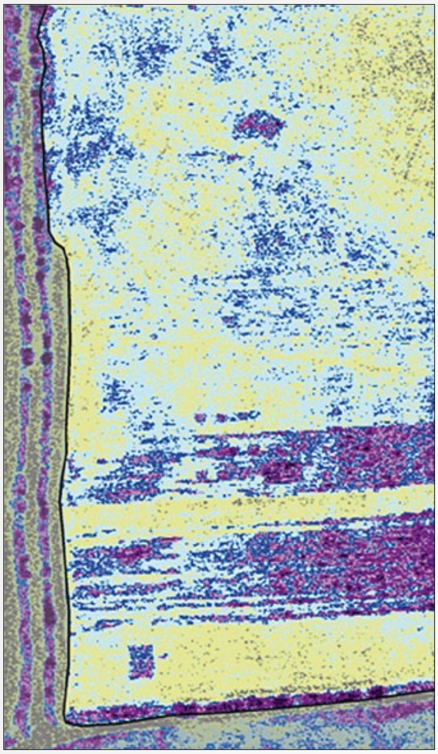

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Fig. 2. An example of a map of nitrogen content in plants, compiled on the basis of the vegetation index image calibration with laboratory data acquired from test areas

measurements at wavelengths longer than 960 nm; problems also arise during the calculation of the amount of green phytomass of wheat at tillering stage, which has low projective cover of.

For the selected indices, mapping was performed. When data of laboratory analyses for test areas were available, index measures were translated into absolute values using the regression formulae.

Series of maps made for the characteristics as listed in Table 1 enable to analyze not only the individual characteristics of vegetation, but also the links between various parameters, and to compare them with respect to two different phases of the wheat growth - tillering and heading. Manifestation of known biophysical patterns and accurate recording of all aspects of various agronomic experiments confirms that the results obtained are true. For an independent verification of quantitative reliability of the study, the authors, unfortunately, had no data, as in other parts of the fields no synchronous plant sampling for laboratory analyses was carried out. However, it is planned at further stages of this research.

Despite the skepticism of many professionals with respect to introducing precision farming in Russia, it could bring significant benefits in comparison with the traditional approaches to crops cultivation. The accomplished study enabled to form a technological way to find the best vegetation indices for specific conditions and to create cartographic materials in absolute units of indicators; qualitative analysis showed that the received materials are highly informative. Planned further research in the same region will make it possible to assess the sustainability of the results obtained from year to year and to verify these results.

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