CROP AND SOIL TEMPERATURE DIFFERENCE AN ADDITIONAL FACTOR FOR ANALYSIS OF THE CONDITION OF CROPS

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Abstract. The study aims to study changes in land surface temperature (LST) of soil and vegetation on agricultural land planted with barley based on unmanned LST data. Simultaneously with the LST data, the spectral characteristics (NDVI) of crops were measured using the DJI P4 Multispectral. The paper shows the variability of vegetation indices and radiation temperature during the growing season. A significant relationship was found between the dynamics of NDVI and the dynamics of radiation temperature. The features of the variability of the spatial distribution of temperatures depending on precipitation are shown. The paper gives an example of a temperature map of the studied areas in the middle of the growing season, which shows the features of the spatial distribution of temperatures.

Keywords: radiation temperature, crop, thermal map, ZENMUSE XT2, DJI P4 Multispectral, CSTD

1 Introduction

Temperature is one of the most important environmental variables affecting plant physiological processes, including transpiration, leaf water potential, and photosynthesis. Minor changes in canopy temperature, which is a function of plant leaf temperature, can be measured with a thermal imaging camera. A temperature image is formed using the long-wavelength range of radiation. Remote sensing thermal imaging cameras installed on unmanned aerial vehicles (UAV) are increasingly used in precision agriculture [1] for detecting water stress and planning irrigation [2–5], as well as for plant phenotyping [6–8]. In this work, special attention is paid to identifying the relationship between the dynamics of thermal data of agricultural lands with the dynamics of their spectrophotometric characteristics.

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2 Objects and Methods

The object of research is agricultural land of experimental production farm (EPF) "Minino" near the village of Minino (Emelyanovsky district) and the educational experimental farm (EEF) "Minderlinskoe" near the village of Borsk (Sukhobuzimsky district) of the Krasnoyarsk region (Fig. 1). Data obtained during the 2020 growing season.

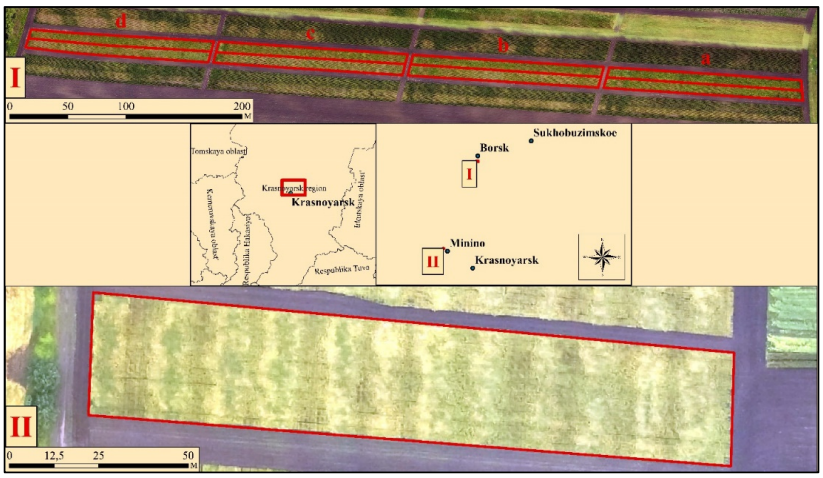

Fig. 1. Study sites: I – EEF "Minderlinskoe", II – EPF "Minino".

On the experimental field of the EEF "Minderlinskoe" grows barley variety "Acha". The fields are divided into 4 test areas in accordance with four types of treatment: deep plowing (20-22 cm) – "a"; sweep treatment (20-22 cm) – "b"; surface treatment (discator by 8-10 cm) – "c"; no tillage – "d". Fertilization was carried out along the northern part of each strip (10 m wide), the southern part remained without fertilizers.

On the experimental field of the Krasnoyarsk Research Institute of Agriculture, Federal Research Center of the KSC SB RAS, barley variety Olenek grows, sowing was carried out with deep plowing.

The work is based on data obtained by the DJI P4 Multispectral and DJI Matrice 210 RTK V2 drones with ZENMUSE XT2 thermal camera. The ZENMUSE XT2 captures images in a thermal range of 7.5-13.5μm with a resolution of 640x512 pixels. The spatial resolution of the obtained images is 12.6 cm. DJI P4 Multispectral performs multispectral imaging in 5 spectral channels (450 ± 16 nm, 560 ± 16 nm, 650 ± 16 nm, 730 ± 16 nm, 840 ± 26 nm). The spatial resolution of the obtained images is 5.3 cm. The obtained data were processed using the Pix4DMapper and QGIS software.

When thematic processing of multispectral data, the NDVI (Normalized Difference Vegetation Index) values were calculated. The CSTD (Crop and Soil Temperature Difference) was calculated as follows. For each study date, the average radiation temperature of the soil (LST_{soil}) was calculated. For this, sites without vegetation was selected as polygons in QGIS. NDVI values from DJI P4 Multispectral were used to identify areas with no vegetation. For bare soil, they range from 0 to 0.15. For visual control, an orthomosaic was used, also obtained with the DJI P4 Multispectral. Further, the values of the radiation temperature over the obtained polygons were averaged (their number varied from 30 to 50 polygons for each date). Thus, for each study date, one value was obtained, which was used in further calculations. Also, for each date of the study, the indicators of the average radiation

temperature of crops (LSTcrop) were calculated separately for each type of treatment and fertilization process. These values were subtracted from the soil radiation temperature (LSTsoil - LSTcrop) to calculate the CSTD.

3 Results and discussion

The study of the relationship between the dynamics of NDVI and CSTD during the growing season was carried out. This correlation was calculated to study the relationship between these characteristics, since the dynamics of temperatures affects the vegetation process and, in turn, vegetation shielding effect affects the temperature of the soil and the retention of moisture in it.

In the initial period after sowing, the microclimate of the agrophytocenosis, in essence, did not differ from the microclimate of the black fallow, but with the emergence of seedlings, and with their further growth, significant differences arose. Due to the increasing height, foliage of plants and the crop closeness, the conditions for the penetration of radiant energy to the soil changed. The temperature regime, the intensity of turbulent exchange, the intensity of evaporation, and the humidity of air and soil changed. The vegetation cover became an active surface.

Calculation of the correlation coefficient of NDVI and CSTD average values for barley (EEF "Minderlinskoye") showed a high degree of correlation – 0.85. At the same time, for individual plots, depending on the type of treatment and fertilization, this relationship is different.

The largest correlation coefficients had data series that include measurements only with a dry soil surface. The maximum value of 0.95 is for surface treatment (fertilized ground), the minimum value is for sweep treatment (nonfertilized fround). Correlation coefficients calculated from data including measurements at dry and wet soil surface have lower values for all plots (table 1).

Table 1. Correlation coefficients of NDVI and CSTD values for barley of the EEF "Minderlinskoye", taking into account the type of processing and fertilization.

$R_{NDVI,CSTD}$	Treatment							
	fertilized ground				nonfertilized ground			
	a	b	c	d	a	b	c	d
Wet and dry soil	**0.87**	0.84	0.86	0.82	0.85	**0.77**	0.85	0.80
Dry soil	0.94	0.93	**0.95**	0.93	0.94	**0.87**	0.93	0.90

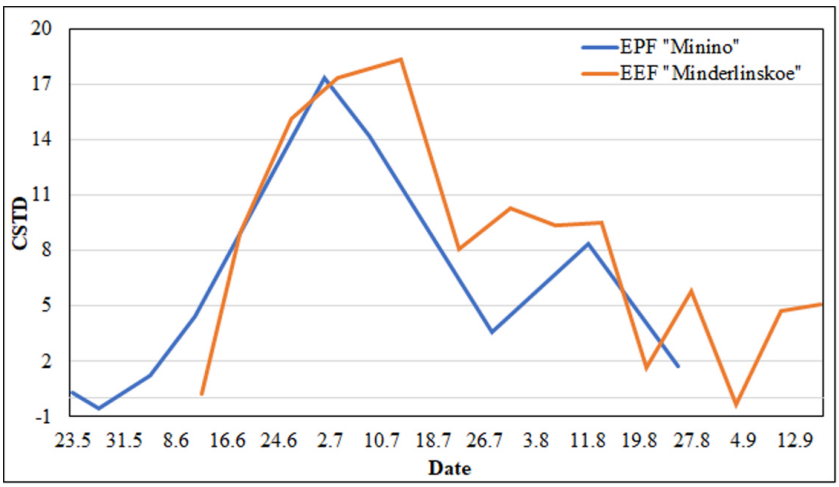

Fig. 2. Average CSTD values of barley EEF "Minderlinskoe" and EPF "Minino" during the growing season of 2020.

Comparison of the obtained data showed that the time series of CSTD crops of barley have the same character of values changes during the study period (Fig. 2).
It was found that the change in the phases of crop vegetation leads initially to an increase in CSTD, reaching maximum values on July 1 (EPF "Minino") and July 13 (EEF "Minderlinskoye"), then this value decreases. The shift in the maximum values is determined by the different sowing times of the crops. The sowing of barley at the EPF "Minino" was carried out 8 days earlier than the sowing at the EEF "Minderlinskoe".
The decrease in CSTD values on the following dates (June 12, July 22, August 20, September 3 and 10) is determined by increased soil moisture. The day before the measurements, these areas had precipitation of 4, 2, 7, 1, 2 mm, respectively. Wet soils have lower surface temperatures than dry soils. Therefore, the difference in values between soil and vegetation will be the smallest.
The general difference between the diagrams of the temperature difference at the EEF "Minderlinskoye" and the EPF "Minino" is also determined by the difference in the microclimate of the studied territories.

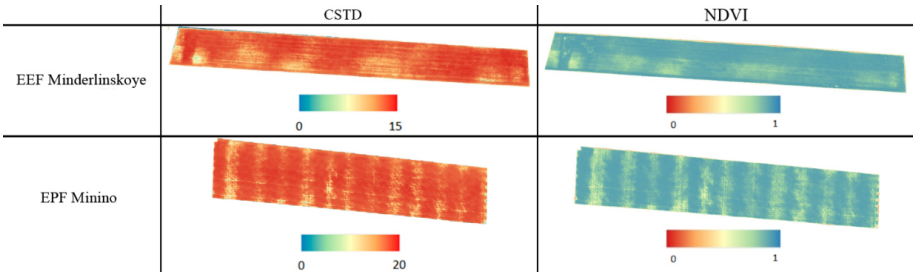

Fig. 3. Spatial distribution of CSTD and NDVI of barley located on the territory the EEF "Minderlinskoye" (type of soil treatment – deep plowing) and the EPF "Minino". The CSTD values on the territory of the EEF "Minderlinskoye" vary from 0 (min) to 15 (max) °C, EPF "Minino" from 0 to 20 °C.

The construction of thermo maps of the studied sites during the growing season made it possible to determine the features of the spatial distribution of temperatures depending on the types of soil treatment and phenological properties of crops (Fig. 3). The maps obtained show the possibility of taking into account the intra-field temperature dynamics when implementing precision farming technologies.

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