IV. SPACE TECHNOLOGY AND ENVIRONMENTAL MONITORING

METHODOLOGY FOR REMOTE SENSING MONITORING OF ORGANIC WHEAT CROPS

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Abstract: In the presented methodology for aerospace monitoring of autumn wheat crops, grown under the conditions of organic farming, the ways of applying ground and aerospace methods are discussed in detail. This includes field experiments, phenological observations, GIS and remote sensing methods and data (data from Sentinel-2 satellite and WingtraOne unmanned aerial vehicle with MicaSense RedEdge-MX multispectral camera and RGB camera) and statistical analyses. In order to achieve the aim and objectives of the study, an experiment was conducted on a organically certified production field sown with einkorn (Triticum monococum) in the period 2020-2021. The field is part of the holding of ET "Borislav Slavchev" in the village of Byala Reka, Parvomai Municipality, South-Central Bulgaria on the soil type of leached chernozem clays, with a size of 136 da.

Keywords: remote sensing, wheat crops, organic agriculture, methodology

INTRODUCTION

The methodology for the remote sensing monitoring includes few interdepended parts of observations which are grouped according to the technology or scientific domain to which the adopted methods belong to. These are: phenological observations, biometrical measurements, GIS and remote sensing methods and statistical analyses. The methodology presented is a complex one but the methods used in orchestration brings the desired outputs from the remote sensing monitoring which are the monitoring of biomass and yield of the organic eikorn field.

PHENOLOGICAL OBSERVATIONS

Registration of the main phenological phases according to the scale of (BBCH) - budding, spindle, milk maturity and technical maturity (Meier, 2001). The onset of each of the phases is when 25% of the plants have entered it. Counting of individual plants is done when 75% of the plants cover the ground in the respective phenophase.

Monitoring the dynamics of biomass accumulation by phenophases

In the EOS Crop-monitoring platform, three pixels are selected in the field with NDVI values of 0.86, 0.74 and 0.63, respectively, in the phenological phase of emergence. The pixels are 20×20 m in size, and in each of them a permanent test site with dimensions of 10×10 m is organized at the end of which markers are placed and GPS coordinates are taken. From these four permanent markers, during the phenological phases of budding, spindle and milk maturity, all plants are taken from 4 plots sized 0.25 × 0.25 m, the einkorn plants in the test plots are first counted, weighed, dried and weighed again (dry in). Figure 1 shows the scheme of the test site and test plots, and Figure 2 shows test plot 1.1.1 in the three phenological phases of the study.
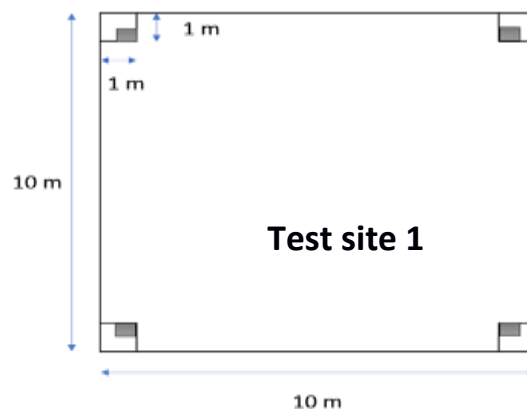

Fig. 1. Scheme of the trial sites and test plots

In the selected pixels of each field during the tillering, spindle and milk maturity phenological phases, a weed count is also carried out as from the 4 test plots - 0.25 × 0.25 m, the weeds are weighed, dried and re-weighed (dry matter). The obtained values are recalculated to 1 m^2 by multiplying by the factor of four.
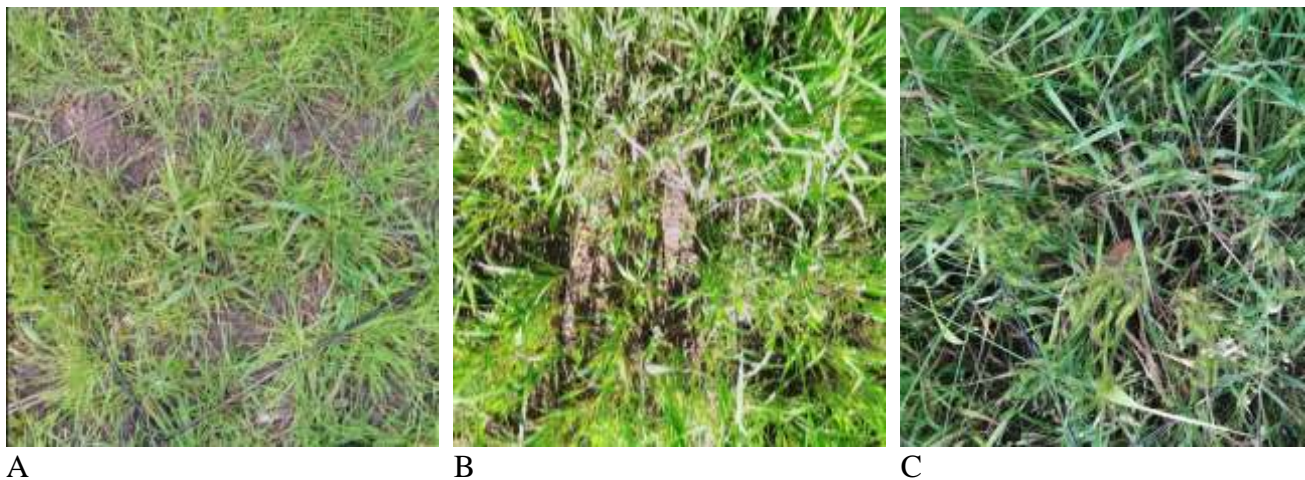

Fig. 2. Phenological monitoring of test plot 1.1.1 through phase (A) twining, (B) spindle and (C) milk maturity

BIOMETRIC MEASUREMENTS

Biometric studies were done according to the methodology of Shanin (1977). Before harvesting, in the three differences of the vegetation index NDVI, all plants were taken from a 0.25 × 0.25 m test plot in 4 replicates.

All plants were counted in each meter, and the following indicators were tracked on 25 plants: Plant height (cm); Spike length (cm); Grains in the class (number); Mass of the grain in the class (g); Biological yield (kg/day); Physical properties of grain. The mass of 1000 grains (g) was determined according to /BDS 13358-76/ for 4 repetitions.

STATISTICAL ANALYSES

To establish statistically reliable relationships of the studied factors and differences between the tested variants, a multifactor analysis of variance was applied. The data were recorded and processed with the statistical package SAS JMP© Statistical Software, with which a Fit Model analysis was performed to statistically prove the differences.

The software product SPSS20© was used for correlation analysis to statistically prove the most suitable vegetation indices (VI) for use. It is assumed that when the correlation coefficient (r) is from 0 to 0.33 - the correlation is weak; when r is in the range of 0.34 to 0.66 it is medium and from 0.67 to 0.99 it is strong (Marinkov and Dimova, 1999). In MS EXCEL©, a linear regression analysis was made between field data and AI with the best statistical significance at $p \leq 0.01$ of the correlation coefficients.

GIS METHODS

In a GIS environment, from the generated VIs, for the field surveyed by an unmanned aerial vehicle (UAV) and the Sentinel-2 satellite, the pixel values for each of the test plots in the field were extracted. The UAV data have a pixel size of 7 × 7 cm for each of the test plots in the field, after which the pixels are aggregated to a size of 1 × 1 m. After that, maps of the field with the corresponding VIs is drawn up. In the next step, yield maps for the surveyed field are compiled from the generated VI and yield data. The software used to process the data obtained from the UAV and the Sentinel-2 satellite is ArcGisPro© Academic License.

REMOTE SENSING DATA AND METHODS

The remote sensing data types used in the proposed methodology are:

1. Data from the Sentinel-2 satellite.

2. Data obtained from a WingtraOne UAV with a MicaSense RedEdge-MX multispectral camera and a Canon RGB camera.

In the Google Earth platform, the boundaries of the field that has been selected as the study area are outlined. The created polygon is exported to a *.kmz file, which is used when working with EOS Crop-monitoring and ArcGisPro software.

Data from the Sentinel-2 satellite

Sentinel-2 is a high-resolution multispectral satellite mission supporting earth observation studies under the EC's Copernicus programme. This includes monitoring vegetation, soil and water cover, as well as monitoring inland waterways and coastal areas. The MultiSpectral Instrument (MSI) onboard Sentinel-2 captures in 13 spectral bands: four bands of 10 m, six bands of 20 m and three bands of 60 m spatial resolution (Fig. 3). The captured data and the high frequency of repeated captures ensure the generation of geoinformation at local, regional, national and international levels. The data are intended to be modified and adapted by users interested in different subject areas (Sentinel-2 MSI, 2022).
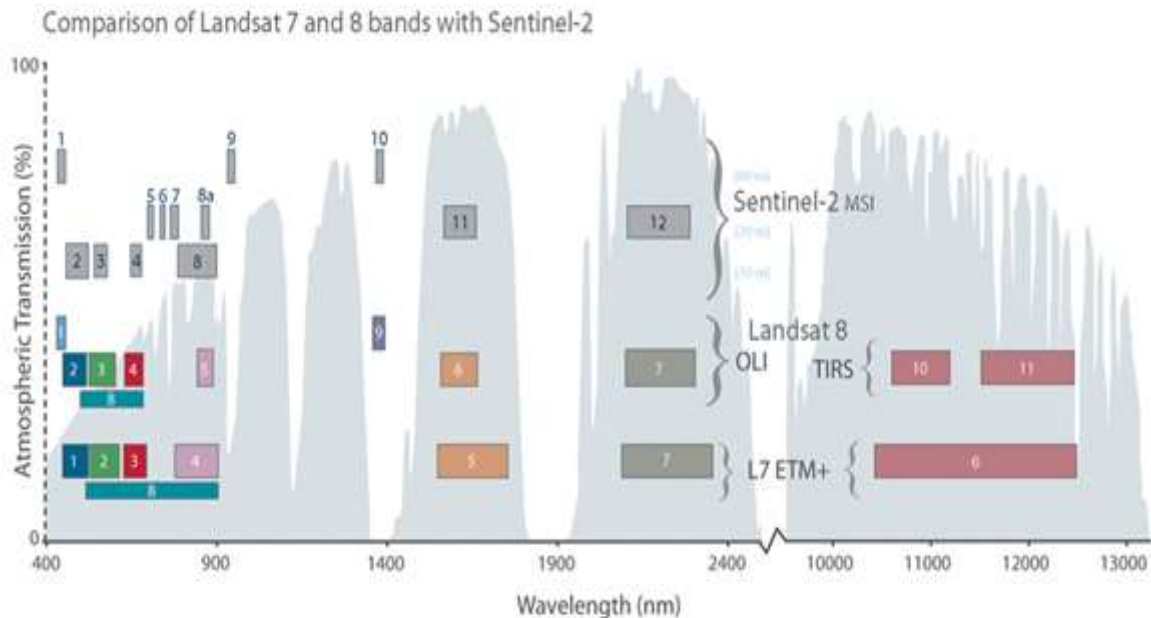

Fig. 3. Distribution of Sentinel-2 bands in the visible part of the electromagnetic spectrum

EOS Crop-monitoring© (EOS Data Analytics inc., CA, USA) is a specialized platform for agricultural crop monitoring that uses data from the Sentinel-2 satellite. The *.kmz file created in Google Earth is imported into it, and a file with the name of the field is created in it. After creating the field vector files, the corresponding field to be surveyed is selected and after its appearance on the screen, the date of sowing and the date of harvesting, respectively, are entered.

The function for generating NDVI is set in the system. After calculating the NDVI index, the function is set to calculate the percentage area distribution of each NDVI value in the surveyed field. The resulting images are saved in *.TIF files. Images for each of the phenophases studied are downloaded from the adjacent image timeline. In addition, the platform exports a diagram of the values of the vegetation index NDVI in combination with the amount of precipitation by date for the period from sowing to harvesting.

In the Land Viewer platform (EOS Data Analytics inc., CA, USA), after importing a field boundary file and using the index calculator function, the selected VIs are generated. The generated VIs are downloaded from the platform as *.TIF files for further statistical and spatial analysis.

Data obtained from an unmanned aerial vehicle

The UAV imaging was performed during the tillering (BBCH 45) and milk maturity (BBCH 75) phenological phases. The imaging was done with a WingtraOne brand UAV with a MicaSense RedEdge-MX multispectral camera and a Canon RGB camera. In Fig. 4 the WingtraOne UAV is presented.

Fig. 4. WingtraOne UAV type wing used in the study

The primary photogrammetric processing of the data obtained from the UAV was done with the specialized software Pix4D. Primary data processing includes creating an orthophoto mosaic of the surveyed field, creating a digital terrain model (DTM), creating a digital land surface model (DSM). In the same software, the VI maps were generated from UAV data.

CONCLUSION

The methodology was tested on a biological field of the einkorn crop (Triticum monococum) in the agricultural year 2020-2021. The field is located in the land of the village of Byala Reka, Parvomai municipality, South-Central Bulgaria on the soil type leached chernozem smolniks, with a size of 136 da. A set of VIs generated by the Sentinel-2 satellite were established, which well characterize the condition of the crop in the different phenological phases, as well as having a good correlation dependence with the elements of productivity and yield. Regarding the data obtained from the UAV, it was found that it is more suitable to be obtained during the milk maturity phase, since it can characterize the elements of productivity and yield in both types of data (pixel size 7×7 cm and 1×1m).

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